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Shock Therapy!

What Role for Thai Monetary Policy?

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Abstract

Thailand had to endure three major shocks during 2008–2011: the global financial crisis, the Japanese earthquake, and the Thai floods of 2011. Over this period, consistent with its inflation targeting framework, the Bank of Thailand (BOT) let the exchange rate depreciate and cut interest rates (to, for example, a historically low level of 1¼ percent by mid-2009). This paper seeks to uncover the role of monetary policy in softening the impact of these shocks. Specifically, it seeks to address the following question: if an inflation targeting framework underpinned by a flexible exchange rate regime had not been in place, how would the economic contractions associated with these shocks have differed? Counterfactual simulations based on an estimated structural model indicate that countercyclical monetary policy and exchange rate flexibility added up to a total of 4 percentage points to real GDP growth during periods when Thailand had to weather these three major shocks.

JEL Classification Numbers: E5, F3, F4, C11

Keywords: Thailand, financial accelerator, Bayesian estimation, DSGE model, global financial crisis, Thai floods, monetary policy, inflation targeting, emerging markets.

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EXECUTIVE SUMMARY

Over the course of 2008–2011, Thailand had to weather the aftereffects of the global financial crisis, the spillovers from the devastating earthquake in Japan which disrupted supply chains, and the most destructive floods in at least 50 years. This paper argues that the monetary policy framework implemented by the Bank of Thailand (BOT) since May 2000 helped soften the impact of these three major shocks.

The focus of this paper is to assess the role of countercyclical interest rate cuts and exchange rate flexibility in mitigating the economic fallout from these three major shocks. To soften the severity of these three major shocks, the BOT let the exchange rate depreciate and cut interest rates when appropriate. For example, starting in the third quarter of 2008, the BOT cut its policy rate by 250 basis points to a historically low level of 1¼ percent. But to what end?

The main results emphasize the macroeconomic stabilization properties of the BOT's inflation targeting framework which is underpinned by a flexible exchange rate regime. Specifically, during the six quarters when output was most severely affected by the three major shocks, results from the model indicate that countercyclical monetary policy and exchange rate flexibility contributed to growth by up to 1.6 and 2.1 percentage points, respectively, for a total of up to 3.7 percentage points. While exchange rate flexibility served as a shock absorber, countercyclical interest rate cuts consistent with the inflation target increased the resilience of the economy to these shocks. These finding are based on counterfactual simulations derived from an estimated structural model which captures the salient features of the Thai economy. In sum, the findings suggest that without the adoption of an inflation targeting framework underpinned by a flexible exchange rate regime, the economic contractions associated with these three major shocks would have been substantially more severe.

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I. INTRODUCTION

During 2008–2011, Thailand had to endure three major shocks. The first was the global financial crisis (GFC) which intensified with the collapse of Lehman Brothers. The second shock was associated with the spillovers from the earthquake in Japan and the ensuing disruption of supply chains which adversely affected Thailand in particular. The third major shock was the worst flooding in at least 50 years, which along with the devastating loss of life, dealt a severe blow to many of the primary sectors that form the backbone of the Thai economy. To mitigate the severity of these shocks, the Bank of Thailand (BOT) let the exchange rate depreciate and cut interest rates when appropriate. For example, starting in the third quarter of 2008, the BOT cut its policy rate by 250 basis points to a historically low level of 1¼ percent. But to what avail?

The focus of this paper is to assess the role of countercyclical interest rate cuts and exchange rate flexibility in mitigating the economic fallout from these three major shocks. Specifically we seek to address the following question: If an inflation targeting framework underpinned by a flexible exchange rate regime had not been in place, how would the economic contractions associated with these shocks have differed?

A structural model is used to provide a quantitative answer to this question. Specifically, we develop and estimate a small open economy dynamic stochastic general equilibrium (DSGE) model designed to capture the salient features of the Thai economy. The model contains a number of nominal and real frictions such as sticky prices, sticky wages, variable capital utilization, investment adjustment costs, habit persistence, and incorporates a financial accelerator mechanism à la Bernanke and others (1999) in an open-economy setup to better fit the data. The model is used to generate counterfactual simulations underpinning the main quantitative results and key policy implications of the paper.

The results indicate that without the adoption of the flexible exchange rate regime and active countercyclical monetary policy guided by an inflation targeting framework, the impact of the three major shocks on the Thai economy would have been substantially more severe. In particular, during the six quarters when output was most severely affected by the three shocks, results from the model indicate that countercyclical monetary policy and exchange rate flexibility contributed to growth by up to 1.6 and 2.1 percentage points, respectively, for a total of up to 3.7 percentage points. While exchange rate flexibility served as a shock absorber, countercyclical interest rate cuts consistent with the inflation target increased the resilience of the economy to these shocks. In fact, the latter result echoes the favorable output stabilization properties of exchange rate flexibility which can be traced back at least to the seminal contributions of Mundell and Fleming. Overall, the BOT's monetary policy framework seems to have increased the robustness of the Thai economy to these three major shocks.

This paper builds on a tradition of small open economy DSGE models popularized by Mendoza (1991). Over time, these real models were augmented with nominal rigidities to motivate and then explore the implications of monetary policy (for example, Gali and Monacelli, 2002, among others). To capture financial frictions more appropriately, building on Bernanke and others (1999), a financial accelerator mechanism was also added on to these models (see for example, Cespedes and others, 2004; Devereux, and others, 2006; Gertler, and others, 2007; as well as Elekdag and Tchakarov, 2007).

With the growing feasibility and popularity of Bayesian method, building upon the closed economy studies of Smets and Wouters (2003, 2007), small open economy models were estimated (Lubik and Schorfheide, 2007; Teo, 2006; as well as Christensen and Dib, 2006). Then, Elekdag, Justiniano, and Tchakarov (2006) estimated a small open economy model with a financial accelerator for an emerging market, which later motivated others to use richer modeling structures (see, for example, Garcia-Cicco, 2010). Against this backdrop, as in Alp and Elekdag (2011), this paper takes Elekdag, Justiniano, and Tchakarov (2006) as a starting point, and augments their model with some of the features in Gertler and others (2007), Smets and Wouters (2007) to improve model fit and to facilitate the counterfactual simulations.

This paper is structured as follows. The next section begins by briefly providing the institutional backdrop of Thai monetary and exchange rate policies, and some background related to the three shocks which hit Thailand during 2008–2011. The paper then goes on to briefly describe the model used in this paper followed by a description of the estimation results for the case of Thailand. This is followed by a discussion of the main results and implications for monetary policy transmission. The final section concludes with some policy implications.

II. Three Major Shocks and Monetary Policy in Thailand

This section provides some context on the BOT's inflation targeting framework, and the policy response to three major shocks that Thailand had to endure throughout 2008–2011: the global financial crisis of 2008–09, the Japanese earthquake of 2011, and the Thai floods of 2011.

Thailand formally adopted an inflation targeting framework in May 2000. Consistent with this target, the exchange rate is allowed to float freely. The main objective of the BOT is to ensure price stability in the economy, which is defined as low and stable inflation. However, the BOT also takes into careful consideration developments pertaining to economic growth and stability.[2] Following the adoption of the new monetary policy framework, the Thai economy had average annual inflation of 2.6 percent during 2001–2007, and average annual GDP growth of 5.1 percent (**Figure 1**).

Strong headwinds from the global financial crisis which intensified with the downfall of Lehman Brothers reached Thailand at end-2008. Before these events transpired, however, Thailand had been in an investment slump since 2006. Nonetheless, export performance had been resilient with average growth of over 10 percent during 2006–07, and helped keep real GDP growth strong. In a rapid turnaround, exports plunged in the last quarter of 2008 in tandem with collapse in global trade. At the same time, the broad-scale pull back from foreign investors was associated with a marked rise in market volatility and an attendant sharp decline in the major stock market index. In parallel with a sequence of fiscal stimulus packages, the BOT cut its policy rate by 250 basis points to a historically low level of 1¼ percent.

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[2] For further details, see: http://www.bot.or.th/English/MonetaryPolicy/Target/Pages/index.aspx

Thailand then faced two additional major shocks in 2011:

- The first was the earthquake which devastated Japan in March. Thailand was particularly affected because Japan is a key source of sophisticated intermediate and capital goods for Thailand (which account for over 90 percent of some components). Because of the specialization and concentration of upstream manufacturers, supply chains were particularly disrupted causing an abrupt production slowdown.

- The second major shock was the worst flooding in at least 50 years, lasting from August to November. Throughout this period, over 800 people were killed and millions of residents were either left homeless or displaced as the floods inundated 66 of the country's 77 provinces. Many of the primary sectors that form the backbone of the Thai economy—including manufacturing—were dealt a severe blow owing to the inundations. About one third of the country experienced flooding, including two key manufacturing provinces producing automobiles and electronic components, bringing down annual GDP growth from 7.8 percent in 2010 to 0.1 percent in 2011 after contracting by an astounding 11 percent in the last quarter of the year (which corresponds to an annualized rate of about 50 percent seasonally adjusted data). The Thai government responded to the floods with a broad set of policies, including fiscal stimulus, an infrastructure investment plan, and the BOT cut policy rates by 50 basis points to further support the recovery.

III. A Model for Thailand's Monetary Policy Framework

This section presents an overview of the structural model underpinning our quantitative results. Readers primarily interested in the main policy implications of the paper could directly proceed to Section V and, in particular, Section VI. The goal here is to present the general intuition of the model, while the details are relegated to the **Appendix**.

The structural framework builds upon a core New Keynesian model. The model used is an open-economy variant of what the literature refers to as a New Keynesian dynamic stochastic general equilibrium (DSGE) model. However, to better fit the data, the model is augmented with a number of features including real and nominal rigidities (including, for example, investment adjustment costs and sticky wages), as well as a financial accelerator mechanism (to capture financial market imperfections) among several others.[3]

The model consists of several agents including households, producers, and the government. There are three types of producers: entrepreneurs, capital producers, and retailers. The government is responsible for implementing monetary and fiscal policy. A visual representation of the flow of goods and services across these agents is shown in **Figure 2**.

[3] In terms of theory, our model brings together elements from papers including Adolfson and others (2007), Bernanke and others (1999), Elekdag and Tchakarov (2007), and Gertler and others (2007) among many others, while, in order to facilitate estimation, we build on the work of Smets and Wouters (2003, 2007) and Elekdag and others (2006). For a recent example, see Alp and Elekdag (2011).

However, rather than elaborate on all aspects of the model, this goal in this section is to focus on the transmission of certain shocks and the role of monetary (and exchange rate) policy.

A. The Transmission of Shocks

Recall that this paper seeks to investigate the role of monetary policy in softening the adverse growth impacts on the Thai economy associated with the GFC, the Japanese earthquake, and the Thai floods.

To help foster intuition, it would be useful to discuss how these three shocks are likely to be captured within the modeling framework that is developed. These three major shocks would most likely be associated with a collapse in foreign demand, distress across international capital markets, heightened uncertainty, and abrupt declines in productivity. While the technical details are in the **Appendix**, an overview of how these shocks are propagated within our model is discussed below.

The export demand shock

The export demand shock, or perhaps equivalently, the foreign demand shock, propagates through the model via the market clearing condition below:

$$Y_t^H = C_t^H + C_t^{eH} + I_t^H + C_t^{H*} + G_t$$

Leaving aside differences in notation, this is basically the standard aggregate demand identity for home (domestically produced) goods, which posits that domestic output is equal to the sum of consumption of domestically produced goods (which is the sum of both household and entrepreneurial consumption, $C_t^H + C_t^{eH}$), domestic investment good, I_t^H, government expenditures, G_t, and (gross) exports, C_t^{H*}. Therefore, a collapse in export (foreign) demand is reflected in a decline in C_t^{H*}.

The sudden stop shock

Thailand's experience during the global financial crisis was also associated with a reversal of capital inflows (a "sudden stop" in the parlance of Calvo and others, 2004), as well as a sharp depreciation of the exchange rate. To capture these interrelated disruptions, we (as in many other papers) augment the uncovered interest parity (UIP) condition with an exogenous shock:

$$i_t = i_t^* E_t \left[\frac{S_{t+1}}{S_t}\right] \Phi_t$$

where, i_t and i_t^*, represent the domestic and international (gross) interest rates, respectively, S_t denotes the nominal exchange rate (Thai baht per US dollar—an increase represents a depreciation), E_t is the expectations operator (conditional on information up to time t), and Φ_t is the sudden stop shock (also referred to an exchange rate shock or UIP shock in the literature). Therefore, as in Gerlter and others (2007), a shock that triggers large capital outflows is captured by this exogenous term which is appended to an otherwise standard UIP condition. When relevant, this sudden stop shock serves to capture the financial aspect of the three major shocks.[4]

The (financial) uncertainty shock

The description of this shock warrants some background. In this model, the real cost of capital departs from the standard representation in other studies because of the existence of an external finance premium. Consider the equation below:

$$E_t[R_{t+1}^k] = \chi_t(\cdot)E_t[R_{t+1}]$$

where we have that the real cost of capital, R_t^k, is equal to the real interest rate, R_{t+1}, augmented by the external finance premium represented by the term $\chi_t(\cdot)$. The external finance premium depends on the leverage ratio (assets scaled by net worth) of the entrepreneurs:

$$\chi_t = \chi_t\left(\frac{Q_t K_{t+1}}{N_{t+1}}\right)$$

Note that total assets, $Q_t K_{t+1}$, depends on the price of equity, Q_t, which is not sticky (by contrast to goods prices or wages). This implies that the leverage ratio is quite sensitive to asset price fluctuations.[5]

The precise specification of the evolution of net worth (equity), N_{t+1}, is complex (and shown in the **Appendix**), so here an abridged version is used:

$$N_{t+1} = \varrho_t V_t + W_t^e$$

where W_t^e and V_t, denote the entrepreneurial wage bill and the value of the firm, respectively. The (financial) uncertainty shock is an exogenous process, represented by the term, ϱ_t, which by construction has a direct impact on the level of aggregate net worth and therefore the external financial premium. Put differently, the net worth shock could be interpreted as a shock to the rate of destruction of entrepreneurial financial wealth (in line with several other studies). This shock directly affects entrepreneurial net worth and has been used in various forms by Elekdag and others (2006), Curdia (2007), Christiano and others (2010), and more recently by Alp and Elekdag (2011). Another way to think about this shock is that it could be thought of capturing counterparty risk—owing part to Knightian uncertainty—a key consideration during the global financial crisis. This heightened uncertainty regarding cash flows, for example, would impair assets and thus disrupt the financial system.

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[4] Note that this shock actually consists of two components: the first is the exogenous component discussed above. The second component is actually endogenous and depends on the levels of debt outstanding thereby accounting for sovereign risk (in line with other recent open-economy DSGE models, see Appendix for further details).

[5] We follow Gertler and others (2007) and also use domestically-denominated debt when modeling the financial accelerator. Given the risks associated with foreign currency-denominated debt, adding this feature as in Elekdag and Tchakarov (2007) is a refinement worth pursuing in future research.

The natural disaster-related shocks

In the case of the Thai floods of 2011, it is clear that this was a disruptive supply shock to say the least. In terms of the model, temporary supply shocks are modeled in a standard fashion, and represented by a decrease in total factor productivity (TFP) consistent with the production function below:

$$Y_t = A_t {K_t}^{\alpha} (z_t L_t)^{1-\alpha}$$

where Y_t, K_t, and L_t denote output, the capital stock, and labor inputs, respectively. In addition, A_t and z_t, represent temporary and permanent technology (or productivity) shocks, respectively. The former is the benchmark supply shock which has been attributed a pivotal role in the real business cycle literature, because it has been documented to be an important source of aggregate business cycle fluctuations. The latter shock affects the growth trend of the economy, and as argued by Aguilar and Gopinath (2007), is a key determinant of business cycle fluctuations across emerging economies. Against this backdrop, if the decline in real GDP is primarily characterized by trend growth shocks, this would imply larger permanent output losses.

Another type of supply shock included in the model affects investment, rather than the stock of capital (in contrast to the temporary productivity shock). This investment-specific technology shocks, ε_t^i, is temporary and, as argued by Justiniano and others (2007), plays a potentially critical role in accounting for output dynamics. The evolution of capital (after taking into consideration adjustment costs, $\psi(\cdot)$, and the depreciation rate, δ_t) has the following properties:

$$K_t = (1 - \delta_t) K_{t-1} + [1 - \psi(\cdot)] I_t \varepsilon_t^i$$

In sum, there are three types of supply shocks which directly affect productive capacity in the model economy, including one which allows for lower trend growth and thereby permanent output losses.[6]

B. What Role for Monetary Policy?

In our model, the central bank alters interest rates in an attempt to achieve certain policy objectives. Before proceeding to the details, note that the policy rule to be described below implies that the monetary authority sets the nominal interest rate, taking into consideration the inflation rate deviation from the time-varying inflation target, the output gap, the rate of exchange rate depreciation, and the previous period's interest rate (policy smoothing).

A simplified version of the empirical interest rate rule takes the following (log-linear) form:

$$\hat{\imath}_t = \rho_i \hat{\imath}_{t-1} + \tau_\pi (\hat{\pi}_t - \hat{\pi}_t^T) + \ + \tau_y \hat{y}_t + \tau_s \Delta \hat{s}_t + \epsilon_t^i$$

where in this flexible specification, $\hat{\imath}_t, \hat{\pi}_t, \hat{y}_t, \hat{s}_t$ denote the (short-term policy) interest rate, the (core CPI) inflation rate, the output gap, and the nominal exchange rate, respectively (see

[6] The model also includes shocks to the Philips curves, but these are typically used to capture terms of trade-related shocks (including commodity price fluctuations).

Appendix for further details). Note that ϵ_t^i denotes the monetary policy shock—interest rate changes that deviate from the (empirical) interest rate rule would be captured by this disturbances and could be considered discretionary monetary policy. The time-varying inflation target, $\hat{\pi}_t^T$, is assumed to evolve according to the following stochastic process:

$$\hat{\pi}_t^T = \rho_{\overline{\pi}}\hat{\pi}_{t-1}^T + \epsilon_t^{\pi}$$

The time-varying inflation target has also been used in the literature to capture structural changes in the conduct of monetary policy that are not captured otherwise (see Adolfson and others, 2007, for further details). In the case of Thailand, the time-varying inflation target, allows the model to capture the change in the inflation target when the core inflation target range was narrowed to 0.5–3.0 percent in 2009, from 0–3.5 percent.[7]

Anticipating the results to follow, notice that when the output gap is negative—that is, output is below potential—strict adherence to the rule above would imply that the interest rate decreases by an amount dictated by the coefficient τ_y. However, the monetary authority might decrease interest rates by more than what the systematic component of the rule would imply. Recall that this deviation from the rule is capture by the error term, ϵ_t^i, which is the monetary policy shock—thereby capturing discretionary monetary loosening. As will be discussed in further detail below, interest rates decreased by more than the amount the empirical counterpart of the rule would have implied, helping soften the impact of the three major shocks.

IV. Estimation of the Model for Thailand

This section gives an overview of model estimation. It briefly reviews issues pertaining to data, parameter calibration, choice of prior distributions, resulting posterior distributions, model fit, and sensitivity analysis. An extensive discussion of these issues is covered in the **Appendix**.

A. Data

The log-linearized model is estimated using Bayesian methods primarily developed by Schorfheide (2000), and later popularized by Smets and Wouters (2003, 2007). The model is estimated using quarterly data from the third quarter of 2000 to the first quarter of 2012 using 12 standard time series, a few of which are shown in **Figure 1**. Specifically, in line with many other studies, we have chosen to match the following set of variables: the levels of the domestic policy and foreign interest rates, the inflation rates of domestic GDP deflator and core consumer price and foreign consumer price indices, as well as the growth rates of GDP, consumption, investment, exports, imports, foreign GDP, and the real exchange rate. The sample period used for estimation (2000–12) covers the period when the BOT was implementing inflation targeting (underpinned by a flexible exchange rate).

[7] For further details: http://www.bot.or.th/English/MonetaryPolicy/Target/Pages/Target.aspx

B. Model Parameters

We follow the literature and calibrate certain parameters (see, for example, Christiano and others, 2010), which could be thought of as infinitely strict priors. Many of the parameters are chosen to pin down key steady state ratios, while the remaining parameters are taken from the literature as summarized in **Table 1**.

The remaining 43 parameters, shown in **Table 2**, are estimated. These parameters determine the degree of the real and nominal rigidities, the monetary policy stance, as well as the persistence and volatility of the exogenous shocks. The table shows the assumptions pertaining to the choice of distribution, the means, standard deviations, or degrees of freedom. The choice of priors is in line with other studies (see Alp and Elekdag, 2011, for a selected review of the literature). The posterior estimates of the variables are shown in the same table, which reports the means along with the 5^{th} and 95^{th} percentiles of the posterior distribution of the estimated parameters obtained through the Metropolis-Hastings sampling algorithm. In general, the parameter estimates are in line with those found in other studies.[8]

C. Sensitivity Analysis

To assess the robustness of the estimated model, we consider a few alternative specifications which include different monetary policy rules and alternative structural features. The results are summarized in **Table 3**, which depicts the log data density of the various models, and the posterior odd ratio contrasting the baseline and the alternative model specifications. While the details are discussed in the **Appendix**, the main takeaway is that we consider 7 alternative specifications, and the results are all decisively in favor of the baseline model.

V. The Monetary Transmission Mechanism

This section aims to explore the dynamics of the estimated model by investigating the monetary transmission mechanism. This is critical because the focus of the paper is to assess the role of monetary policy during the global financial crisis.

To this end, we consider the impulse responses to a one standard deviation monetary tightening shock as shown in **Figure 5.** To more openly communicate the degree of uncertainty regarding the monetary transmission mechanism in Thailand during a sample period which encompasses the global financial crisis, we present Bayesian impulse response functions for a selected set of variables along with their 90 percent bands which take into consideration parameter uncertainty.

A one standard deviation contractionary monetary policy shock corresponds to a 80 basis point (quarterly) increase in the nominal interest rate (**Table 2**), which implies an annual increase in the policy rate of about three percent. The output gaps dips below the steady state

[8] The model is intentionally estimated to include the tumultuous period of 2008-2011 during which Thailand had to endure three major shocks to evaluate the effectiveness of countercyclical monetary policy. However, it should be recognized that the sample ends only one quarter after the Thai floods intensified, and therefore, parameter estimates may be less stable than in the case when a more tranquil sample was used for estimation. Nonetheless, the results are generally plausible, and yield informative policy implications.

by 31 basis points, whereas the year-over-year inflation rate reaches a trough of about 63 basis points below steady state after four periods.

The shock propagation is effected via three main channels:

- The first channel operates as interest rates affect domestic demand, which primarily comprises consumption and investment. Working through the Euler equation, higher real interest rates foster an increase in saving as consumption is postponed to later periods. At the same time, higher real interest rates increase the opportunity cost of investment, decreasing the rate of capital accumulation. As a result, domestic demand decreases, putting downward pressure on inflation.

- The second channel brings out the open economy features of the model as it works via the exchange rate. Because of the nominal rigidities, the increase in the nominal interest rate translates into higher real interest rates and is associated with an increase in the real exchange rate. In turn, this appreciation of the real exchange rate suppresses net exports (the expenditure switching effect), further decreasing aggregate demand.

- The third channel is characterized by the financial accelerator mechanism. Higher interest rates depress asset prices (the real price of capital) bringing about a deterioration in net worth. Weaker balance sheet fundamentals cause an increase in the external finance premium thereby raising the opportunity cost of investment above and beyond the initial effect generated by the monetary tightening. This brings about an even sharper contraction in investment, which is the primary determinant of the deeper contraction. As discussed in further depth in other papers, the financial accelerator mechanism can amplify the effects of certain shocks (Bernanke, Gertler, and Gilchrist, 1999).

The model includes 15 structural shocks including the monetary policy shock discussed above. While we do not present the details here, in terms of our structural model, the dynamic implications of these shocks are in line with the literature, and therefore, in the interest of brevity, we refer the reader to other studies for further details (including, for example, Elekdag and others, 2006; Gertler and others, 2007; Curdia, 2007; Christiano and others, 2010; Alp and Elekdag, 2011).[9]

[9] Nonetheless, after estimating the model over the 1993–2012 sample, three results noteworthy. First, the main structural shocks accounting for year-over-year output growth are those to foreign demand (capturing, in large part, shocks transmitted via the trade channel), trend productivity (associated with shocks primarily associated with the natural disasters), and those to government spending (capturing, in a cursory way, fiscal policy). As noted above, the trend productivity shocks can permanently affect the growth trend of the economy, and as argued by Aguilar and Gopinath (2007), is a key determinant of business cycle fluctuations across emerging economies. Second, in tandem with lower output volatility in the second half of the sample, the standard deviations of all major structural shocks are also lower in the 2001–2012 period. Third, the correlation between the government spending and monetary policy shocks decreases in the second half of the sample, indicating that policies have become more countercyclical. In the case of government spending shocks, a sizeable positive correlation (typical in many emerging economies, see Kaminsky and others, 2005) switches to a negative correlation.

VI. MONETARY POLICY IN THAILAND AND THREE MAJOR SHOCKS

In this section of the paper, we conduct counterfactual experiments with the goal of answering the following general question: If the BOT did not implement on inflation targeting framework underpinned by a flexible exchange rate regime, how much deeper would the output contractions have been?

As will be discussed below, that answer is that the output losses associated with the three major shocks (global financial crisis, Japanese earthquake, and the Thai floods) would have been significantly more severe. In fact, without countercyclical monetary policy, the cumulative growth losses associated with these three shocks would have been about 1.6 percentage points. Moreover, in another illustrative counterfactual simulation with financial fragilities mimicking those which existed during the mid-1995s, and with a fixed exchange rate regime in place, suggests that the cumulative growth losses would have been close to 4.1 percentage points.

A. Setting Up the Counterfactual Simulations

Though intimately related, the model allows us to separately investigate the contributions of countercyclical interest rate policy and exchange rate flexibility in terms of softening the impact of the three major shocks. Therefore in what follows, by altering the monetary policy response, we consider four counterfactual simulations and compare the output implications they imply with the actual realization under the baseline model specification. Under the baseline, the monetary policy framework (which is underpinned by a flexible exchange rate) operates in accordance with estimated baseline interest rate rule discussed above. In this context, the three counterfactual experiments are as follows:

- **No monetary policy shocks**: this counterfactual posits strict adherence to the baseline empirical interest rate rule. It is a simulation which excludes the monetary policy shocks—that is, the monetary policy shocks, ϵ_t^i, are all set to zero in this simulation. It serves to address the following question: What would the dynamics of output have been if the BOT did not implement any discretionary loosening (deviations from the interest rate rule) when the shocks materialized?

- **No response to the output gap**: under this counterfactual, the output gap coefficient in the empirical interest rate rule is set to zero ($\tau_y = 0$). Furthermore, as these counterfactuals are "cumulative," this scenario also sets the monetary policy shocks to zero. It serves to address the following question: What would the dynamic of output have been if the BOT did not implement any countercyclical policy? While interest rate smoothing is still allowed, in this case, a form of strict inflation targeting is implemented without any due regard to the output gap.

- **Peg**: in this counterfactual, the BOT is assumed to implement a strict fixed exchange rate regime.[10] Intuitively, there are no discretionary deviations from the rule (which

[10] Just as the model-based framework assumes that the inflation targeting regimes are fully credible, it also assumes that the exchange rate regimes are fully credible. While the latter assumption is harder to justify, the credibility of both regimes is needed for comparability. For a lack of a better term, credibility was used, but perhaps sustainability is a more related or even more appropriate characterization.

solely focuses on stabilizing the nominal exchange rate). Here we seek to address the following question: What would the dynamic of output growth have been if the BOT was implementing a fixed exchange rate regime?

- **Peg with heightened financial vulnerability**: under the last counterfactual, the BOT is presumed to operate under a fixed exchange rate regime as above, but the leverage ratio is calibrated to correspond to the case where it equals three (rather than the baseline of two under the baseline, see Alp and Elekdag, 2011, for further details). While not the main focus of the paper, our modeling framework allows us to construct such an *illustrative* counterfactual serving to address the following question: What would the dynamic of output growth have been if the BOT was implementing a fixed exchange rate regime *and* the economy was financially more fragile?

B. Results Based on the Counterfactual Simulations

The counterfactual simulations are summarized in **Figure 4** and in **Figure 5**. These figures depict the level of real GDP with the third quarter of 2008 (the pre-global financial crisis peak) normalized to 100 to allow the reader to better distinguish the (cumulative) effects of each counterfactual. For presentation purposes and to really emphasize the main policy implications, the figures start in 2006:Q1, and only show the counterfactual simulations over selected periods.[11] **Figure 4** displays (1) the actual realization of real GDP (the baseline scenario), (2) the counterfactual scenario without the monetary policy shocks, and (3) the counterfactual scenario without any due regard to the output gap. These scenarios emphasize the role of countercyclical monetary policy. In contrast, **Figure 5** shows (1) the actual realization of real GDP, (2) the counterfactual with a fixed exchange rate regime (peg), and (3) an another illustrative scenario with the peg combined with heightened financial fragilities. This latter figure only shows the counterfactual simulations over 2008:Q3–2009:Q4 because this is the period when the differences between the counterfactual simulations differs noticeably from the baseline.

The main message to take away from these simulations is that the inflation targeting framework underpinned by a flexible exchange rate regime implemented by the BOT clearly softened the impact of the GFC, the Japanese earthquake, and the floods which Thailand had to endure.[12] More specifically, it is useful to discuss two main results:

- The discretionary cuts in the policy rate helped soften the impact of the shocks throughout the period when the three major shocks hit as shown in **Figure 4**. This is most noticeable during GFC when the BOT cut policy rates 250 basis points to a historically low level of 1¼ percent. In addition, the results suggest that taking the output into consideration also help dampen the economic contractions that unfolded during 2008–2011. Consider the two most severe output contractions which were associated with the GFC and the Thai floods. Without these countercyclical monetary responses, results from the model indicate that the peak-to-trough decline in output would have increased to 8.7 percent from the actual of 7.3 percent during the GFC (for

[11] All results are available from the authors' upon request; Table 4 (below) presents results in further detail.

[12] It should be underscored that this paper focuses on the role of interest rate and exchange rate fluctuations, and therefore does not capture the role of other policies.

a difference of 1.3 percentage points), and increased to 12.3 percent from the actual of 11.1 percent in the aftermath of the floods (for a difference of 1.2 percentage points). To put these numbers in context, recall that the peak-to-trough real GDP decline during the 1990s U.S. recession was about 1.3 percent. Therefore, the additional total output loss of up to 2.5 percentage points implied by the simulations without countercyclical monetary policies is clearly quite substantial.

- Along with the actual path of real GDP, **Figure 5** presents two additional illustrative counterfactual simulations seeking to explore the role of exchange rate flexibility and the financial reforms implements since the late 1990s. The main differences occur during the GFC, which was characterized by a sharp slowdown in global trade and an episode of acute financial stress across international capital markets. The simulations indicate that the output losses would have been larger under a fixed exchange rate regime. The lack of the exchange rate to serve as a shock absorber decreases the resiliency of the economy to the shocks—particularly those transmitted via the trade channel—which ensued during the GFC. Nevertheless, in contrast to some other emerging economies, the real exchange rate in Thailand depreciated only by about 4 percent during the GFC, which is why the quantitative difference between the actual outcome and the simulation are visibly not that large. Intuitively, the illustrative counterfactual experiment with heightened financial fragilities leads to an even sharper decline in output. The acute episode of financial stress associated with the GFC is amplified because of a more pronounced balance sheets channel, and thereby characterized with larger output losses. In sum, and further discussed below, these counterfactual experiments highlight the importance of exchange rate flexibility and financial reforms in promoting macroeconomic stability and financial system soundness.

C. How Do the Results Compare with Those in the Literature?

This section starts by focusing on the contributions of the implemented countercyclical monetary policies to growth under the various counterfactuals during the three major shocks, which are shown in **Table 4**. It then compares these results to some related studies in the literature.

Before investigating the details, it would be useful to clarify the information contained in **Table 4**. Three episodes are considered: the GFC (2008:Q4–2009:Q3), the quarter when the spillovers from the Japanese earthquake were most forcefully felt (2011:Q2), and the quarter during which the Thai floods intensified (2011:Q4). Unless otherwise stated, the values under columns show the average year-over-year contributions to growth during these episodes under the four counterfactual simulations. After tabulating the number of quarters associated with each of the three shocks, columns [1] through [4] indicate the incremental contributions to growth owing to the consecutive implementation of each policy. For example, in the case of the GFC, under column [1], the results from the model suggest that the discretionary loosening by the BOT (owing to the monetary policy shocks which decreased policy rates) added ¼ percentage point to the average year-over-year real GDP growth during 2008:Q4–2009:Q3. Furthermore, the simulations suggest that because the BOT also took into consideration the widening of the output gap during this period, it supported growth by an additional 55 basis points as shown under column [2]. In other words, without the countercyclical monetary policy response by the BOT during the GFC, growth during the year under consideration would have been lower by ¾ percentage point. The other illustrative scenarios indicate that reduced financial fragilities and adopting a flexible exchange rate regime added up to 35 and 43 basis points to growth as depicted under columns [4] and [3], respectively.

The effectiveness of the policy response seems to be related to the nature of the shock confronted by the Thai economy. Consider columns [1] and [3]. In contrast to the external shocks, monetary policy seems to have contributed relatively more to growth during the Thai floods. On the contrary, when the aftereffects of the Japanese earthquake were felt in Thailand, results from the model suggest that exchange rate flexibility helped support growth by up to about 1¼ percentage points. These findings echo the seminal theoretical contribution of the textbook exposition of the Mundell-Flemming model, but also highlight the macroeconomic stabilization benefits of the BOT's inflation targeting framework which is underpinned by a flexible exchange rate regime.

It would be useful to compare the results in **Table 4** with the literature. A study by Christiano and others (2007) is somewhat related to ours in terms of conducting counterfactual experiments. Turning our attention to column [1], results from the model indicate that the total average contribution of the monetary shocks (discretionary deviations from the empirical interest rate rule) to output growth during the three episodes under consideration is about 70 basis points, which is in line with the values found by Chrisitiano and others (2007) for the U.S. (75 basis points) and the euro area (127 basis points). Moreover, accounting for the role played by actively responding to the output gap implies a total growth contribution of 91 basis points over the three shock episodes. Taken together, during the six quarters when output was most severely affected by the three major shocks, countercyclical monetary policy and exchange rate flexibility contributed to growth by up to 1.6 and 2.1 percentage points, respectively, for a total of up to 3.7 percentage points.

Table 5 summarizes our main findings. It tabulates the actual and simulated average year-over-year growth rates during the three episodes under consideration (columns [1], [2], and [4]). It also displays the differences in growth (columns [3] and [4]), and the totals for each of the three episodes. Overall, results from the model suggest that without countercyclical monetary policy, average growth across these three episodes would have been lower by a total of up to 1.6 percentage points. Without exchange rate flexibility (and a more financially fragile economy), growth would have been lower by an additional up to 2.5 percentage points, for a grand total of up to 4.1 percentage points. It would be useful to emphasize that these simulations only focus on the role of countercyclical monetary policy and exchange rate flexibility as defined above. Other countercyclical measures (for example fiscal policy and liquidity support) are not explicitly captured in this modeling framework and could be pursued in future research. In sum, without the adoption of the flexible exchange rate regime, and active countercyclical monetary policy guided by an inflation targeting framework, the impact of the three major shocks on Thailand's economy would have been substantially more severe.

VII. SUMMARY AND MAIN POLICY IMPLICATIONS

Over the course of 2008-2011, Thailand had to weather the aftereffects of the global financial crisis, the spillovers from the devastating earthquake in Japan which disrupted supply chains, and the most destructive floods in at least 50 years. The focus of this paper is to assess the role of countercyclical interest rate cuts and exchange rate flexibility in mitigating the economic fallout from these three major shocks. The results indicate that the monetary policy framework implemented by the Bank of Thailand (BOT) helped soften the impact of these three major shocks on the Thai economy.

Since May 2000, underpinned by a flexible exchange rate regime, the BOT has been an inflation targeting central bank. During the global financial crisis, for example, consistent with its inflation targeting framework, the BOT let the exchange rate depreciate and cut interest rates to a historically low level of 1¼ percent by mid-2009. In this context, this paper seeks a quantitative answer to the following question: If an inflation targeting framework underpinned by a flexible exchange rate regime had not been in place, how would the economic contractions associated with these shocks have differed?

The quantitative results emphasize the macroeconomic stabilization properties of the BOT's inflation targeting framework which is underpinned by a flexible exchange rate regime. Specifically, results from the model indicate that during the six quarters when output was most severely affected by the three shocks, countercyclical monetary policy and exchange rate flexibility contributed to growth by up to 1.6 and 2.1 percentage points, respectively, for a total of up to 3.7 percentage points. Exchange rate flexibility and countercyclical interest rate policy served as shock absorbers and facilitated the recovery in the aftermath of these three major shocks. These finding are based on counterfactual simulations derived from an estimated structural model which captures the salient features of the Thai economy.

In sum, given the openness of the Thai economy through financial and especially trade channels, the flexibility and resilience of the economy are especially important when faced with severely disruptive exogenous shocks. In line with this, Thailand's monetary policy framework, underpinned by a flexible exchange rate, is well suited to the characteristics of Thailand's economy, as demonstrated through the counterfactual experiments discussed in this paper in the context of the three major shocks.

APPENDIX

This appendix has four main sections providing further details regarding some of our main results. First, we present a detailed description of the structural dynamic stochastic general equilibrium (DSGE) model that underpins our quantitative results. The next two sections discuss model estimation and sensitivity analysis, while the fourth section sheds further light on model dynamics, and the final section presents the counterfactual simulations using the time series of year-over-year growth rates.

The Model

This section presents a detailed description of the DSGE model that serves as our analytical framework. The model is an open economy New Keynesian DSGE model equipped with additional features to better fit the data including a number of nominal and real rigidities, a stochastic trend, and a financial accelerator mechanism among others. Our model brings together elements from papers including Adolfson and others (2007), Bernanke and others (1999), Elekdag and others (2006), as well as Gertler and others (2007) among many others. For a recent example, see Alp and Elekdag (2011), which provides further details on the model description provided below.

The model consists of several agents including households, producers, and the government. There are three types of producers: entrepreneurs, capital producers, and retailers. The government is responsible for implement monetary and fiscal policy. A visual representation of the flow of goods and services across these agents is shown in **Figure 2**. We consider the role of each of these agents, and there interactions with the rest of the world in turn below.

Households

There is a continuum of households, which attain utility from aggregate consumption, C_t, and leisure, L_t. Aggregate consumption is given by a standard CES index of domestically produced and imported goods according to:

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

where C_t^H and C_t^F are the consumption of the domestic and imported goods, respectively, and intra-temporal optimization by the household implies the following two conditions, the latter being the consumer price index, P_t:

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

$$P_t = [\gamma(P_t^H)^{1-\rho} + (1-\gamma)(P_t^F)^{1-\rho}]^{\frac{1}{1-\rho}} \tag{3}$$

The households decide on their current and future level of consumption as well as their amount of domestic and foreign bond holdings based on the following preference structure which allows for habit persistence as captured by the term bC_{t-1}:

$$U_t = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \varepsilon_t^c \ln(C_t - bC_{t-1}) - \frac{\varepsilon_t^l}{1+\sigma_l} (L_t)^{1+\sigma_l} \right\} \tag{4}$$

where ε_t^c and ε_t^l are the preference and labor supply shocks, respectively, each having the following first-order autoregressive (AR(1)) time series representations:

$$log\, \varepsilon_t^c = \rho_c\, log\, \varepsilon_{t-1}^c + \epsilon_t^c \tag{5}$$

$$log\, \varepsilon_t^l = \rho_l\, log\, \varepsilon_{t-1}^l + \epsilon_t^l \tag{6}$$

The representative household is assumed to maximize the expected discounted sum of its utility subject to budget constraint:

$$C_t = \frac{W_t}{P_t} L_t + \Pi_t - \frac{B_{t+1} - i_{t-1} B_t}{P_t} - \frac{S_t B_{t+1}^* - S_t \Phi_{t-1} i_{t-1}^* B_t^*}{P_t} \tag{7}$$

Note that the foreign interest rates is modeled as an exogenous AR(1) process and that Φ_t represents a gross borrowing premium that domestic residents must pay to obtain funds from abroad, specifically:

$$\Phi_t = \Phi(b_{t+1}^*, \varepsilon_t^{\Phi}) \tag{8}$$

$$b_{t+1}^* \equiv \frac{S_t B_{t+1}^*}{P_t} \tag{9}$$

As in Gertler and others (2007), the country borrowing premium depends on total net foreign indebtedness and an exogenous process, ε_t^{Φ}, also modeled as an AR(1) process. The introduction of this risk-premium is needed in order to ensure a well-defined steady state in the model (see Schmitt-Grohe and Uribe, 2003, for further details).

The solution of the household's intertemporal utility maximization problem yields the following Euler equation:

$$E_t \left[\beta \frac{\lambda_{t+1}}{\lambda_t} \frac{i_t P_t}{P_{t+1}} \right] = 1 \tag{10}$$

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

$$\lambda_t = \frac{\varepsilon_t^c}{C_t - bC_{t-1}} \tag{11}$$

In addition, the optimality condition governing the choice of foreign bonds yields the following uncovered interest parity condition (UIP), where it is now clear that the exogenous process, ε_t^{Φ}, could be interpreted as a risk premium (UIP) shock:

$$E_t\left\{\lambda_{t+1}\frac{P_t}{P_{t+1}}\left[i_t - \Phi_t i_t^* \frac{S_{t+1}}{S_t}\right]\right\} = 0 \tag{12}$$

As will be discussed below, shocks to the UIP condition are typically used to imitate a sudden stop shock (in parlance of Calvo and other, 2004), that is a shock that is causes large capital outflows (see, for example, Gertler and others, 2007). In the context of this paper, we follow suit, and use this shock to capture the financial aspect of the global financial crisis.

Wage setting

Each household is a monopolistic supplier of a differentiated labor service desired by the domestic firms. This implies that each household has some pricing power over the wage it charges, $W_{j,t}$. After having set their wages, households inelastically supply the firms' demand for labor at the going wage rate.

Each household sells its labor services, $l_t(j)$, to a firm which transforms household labor into a homogenous input good, L_t, good using the following production function:

$$L_t = \left[\int_0^1 (l_t(j))^{\frac{1}{\mu^w}} dj\right]^{\mu^w} \tag{13}$$

where $\mu^w$is the wage markup. This firm takes the input price of the differentiated labor input as given, as well as the price of the homogenous labor services. The demand for labor that an individual household faces is determined by:

$$l_t(j) = \left[\frac{W_{j,t}}{W_t}\right]^{\frac{\mu^w}{1-\mu^w}} L_t \tag{14}$$

Following Kollmann (1997) and Erceg and others (2000), we assume that wages can only be optimally adjusted after some random "wage change signal" is received. Formally, a household who does not re-optimize in period *t* sets its wage as:

$$W_{j,t} = \pi_{t-1}{}^{\gamma_w}(\pi_t^T)^{1-\gamma_w}\zeta_t W_{j,t-1} \tag{15}$$

where γ_w is the degree of wage indexation, with $\pi_t = P_t/P_{t-1}$.

Household j can re-optimize its wage according to the following dynamic program:

$$\max_{W_{new,t}} E_t \sum_{s=0}^{\infty} (\beta\theta_w)^s \left[-\frac{\varepsilon_{t+s}^l}{1+\sigma_l}(l_{t+s}(j))^{1+\sigma_l}\right.$$
$$\left. + \lambda_{t+s}(\pi_t\pi_{t+1} \dots \pi_{t+s-1})^{\gamma_w}(\pi_{t+1}^T\pi_{t+2}^T \dots \pi_{t+s}^T)^{1-\gamma_w}(\zeta_{t+1} \dots \zeta_{t+s})W_{new,t}l_{t+s}(j)\right] \tag{16}$$

where θ_w is the probability of not changing the wage rate. Then the optimization problem, the following first order condition can be derived:

$$E_t \sum_{s=0}^{\infty} (\beta\theta_w)^s l_{t+s}(j) \left[-\varepsilon_{t+s}^{l} (l_{t+s}(j))^{\sigma_l} + \frac{W_{new,t}}{P_t z_t} \frac{z_{t+s}}{\mu^w} \lambda_{t+s} P_{t+s} \left(\frac{P_{t+s-1}}{P_{t-1}} \right)^{\gamma_w} (\pi_{t+1}^{T} \dots \pi_{t+s}^{T})^{1-\gamma_w} \frac{P_{w,t}}{P_{w,t+s}} \right] = 0 \tag{17}$$

where $-\varepsilon_{t+s}^{l}(l_{t+s}(j))^{\sigma_l}$ is the marginal disutility of labor. The log-linearized real wage equation, which is derived from the above equation, can be obtained as:

$$\begin{aligned} &\Xi\theta_w \hat{w}_{t-1} + \left(\sigma_l \mu^w - \Xi(1+\beta\theta_w^2)\right)\hat{w}_t + \beta\Xi\theta_w E_t \hat{w}_{t+1} - \Xi\theta_w(\hat{\pi}_t - \hat{\pi}_t^T) \\ &+\beta\Xi\theta_w(E_t\hat{\pi}_{t+1} - \rho_{\bar{\pi}}\hat{\pi}_t^T) + \gamma_w\Xi\theta_w(\hat{\pi}_{t-1} - \hat{\pi}_t^T) - \gamma_w\beta\Xi\theta_w(\hat{\pi}_t - \rho_{\bar{\pi}}\hat{\pi}_t^T) \\ &+ (1-\mu^w)\hat{\lambda}_t - \sigma_l(1-\mu^w)\hat{l}_t - (1-\mu^w)\hat{\varepsilon}_t^l = 0 \end{aligned} \tag{18}$$

with

$$\Xi = \mu^w \sigma_l - (1-\mu^w)/(1-\beta\theta_w)(1-\theta_w) \tag{19}$$

Foreign economy

In considering arbitrage in goods markets, we distinguish between the wholesale (import) price of foreign goods and its retail price in the domestic market by allowing for imperfect competition and pricing-to-market in the local economy. At the wholesale level, the law of one price holds, which implies:

$$P_{w,t}^{F} = S_t P_t^{F*} \tag{20}$$

Following Gertler and others (2007), we assume that foreign demand for the home tradable good, C_t^{H*}, is given by:

$$C_t^{H*} = \left[\left(\frac{P_t^{H*}}{P_t^{*}} \right)^{-\chi} Y_t^{*} \right]^{\varpi} (C_{t-1}^{H*})^{1-\varpi} \tag{21}$$

where, a shock to Y_t^*, would capture the trade channel of the global financial crisis.

Entrepreneurs

The set up for entrepreneurs is similar to the framework in Gertler and others (2007), who build upon the framework introduced by Bernanke and others (1999). Risk neutral entrepreneurs manage production and obtain financing for the capital employed in the production process. To ensure that they never accumulate enough funds to fully self-finance their capital acquisitions, we assume they have a finite expected horizon. Each entrepreneur survives until the next period with probability ϱ_t , which is time-varying, and subject to an exogenous shock. Intuitively, an adverse shock could be interpreted as an impairment of the entrepreneurs assets caused by heighted financial uncertainty. Variations of this shock have been used by Christiano and others (2003), Elekdag and others (2006), Curdia (2007), as well as Christensen and Dib (2008).

With capital acquired in the previous period, the entrepreneur produces domestic output using capital services (which account for the utilization rate of capital) and labor which is assumed to be a composite of household and managerial labor:

$$H_t = L_t^{\Omega} L_{e,t}^{1-\Omega} \tag{22}$$

The entrepreneurs' gross project output, GY_t, consists of the sum of his production revenues and the market value of his remaining capital stock. In addition, we assume the project is subject to an idiosyncratic shock (with expected value of unity) which affects both the production of new goods and the effective quantity of his capital.

$$GY_t = \frac{P_{w,t}}{P_t} Y_t + \left(Q_t - \frac{P_{I,t}}{P_t} \delta_t \right) \omega_t K_t \tag{23}$$

With the wholesale good production following the technology:

$$Y_t = \omega_t A_t (u_t K_t)^{\alpha} (z_t H_t)^{1-\alpha} \tag{24}$$

where A_t is a stationary productivity shock and z_t is permanent technology shock, which is exogenously given by :

$$\frac{z_t}{z_{t-1}} = \zeta_t \tag{25}$$

$$\log \zeta_t = \rho_{\zeta} \log \zeta_{t-1} + \epsilon_t^{\zeta} \tag{26}$$

Following Greenwood and others (1988), we endogenize the utilization decision by assuming that the capital depreciation rate is increasing in u_t. The depreciation rate, δ_t, is a function of the utilization rate taking the following form:

$$\delta_t = \delta + \frac{\tau}{1+\epsilon} u_t^{1+\epsilon} \tag{27}$$

The problem of the entrepreneur is to choose labor and the capital utilization rate to maximize profits, given the values of $K_t, z_t, A_t,$ and ω_t . The optimality conditions imply the following labor demand functions:

$$(1-\alpha)(1-\Omega) \frac{Y_t}{L_t} = \frac{W_t}{P_{w,t}} \tag{28}$$

$$(1-\alpha)\Omega \frac{\mathrm{Y_t}}{\mathrm{L_t^e}} = \frac{\mathrm{W_t^e}}{\mathrm{P_{w,t}}} \tag{29}$$

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

$$\alpha \frac{Y_t}{u_t} = \delta'(u_t) K_t \frac{P_{I,t}}{P_{w,t}} \tag{30}$$

The entrepreneurs also make capital acquisition decisions. At the end of period *t*, the entrepreneur purchases capital that can be used in the subsequent period *t +1* to produce output at that time. The entrepreneur finances the acquisition of capital partly with his own net worth available at the end of period t, N_{t+1}, and partly by issuing nominal bonds, B_{t+1}, which are purchased by the household. Then capital financing is divided between net worth and debt, as follows (a standard balance sheet identity):

$$Q_t K_{t+1} = N_{t+1} + \frac{B_{t+1}}{P_t} \tag{31}$$

The entrepreneur's demand for capital depends on the expected marginal return and the expected marginal financing cost. The marginal return to capital, R^k_{t+1}, is given by:

$$R^k_{t+1} = \frac{GY_{t+1} - \frac{W_{t+1}}{P_{t+1}} H_{t+1}}{Q_t K_{t+1}} = \frac{\omega_{t+1}\left[\frac{P_{w,t+1}}{P_{t+1}} \alpha \frac{\bar{Y}_{t+1}}{K_{t+1}} - \frac{P_{I,t+1}}{P_{t+1}} \delta_{t+1} + Q_{t+1}\right]}{Q_t} \tag{32}$$

where R^k_{t+1}, depends on the next period's ex-post gross output net of labor costs, normalized by the period t market value of capital. Here, $\bar{Y}_{t+1}$ is the average level of output per entrepreneur, ($Y_{t+1} = \omega_{t+1}\bar{Y}_{t+1}$). Taking expectations, the equation above can be recast as:

$$E_t R^k_{t+1} = \frac{E_t\left\{\frac{P_{w,t+1}}{P_{t+1}} \alpha \frac{\bar{Y}_{t+1}}{K_{t+1}} - \frac{P_{I,t+1}}{P_{t+1}} \delta_{t+1} + Q_{t+1}\right\}}{Q_t} \tag{33}$$

The marginal cost of funds to the entrepreneur depends on financial conditions. As in Bernanke and others (1999), we assume a costly state verification problem. In this setting, it is assumed that the idiosyncratic shock ω_t is private information for the entrepreneur, implying that the lender cannot freely observe the project's gross output. To observe this return, the lender must pay an auditing cost—interpretable as a bankruptcy cost—that is a fixed proportion of the project's ex-post gross payoff. Since the lender must receive a competitive return, it charges the borrower a premium to cover the expected bankruptcy costs. The external finance premium affects the overall financing cost, thereby influencing the entrepreneur's demand for capital.

In general, the external finance premium varies inversely with the entrepreneur's net worth: the greater the share of capital that the entrepreneur can self-finance, the smaller the expected bankruptcy costs and, hence, the smaller the external finance premium. Then, the external finance premium, χ_t, may be expressed as:

$$\chi_t(.) = \chi_t\left(\frac{Q_t K_{t+1}}{N_{t+1}}\right) \tag{34}$$

$$\chi'(.) > 0, \;\; \chi(1) = 1$$

Note that role played by Q_t, the real price of capital, or perhaps more intuitively, the asset price. The equation for external finance premium suggests that, through its effect on the leverage ratio, the movements in real price of capital may affect the external finance premium significantly. Therefore, this equation provides an explicit mechanism that captures the link between asset price movements and variations in firms' cost of financing.

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

$$E_t R_{t+1}^k = \chi_t\left(\frac{Q_t K_{t+1}}{N_{t+1}}\right) E_t\left[i_t \frac{P_t}{P_{t+1}}\right] \tag{35}$$

This equation provides the basis for the financial accelerator. It links movements in the borrower financial position to the marginal cost of funds and, hence, to the demand for capital. Note, as mentioned above, that fluctuations in the price of capital, Q_t, may have significant effects on the leverage ratio.

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

$$V_t = R_t^k Q_{t-1} K_t - \left\{\chi_{t-1}\left(\frac{Q_{t-1} K_t}{N_t}\right) E_t\left[i_{t-1} \frac{P_{t-1}}{P_t}\right]\right\} \frac{B_t}{P_{t-1}} \tag{36}$$

Then, net worth is expressed as a function of V_t and the managerial wage.

$$N_{t+1} = \varrho_t V_t + \frac{W_t^e}{P_t} \tag{37}$$

where the weight ϱ_t reflects the time-varying survival rate, which is a stochastic exogenous process, specifically:

$$\varrho_t = \varrho \varepsilon_t^N \tag{38}$$

$$\log \varepsilon_t^N = \rho_N \log \varepsilon_{t-1}^N + \epsilon_t^N \tag{39}$$

Here, the net worth shock, ε_t^N, can be interpreted as a financial uncertainty shock since it has direct impact on the level of aggregate net worth and therefore the external financial premium. Put differently, the net worth shock could be interpreted as a shock to the rate of destruction of entrepreneurial financial wealth. As is clear from above, this financial uncertainty shock directly affects entrepreneurial net worth and has been used in various forms by Elekdag and others (2006), Curdia (2007), Christiano and others (2003). Another way to think about this shock is that it could be thought of capturing counterparty risk—owing part to Knightian uncertainty—a key consideration during the global financial crisis. This heightened uncertainty regarding cash flows, for example, would impair assets and thus disrupt the financial system.

Lastly, entrepreneurs going out of business at time *t* consume their remaining resources. Then the consumption of entrepreneur is given by:

$$C_t^e = (1 - \varrho_t) V_t \tag{40}$$

where C_t^e denote the amount of the consumption composite consumed by the existing entrepreneurs.

Capital producer

We assume that capital goods are produced by a separate sector in a competitive market. Capital producers are price takers and owned by the representative households. At the end of the period *t*, they buy the depreciated physical capital stock from the entrepreneurs and by using total investment good, they convert them into capital stock, which is sold to entrepreneurs and used for production at period *t+1*. Production technology is described by the following evolution of capital:

$$K_t = (1-\delta_t)K_{t-1} + \left[1-\psi\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \varepsilon_t^i \tag{41}$$

where ψ is the capital adjustment cost with the following properties:

$$\psi(\zeta) = \psi'(\zeta) = 0,\ \psi''(\zeta) = \ \psi > 0$$

and, ε_t^i, is a stationary investment-specific technology shock following an AR(1) process. Note that only the parameter, ψ'', is identified and used in the log-linearized model.

As with consumption, the total investment good is assumed to be given by a CES aggregate of domestic and imported investment goods ($I_t^H$and I_t^F, respectively):

$$I_t = \left[(\gamma_i)^{\frac{1}{\rho_i}}(I_t^H)^{\frac{\rho_i-1}{\rho_i}} + (1-\gamma_i)^{\frac{1}{\rho_i}}(I_t^F)^{\frac{\rho_i-1}{\rho_i}}\right]^{\frac{\rho_i}{\rho_i-1}} \tag{42}$$

where $\gamma_i$is the share of imports in investment, and ρ_i is the elasticity of substitution between domestic and imported investment goods. Because prices of the domestically produced investment goods coincide with the prices of the domestically produced consumption goods we have the following investment demand function:

$$\frac{I_t^H}{I_t^F} = \frac{\gamma_i}{1-\gamma_i}\left(\frac{P_t^H}{P_t^F}\right)^{-\rho_i} \tag{43}$$

where the aggregate investment price, P_t^I, is given by:

$$P_t^I = [\gamma_i(P_t^H)^{1-\rho_i} + (1-\gamma_i)(P_t^F)^{1-\rho_i}]^{\frac{1}{1-\rho_i}} \tag{44}$$

The problem of capital producer is to maximize its future discounted profit stream:

$$\max_{\{I_t\}} \sum_{t=0}^{\infty} E_0\left\{\beta^t\lambda_t\left[Q_t(K_t-(1-\delta_t)K_{t-1}) - \frac{P_{I,t}}{P_t}I_t\right]\right\} \tag{45}$$

subject to the evolution of capital, and implies the following first order condition:

$$\frac{P_{I,t}}{P_t} = Q_t\varepsilon_t^i\left[1-\psi_t-\psi_t^{'}\frac{I_t}{I_{t-1}}\right] + \beta E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}Q_{t+1}\varepsilon_{t+1}^i\psi_{t+1}^{'}\left(\frac{I_{t+1}}{I_t}\right)^2\right\} \tag{46}$$

Retailers of domestic goods

We assume that there is a continuum of monopolistically competitive retailers of measure unity. Retailers of domestic goods buy wholesale goods from entrepreneurs in a competitive manner at price $P_{w,t}$ and then differentiate the product slightly and sell their output to households, capital producers, and foreign country. Given that their output is differentiated, retailers have the monopolistic power to set prices of these final output goods.

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

$$Y_t^H = \left[\int_0^1 Y_t^H(i)^{\frac{1}{\mu_t^H}} di\right]^{\mu_t^H} \tag{47}$$

where μ_t^H is a stochastic process determining the time-varying markup which is assumed to follow:

$$\mu_t^H = \left(1 - \rho_{\mu^F}\right)\mu^H + \rho_{\mu^F}\mu_{t-1}^H + \epsilon_t^{\mu^H} \tag{48}$$

The cost minimization problem implies that each retailer faces an isoelastic demand for his product given by:

$$Y_t^H(i) = \left[\frac{P_t^H(i)}{P_t^H}\right]^{\frac{\mu_t^H}{1-\mu_t^H}} Y_t^H \tag{49}$$

where $P_t^H(i)$ is the price of retailer i and P_t^H is the corresponding price of the composite final domestic good, given by:

$$P_t^H = \left[\int_0^1 P_t^H(i)^{\frac{1}{1-\mu_t^H}} di\right]^{1-\mu_t^H} \tag{50}$$

In parallel to the problem considered for wage determination, the price setting decision in retail sector is modeled as a variant of the Calvo (1983) framework with indexation. In this setting, each retailer can re-optimize its price with probability, $(1 - \theta_H)$, independently of time elapsed since the last adjustment. With probability, θ_H, on the other hand, the retailer is not allowed to re-optimize, and its price in the next period is updated according to the scheme:

$$P_t^H(i) = \pi_{H,t-1}^{\gamma_H}(\pi_t^T)^{1-\gamma_H} P_{t-1}^H(i) \tag{51}$$

with $\pi_t^H = P_t^H / P_{t-1}^H$.

Under these assumptions, the retailer of domestic good which is allowed to set its price, $P_{new,t}^H$, solves the following optimization problem when setting its price:

$$\max_{P^H_{new,t}} E_t \sum_{s=0}^{\infty} (\beta\theta_H)^s \lambda_{t+s} \left\{ \begin{bmatrix} \left(\pi_{H,t}\pi_{H,t+1} \dots \pi_{H,t+s-1}\right)^{\gamma_H} \times \\ (\pi^T_{t+1}\pi^T_{t+2} \dots \pi^T_{t+s})^{1-\gamma_H} P^H_{new,t} \end{bmatrix} Y^H_{t+s}(i) \right. \\ \left. - MC^H_{t+s}(i)(Y^H_{t+s}(i) + z_{t+s}\kappa^H) \right\} \tag{52}$$

Where, κ^H, is a fixed cost, in real terms, ensuring that the profits are zero in steady state and $MC^H_t = P_{w,t}$.

Solving this problem, the following first-order condition is obtained:

$$E_t \sum_{s=0}^{\infty} (\beta\theta_H)^s \lambda_{t+s} \left[\frac{\left(\frac{P^H_{t+s-1}}{P^H_{t-1}}\right)^{\gamma_H} (\pi^T_{t+1}\pi^T_{t+2} \dots \pi^T_{t+s})^{1-\gamma_H}}{\left(\frac{P^H_{t+s}}{P^H_t}\right)} \right]^{\frac{\mu^H_{t+s}}{1-\mu^H_{t+s}}} Y^H_{t+s} P^H_{t+s} \\ \times \left[\frac{\left(\frac{P^H_{t+s-1}}{P^H_{t-1}}\right)^{\gamma_H} (\pi^T_{t+1}\pi^T_{t+2} \dots \pi^T_{t+s})^{1-\gamma_H}}{\left(\frac{P^H_{t+s}}{P^H_t}\right)} \frac{P^H_{new,t}}{P^H_t} - \mu^H_t \frac{MC^H_{t+s}}{P^H_{t+s}} \right] = 0 \tag{53}$$

From the aggregate price index discussed above follows that the average price in period *t* is:

$$P^H_t = \left[\int_0^{\theta_H} (P^H_{t-1}(\pi^H_{t-1})^{\gamma_H}(\pi^T_t)^{1-\gamma_H})^{\frac{1}{1-\mu^H_t}} + \int_{\theta_H}^{1} \left(P^H_{new,t}\right)^{\frac{1}{1-\mu^H_t}} \right]^{1-\mu^H_t} \\ = \left[\theta_H (P^H_{t-1}(\pi^H_{t-1})^{\gamma_H}(\pi^T_t)^{1-\gamma_H})^{\frac{1}{1-\mu^H_t}} + (1-\theta_H)\left(P^H_{new,t}\right)^{\frac{1}{1-\mu^H_t}} \right]^{1-\mu^H_t} \tag{54}$$

where we have exploited the fact that all firms that re-optimize set the same price. Log-linearizing and combining the previous two equations yields the following aggregate Phillips curve relation:

$$\hat{\pi}^H_t - \hat{\pi}^T_t = \frac{\beta}{1+\beta\gamma_H}(E_t\hat{\pi}^H_{t+1} - \rho_{\bar{\pi}}\hat{\pi}^T_t) + \frac{\gamma_H}{1+\beta\gamma_H}(\hat{\pi}^H_{t-1} - \hat{\pi}^T_t) \\ - \frac{\gamma_H\beta(1-\rho_{\bar{\pi}})}{1+\beta\gamma_H}\hat{\pi}^T_t + \frac{(1-\theta_H)(1-\beta\theta_H)}{\theta_H(1+\beta\gamma_H)}(\widehat{mc}^H_t + \hat{\mu}^H_t) \tag{55}$$

Retailers of imported goods

The import sector consists of a continuum of retailers that buy a homogenous good in the world market, turn the imported product into a differentiated (consumption and investment) good and sell it to the consumers and capital producers. Different importing firms buy the homogenous goods at price $S_t P^{F*}_t$. In order to allow for incomplete exchange rate pass-through to the consumption and investment import prices, we assume local currency price stickiness. In particular, similar to the domestic good retailer case, the importing firms follow a Calvo (1983) price setting framework and are allowed to change their price only when they receive a random price change signal with probability $(1-\theta_F)$. The firms that are not allowed to re-optimize, update their prices according to the scheme similar to the domestic retailer's case:

$$P_t^F(i) = \pi_{F,t-1}^{\gamma_F}(\pi_t^T)^{1-\gamma_F} P_{t-1}^F(i) \tag{56}$$

where $\pi_t^F = P_t^F / P_{t-1}^F$.

Let $Y_t^F(i)$ denote the good sold by imported retailer i. Then, the final imported good (sum of consumption and investment imported good) is a CES composite of individual retail goods, given by:

$$Y_t^F = \left[\int_0^1 Y_t^F(i)^{\frac{1}{\mu_t^F}} di\right]^{\mu_t^F} \tag{57}$$

where μ_t^F is a stochastic process determining the time-varying markup for importing good firms which is assumed to follow:

$$\mu_t^F = \left(1-\rho_{\mu^F}\right)\mu^F + \rho_{\mu^F}\mu_{t-1}^F + \epsilon_t^{\mu^F} \tag{58}$$

The cost minimization problem implies that each retailer faces an isoelastic demand for his product given by:

$$Y_t^F(i) = \left[\frac{P_t^F(i)}{P_t^F}\right]^{\frac{\mu_t^F}{1-\mu_t^F}} Y_t^F \tag{59}$$

where $P_t^F(i)$ denotes the price of retailer i and P_t^F is the corresponding price of the composite final imported good, given by:

$$P_t^F = \left[\int_0^1 P_t^F(i)^{\frac{1}{1-\mu_t^F}} di\right]^{1-\mu_t^F} \tag{60}$$

Under these assumptions, the profit maximization problem of the imported good firm which is allowed to set its price is given by:

$$\begin{aligned} \max_{P_{new,t}^F} E_t \sum_{s=0}^{\infty} (\beta\theta_F)^s \lambda_{t+s} \Bigg\{ & \left[\begin{matrix} \left(\pi_{F,t}\pi_{F,t+1} \ldots \pi_{F,t+s-1}\right)^{\gamma_F} \times \\ (\pi_{t+1}^T\pi_{t+2}^T \ldots \pi_{t+s}^T)^{1-\gamma_F} P_{new,t}^F \end{matrix}\right] Y_{t+s}^F(i) \\ & - MC_{t+s}^F(i)(Y_{t+s}^F(i) + z_{t+s}\kappa^F) \Bigg\} \end{aligned} \tag{61}$$

where κ^F is fixed cost of the imported good firm and $MC_t^F = S_t P_t^{F*}$.

The problem yields the following first-order condition:

$$E_t \sum_{s=0}^{\infty} (\beta\theta_F)^s \lambda_{t+s} \left[\frac{\left(\frac{P_{t+s-1}^F}{P_{t-1}^F}\right)^{\gamma_F} (\pi_{t+1}^T \pi_{t+2}^T \dots \pi_{t+s}^T)^{1-\gamma_F}}{\left(\frac{P_{t+s}^H}{P_t^H}\right)} \right]^{\frac{\mu_{t+s}^F}{1-\mu_{t+s}^F}} Y_{t+s}^H P_{t+s}^H$$
$$\times \left[\frac{\left(\frac{P_{t+s-1}^F}{P_{t-1}^F}\right)^{\gamma_F} (\pi_{t+1}^T \pi_{t+2}^T \dots \pi_{t+s}^T)^{1-\gamma_F}}{\left(\frac{P_{t+s}^F}{P_t^F}\right)} \frac{P_{new,t}^F}{P_t^F} - \mu_t^F \frac{MC_{t+s}^F}{P_{t+s}^F} \right] = 0 \tag{62}$$

The first order condition and aggregate price index for imported goods given above yield the following log-linearized Phillips curve relation for imported good inflation;

$$\begin{aligned} \hat{\pi}_t^F - \hat{\pi}_t^T = {} & \frac{\beta}{1+\beta\gamma_F}(E_t\hat{\pi}_{t+1}^F - \rho_{\bar{\pi}}\hat{\pi}_t^T) + \frac{\gamma_F}{1+\beta\gamma_F}(\hat{\pi}_{t-1}^H - \hat{\pi}_t^T) \\ & - \frac{\gamma_F \beta(1-\rho_{\bar{\pi}})}{1+\beta\gamma_F}\hat{\pi}_t^T + \frac{(1-\theta_F)(1-\beta\theta_F)}{\theta_F(1+\beta\gamma_F)}(\widehat{mc}_t^F + \hat{\mu}_t^F) \end{aligned} \tag{63}$$

Monetary policy

In our model, we include a central bank that implements a general interest rate rule to achieve specific policy objectives. The empirical interest rate rule takes the following (log-linear) form:

$$\hat{\imath}_t = \rho_i \hat{\imath}_{t-1} + (1-\rho_i)\left[\hat{\pi}_t^T + \tau_\pi(\hat{\pi}_t - \hat{\pi}_t^T) + \tau_y \hat{y}_t + \tau_s(\hat{s}_t - \hat{s}_{t-1})\right] + \epsilon_t^i \tag{64}$$

where ϵ_t^i denotes an independent and identically distributed domestic monetary policy shock. The policy rule implies that the monetary authority sets the nominal interest rate, taking into consideration the inflation rate deviation from the time-varying inflation target, the output gap, the rate of exchange rate depreciation, and the previous period's interest rate. The time-varying inflation target, in the case of Thailand, for example, allows the model to capture the (subtle) change in the inflation target when the core inflation target range was narrowed to 0.5–3.0 percent in 2009, from 0–3.5 percent. The inflation target is assumed to evolve according to the following stochastic process:

$$\hat{\pi}_t^T = \rho_{\bar{\pi}} \hat{\pi}_{t-1}^T + \epsilon_t^\pi \tag{65}$$

Notice that when the output gap is negative—that is output is below potential—strict adherence to the rule above would imply that the interest rate decreases by an amount dictated by the coefficient τ_y . However, the monetary authority might decrease interest rates by more than what the systematic component of the rule would imply. This (discretionary) deviation from the rule is capture by the error term, which is the monetary policy shock.

Market clearing conditions

Finally, good market equilibrium is defined by the following equations:

$$Y_t^H = C_t^H + C_t^{eH} + I_t^H + C_t^{H*} + G_t \tag{66}$$

where G_t is AR(1) exogenous spending process as in Smets and Wouters (2007), implying that fiscal policy is modeled in a rudimentary fashion.

In the model, all nominal variables are scaled by consumer price index, P_t, and all real variables, except labor, are scaled by the real stochastic trend, z_t, in order to render the model stationary. Then the model is log-linearized around its steady state.

Estimation

The log-linearized model is estimated using Bayesian methods primarily developed by Schorfheide (2000), and later popularized by Smets and Wouters (2003, 2007). In what follows, we discuss the data used in the estimation process, the calibration of the parameters that pin down key steady state ratios, the prior and posterior distributions of the estimated parameters, and then end with an assessment of the fit of the model.

Data

The model is estimated using quarterly data from the third quarter of 2000 to the first quarter of 2012 using 12 standard time series, some of which are shown in **Figure 1**. In line with many other studies, we have chosen to match the following set of variables: the levels of the domestic policy and foreign interest rates, the inflation rates of domestic GDP deflator and core consumer price and foreign consumer price indices, as well as the growth rates of GDP, consumption, investment, exports, imports, foreign GDP, and the real exchange rate. This implies that we derive the state space representation for the following vector of observed variables (shown using model notation):

$$Y_t^{observable} = \{\pi_t^H, \pi_t, \pi_t^*, i_t, i_t^*, \Delta lnY_t, \Delta lnC_t, \Delta lnI_t, \Delta lnC_t^{H*}, \Delta lnM_t, \Delta lnY_t^*, lnRER_t\},$$

where, just to avoid any ambiguity, $\Delta \mathrm{lnC}_t^{H*}$, and, lnRER_t, denote the growth rates of exports and the real exchange rate (using its deviation from HP trend as in some other studies does not change out results substantively), respectively. As is common in the literature, standard transformations were needed to align the data with the model-based definitions. For example, all interest rates are divided by four so that the periodic rates are consistent with the quarterly time series. In addition, in order to make observable variables consistent with the corresponding model variables, the data are demeaned by removing their sample mean, with the exception of inflation and the interest rates, which are demeaned by subtracting their steady-state values, A spreadsheet which contains our estimation dataset and shows in detail all of our data transformations (including, for example, seasonal adjustment) is available upon request.

Regarding the foreign variables, a weighted average of the time series from China, the United States, Japan, and Hong Kong (four largest trading partners) were used for real GDP, interest rate, and inflation rate.[13] We tried various other combinations, including, for example, using just the time series from the United States (source of global crisis), and found that our main results do not change noticeably.

[13] China, Japan, the United States, and Hong Kong SAR are Thailand's largest export destinations accounting for 12, 11, 10, and 7 percent, respectively, of total exports.

Calibrated parameters

We chose the values of α, δ, γ, and γ_i, to calibrate the consumption-, investment-, government expenditures-, and exports-to-GDP ratios to the values of around 62, 21, 5, and 70 percent, respectively in line with Thailand's longer-term averages. The parameter β was fixed at 0.9988 implying an annual riskless real interest rate of approximately 2.5 percent, close to many other studies in the literature.

Regarding the calibration of the financial accelerator, we wanted to match the steady-state external finance premium to an empirical counterpart. To this end, we used the 2001–07 average spread between the bank lending rate and the BOT policy rate.[14] The idea was to capture the spread between a riskless rate and the rate at which entrepreneurs could finance themselves using debt instruments (external finance) to be consistent with the model. This average spread was around 320 basis points, and to achieve this steady state value, along with a leverage ratio of around two (as in Bernanke and others, 1999), parameters for the entrepreneurial survival rate, the monitoring cost fraction, and the variance of the shocks to entrepreneurial productivity were chosen to be 0.9728, 0.15, and 0.40, respectively.

The remaining calibrated parameters were taken from the literature. For example, the share of entrepreneurial labor is set at 0.01 as in Bernanke and others (1999). The steady state price and wage markups were chosen to be 15 percent, which lies in the 10 to 20 percent range utilized in many other studies. The remaining parameters were based off Gertler and others (2007) and include various elasticities of substitution summarized in **Table 1**.

Prior distributions of the estimated parameters

The remaining 43 parameters, shown in **Table 2**, are estimated. These parameters determine the degree of the real and nominal rigidities, the monetary policy stance, as well as the persistence and volatility of the exogenous shocks. The table shows the assumptions pertaining to the choice of distribution, the means, standard deviations, or degrees of freedom.

The choice of priors is in line with the literature. General principles guiding the choice of the distributions are as follows: For parameters bounded between zero and unity, the beta distribution was used. For those assumed to take on positive values only (standard deviations), the inverse gamma distribution was used. Lastly, for unbounded parameters, a normal distribution was chosen.

It may also be useful to compare some parameters choices across some selected papers that also consider small open economy frameworks. We elaborate on the interpretation of these parameters below when the posterior distributions are discussed. For the Calvo (1983) parameters, we set the mean of the prior distribution to 0.5 as in Teo (2009). Similarly, the indexation parameter is set to 0.5 as well, as in Adolfson and others (2007). Turning to the baseline monetary policy rule, interest rate persistence takes a value of 0.7, which is in line

[14] Specifically, IFS codes 57860...ZF... and 57860P...ZF..., respectively for the BOT policy and lending rates, where 578 is Thailand's IFS country code; using the discount rate yields on even lower external finance premium proxy.

with Elekdag and other (2006). In line with the Taylor principle, the responsiveness to inflation was set at 1.5, slightly lower than in other studies, including, for example, Garcia-Cicco (2010). The habit persistence parameter is chosen to be 0.7 as in Adolfson and others (2007), whereas the investment adjustment cost parameter is relatively lower than in that study. Turning finally to the shocks, the persistence parameter was set at 0.8, lower than in Adolfson and others (2007) who use 0.85, but higher than Elekdag and others (2006) as well as Garcia-Cicco (2010), both of which use 0.5. Lastly, the priors guiding most of the standard deviations of the shocks are based on an inverse gamma distribution, typically centered on 0.05 with one degree of freedom.

Posterior distributions of the estimated parameters

The posterior estimates of the variables are also shown in **Table 2**. The table reports the means along with the 5th and 95th percentiles of the posterior distribution of the estimated parameters obtained through the Metropolis-Hastings sampling algorithm. The results are based on a total of 500,000 draws and two independent chains, and the Brooks and Gelman (1998) convergence criteria are achieved.[15]

In general, the parameter estimates are in line with those found in other studies. While comparing parameter estimates across studies is potentially useful, three important issues should be kept in mind. First, various studies consider distinct countries. For example, Garcia-Cicco (2010) considers Mexico (which exports a sizable amount of oil), Elekdag and others (2006) investigate Korea, Teo (2009) focuses on Taiwan, and Adolfson and others (2008) examine Sweden, and Alp and Elekdag (2011) examine Turkey, not to mention closed-economy counterparts focusing on the United States and the euro area as done in Christiano and others (2008). Second, just as the structural features of the economies investigated are different, sample periods and the choice of time series used also differ. For example, this paper deliberately includes a period when Thailand was hit by three major shocks, while most (if not all) other studies do not (and rather focus on more tranquil samples). Third, while most of the models build upon a common core, important differences still remain, most relevantly, for example, in the choice of the monetary policy rule used. In sum, modeling, sample period, and data differences should be recognized when comparing posterior estimates across various studies.

We now compare some selected posterior estimates with those found in some other estimated open economy models. Starting off with nominal rigidities, we find the wage-Calvo parameter of 0.7, which implies that wages are adjusted on average every 10 months (3.33 quarters). By contrast, domestic prices seem to adjust every 5 months (1.63 quarters). Relatedly, the parameters dictating the degrees of indexation are found to be in the 0.5 range, implying that the Philips curve have significant backward looking components. These findings are quite close to those presented by Adolfson and others (2007), Teo (2009), and Alp and Elekdag (2011). As for the real rigidities, the estimates regarding habit formation and investment adjustment costs are 0.75 and 4.2, respectively. Regarding the former, Garcia-Cicco (2010) finds an estimate of 0.8, and as for the latter, Teo (2009) estimates the parameter to be 3.2.

[15] Additional information on our estimation results including, for example, kernel density estimates for the posteriors, together with the priors are available from the authors upon request.

Comparison of estimated policy rules is much more challenging because various studies focus on substantially different specifications. For example, Teo (2009) uses a money-based postulation, whereas Adolfson and others (2007) include the real exchange rate, as well as output growth and the change in inflation along with the more typical output gap and deviation of inflation from target. With these considerations in mind, we first discuss the interest smoothing parameter which is found to be 0.4, which lower when compared with other studies. One reason behind such a low value is unprecedented interest rate cuts implemented by the BOT, especially during the global financial crisis. As for the responsiveness of inflation deviation from target, our estimate is 1.9, which is similar to the value of 1.6 found by Adolfson and others (2007), but more importantly greater than unity. The responsiveness to the nominal exchange rate depreciation is smaller, echoing the findings of Elekdag and others (2006). The responsiveness of policy rates to the output gap takes on a slightly lower value of 0.13.

Turning to the exogenous shocks, we start off by discussing persistence. The estimated persistence parameters lie within the range of 0.26 for the unit root technology shock, and 0.99 for the UIP shock. The 95th percentile of this shock's persistence parameter is estimated to be 0.998, which while high, indicates an absence of unit roots in these processes. As for standard deviations, the foreign interest rate shock is least volatile, whereas the variability of the investment shocks is noteworthy. It may also be useful to point out that as in other studies, the unit-root technology shock is more volatile than the stationary technology shock. This is consistent with the theoretical predictions of Aguiar and Gopinath (2007), who argue that in terms of driving the business cycle, unit-root technology shocks play a prominent role.

Sensitivity analysis

To assess robustness, and gauge the fit of the baseline model with alternative specifications, we conduct sensitivity analysis. One approach would be to investigate the importance of the various features of the model that differentiate it from its New Keynesian core. As discussed in the main text, we investigate the importance of the various features of the model by either reducing the degree of certain nominal and real frictions, omitting a shock process, or evaluating another policy rule. Using the posterior odds ratio as our decision metric, the baseline model seems to decisively outperform the other competing models.

As summarized in **Table 3**, we consider 7 alternative specifications, and in all cases, the results are decisively in favor of the baseline. By way of interpreting the posterior odds ratios, we adapt the guidance provided by Jeffreys (1961) which suggests that ratios above 100 provide decisive evidence in favor of our baseline model—although not shown, the lowest odd ratios calculated was comfortably over 100.

In this context, several results are worth emphasizing.

- First, the exclusion of the financial accelerator mechanism is decisively rejected in favor of the baseline model, which underscores the importance of incorporating such financial frictions in models, particularly when investigating emerging markets, a result also discussed extensively in Elekdag and others (2006), and later in Garcia-Cicco (2010) as well as in Alp and Elekdag (2011).

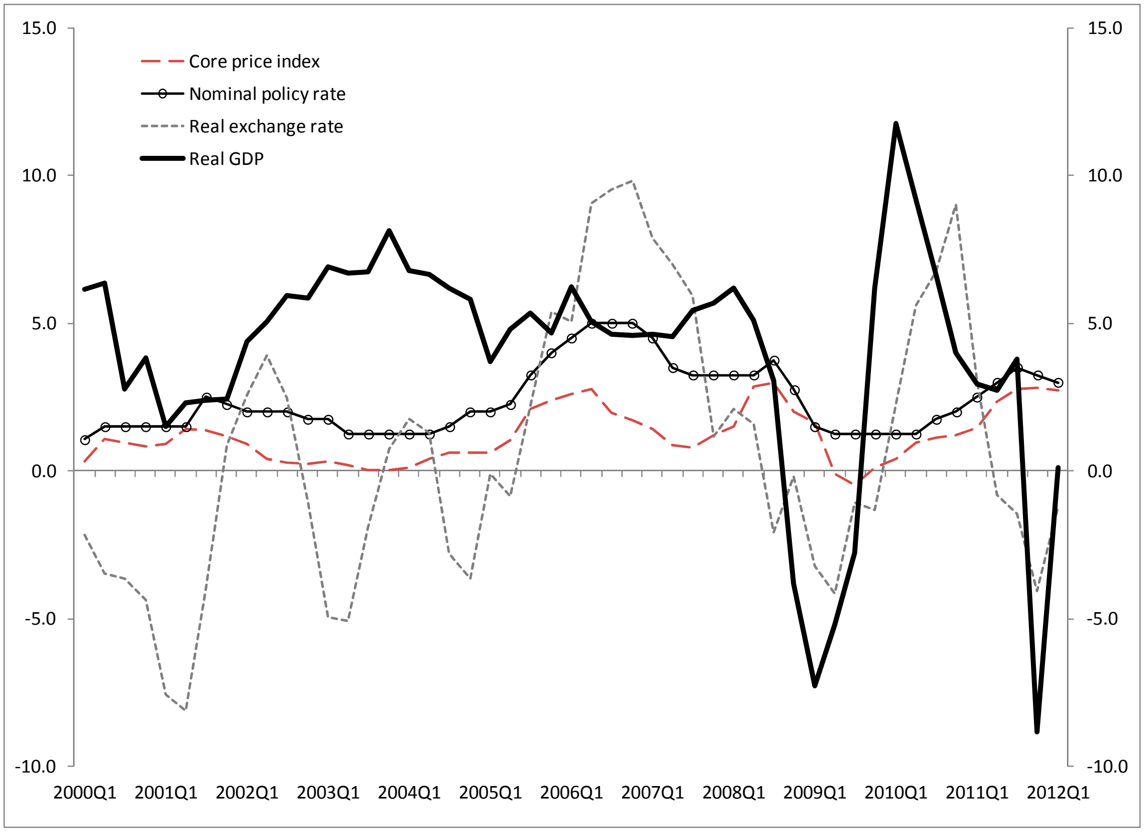
- Second, the baseline is favored to models with low nominal rigidities. In other words, as compared to the canonical real business cycle, other features—typically included in New Keynesian models are needed to better fit the data.

- Third, turning our attention to the role of structural shocks, the table indicates the importance of technology shocks. Aguilar and Gopinath (2007) have argued for the importance of trend shocks, and, for example, Justiniano and others (2007) find a critical role of investment-technology shocks in accounting the variability of output dynamics. The sensitivity analysis confirms the insight of these previous studies. Demand shocks also seem to be important, as models without preference or government spending shocks are rejected in favor of the baseline. In addition, the baseline model is decisively chosen in contrast to a specification where the financial shocks (financial uncertainty and the UIP shocks) are eliminated.

- Fourth, we consider two alternative monetary policy rules. In sum, the results are decisively in favor of the baseline specification. While the data is in favor of giving some weight to the nominal depreciation rate, it decisively rejects a model with a fixed exchange rate regime.[16]

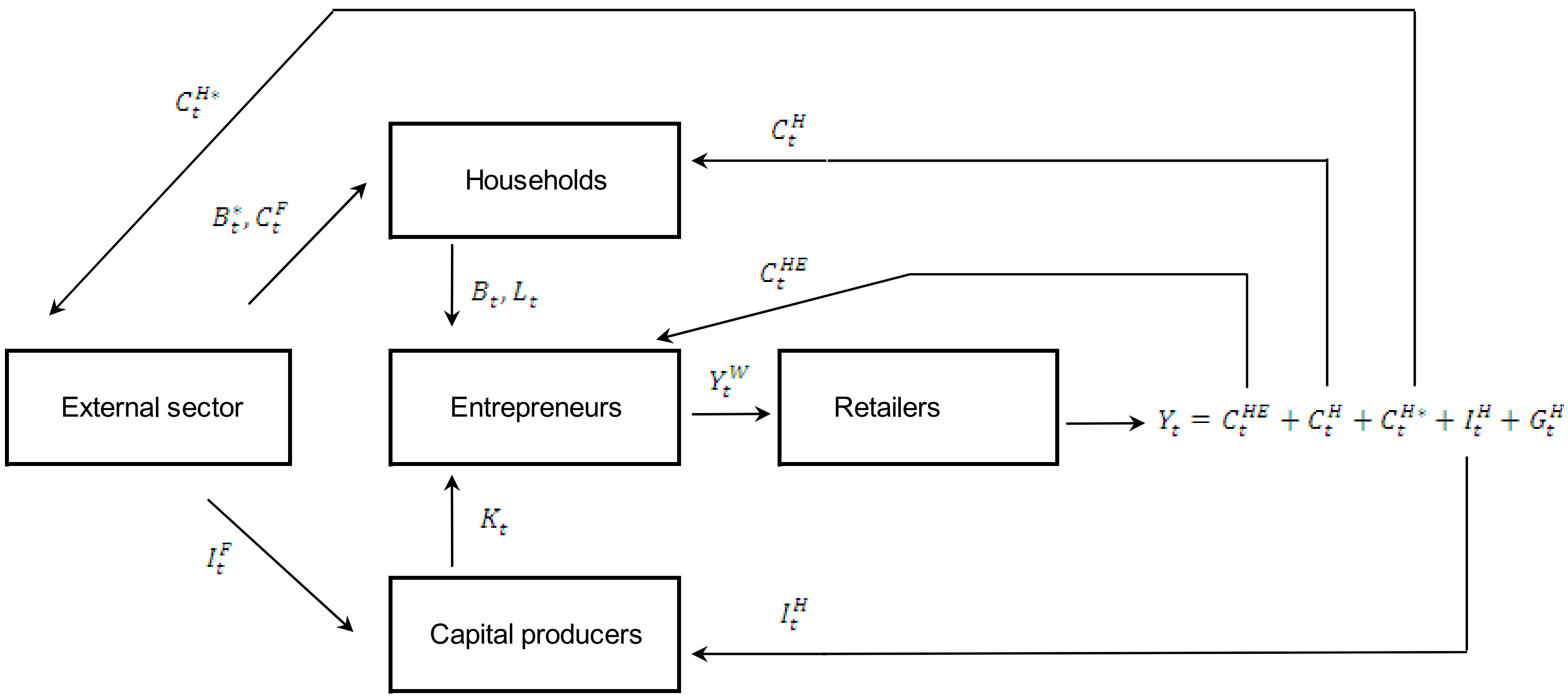
[16] While other rules can be tested, these are not specifications that would describe the past behavior of policy makers accurately, and as discussed in Alp and Elekdag (2011), are rejected by the data.

Figure 1. Thailand: Selected Macroeconomic Indicators



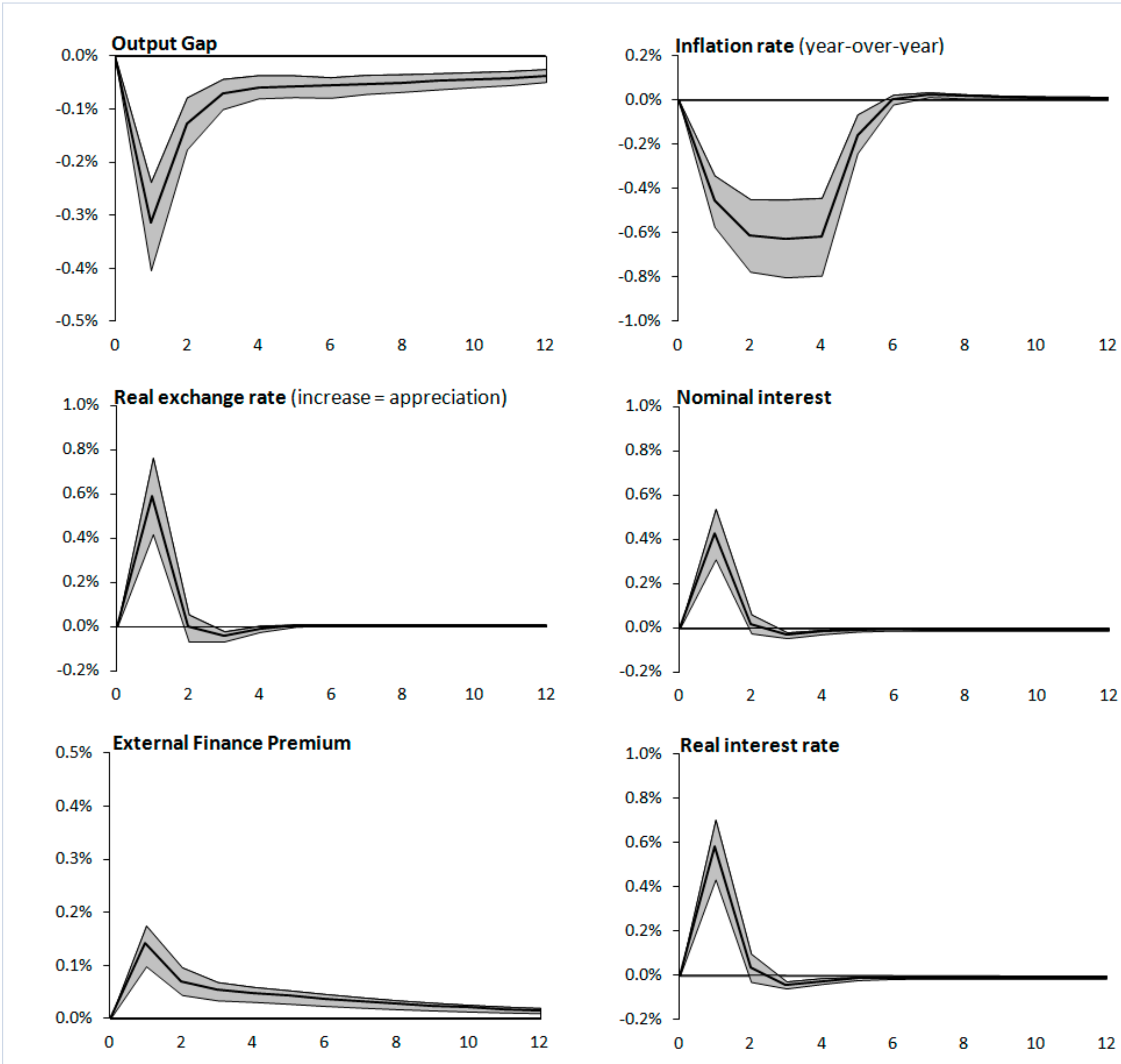
Source: IMF APDCore database and authors' calculations.
Note: All series in percent; year-over-year growth rates shown except for policy rates.

Figure 2. Model Schematic



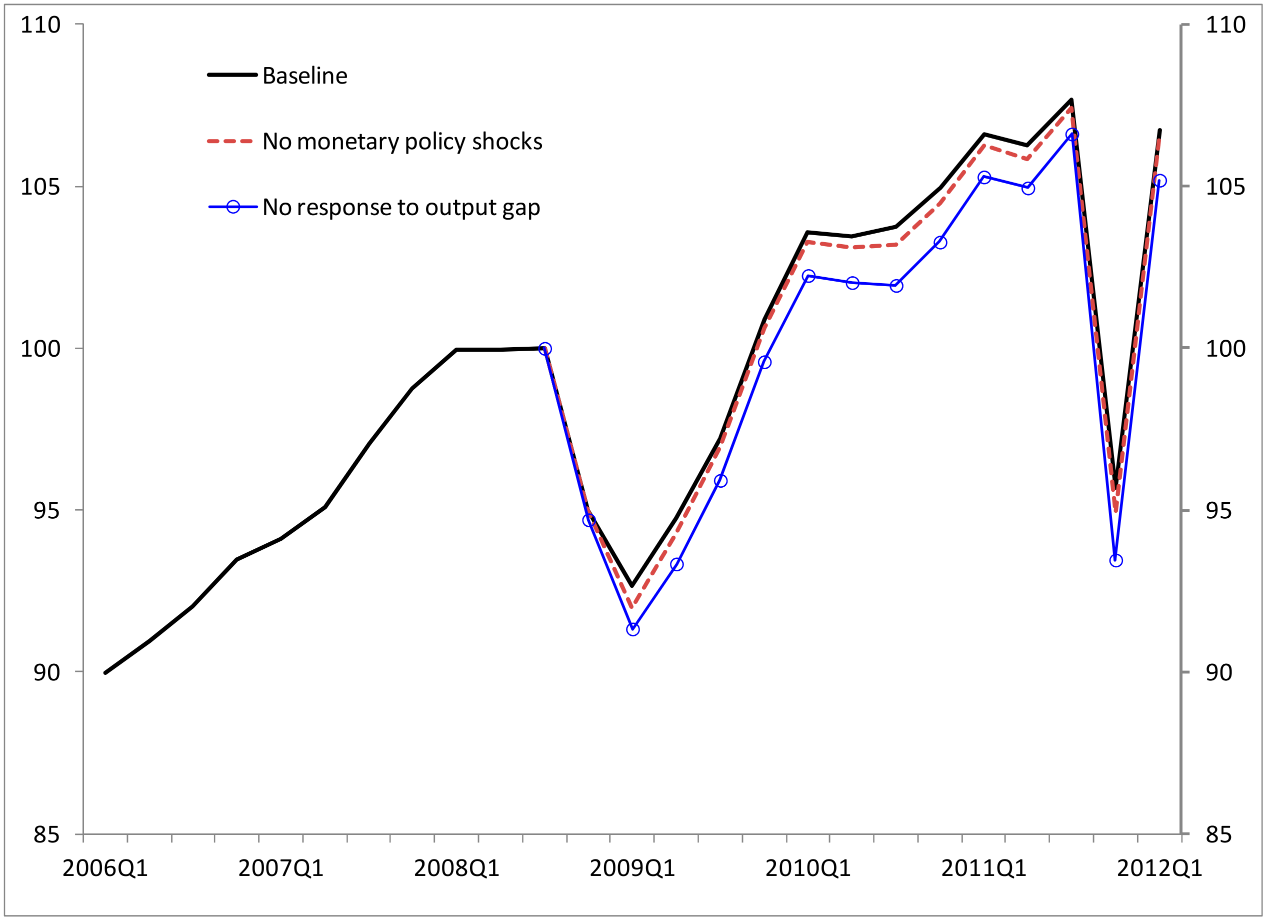
Source: Authors' calculations.

Figure 3. Thailand: The Monetary Transmission Mechanism



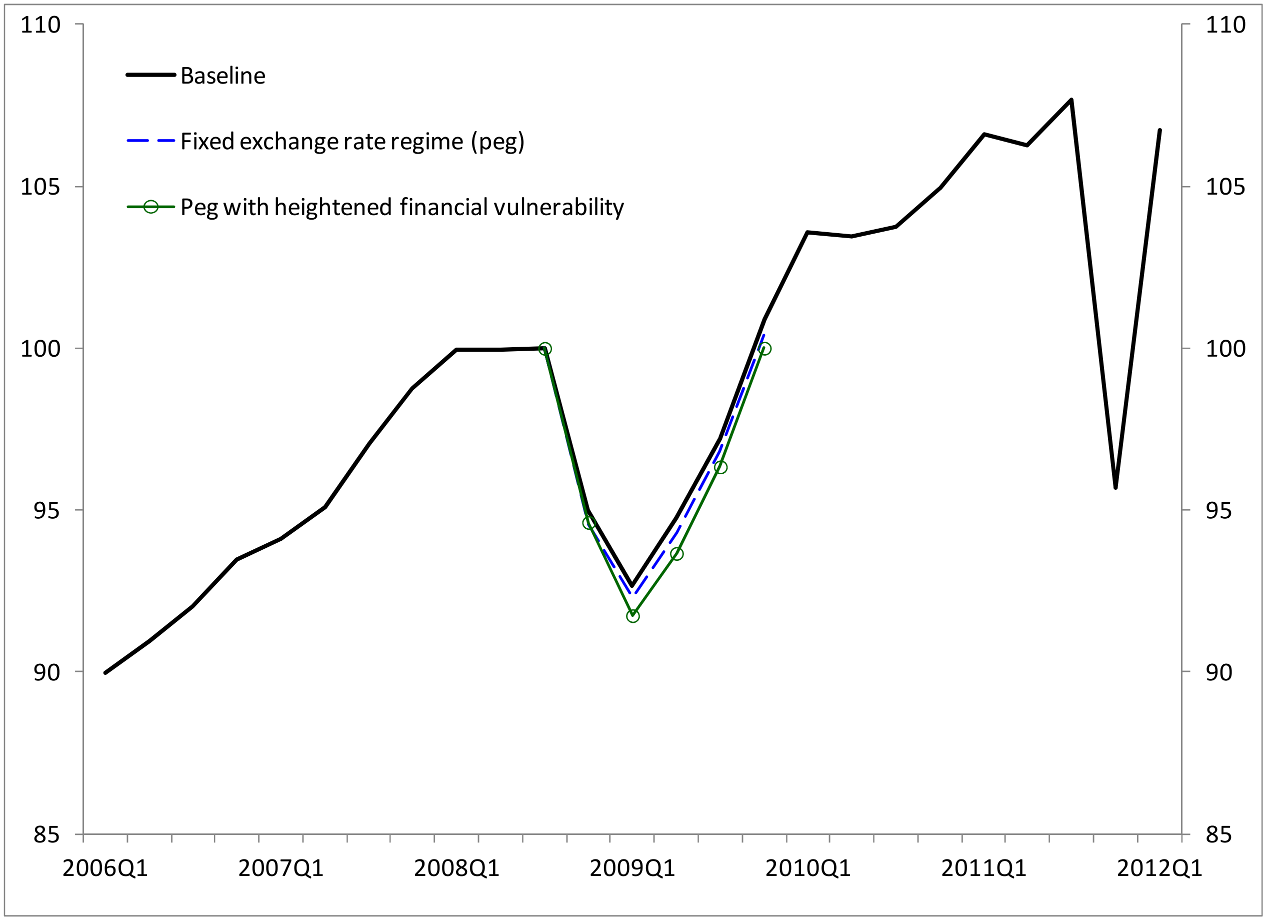
Source: Authors' calculations.
Note: Bayesian impulse response functions to a contractionary monetary policy shock. Interest rates, inflation rates, and the external finance premium are shown as absolute deviations from their steady states, while the other variables are percentage deviations from their steady states.

Figure 4. Counterfactual Scenarios: The Role of Countercyclical Monetary Policy



Source: Authors' calculations.
Note: Figure denotes the level of real GDP as an index with 2008Q1=100.
Baseline denotes the actual evoluation of Thai real GDP.

Figure 5. Counterfactual Scenarios: The Role of Exchange Rate Flexibility and Financial Reforms



Source: Authors' calculations.
Note: Figure denotes the level of real GDP as an index with 2008Q1=100.
Baseline denotes the actual evoluation of Thai real GDP.

Table 1. Calibrated Parameters

Parameter	Symbol	Value
Discount factor	β	0.9988
Consumption intra-temporal elasticity of substitution	ρ	1.00
Share of domestic goods in consumption	γ	0.075
Investment intra-temporal elasticity of substitution	ρ_i	0.25
Share of domestic goods in investment	γ_i	0.125
Inverse of the elasticity of work effort with respect to the real wage	σ_l	1.00
Share of capital in production function	α	0.50
Elasticity of marginal depreciation with respect to utilization rate	ϵ	1.00
Steady state markup rate for domestically produced goods	μ^H	1.15
Steady state markup rate for imported goods	μ^F	1.15
Steady state markup rate for wages	μ^W	1.15
Share of entrepreneurial labor	$1-\Omega$	0.01
Steady state external finance premium	χ	1.03
Number of entrepreneurs who survive each period (at steady state)	ϱ	0.9728
Variance of idiosyncratic shock to entrepreneur production	σ_ω	0.40
Fraction of monitoring cost	μ_ω	0.15
Depreciation rate (at steady state)	δ	0.025
Elasticity of country risk premium with respect to net foreign debt	Φ	0.001

Source: Authors' calculations.

Table 2. Prior and Posterior Distributions

Parameter		Prior distribution			Posterior distribution		
Description	Symbol	Type	Mean*	Standard deviation	Mean	Confidence interval 5%	95%
Calvo parameter							
Domestic prices	θ_H	Beta	0.50	0.10	0.364	0.239	0.497
Import prices	θ_F	Beta	0.50	0.10	0.385	0.312	0.455
Wages	θ_w	Beta	0.50	0.10	0.705	0.593	0.817
Indexation							
Domestic prices	γ_H	Beta	0.50	0.10	0.536	0.374	0.695
Import prices	γ_F	Beta	0.50	0.10	0.452	0.282	0.607
Wages	γ_w	Beta	0.50	0.10	0.517	0.354	0.684
Monetary policy							
Interest rate smoothing	ρ_i	Normal	0.70	0.20	0.37	0.21	0.54
Inflation reponse	τ_π	Normal	1.50	0.20	1.94	1.65	2.23
Output gap response	τ_y	Beta	0.50	0.10	0.13	0.07	0.18
Nominal exchange rate depreciation response	τ_s	Beta	0.10	0.05	0.16	0.08	0.23
Others							
Export demand elasticity	χ	Normal	1.00	0.20	0.508	0.426	0.596
Export demand interia	ϖ	Beta	0.50	0.20	0.929	0.872	0.990
Habit formation	b	Beta	0.70	0.20	0.752	0.671	0.840
Invesment adjustment cost	ψ	Normal	4.00	0.50	4.224	3.519	4.925
Shock persistence							
Stationary technology	ρ_a	Beta	0.80	0.10	0.794	0.649	0.957
Unit root technology	ρ_ζ	Beta	0.80	0.10	0.258	0.176	0.339
Investment specific technology	ρ_{inv}	Beta	0.80	0.10	0.926	0.911	0.940
Domestic markup	ρ_{μ^h}	Beta	0.80	0.10	0.739	0.567	0.921
Import markup	ρ_{μ^f}	Beta	0.80	0.10	0.849	0.766	0.941
Foreign inflation	ρ_{π^*}	Beta	0.80	0.10	0.413	0.261	0.558
Foreign interest rate	ρ_{i^*}	Beta	0.80	0.10	0.877	0.801	0.954
Foreign demand	ρ_{y^*}	Beta	0.80	0.10	0.975	0.956	0.994
Country risk premium	ρ_{Φ}	Beta	0.80	0.10	0.986	0.974	0.998
Preference	ρ_c	Beta	0.80	0.10	0.742	0.564	0.935
Labor supply	ρ_l	Beta	0.80	0.10	0.788	0.637	0.935
Exogenous spending	ρ_g	Beta	0.80	0.10	0.922	0.875	0.971
Net worth	ρ_N	Beta	0.80	0.10	0.657	0.508	0.811
Inflation target	$\rho_{\bar{\pi}}$	Beta	0.80	0.10	0.867	0.783	0.952
Shock volatility							
Stationary technology	σ_a	Inverse gamma	0.05	2.00	0.018	0.012	0.024
Unit root technology	σ_ζ	Inverse gamma	0.05	2.00	0.052	0.043	0.062
Investment specific technology	σ_{inv}	Inverse gamma	0.05	2.00	0.243	0.204	0.284
Domestic markup	σ_{θ^H}	Inverse gamma	0.05	2.00	0.017	0.011	0.022
Import markup	σ_{θ^F}	Inverse gamma	0.05	2.00	0.014	0.009	0.018
Foreign inflation	σ_{π^*}	Inverse gamma	0.01	2.00	0.008	0.006	0.009
Foreign interest rate	σ_{i^*}	Inverse gamma	0.01	2.00	0.002	0.001	0.002
Foreign demand	σ_{y^*}	Inverse gamma	0.01	2.00	0.060	0.050	0.071
Country risk premium	σ_{Φ}	Inverse gamma	0.05	2.00	0.010	0.008	0.011
Preference	σ_c	Inverse gamma	0.05	2.00	0.060	0.021	0.095
Labor supply	σ_l	Inverse gamma	0.05	2.00	0.032	0.012	0.053
Exogenous spending	σ_g	Inverse gamma	0.05	2.00	0.021	0.017	0.025
Net worth	σ_N	Inverse gamma	0.05	2.00	0.019	0.012	0.026
Inflation target	$\sigma_{\bar{\pi}}$	Inverse gamma	0.05	2.00	0.011	0.008	0.013
Monetary policy		Inverse gamma	0.05	2.00	0.008	0.007	0.010
Log data density	1394.9						

* For the inverse gamm distributions, the mean and the degress of freedom are reported.

Source: Authors' calculations.
Note: Log data density is 1,265. For inverse gamma distributions, mean and degrees of freedom are reported.

Table 3. Sensitivity Analysis

		Log data density	Is the alternative model superior?
	Baseline model	1394.889	
	Sensitivity to frictions		
1	Financial accelerator	1353.392	No
2	Low stickness including wages	1364.028	No
	Sensitivity to shocks		
3	Technology (all)	1162.531	No
4	Preference and Government	1156.878	No
5	Financial (uncertainty and UIP)	1390.121	No
	Sensitivity to policy rules		
6	Baseline rule, but without ΔS rule	1338.884	No
7	Fixed exchange rate regime	1276.392	No

Source: Authors' calculations.
Note: UIP and ΔS denoted uncovered interest rate parity and the change in the nominal (won/dollar) exchange rate, where an increase in S denotes a depreciation of the Thai baht.

Table 4. The Role of Monetary Policy and Three Major Shocks

Episode	Quarters	Average year-over-year growth contributions of monetary policy owing to: [1] Monetary policy shocks	[2] Responsiveness to the output gap	[3] Flexible exchange rate regime	[4] Reduced financial vulnerability	[5] Total ([1]—[4])
Global financial crisis						
2008Q4—2009Q3	4	0.24	0.55	0.43	0.35	1.57
Japan earthquake						
2011Q2	1	0.07	—	1.18	—	1.26
Thai floods						
2011Q4	1	0.40	0.37	0.45	0.11	1.32
Total	6	0.71	0.91	2.06	0.45	4.14
Christiano and others (2008)						
United States (2001Q2-2002Q2)	4	0.75				
Euro area (2001Q4-2004Q4)	13	1.27				

Source: Authors' calculations.
Note: In percent.

Table 5. Summary of the Role of Monetary Policy

Real GDP Growth

(Year-over-year)

Episode	[1] Actual (Baseline)	[2] Without countercyclical monetary policy	[3] Difference (= [2] – [1])	[4] Peg with financial fragility	[5] Difference (= [4] – [2])
Global financial crisis (2008Q4—2009Q3)	-4.8	-5.6	-0.8	-6.4	-0.8
Japanese earthquake (2011Q2)	2.8	2.8	-0.1	1.6	-1.2
Thai floods (2011Q4)	-8.9	-9.7	-0.8	-10.3	-0.6
Total growth drag			-1.6		-2.5

Source: Authors' calculation
Note: In percent.

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