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

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Abstract

This paper conducts a quantitative investigation of the East Asian crisis, within a calibrated dynamic general equilibrium model. The central question addressed by the paper is this; to what extent can the crisis can be *accounted* for by the measured shocks to country risk-premia? The model is calibrated to match three East Asian economies: Thailand, Korea, and Malaysia. Using published data on country-risk premium, we find that a single interest rate shock of the size observed can explain a large share of the real sectoral outcomes in those countries, especially in Korea and Thailand. The model has more difficulty explaining the large exchange rate devaluations that occurred in those economies.

Keyword: East Asian crisis, sticky prices, small open economy.
JEL Code: F4 Macroeconomic Aspects of International Trade and Finance

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I. Introduction

Many countries in East Asia developed a reputation as "miracle" economies due to their rapid growth in the post-war period. Beginning in late-1997, a number of emerging market economies in East Asia underwent a common set of events known as the Asian crisis. Indonesia, Korea, Malaysia and Thailand each experienced severe exchange rate devaluations and current account reversals. In all of the economies, the currency devaluations were followed by large real contractions. Other economies in the region including Hong Kong, the Philippines, Singapore and Taiwan were also affected to varying degrees. This paper will examine some of the common features of these contractions and examine the ability of standard, but modern business cycle theory to quantitatively capture these features.

The purpose of the paper is to "account" for the East Asian crisis using a quantitative model whose principles are drawn from the sticky-price open-economy macroeconomic (S-POEM) literature. We wish to assess how much of the quantitative macroeconomic impact of the shock in three East Asian economies among those severely affected by the crisis (Korea, Malaysia and Thailand) that we can explain with an S-POEM model calibrated to data from the same countries. The key feature of our paper is the manner in which we *account* for the crisis. We assume that the driving force in this crisis was a single shock, an exogenous rise in the external country premium on foreign lending into a small open economy. Since the defining characteristic of the Asian crisis was a large and sudden collapse in capital flows from the world economy to each of the individual economies, this represents a natural way to identify the crisis 'shock'. 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 for all three countries. We set the rise in the country risk premium in our model to exactly match the rise in the country risk premium observed in international bond market indices. We also quantify the monetary policy response of the expected countries by matching the response of domestic nominal interest rates.

In S-POEM models (see Lane, 2001, for a literature review), an equilibrium includes the optimal decision rules of forward looking agents with rational expectations. Prices converge only over time to market clearing levels due to menu costs. Some of the effects of a rise in the external interest rate on a sticky price small open economy model are clear. A rise in the intertemporal price of goods causes households to delay consumption and firms to delay investment spending. However, the effect on production is less clear. In the tradition of the Mundell-Fleming analysis, a rise in external interest rates will lead to an exchange rate depreciation. Given sticky prices in the domestic currency, the nominal devaluation reduces the relative prices of exports, leading to an increase in real demand for domestic goods. This expenditure switching is embedded much of the new S-POEM literature following Obstfeld & Rogoff (1995). Betts and Devereux (1996, 2000) introduce local currency pricing into this literature. In the LCP models, prices are pre-set in foreign currencies. Thus, in the short-run, exchange rate depreciations have no expenditure switching effects. In this model, we adopt a combination of the two models which we refer to as Dollar Currency pricing. What this means is that both domestic and foreign agents set prices in the foreign currency. Thus, an exchange rate devaluation does not increase demand for exports. However, the devaluation does increase the real price of imports reducing demand for imports and improving the trade balance. This model of pricing does a good job in matching the immediate response of export and import prices to the currency devaluations observed in East Asia.

The response of output to a given shock will depend on the stance of monetary policy. Many papers in the S-POEM literature represent monetary policy through some interest-targeting rule. We follow this practice. However, it is as yet unclear what sort of rule might best represent post-crisis monetary policy. One aspect of post-crisis monetary policy is clear. Inter-bank lending rates rose dramatically during the onset of the crisis. We model the steep rise in nominal interest rates that occur in the periods immediately following the shock as deviations from a long-term Taylor style interest rate rule that targets domestic inflation and output. The deviations are calibrated to exactly match the rise in interest rates that occurred in this period. This monetary stance combined with the real shock to the economy generates a contraction in nominal demand for domestic goods. The result is a large immediate contraction in output.

Another aspect of the data that we are interested in is the sectoral response of output. A textbook response of a small open economy to an external interest rate shock is a switch in production from the production of non-traded goods for domestic use to production of traded goods needed to repay foreign debts (see for example Sachs and Larrain, 1993). However, this does not match the sectoral response observed in the data. In the data we see a sharp drop in production in traded goods sectors along with a more persistent drop in non-traded goods production. We conjecture that imported intermediate materials are an important factor in the production of traded goods. 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 can result in a drop in output of traded goods.

The mid-to-late 1990's were a period of frequent financial crises in emerging markets. A large number of papers have offered theoretical models to explain these events. Explanations might be divided into two broad categories: internal and external. Internal crisis papers explain the crisis as the result of either policy failings or 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. Since we match the crisis shock from observed country risk spreads on US dollar bonds, the shock in our model is exogenous. In this sense the shock may be consistent with either an internal or external ultimate source. The only maintained hypotheses that are built into our approach are that, whatever the ultimate source of the crisis, the crisis itself may be identified from observed risk-spreads, and secondly, that the macroeconomic propagation of the crisis may be reasonably described using a sticky price multi-sector dynamic open economy model.

A number of theories have explained the crisis as the outcome of policy errors or market failures internal to the affected countries. In a series of papers, Chang and Velasco (1998, 2000a & b, 2001) implicate bank runs caused by a maturity mismatch in the domestic banking sector as the source of the crisis. Chang and Velasco (2000a) pointed out the inherent conflict between a central banks role in maintaining a fixed exchange rate and maintaining domestic financial stability. Another school of thought has argued that implicit government loan guarantees led to capital mis-allocation and the onset of a currency crisis. Dooley (2000) warned that implicit loan guarantees of private sector debt in East Asia might lead to a currency crisis if those guarantees were called and the resulting debts monetized. Krugman (1998a) is an influential early paper calling attention to crony capitalism that characterized some East Asian economy. Burnside, Eichenbaum and Rebelo (2001) 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. Corsetti, Pesenti, and Roubini (1999) argue that government loan guarantees would lead to over-investment; when a crisis caused guarantees to be removed, the resulting dis-investment would result in a real contraction.

Yet another school stresses the state of balance sheets of East Asian debtors. Many private East Asian debtors faced a mismatch in the currency denomination of their assets and liabilities. Aghion, Bachetta, and Bannerjee (2000, 2001) describe a multiple-equilibrium model in which domestic firms have sticky prices in domestic currency but assets denominated in foreign currency. In their economy, self-fulfilling expectations of a currency depreciation damage firm balance sheets, ultimately reduce domestic money demand (which supports currency depreciation as an equilibrium outcome). Krugman (1998b) is an early, influential paper explaining the channels through which a currency mismatch might lead to a crisis. A wide variety of papers embed the financial accelerator model of Carlstrom and Fuerst (1997) and Bernanke, Gertler, and Gilchrist (2000) into economies with firms with foreign currency debt to study monetary policy models. Burstein, Eichenbaum, and Rebelo (2002) synthesize the crony-capitalism literature with the currency mismatch literature by constructing a model in which government debt guarantees cause banks to ignore cheap opportunities to hedge their debt.

Other papers argue that the source of the crisis lay more with flaws in international financial markets. Some of this literature concentrated on constructing microeconomic theories for this breakdown. Calvo and Mendoza (2000) construct a model in which externalities in information gathering lead to multiple equilibria. Cook and Devereux (2000) construct a model in which short-term lending to emerging markets is subject to bank-run style financial panics. Calvo and Reinhart (1999) construct a tractable framework for examining the impact of breakdowns of capital flows to emerging markets which is referred to as a Sudden Stop. A Sudden Stop is the exogenous and random imposition of collateral constraints on lending to emerging markets whose net debt exceeds current collateral. Arrellano and Mendoza (2002) examine the qualitative and quantitative effects of some refinements of the Sudden Stops literature. Christiano, Gustav, and Roldos (2002) examine monetary policy responses to a Sudden Stop in a model in which portfolio adjustment rigidities lead monetary policy changes to have real effects.

A few papers have studied the quantitative impact of interest rate shocks. Mendoza (2001) studies the business cycle effects of sudden capital stocks in a quantitative business cycle model. McKibbin (1998) studies the effect of an interest rate shock on a multi-country model at annual frequencies. Neumayer and Perri (2001) study 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.

The rest of the paper is organized as follows. Section II documents the key macroeconomic facts of the East Asian crisis in Korea, Malaysia, and Thailand. Section III sets out a two sector sticky price model of a small open economy. Section IV explains how we calibrate the model. Section V presents the results. Section VI offers some conclusions.

II. The East Asian Crisis

This section documents the real response of some emerging East Asian economies to the East Asian crisis. We outline the sectoral price and quantity responses of production and expenditure. Figure 1, Column A graphs the month by month movements in the US dollar exchange rate in Korea (the won), Malaysia (the ringit), and Thailand (the baht) over 1997 through 2002. During the early 1990s through early 1997, each of these countries currencies maintained tight stability against the US dollar. Each of these graphs shows a similar pattern. In the 3rd quarter of 1998 the currencies experienced a large depreciation. In the initial months, there was a large brief overshooting. After several months, the currencies settle down at a level between 30 and 40% weaker than previous levels. The timing of the depreciations is somewhat varying across countries. The Thai baht began depreciating at the outset of the 3rd quarter, while the Malay ringit and Korean won do not begin to depreciate until late in the 3rd quarter. Column B of the same figure shows the response of the country risk premium for each of these economies. Since early 1997, HSBC has calculated yields on an index of US dollar bonds issued in each of a number of Asian emerging markets. We calculate the country-risk premium as the spread between these yields and contemporaneous yields on 3-month US Treasury bills. In early 1997, the observed spreads were relatively moderate between 100 and 200 annualized basis points in each of the three countries. During late 1997, spreads rise dramatically in Korea and Thailand approaching levels near 800 basis points in the former and 600 basis points in the latter. In both countries, risk premia reach a peak in late 1998. In Malaysia, country risk premium also begin to rise in late 1997, however the rise is more moderate, reaching a maximum of about 400 basis points. However, in late 1998, Malaysia also experiences a sudden rise in the risk premium reaching more than 1200 basis points. After reaching these peaks, the risk premium began to fall in all countries. However, in all countries the risk premia remain significantly above pre-crisis levels even 5 years later. At the time of writing, risk premia range between nearly 300 basis points in Korea to above 500 basis points in Thailand.

We use the clear timing of the event to identify the East Asian crisis. Essentially, we assume that a major shock occurred in the 3rd quarter of 1997 and that shock was the main driving force explaining the dynamics in the following years. Of course, the countries were subject to standard business cycle shocks. But the unprecedented size of the crisis makes it possible to trace out its impact even in the presence of background noise.

We examine the impact on the macroeconomic aggregates of the economy. We first detrend all variables except the exchange and interest rates with a log linear-quadratic trend. In many cases, real variables were substantially above trend in mid 1997. We estimate AR(1) processes for each of the detrended variables. Figures 2-4 show the difference between the actual realizations of the series and their outcomes if they had reverted geometrically back to trend after the 3rd quarter of 1997. We report results from seasonally adjusted quarterly national income accounts. The real variables examined 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 examined are the deflators of domestic absorption, exports, imports, traded goods and non-traded goods.

We also show the response of the nominal and real exchange rate with the United States (using absorption deflators as relative prices) and nominal interest rates. To assess the response of the nominal exchange rate, we examine deviations from the mean exchange rate in the first half of 1997. Our measure of the nominal interest rate is the short-term inter-bank lending rate. To assess the response of the nominal interest rate, we examine deviations from the mean interest rate in the first half of 1997.

All of the countries share some common features. Each of the countries experienced a sharp real contraction in both production and absorption of goods. The real decline begins at the end of 1997 in all countries. In all countries, the decline in GDP reaches a trough of more than 10% below the pre-shock path. In Korea and Malaysia, the economy recovers back to the long-term path by early 2000. The recovery in Thailand is slightly slower, recovering later in 2001. On the demand side, the contraction in demand occurs in both personal consumption expenditure and gross fixed capital formation. In Thailand, the contraction in consumption is of approximately the same size as GDP. In Korea and Malaysia, the contraction in consumption is slightly more severe than the contraction in GDP, reaching a trough more than 15% below GDP. In all of the economies, the sharpest contraction occurs in fixed investment. At a trough, investment falls 25% below the previous path in Korea. In Thailand and Malaysia, investment falls by more than 50% below the previous path

In all three countries, the contraction occurs in both the traded and non-traded goods sector and is of approximately the same size in the two sectors. The recovery is much sharper in the traded sector and the contraction much more persistent in the non-traded sector. The contraction in absorption is much sharper than the contraction in output. In each of the countries, there is a sharp decline in imports on the order of 30% below the previous path. By comparison, there is no obvious immediate impact of the crisis on exports. Two years after the crisis, however, there is a large surge in exports in each country, rising 8-12% above the previous path of exports.

The behavior of nominal prices in these economies also shows some interesting patterns. In each of these economies, the domestic currency prices of both exports and imports rise contemporaneously with the exchange rate depreciation. The price shock in these categories is of comparable size with the exchange rate depreciation. Over time, though, the price rapidly converges back to the long-term level. In each country, there is a much smaller rise in the absorption deflator (perhaps reflecting the rise in the price of imports). In each country, there is a rise in the price of traded goods (perhaps reflecting the rise in domestic currency export prices). In each case, all of these price spikes converge back with export and import prices. In Thailand, there is a mild rise in non-traded prices in the immediate aftermath of the shock. Contemporaneous changes in the non-traded price level are minimal in Korea and Malaysia.

As noted, each of these economies experienced a sharp exchange rate depreciation in mid-1997. The size of these depreciations are large with the won and baht depreciating by more than 60% and the ringit depreciating by more than 40%. There is some overshooting in each country with the currencies finding a persistent level somewhere near 40% of the original value. Malaysia adopted a peg in late 1998, while Korea and Thailand float their currency. The persistent nominal depreciation translates into a prominent real exchange rate depreciation. In each case, crisis era inflation is higher in the affected economies than the US, so the real exchange rate depreciates by less than the nominal exchange rate. However, the price rise experienced in the economies is not as large as the exchange rate depreciation, so the real exchange rate depreciations are substantial. In each economy, the real exchange rate initially depreciates by 30-40% in late 1997. The real exchange rate depreciation appears quite persistent. In both Malaysia and Thailand, the real exchange rate remains more than 20% above the pre-crisis path. The rapid disinflation that has occurred in Korea has led to a real exchange rate that is currently 50% above the pre-crisis path.

Each of the economies also displays a similar pattern for the nominal interest rate. In each case, 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.

III. The Model

We model a small open economy that produces a range of non-traded and traded goods. The traded goods are imperfect substitutes for foreign produced traded goods. Residents of the country can borrow or lend externally in terms of a non-state-contingent bond, but international lenders apply a country-specific risk premium to loans given to the country. Within the country, there is a representative agent.

A. The Representative Agent

The representative worker-saver is infinitely lived and has rational expectations. In any period, the agent derives utility from consumption, C_t, and disutility from labor, H_t. The agent's subjective discount function is a declining function of the agent's consumption level.

$$V_t = \max_{C,H}[\log(C_t) - \Gamma H_t] + \beta(C_t)E_t[V_{t+1}]$$

The discount function is a concave function of the current level of consumption with enough curvature to ensure a stationary level of wealth, so that β' < 0 and β''> 0. The consumer accumulates foreign currency debt, D_t, with gross nominal interest rate $1+r_t$. The agent separately accumulates capital that is specific to the traded goods industry K_t^T, and the non-traded goods industry K_t^N. This capital is rented in competitive markets to domestic firms at rate R^T and R^N. The agent supplies labor in competitive markets at wage rate W, and receives profits from the traded and non-traded industries and exporters, so that total profits are $\Pi = \Pi^T + \Pi^N + \Pi^{EX}$. Then the agents purchase goods to allocate to consumption and investment in the traded and non-traded sectors, I^T and I^N. In addition, taxes are paid which finance government spending, G. Since all these activities are produced in the same way, they all have the same price, which we represent by the price index, P. The agent's flow budget constraint is (where S is the spot exchange).

$$S_t D_t = (1+r_{t-1})S_t D_{t-1} + P_t\left[C_t + I_t^T + I_t^N + G_t\right] - \left(W_t H_t + R_t^T K_t^T + R_t^N K_t^N + \Pi_t\right)$$

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 a combined into a quantity of traded goods absorbed, X^T. The price index is the cost-minimizing marginal cost of acquiring these goods

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

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

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 index of domestic traded and non-traded goods are P^T and P^N.

$$X_t^N = \left[\int_o^1 \left\{ x_{t,i}^N \right\}^{\xi} di \right]^{\frac{1}{\xi}} \qquad P_t^N = \left[\int_o^1 \left\{ p_{t,i}^N \right\}^{\frac{1}{1-\xi}} di \right]^{1-\xi}$$

$$X_t^{Td} = \left[\int_o^1 \left\{ x_{t,i}^{Td} \right\}^{\xi} di \right]^{\frac{1}{\xi}} \qquad P_t^{Td} = \left[\int_o^1 \left\{ p_{t,i}^{Td} \right\}^{\frac{1}{1-\xi}} di \right]^{1-\xi}$$

The price index of imported goods is $S \times P^{T*}$ where S is the spot exchange rate. The price of the cost minimizing combination of domestic traded goods and imports is P^T.

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

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

$$K_{t+1}^N = (1-\delta)K_t^N + I_t^N - \tfrac{e}{2}(\frac{I_t^N}{K_t^N} - \delta)^2 K_t^N$$

The first order conditions that characterize the optimal plans are:

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

$$\frac{B}{T - H_t} = W_t \Omega_t$$

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

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

$$P_t (1-a)^{\phi-1} \left\{ X_t^T \right\}^{\phi-1} \left\{ X_t \right\}^{1-\phi} = P_t^T$$

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

$$P_t^T (1-b)^{\mu-1} \left\{ X_t^{Tm} \right\}^{\mu-1} \left\{ X_t^T \right\}^{1-\mu} = S_t \times P_t^{*T}$$

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

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

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

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

B. Production

1. Traded Goods

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

$$Y_t^T = A^1\left[d^{\gamma-1}\left\{V_t^T\right\}^{\gamma}+\left(1-d\right)^{\gamma-1}\left\{M_t\right\}^{\gamma}\right]^{\frac{1}{\gamma}} \qquad V_t^T \equiv A^2\left\{K_t^T\right\}^{\theta}\left\{H_t^T\right\}^{1-\theta}$$

where V^T is domestic value added in the traded goods sector. Traded goods manufacturers are price takers in output and input markets. The manufacturers must purchase the imported materials at price P_{t-1}^{T*}, one period in advance. They borrow the foreign currency needed to purchase these funds at rate r_{t-1} and repay this at production. They sell their goods to retailers and exports at PPI^T and maximize profits.

$$PPI_t^TY_t^T - W_tH_t - R_t^TK_t^T-(1+r_{t-1})S_tP_{t-1}^{T*}M_t$$

The first order conditions describing the profit maximizing plans are:

$$PPI_t^T(1-\theta)\frac{V_t^T}{H_t^T}d^{\gamma-1}\left\{\frac{V_t^T}{Y_t^T}\right\}^{\gamma-1}=W_t$$

$$PPI_t^T\theta\frac{V_t^T}{K_t^T}d^{\gamma-1}\left\{\frac{V_t^T}{Y_t^T}\right\}^{\gamma-1}=R_t^T \qquad \frac{PPI_t^T}{S_t}(1-d)^{\gamma-1}\left\{\frac{M_t}{Y_t^T}\right\}^{\gamma-1}=(1+r_{t-1})P_{t-1}^{T*}$$

2. Non-Traded Goods

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

$$Y_t^N = \left\{K_t^N\right\}^{\theta}\left\{H_t^N\right\}^{1-\theta}$$

The first order conditions of the firms profit maximization problem are

$$PPI_t^N(1-\theta)\frac{V_t^N}{H_t^N}=W_t \qquad PPI_t^N\theta\frac{V_t^N}{K_t^N}=R_t^N$$

C. Exports

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

$$EX_t^T = \left[\int_o^1 \left\{ex_{t,i}^T\right\}^{\xi} di\right]^{\frac{1}{\xi}} \qquad P_t^{\$T} = \left[\int_o^1 \left\{p_{t,i}^{\$T}\right\}^{\frac{1}{1-\xi}} di\right]^{1-\xi}, \quad 0<\xi<1$$

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

$$CPI_t^{*T}(1-b^*)^{\mu-1}\left\{EX_t^T\right\}^{\mu-1}\left\{A_t^{*T}\right\}^{1-\mu} = P_t^{\$T} \qquad \frac{p_{t,i}^{\$T}}{P_t^{\$T}} = \left(\frac{ex_{t,i}^T}{EX_t^T}\right)^{\xi-1}$$

D. Sticky Prices

In this model, there are 3 types of sticky prices: nominal prices of domestic traded goods, nominal prices of non-traded goods, and nominal prices of exported goods. For each of these prices, there is a range of monopolistically competitive price setters who purchase an undifferentiated input good at a scale invariant marginal cost, MC_t, and face a demand curve with constant elasticity ξ. In each period, a random fraction 0¡(1-κ)¡1 of price setters get a chance to adjust prices as in Calvo (1983) and Yun (1996). The price-setting mechanism can be described as follows. Say that the price index is $\tilde{P}_t$ and the individual firm□s price is $\tilde{p}_t$. Demand facing any firm is

$\left(\frac{\tilde{p}_t}{\tilde{P}_t}\right)^{-\frac{1}{1-\xi}} Q_t$. Then, defining $Z_t \equiv \tilde{P}_t^{\frac{1}{1-\xi}} Q_t$, the price setters maximize the sum of

expected discounted profits over the expected life of the profits.

$$\max_p \sum_{j=t}^{\infty}\left(\prod_{l=t}^{j}\kappa(1+i_l)^{-1}\right)\Pi_j = \max_p \sum_{j=t}^{\infty}\left(\prod_{l=t}^{j}\kappa(1+i_l)^{-1}\right)\Omega_j Z_j\left\{\tilde{p}_t^{\frac{\xi}{\xi-1}} - \tilde{p}_t^{\frac{1}{\xi-1}} MC_j\right\}$$

For a firm that has the opportunity of adjusting its price, it will choose the price $\tilde{p}_t^*$ choice that maximizes expected profits as

$$\tilde{p}_t^* = \frac{\sum_{j=t}^{\infty}\left(\prod_{l=t}^{j}\kappa(1+i_l)^{-1}\right)\Omega_j Z_j MC_j}{\sum_{j=t}^{\infty}\left(\prod_{l=t}^{j}\kappa(1+i_l)^{-1}\right)\Omega_j Z_j MC_j}$$

The price index will then evolve over time

$$\tilde{P}_t^{\xi-1} = \kappa \tilde{P}_{t-1}^{\xi-1} + (1-\kappa)\,\tilde{p}_t^{*\xi-1}$$

Following Rotemberg and Woodford (1997), any shocks occur after the price setters have chosen their prices. Thus, the level of the price index is quasi-fixed in any period.

Each of the price setters in the three areas follows this pattern. A unit measure of non-traded (traded) retailers purchases undifferentiated goods in the non-traded (traded) sector and sells 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 costs PPI^T, and sell at price p^T (domestic traded goods retailers) or $Sp^{\$T}$ (export retailers). See Table 1 for an exact analog between the particular price setter and the basic sticky price framework.

Table 1. Sticky Price Framework

Sticky Price	Non-Traded Prices P_t^N	Domestic Traded Prices P_t^T	Export Prices $P_t^{\$T}$
Firm Level Price (p_t)	$p_{i,t}^{NT}$	$p_{i,t}^{T}$	$p_{i,t}^{\$T}$
Marginal Cost (MC_t)	PPI_t^N	PPI_t^T	$\frac{PPI_t^T}{S_t}$
Demand (Z_t)	$\{P_t^N\}^{\frac{1}{1-\xi}} A_t^N$	$\{P_t^T\}^{\frac{1}{1-\xi}} DOM_t$	$\{P_t^{\$T}\}^{\frac{1}{1-\xi}} EX_t$
Aggregate Profits (Π_t)	Π_t^N	Π_t^T	Π_t^{EX}

E. Monetary Policy

Define real GDP as the sum of the value added in the traded and non-traded sectors. The former is measured as the sales to domestic consumers, plus the sales to foreigners, less the cost of material imports. Real GDP is then implicitly defined as

$$P_t GDP_t = P_t^{Td} X_t^{Td} + S_t P_t^{\$T} EX_t - (1+r_{t-1}) S_t P_{t-1}^{*T} M_t + P_t^N Y_t^{NT}$$

The monetary policy rule has two components. The central bank determines a long term nominal growth rate which implies a long-term nominal interest rate, $\bar{i}$, and CPI inflation rate, $\bar{\pi}$. The authorities also set short-term interest rates to respond to fluctuations in inflation and GDP from their stationary steady states.

$$i_t - \bar{i} = \rho_\pi \left(\frac{P_t}{P_{t-1}} - \bar{\pi} \right) + \rho_Y \left(GDP_t - \overline{GDP} \right) + \varepsilon_t$$

where ε_t is a stationary function that allows the monetary authority to target interest rates for a finite time period in response to shocks.

F. Equilibrium

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: $C(\Xi_t)$, $I^T(\Xi_t)$, $I^N(\Xi_t)$, $X(\Xi_t)$, $X^T(\Xi_t)$, $X^N(\Xi_t)$, $X^{Td}(\Xi_t)$, $EX(\Xi_t)$, $IM(\Xi_t)$, $Y^T(\Xi_t)$, $Y^N(\Xi_t)$, $V(\Xi_t)$, $M((\Xi_t)$, $H(\Xi_t)$, $H^T(\Xi_t)$, $H^N(\Xi_t)$, $D(\Xi_t)$, $K^T(\Xi_t)$, $K^N(\Xi_t)$, $w^T(\Xi_t)$, $w^N(\Xi_t)$, $p^T(\Xi_t)$, $p^N(\Xi_t)$, $p^{\$T}(\Xi_t)$; and price functions: $CPI(\Xi_t)$, $CPI^T(\Xi_t)$, $W(\Xi_t)$, $R^T(\Xi_t)$, $R^N(\Xi_t)$, $PPI^T(\Xi_t)$, $PPI^N(\Xi_t)$, $S(\Xi_t)$, $i(\Xi_t)$; which solve the first order conditions of the agents optimizations problems and labor and goods markets clear:

$$H_t^T + H_t^{NT} = H_t \qquad \int_0^1 x_{t,i}\,di + \int_0^1 ex_{t,i}^T\,di = Y_t^T \quad \int_0^1 x_{t,i}^{NT}\,di = X_t^N$$

G. The Shock

We study the response of the economy to a single shock that occurs at time zero. The single shock generates a dynamic path for both the country risk premium, $\{r_t\}_{t=0}^T$, and monetary policy, $\{\varepsilon_t\}_{t=0}^L$. The shock generates deviations from steady state for the country risk premium through finite time period T and deviations from zero for the monetary policy shocks through time period L.

IV. Calibration

Lacking a closed form solution, we log-linearize and solve the approximate linear model using the solution algorithm in King and Watson (1995). The numerical solution requires the calibration of the parameters of the model. We simulate three cases based on numbers drawn from Korea, Malaysia, and Thailand respectively. Many of the aspects of the model are standard in the international real business cycle literature. As such, some parameters will be drawn from this literature and will not vary across cases. The depreciation rate of capital is set at δ=.025 and the capital adjustment cost is set so the steady-state elasticity of the investment capital ratio with respect to marginal Tobin's q $(e\delta)^{-1}$ = 15 as in Baxter and Crucini (1993). The size of steady state markups is determined by ξ. We calibrate the economy near the case where steady-state profits are arbitrarily near zero. We calibrate the frequency of price changes, κ=.75, so that prices change on average, once per year.

The elasticity of substitution between materials and value added is set at .7 following Rotemberg and Woodford (1996).

The elasticity of substitution between various goods must be calibrated. A range of estimates are available in the literature. The central mechanism behind the model is the rise in the external interest rate (or risk-premium). A rise in the external interest rate reduces the equilibrium level of domestic consumption and investment. If foreign goods are perfect substitutes for domestic goods, there is no reason for a drop in domestic demand to translate into a drop in demand for domestic goods. The experience during the East Asian crisis was a simultaneous drop in output and absorption in both countries. Thus, we begin with a bias toward assuming that foreign goods are poor substitutes for domestic goods (within a reasonable range). The elasticity of substitution between domestic production and imports is set at 0.6, which is an average of the estimates from Asia, reported in Reinhart (1995). Kollmann (2001) uses the same figure for a model of developed economies. We draw the non-traded-traded elasticity of .66 from a GMM estimate using pooled data from 5 Asian countries in Ostry and Reinhart (1992).

Table 2 Parameter Estimates

	Korea	Malaysia	Thailand
Exports as a % of GDP	.328	.728	.308
Imported Materials as a % of Inputs	.583	.689	.273
Non-Traded Goods as a % of GDP	.597	.512	.578
External Debt as a % of GDP	.88	1.78	1.41
Government Consumption as a share of GDP	.104	.123	.112
Traded Capital Intensity	.307	0.350	.307
Non-Traded Capital Intensity	.306	.296	.234

We will examine a case calibrated according to each of the three countries. We calibrate the production structure and openness of each case according to great ratio averages over the time period 1980-1996 in Korea and Thailand and 1987-1996 for Malaysia. Exports as a share of GDP are reported in the first row of Table 2. The share of imports that is intermediate materials is reported in the second row. We calibrate b and d in each case to match these shares. Non-traded goods as a share of GDP in Korea, Malaysia, and Thailand are reported in the third row of Table 2. We calibrate a in each case to match these shares. Lane and Milesi-Feretti (2001) construct data on the net international investment positions of various national economies. The fourth row of Table 2 shows the time averages on these net external assets positions as a share of GDP. The fifth row shows government spending as a share of GDP. We calibrate the steady state government consumption-GDP ratio to match this number.

Sarel (1997) provides cross-country estimates of the average capital intensity of various 1 digit ISIC code industries. We use these estimates to calibrate the capital intensities in the traded and non-traded sector respectively. For each year for each of the three countries, we calculate a weighted average of the capital intensities of those sectors which are classified as traded (Agriculture, Manufacturing, and Mining). The weights are the share of the 1 digit industry in total value added in the traded sector. We then average the yearly estimates across the period 1990-1996 to calculate an average traded goods capital intensity. We repeat the process for the remaining 1 digit sectors which are classified as non-traded. The capital intensity parameters are reported in Table 2, row 6 and 7.

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 1. We calibrate the subjective discount rate function so that at the steady state external interest rate, the steady state debt as a share of GDP matches these levels.

We calibrate the shock by examining actual outcomes in financial markets. Beginning in 1997, HSBC constructs yield indices for US dollar bonds issued by debtors in each of Korea, Malaysia, and Thailand. The quarter-by-quarter spreads between these yields and US treasury bills will represent the external borrowing premium, abstracted from currency risk. We set the stationary interest rate equal to the average interest experienced in the periods of the series prior to the 3rd quarter of 1997 and the steady state risk premium as the difference between the HSBC index and US Treasury bill yields during this period. The modeled shock, which represents a crisis, will generate a path for the country-risk premium. For 19 periods, this path will follow the observed spread between the HSBC index and the 1-year US Treasury rate country risk premium for the period 1997:4 to 2002:2. For the periods t = 20…80, the country risk premium follows the average over the initial 5 years of the shock. Subsequent to that period, the country-risk premium reverts to zero. Figure 1, Column B shows the dynamic path of the country risk premium for the three countries.

The response of monetary policy to the shock will be an important determinant of the response of nominal variables and, given nominal rigidities, the response of real variables. Here, monetary policy is entirely described by the setting of the nominal interest rate. In the immediate aftermath of the Asian crisis, all three of the affected countries experienced high short-term nominal interest rates. Figure 1, Column C shows the path of domestic currency short-term inter-bank lending rates. Following the crisis the monetary policies of the countries diverged, with Korea and Thailand adopting some form of inflation targeting and Malaysia adopting an exchange peg with the US dollar. However, we take the position that the long-term monetary policy was difficult to predict, following the large exchange rate devaluations. As a default, we assume that policy converges to the basic rule described by Taylor (1996) as describing the monetary policy of the US , $\rho_\pi = 1.5$, and $\rho_Y = .5$. In the short-run, we set monetary policy so that the rise in nominal interest rates in the model exactly matches the rise in interest rates observed in the data. In the data, we identify the rise in the nominal interest rate as the difference between the actual interest rate and the average interest rate observed in the first half of 1997. We set $\{\varepsilon_t\}_{t=0}^{L=2}$ so that the modeled rise in the interest rate above steady state level matches the rise in interest rate observed.

V. Impulse Responses

An advantage in examining the East Asian crisis is that the singular, unpredicted nature of the event makes it possible to identify the macroeconomic effects. However, the same singular nature makes it more difficult to use standard statistical analysis to formally test the model. Our main analysis will consist of visually and numerically comparing the impulse responses of an external risk premium shock to the actual paths of output and other variables. We examine three different cases each corresponding with Korea, Malaysia or Thailand. Each model economy differs along three dimensions; the calibrated parameters, the pattern of the risk premium shock, and the monetary policy response. We will compare the impulse responses both among the models and with the data. The responses of 15 variables are reported in

Table 5-7. Each of these variables is the counterpart of the 15 variables reported in Table 2-4.

A. Qualitative Outcome

Here we briefly summarize the qualitative effects of the shock. The rise in the country risk premium will raise the cost of repaying 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 will 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 requires a depreciation in the nominal exchange rate followed by a persistent expected appreciation. Since there is 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 in decline in demand. Domestic goods, however, are relatively imperfect substitutes for foreign goods, so changes in the relative price generate small substitution effects, leading to a big fall in demand for domestic goods. Because exporters practice local currency pricing, the exchange rate depreciation does not immediately increase exports. Only over time, as exporters lower their prices to reflect the weakening exchange rate, do exports increase.

The impact of the risk premium shock on real variables depends on the stance of monetary policy. With a passive or expansionary monetary policy, the authorities could leave domestic nominal interest rates unchanged, or even attempt to reduce interest rates, in response to the risk premium shock. Given the presence of uncovered interest rate parity, this would involve a large immediate real and nominal exchange rate depreciation. The depreciation would lead to a cushioning of the demand effects of the shock on domestic traded and non-traded goods. But a contractionary monetary policy (of the form that actually takes place in our model, given that we match the observed interest rate response in the three countries), involving an increase in domestic interest rates in response to the shock, will mitigate the immediate real exchange rate depreciation, and hence lead to a greater fall in absorption and output in domestic traded and non-traded goods. In this case, the fall in overall output will be greater.

The decline in domestic absorption induced by a rise in the external risk premium can potentially have different effects by 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 domestic traded goods are better substitutes for imported traded goods than are non-traded goods, the nominal depreciation will elicit a bigger substitution response towards domestic traded goods. Thus, we would anticipate a bigger fall in output in the non-traded sector. On the other hand, 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 particular pricing structure that we assume will also generate some results for outcomes of nominal prices. The local currency pricing that we assume for exports imply that, in the short-run, export prices will rise in the domestic currency with the exchange rate devaluation. Since home 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. Since importers pass the full effects of changes in the exchange rate through to domestic prices, the exchange rate depreciation leads to a 1-for-1 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. As a result, the CPI, which is the price of the absorption good, will rise 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.

B. Quantitative Comparison: Model vs. Data

We now present the quantitative comparison between the response of the three models to the observed effects in each country. Figures 5, 6 and 7 illustrate the theoretical impulse responses for 15 macroeconomic series for Korea, Malaysia and Thailand, respectively. The benchmark responses are represented by the solid line with stars.

With respect to the response of quantities, the findings of the model are quite close to the data, both qualitatively and quantitatively. In each of the economies, GDP contracts sharply in the period of the shock, converges back to mean in subsequent periods, before ultimately achieving a level slightly higher than the initial steady state. Quantitatively, the trough of GDP is comparable with that observed in the data. In the sample data, GDP for all three economies reached a trough approximately 10% below the previous path. In the models calibrated according to Korea, Malaysia and Thailand, GDP reaches a trough of approximately 10% below the steady state. Moreover, comparison of Figures 2,3,4 with 5,6 and 7 indicate that the shape of the response of GDP in the data and the models is quite similar. In both there is a very sharp but transitory fall in GDP (i.e. a V-shaped contraction).

Though the models do match the output impact in size, they do not fully match the persistence of the contractions observed in the data. This is to be expected, given that we are using a relatively parsimonious dynamic general equilibrium specification without other mechanisms for generating endogenous propagation. Nevertheless, because the observed shocks to the risk premium are somewhat persistent, the model does display substantial persistence nonetheless. However, actual output is below the previous path for at least 8 quarters. By contrast, output has substantially reverted back to steady state after 4 quarters in all modeled economies.

The model's response for investment and consumption is also quite close to the data. Panel (B) and (C) show the response of investment and consumption to the shock in the calibrated models. A rise in the external interest rate leads to large contractions in consumption and investment in all models. In the data, in each country, gross fixed capital formation contracted far more sharply than GDP. The models match this qualitative feature. Moreover, we observe that investment fell between 25 to 50 percent in the three economies. The model's investment response varies between 30 and 50 percent. However, the pattern of investment response across countries is slightly counterfactual: the model predicts a higher investment response (50 percent decline) in Korea and Thailand, with a smaller response in Malaysia, while in reality Malaysia and Thailand experienced the largest response (about 50 percent), with Korea having a lower response (25 percent).

Empirically, personal consumption expenditure fell by approximately the size of the contraction in output. In the data, this implies contractions in consumption of more than 14% below steady state. In the model economies, consumption also falls sharply, varying between a fall of 10% in the case of Korea, and approximately 15% percent in the Thailand and Malaysia model. The modeled consumption contractions are quite persistent due to the permanent income effects.

Panels (D) and (E) display the response of exports and imports. In each of the model economies, local currency pricing prevents the exchange rate depreciation from generating any immediate increase in exports. This aspect of the model is in accord with the data. In contrast to what one would anticipate based on standard theory, export growth remained very slow in each of the countries following the very large depreciation. However, over time as export firms adjust their prices, modeled exports increase by between 3% (Korea) and 8% (Thailand). Empirically, in each country, there is a mild increase in exports prior to the weakening of the US business cycle after 2000. On the other hand, each modeled economy faces a sharp decline in imports; following a trough contraction in the first period of the crisis ranging between approximately 15% (in the Korea and Malaysia model) and more than 25%

(in the Thailand), imports converge nearly geometrically back to steady state. In the data, each of the economies faces a sharp contraction in imports early in the crisis period. In each case, the trough contraction is approximately 30% below the previous path. In all cases, imports return to their long run level after approximately 3 years.

The close accord between model and data in the individual response of export and import volume following the crisis seems to be a strong endorsement of the 'dollar-currency pricing' mechanism in our modeling strategy. It allows us to understand the simultaneous observation of weak export response with a large fall in imports purely through substitution and income responses to the crisis, and without recourse to exogenous credit or financial constraints.

Another aspect of the production response to the crisis is the breakdown between the traded and non-traded sector. As we saw in the data, both sectors contracted sharply in the initial periods of the shock, although subsequently traded goods production bounced back more quickly. In all cases, traded goods converge back to the previous path by something on the order of 2 years before non-traded goods production recovers. In the model, the presence of short term price stickiness in the domestic component of traded goods and the slow adjustment of export quantities combine to cause a fall in the output of traded goods in the immediate aftermath of the shock. In the model calibrated to Korea, traded goods production contracts by more than 10% in the period of the shock. In the model calibrated to Malaysia and Thailand, traded goods production contracts between 7-10% in the period of the shock. As in the data, the contraction in traded goods production more transitory than that in non-traded goods. By the third period of the crisis, traded goods production is slightly above steady state in each case, and expands in subsequent periods both because exporters are able to reduce foreign currency prices of exports in those periods and traded goods producers are able to substitute cheaper imported materials for domestic value added.

So far we have seen that the model does quite a good job in terms of matching the movements in quantities following the risk premium shock. How does it do with regard to prices? Qualitatively, the model generates a large and persistent depreciation in the nominal exchange rate. Quantitatively, however, the exchange rate depreciation is in the range of between 10 and 20%. Compare this with persistent depreciations of at least 40% observed in the data. Moreover, the data describes none of the overshooting of the exchange rate seen in the data. This relatively small impact of the shock on exchange rate arises because, in the model, we have matched the monetary policy response with that seen in the countries. If monetary policy was entirely passive, keeping nominal interest rates unchanged following the shock, the nominal exchange rate depreciation would be much larger. We return to this question in the discussion below.

In the model, the dynamic response of the imports deflator to the shock is equal to the response of the nominal exchange rate. In each of the country models, the import price level immediately rises in the period of the shock. This rise is small relative to the data (just as the exchange rate depreciation is small relative to the data). Qualitatively, the import price rise is persistent in the model (as are exchange rates). In the data, in each case, import prices converge back to the previous path as if foreign producers were cutting their foreign currency prices. In the model, the rise in export prices in the period of the shock exactly matches the exchange rate depreciation. Over time, the foreign currency price of export goods is adjusted downward. The data also follows this pattern. However, the initial rise of the export price in the model is substantially smaller than that in the data (just as the exchange rate rise is smaller in the model than in the data).

In the model, the rise in import prices results in a small rise in the overall price index. Quantitatively, this ranges between .5% (in the model calibrated to Korea) and 5% (in the model calibrated to Thailand). Over time, in each case, prices converge back to the initial steady state as domestic prices fall. On this count, our model seems to match the data quite closely. However, the empirical price level seems to be subject to large, high frequency movements making delineating the effects of the shock somewhat difficult. The peak rise in the price level seems to range between 6-8%, but the noise in the data makes comparison with the model somewhat difficult. In the model, traded goods prices rise initially, as part of traded goods is used for exports. Over time, traded prices fall as domestic prices are reduced. This pattern is reflected in the data. The rise in traded prices ranges between 12 and 16% in the data and between 4 and 12% in the models. This reflects the relatively small exchange rate depreciation in the models.

In the model, the non-traded price level is quasi-fixed. Over time, the decline in nominal demand results in a fall in the price level. The empirical behavior in non-traded prices in Korea seems to match this pattern, both qualitatively and quantitatively. In Thailand and Malaysia, the non-traded price level is subject to high frequency movements, again making the effect of the shock difficult to delineate. In Thailand and Malaysia, the quantitative decline in the non-traded price level is small in the data relative to the model.

By construction, the response of nominal interest rates to the shock in the model exactly matches the response in the data in the first 3 periods of the crisis. In subsequent periods, when monetary policy follows a Taylor rule, the interest rate declines in the model as in the data. The empirical size of the decline in the interest rate in Korea is larger than in the model. The empirical declines in Thailand and Malaysia seem comparable with the outcomes in the model.

A natural question to ask of this model is what would the alternative paths of variables be under alternative monetary policies. The dotted lines in each panel show the path of the variables under a strict Taylor rule with no exogenous rise in interest rates (i.e. $\{\varepsilon_t = 0\}_{t=0}^{\infty}$). In Thailand, which has a relatively high share of imports in final goods and thus a relatively sharp modeled response of inflation to an exchange rate devaluation, the Taylor rule proscribes a sharp immediate rise in the nominal interest rate. Though the rise in the nominal interest rate is less persistent than that observed in the data, of the three countries, Thailand's actual nominal interest rate was closest to that modeled under a Taylor rule. Thus, in Thailand, of the three countries, the modeled results under the actual interest rates are closest to the modeled results under the pure Taylor rule. The contraction in Thailand, in terms of each of the depicted real variables, is slightly milder and noticeably less persistent under a pure Taylor rule than under observed interest rates. The nominal exchange rate depreciates slightly more in Thailand under a Taylor rule response than under observed interest rates. However, this effect is small.

In the model of Korea, the monetary policy response is a mild but persistent cut in the nominal interest rate. In the model of Malaysia the monetary policy response in the first period is a small rise in the interest rate followed by a persistent, but mild cut in nominal interest rates. This more expansionary monetary policy results in a less contractionary response of output in both traded and non-traded goods sectors. The result is a much less sharp and less persistent contraction in GDP and investment. The rise in the external interest rate implies a persistent decline in consumption under each monetary policy. The exchange rate depreciation is sharper under the Taylor rule, especially in Korea. However, this exchange rate depreciation is still much smaller than that observed in the data.

V. Conclusion

Our interpretation of these results is that there is 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 experiencing of these three countries following the East Asia crisis, when we measure the shocks using the observed rise in foreign currency risk premium, calibrate the structural models of these economies to reflect the observed features of these economies, and specify a monetary reaction rule that mirrors the behavior of domestic interest rates in the aftermath of the crisis. 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. In terms of the response of price variables, including the exchange rate, the model□s qualitative implications are in accord with the data, but quantitatively, the response is lower than that actually observed during the East Asian crisis.

The key shortcomings of the model include:

Lack of Persistence of Output The model generates contractions in output in both the traded goods and non-traded goods sector that at trough is comparable in size with the decline observed in the data. However, the output decline in the model is less persistent in the model than the data, especially in the non-traded sector. This lack of persistence has two manifestations. First, the trough of the contraction occurs in the period of the shock in the model but several periods later in the data. Second, production converges back to steady state faster in the model than in the data.

The multi-structural model here lacks many of the mechanisms that might lead to greater propagation in the stochastic growth models. Modeling inter-temporal production relationships (such as the inventories model of Backus, Kehoe and Kydland, 1992) or short-term real demand rigidities (such as the time to plan investment model of Christiano and Todd, 1996, or consumption habit formation as in Boldrin, Christiano and Fischer, 2001) would likely increase the persistence and propagation in the model.

A partial explanation of the failure of the model to generate the same contraction in traded goods as seen in the data may reflect our naïve empirical division of 1 sector SIC code industries into traded and non-traded goods. Many manufacturing industries in East Asia, protected by trade barriers and government subsidies, are produced almost entirely for domestic markets. Cook and Devereux (2001) show that the crisis period contraction in traded goods in Malaysia was concentrated in industries that produced primarily for domestic markets. It might be useful to think of these industries as behaving more like non-traded goods producers than traded goods producers. Accurately splitting the data (at higher levels which are unfortunately too refined for current national income accounts) would likely reconcile model with data to a larger extent.

Exchange Rate Devaluations are too small. The model generates too small an exchange rate depreciation relative to the data despite the construction of exact matches of domestic and foreign interest rates in the periods following the shock. The model embeds an uncovered interest rate parity assumption that has been rejected in the paper and seems to display some shortcomings here. Cook and Devereux (2001) show that external capital portfolio costs (on the lines of those modeled by Sutherland, 1996) can lead to sharper movements in exchange rates. These portfolio adjustment costs may be an important part of the response of exchange rates in the model.

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Figure 1: Financial Market Outcomes

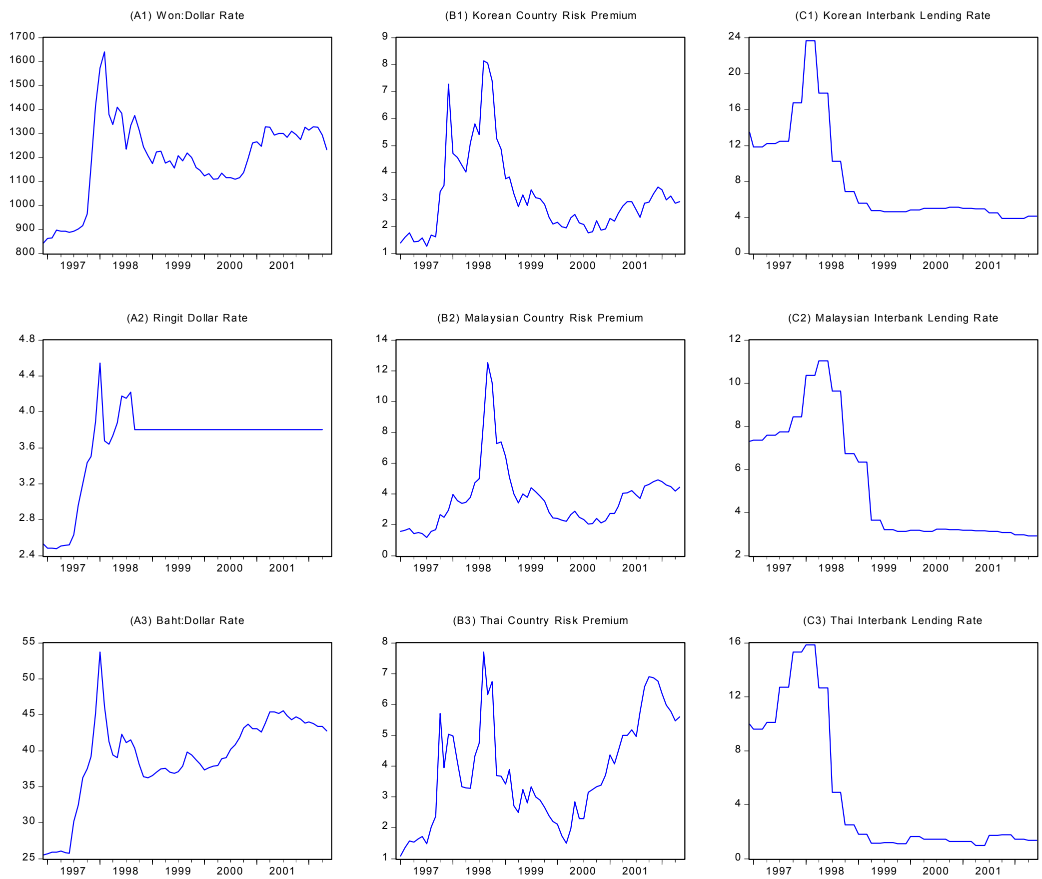

Figure 2: Korea–1997:3/2002

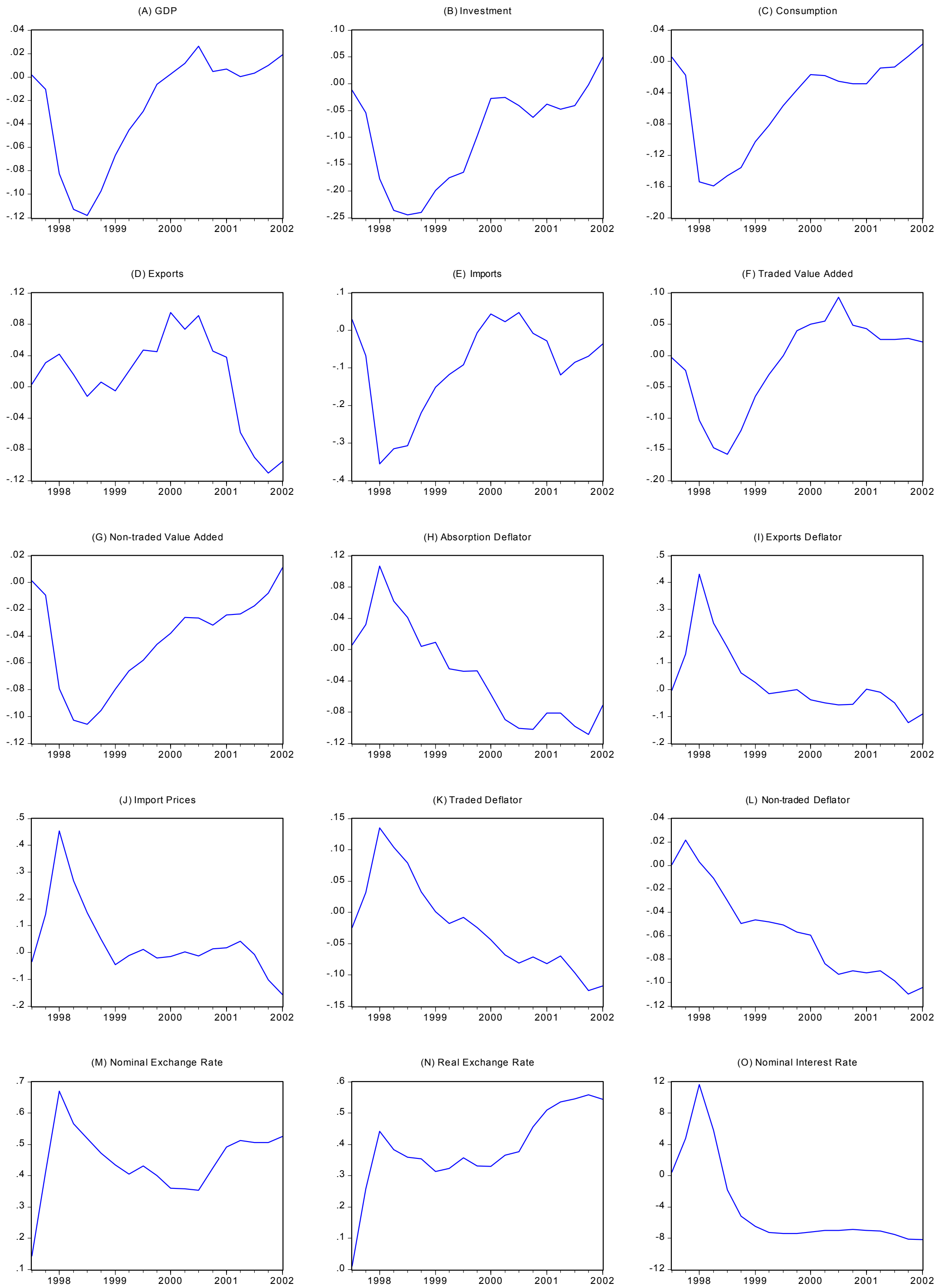

Figure 3: Malaysia 1997:3/2002:2

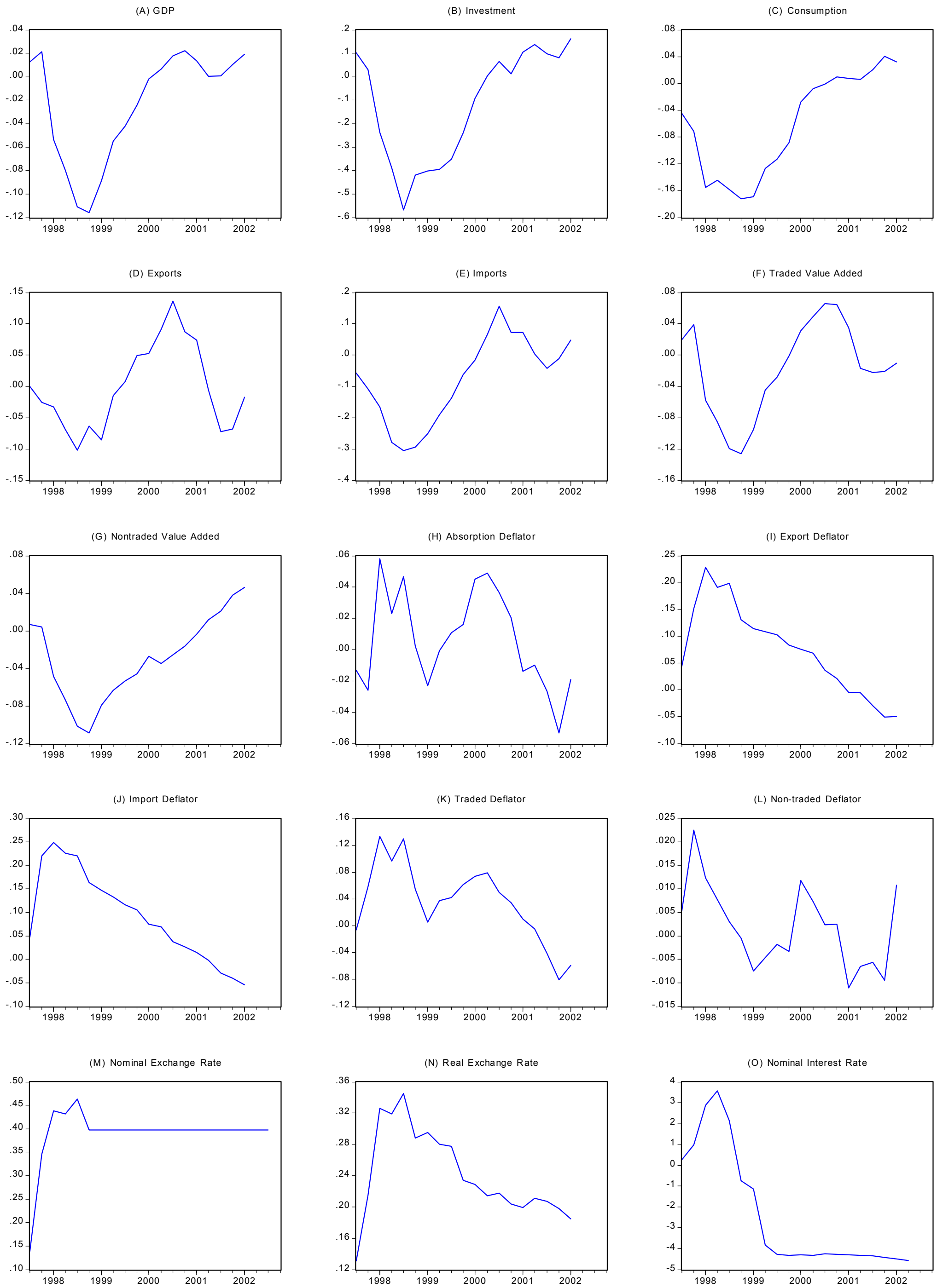

Figure 4: Thailand 1997:3/2002:2

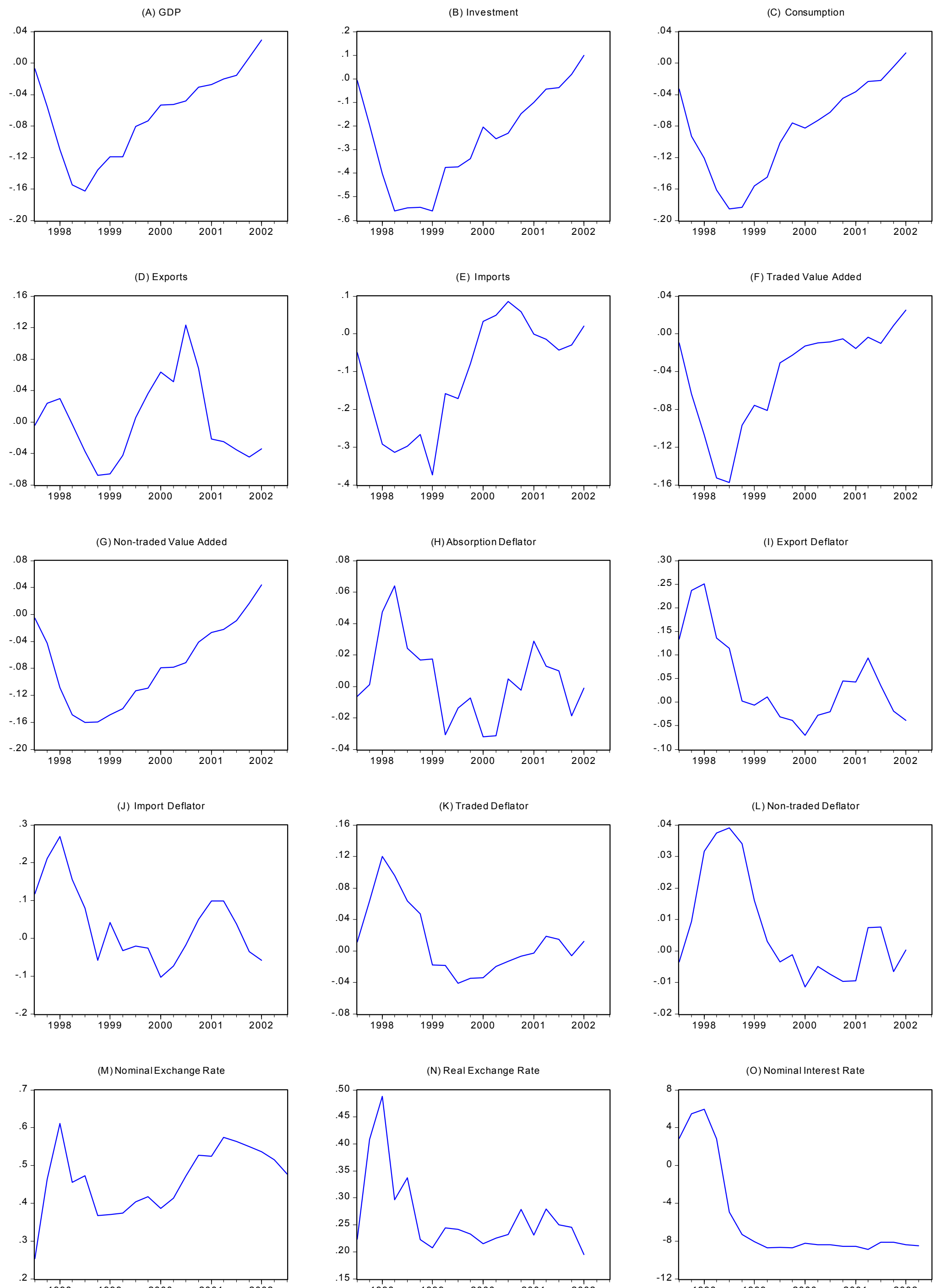

Figure 5: Model Calibrated to Korea

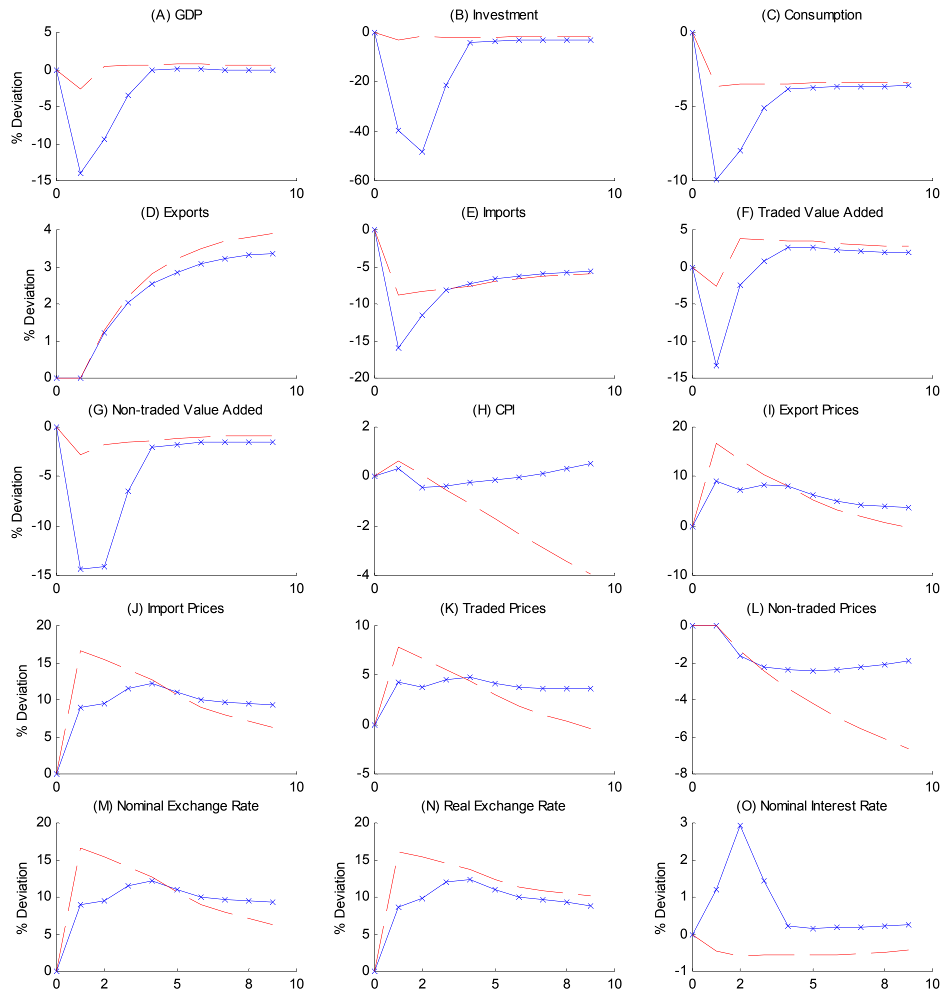

Figure 6: Model Calibrated According to Malaysia

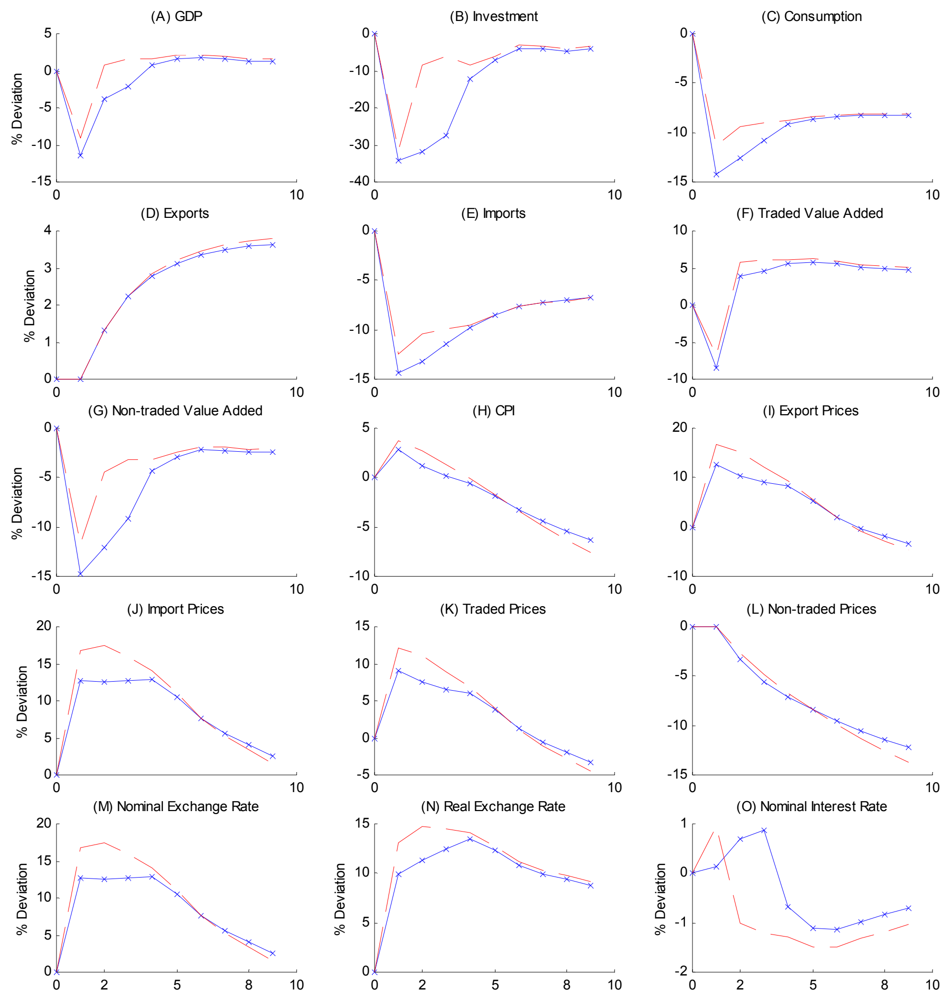

Figure 7: Model Calibrated According to Thailand