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Did Korean Monetary Policy Help Soften the Impact of the Global Financial Crisis of 2008–09?

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Abstract

Korea was one of the Asian economies hardest hit by the global financial crisis. Anticipating the downturn that would follow the episode of extreme financial stress, the Bank of Korea (BOK) let the exchange rate depreciate as capital flowed out, and preemptively cut the policy rate by 325 basis points. But did it work? This paper seeks a quantitative answer to the following question: Were it not for an inflation targeting framework underpinned by a flexible exchange rate regime, how much deeper would the recession have been? Taking the most intense year of the crisis as our baseline (2008:Q4–2009:Q3), counterfactual simulations indicate that rather the actual outcome of a –2.1 percent contraction, the outturn would have been –2.9 percent if the BOK had not implemented countercyclical and discretionary interest rate cuts. Furthermore, had a fixed exchange rate regime been in place, simulations indicate that output would have contracted by –7.5 percent over the same four-quarter period. In other words, exchange rate flexibility and the interest rate cuts implemented by the BOK helped substantially soften the impact of the global financial crisis on the Korean economy. These counterfactual experiments are based on an estimated structural model, which, along with standard nominal and real rigidities, includes a financial accelerator mechanism in an open-economy framework.

JEL Classification Numbers:E5, F3, F4, C11

Keywords: financial accelerator, Bayesian estimation, DSGE model, financial crises, sudden stops, monetary policy, Korea, emerging economies, emerging markets.

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EXECUTIVE SUMMARY

This paper argues that the proactive monetary policy stance implemented by the Bank of Korea (BOK) helped soften the impact of the global financial crisis of 2008–09. Specifically, the findings suggest that without the adoption of an inflation targeting framework underpinned by a flexible exchange rate regime, the global financial crisis would have been associated with a much deeper economic contraction in Korea.

Korea is an interesting case study because it was one of the Asian economies which was most adversely affected by the global financial crisis and the sudden stop in capital flows. To mitigate the severity of the downturn that would very likely follow the financial stress episode (see for example, Cardarelli and others, 2011), the Bank of Korea (BOK) let the exchange rate depreciate and cut policy rates by 325 basis points.

But did this help? Specifically, this paper seeks to find a quantitative answer to the following question: If an inflation targeting framework underpinned by a flexible exchange rate regime were not in place, how much deeper would the recent recession have been? This paper finds that the recession would have been substantially more severe.

The most intuitive way to communicate our quantitative results is by taking the growth rate during the most intense year of the global financial crisis as our baseline, namely the 2008:Q4–2009:Q3 period. Model-based counterfactual simulations indicate that without the countercyclical and discretionary interest rates cuts implemented by the BOK, output would have contracted by 2.9 percent rather than the actual 2.1 percent during these four quarters. Moreover, if a fixed exchange rate regime would have been in place instead of the current inflation targeting regime (which is underpinned by a flexible exchange rate), the results indicate that growth over the same 2008:Q4–2009:Q3 period would have been –7.5 percent. In other words, these simulations underscore the favorable output stabilization properties owing to the combination of countercyclical monetary policy and exchange rate flexibility.

These finding are based on counterfactual simulations derived from an estimated dynamic stochastic general equilibrium (DSGE) model which, along with standard nominal and real rigidities, includes a financial accelerator mechanism in an open-economy framework.

In sum, without the adoption of an inflation targeting framework underpinned by a flexible exchange rate regime, the impact of the recent global financial crisis would have been substantially more severe.

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I. INTRODUCTION

The global financial crisis which intensified during September 2008 was associated with an episode of acute international financial distress and a sharp global economic slowdown. In this context, taking the most intense year of the crisis as our baseline, namely the four quarters spanning the 2008:Q4–2009:Q3 period, Korean real GDP contracted by 2.1 percent. While such a downturn is quite moderate relative to many other countries' experiences, Korea was one of the most adversely affected Asian economies. To mitigate the severity of the recession, the Bank of Korea (BOK) let the exchange rate depreciate and cut policy rates by 325 basis points. But did this help?

The focus of this paper is to assess the role of countercyclical interest rate cuts and exchange rate flexibility in mitigating the fallout from the global financial crisis. Specifically we seek to address to following question: If an inflation targeting framework underpinned by a flexible exchange rate regime had not been in place, how much deeper would the downturn in Korea have been? This paper finds that the downturn would have been substantially more severe.

To provide a quantitative answer to this question, we develop and estimate a small open economy dynamic stochastic general equilibrium (DSGE) model designed to capture salient features of the Korean 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. To more intuitively convey our quantitative results, we consider the growth rate during the most intense year of the global financial crisis as our baseline, namely the four quarters covering the 2008:Q4–2009:Q3 period. In this context, our counterfactual simulations indicate that without the countercyclical and discretionary interest rate cuts possible under the inflation targeting regime, growth over the four quarters under consideration would have been –2.9 percent instead of the actual outcome of –2.1 percent. This lies within the range found by Christiano and others (2008), which finds growth contributions of 75 basis points and 127 basis points for the United States and the Euro area, respectively, which is further discussed below.

Other counterfactual experiments are also insightful. For example, if a fixed exchange rate regime would have been in place instead of the current inflation targeting regime which operates with a flexible exchange rate, the results indicate that growth over the 2008:Q4–2009:Q3 period have been –7.5 percent—a difference from the actual outcome of 5.4 percentage points.

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 recent global financial crisis would have been substantially more severe. The inflation targeting framework underpinned by a flexible exchange rate seems to have increased the robustness of the Korean economy to shocks. The inflation targeting framework allowed the BOK to implement countercyclical and discretionary interest rate cuts, with exchange rate flexibility also serving as a shock absorber, both of which increased the resilience of the economy. The latter result echoes the favorable output stabilization properties of exchange rate flexibility which can be traced back to at least to the seminal contributions of Mundell and Fleming.

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 discussed below.[2]

This paper is structured as follows. The next section begins by briefly providing the institutional backdrop of Korean monetary and exchange rate policies, and some relevant on the nature of the shock that hit Korea in 2008 in the immediate aftermath of the collapse of Lehman Brothers in September 2008. The paper then goes on to describe the model used in this paper, followed by a description of the estimation results for the case of Korea. This is followed by an assessment of the result and its implications for the channels of transmission of monetary policy. The final section concludes with some policy implications.

II. Background to the 2008–09 Crisis and its Impact

Korea formally adopted an inflation targeting framework in 1998. Consistent with this target, the exchange rate was allowed to float freely. Following the adoption of the new monetary policy framework, the Korean economy had average annual inflation of 2.7 percent during 1999–2007, and average annual GDP growth of 5.8 percent.

With the financial crisis that originated in the U.S. subprime market going global following the collapse of Lehman Brothers in September 2008, the accompanying global liquidity squeeze hit Korea hard. The capital account deteriorated by over 6 percentage points of GDP, compared with 5½ percentage points of GDP during the 1997–98 Asian crisis. Both the currency and the equity markets declined by around 30 percent, the severe dollar shortage spilled over into domestic money markets, and the perceived default risk of Korean banks, which relied heavily on wholesale funding, increased by more than anywhere else in Asia.

In response to this abrupt reversal of capital flows, and the accompanying collapse of global trade, the Korea authorities undertook swift and decisive policy actions along a number of fronts. The authorities set aside $55 billion in foreign exchange reserves to provide as swaps or loans to banks and trade-related businesses. They implemented significant monetary and

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[2] For a model which investigates possible refinements to an inflation targeting framework by incorporating financial stability considerations focusing on Korea, see Aydin and Volkan (2011).

fiscal stimulus to arrest the slide in confidence and support the real economy. They also set up preemptively a bank recapitalization fund and a toxic asset fund to shield the banking system from the downturn and prevent an abrupt deleveraging. In addition, the authorities initiated a swap facility with the U.S. Federal Reserve for around $35 billion, as well as bilateral swap facilities with the People's Bank of China (equivalent to around $26 billion) and the Bank of Japan (equivalent to around $20 billion). To ensure adequate liquidity in the domestic market, the Bank of Korea also broadened the list of eligible counterparties and collateral in its repurchase operations and relaxed banks' liquidity requirements.

These policy measures helped avert a credit crunch or an abrupt deleveraging, and the financial system remained sound. However, the economic downturn was unavoidable. Korea suffered its greatest export slump on record. By January 2008, exports were down 35 percent year-on-year. This spilled over to domestic demand, with real investment contracting 6½ percent quarter-on-quarter, and private consumption falling 4½ percent, quarter-on-quarter. Overall, the Korean economy contracted 5.1 percent, quarter-on-quarter in end-2008, among the sharpest contractions worldwide (**Figure 1**). However, Korea's subsequent recovery was among the fastest and strongest in Asia with GDP growth of 6.2 percent for 2009 as a whole, and by the middle of 2010, the output gap had closed.

III. A Model for Korea's Monetary Policy

This section presents an overview of the structural model underpinning our quantitative results on the role of monetary policy during the downturn. As mentioned above, readers primarily interested in the main policy implications of the paper could directly proceed to Section VII and Section VIII. 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 implement monetary and fiscal policy. A visual representation of the flow of goods and services across these agents is shown in **Figure 2**. 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.

[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).

A. The Transmission of Shocks

Recall that this paper seeks to investigate the role of monetary policy in softening the impact of the global financial crisis on the Korean economy. To help foster model intuition, it would be useful to focus on three shocks associated with the crisis and explore how they were transmitted to the Korean economy. These shocks are: a collapse in foreign demand, distress across international capital markets, and heightened uncertainty. 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 exports, C_t^{H*}. Therefore, a collapse in export (foreign) demand is simply represented by a decline in C_t^{H*}.

The sudden stop shock

Korea'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 (Korean won 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 other 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. This sudden stop shock would serves to capture an important dimension of the financial aspect of the recent crisis.[4]

[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).

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 $\chi_t(\cdot)$. In turn, 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, N_{t+1}, is complex (and shown in the Appendix), so here we use an abridged version:

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

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.

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

[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.

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 (see Appendix for further details):

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

where in this flexible specification, $\hat{\imath}_t, \hat{\pi}_{t+1}, \hat{y}_t, \hat{s}_t$ denote the (short-term policy) interest rate, the (core CPI) inflation rate, the output gap, and the nominal exchange rate, respectively. 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:

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

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).

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, during the most intense episode of the global financial crisis, interest rates decreased by more than the amount the empirical counterpart of the rule would have implied, helping soften the impact of the global financial crisis.

IV. Estimation of the Model for Korea

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 first quarter of 2000 to the third quarter of 2010 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 (2002–10) covers the period when the BOK was fully transitioned into an inflation targeting central bank.

B. Model Parameters

We followed 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.

C. Sensitivity Analysis

To assess the robustness of the estimated model, we consider a battery of 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 extensively in the Appendix, the main takeaway is that we consider 11 alternative specifications, and the results are decisively in favor of the baseline.

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 Korea during a sample period which encompasses the global financial crisis, we present Bayesian impulses 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 18 basis point (quarterly) increase in the nominal interest rate (**Table 2**), which implies an annual increase in the policy rate of about 72 basis points. The output gaps dips below the steady state by 38 basis points, whereas the year-over-year inflation rate reaches a trough of about 33 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 is 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 global financial crisis is primarily captured using shocks to foreign demand, financial uncertainty, and the uncovered interest rate parity (UIP) condition. 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).[6]

VI. The Role of Monetary Policy During the Crisis

In this section of the paper, we conduct some counterfactual experiments with the goal of answering the following question: If the adoption of the flexible exchange rate regime and the implementation of active countercyclical monetary policy within an inflation targeting framework were not carried out, how much deeper would the recent recession been?

As will be discussed below, that answer is that the recession would have been significantly more severe. In fact, the counterfactual simulations indicate that without the countercyclical and discretionary interest rates cuts implemented by the BOK, growth over the 2008:Q4–2009:Q3 period would have decreased from the actual realization of -2.1 percent to -2.9 percent. Moreover, if a fixed exchange rate regime were in place instead of the current inflation targeting regime (which is underpinned by a flexible exchange rate), the results indicate that growth in over the same four quarters would have been -7.5 percent, a difference from the actual outcome of 5.4 percentage points.

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[6] Further details, including impulse response analysis of the other structural shocks are available from authors upon request.

A. Setting Up the Counterfactual Simulations

Recall that this paper is trying to assess the role of the BOK's inflation targeting regime in terms of mitigating the impact of the global financial crisis on the Korean economy.

Though intimately related, the model allows us to separately investigate the contributions of countercyclical interest rate policy and exchange rate flexibility in terms softening the impact of the crisis. Therefore in what follows, we consider three counterfactual simulations and compare them with the actual realization which is our baseline. 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 BOK did not implement any discretionary loosening (deviations from the interest rate rule) during the crisis?

- **Peg**: in this counterfactual, the BOK is assumed to implement a strict fixed exchange rate regime.[7] Intuitively, there are no discretionary deviations from the rule (which 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 BOK was implementing a fixed exchange rate regime?

- **Peg with heightened financial vulnerability**: under the last counterfactual, the BOK 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 BOK was implementing a fixed exchange rate regime *and* the economy was financially more vulnerable?

B. Results Based on the Counterfactual Simulations

Figure 4 depicts the level of real GDP with the first quarter of 2008 (the pre-crisis peak) normalized to 100 to allow the reader to better distinguish the (cumulative) effects of each counterfactual. To further highlight the main results, the figure starts in 2005:Q1, and only shows the counterfactuals over the 2008:Q1–2009:Q3 period.[8] The figure depicts (1) the actual realization of real GDP (the baseline scenario), (2) the counterfactual scenario without

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[7] 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.

[8] All results are available from the authors' upon request.

the monetary policy shocks, (3) the counterfactual scenario with the fixed exchange rate regime (peg), and (4) an illustrative counterfactual scenario with the peg under heightened financial vulnerabilities.

As clearly seen from **Figure 4**, the inflation targeting framework underpinned by a flexible exchange rate regime clearly softened the impact of the global financial crisis. More specifically, it is useful to discuss two main results:

- First, as expected, output growth declines the most under the 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 that ensued during the global crisis. Intuitively, the illustrative counterfactual experiment with heightened financial vulnerabilities, and thereby a more pronounced balance sheets channel, leads to an even sharper decline in output. These counterfactual experiments highlight the role of the exchange rate flexibility as well as financial reforms that promote the soundness of the financial system.

- Second, as discussed in the previous section, there is an important role for the discretionary departure from the interest rate rule, which helped soften the impact of the crisis. At first glance, while they may seem small, as we discuss in further detail in the next subsection, the role of these discretionary departures from the interest rate rule (the monetary policy shocks) are very much in line with the literature.

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

We now focus on the growth implications associated with the counterfactuals discussed above. The main takeaways discussed above could have also been based using (year-over-year, demeaned) growth rates as shown in **Figure 5**. However, this section tabulates the precise contributions to growth under the various counterfactuals discussed above, which are shown in **Table 5**. As before, the intention is to focus on the most intense period of the global financial crisis, which for Korea, covered the four quarters spanning the 2008:Q4–2009:Q3 period.

Before investigating the details, it would be useful to clarify the information contained in **Table 5**. The values under columns show either the average or cumulative contributions to growth during the 2008:Q4–2009:Q3 period. It presents our results, as well as the results of Christiano and others (2007)—the most closely related study to ours in terms of conducting counterfactual experiments. After tabulating the number of quarters, columns [1] through [4] indicate the incremental contribution to growth owing to the consecutive implementation of each policy. For example, under Column [3] indicates that reducing financial vulnerabilities added, on average, 1.05 percentage points to growth. In addition to this effect, the incremental growth contribution of adopting a flexible exchange rate regime, denoted under column [2], is 4.27 percentage points.

It would be useful to compare the results in **Table 5** with the literature. Turning our attention to column [1], we see that the average contribution of the monetary shocks (discretionary deviations from the empirical interest rate rule) to output growth is about 77 basis points, which lies in between the values found by Chrisitiano and others (2007) for the U.S. (0.75 percent) and the euro area (1.27 percent). The cumulative growth contributions also seem reasonable, and give some further context on the role of monetary policy in terms of softening the impact of the crisis.

Table 5 summarizes our main findings. During the year covering 2008:Q4–2009:Q3, the actual growth rate was –2.1 percent. Our model-based simulations suggest that if the BOK had not departed from the empirical interest rate rule, growth would have instead been –2.9 percent, a difference of nearly one percentage point. Furthermore, if instead of the inflation targeting regime, a peg was in place, the results imply a growth rate of –7.5 percent, a difference from the actual of 5.4 percentage points. 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 recent global financial crisis would have been substantially more severe.

D. What Role for Fiscal Policy?

While our results suggest that the inflation targeting framework underpinned by a flexible exchange rate supported growth during the global financial crisis, clearly other policies also played a role. It should be noted that we do not capture the direct effects of the liquidity measures enacted by the BOK starting in the fourth quarter of 2008.[9] Therefore, the results from the counterfactual scenarios on the extent to which BOK policies help soften the crisis could be viewed as conservative estimates.

In this context, fiscal policy also likely helped soften the impact of the crisis. Note that, as in many other studies in this strand of the literature, fiscal policy is modeled in a very cursory manner. However, an illustrative counterfactual scenario without government spending shocks can be generated using the model. As shown in **Figure 6**, real GDP growth would have been substantially lower without countercyclical fiscal policy as proxied in our model by the government spending shocks.

VII. Summary and Main Policy Implications

This paper argues that monetary policy implemented by the Bank of Korea (BOK) helped soften the impact of the global financial crisis. Specifically, the findings suggest that without the adoption of an inflation targeting framework underpinned by a flexible exchange rate regime the global financial crisis would have been associated with a much deeper economic contraction.

The main question this paper seeks to address is the following: If an inflation targeting framework underpinned by a flexible exchange rate regime was not adopted, how much deeper would the recent recession have been? The findings indicate that the recession would have been substantially more severe. This result is based on counterfactual simulations derived from an estimated dynamic stochastic general equilibrium (DSGE) model which, along with standard nominal and real rigidities, includes a financial accelerator mechanism in an open-economy framework.

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[9] See IMF 2009 staff report for details of the authorities' comprehensive policy responses:

http://www.imf.org/external/pubs/cat/longres.aspx?sk=25139.0

The most intuitive way to communicate our quantitative findings is by taking the growth rate during the most intense year of the global financial crisis as our baseline, namely the 2008:Q4–2009:Q3 period. Model-based counterfactual simulations indicate that without exchange rate flexibility and the countercyclical and discretionary interest rates cuts allowed under an inflation targeting framework, growth over the most intense period of the crisis, namely, 2008:Q4–2009:Q3, would have decreased from the actual realization of –2.1 percent to –7.5 percent. In other words, these simulations underscore the favorable output stabilization properties owing to the combination of countercyclical monetary policy and exchange rate flexibility.

In sum, given the openness of the Korean economy through both trade and financial channels, the flexibility and resilience of the economy are especially important when faced with exogenous shocks coming from elsewhere. In line with this, Korea's monetary policy regime, underpinned by a flexible exchange rate, is well suited to the characteristics of the Korean economy, as demonstrated through the counterfactual experiments discussed in this paper in the context of the 2008–09 global financial crisis.

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:

$$E_t\left\{\lambda_{t+1}\frac{P_t}{P_{t+1}}\left[i_t - \Phi_t \mathrm{i}_t^* \frac{\mathrm{S}_{t+1}}{\mathrm{S}_t}\right]\right\} = 0 \tag{12}$$

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 homogeneous input good, L_t, 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 μ^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:

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

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:

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

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 shocks (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:

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

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

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 properties :

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

and
ε_t^i is stationary investment − specific technology shock following an AR(1) process. Note that only the parameter ψ'' is identified and will be 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 good

We assume that there is a continuum of monopolistically competitive retailers of measure unity. Retailers of domestic good 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:

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

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 the 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 period *t+1* is updated according to the scheme:

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

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

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:

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

where
κ^H is fixed costs, in real terms, ensuring that the profits are zero in steady state and $MC_t^H = P_{w,t}$.

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

$$E_t \sum_{s=0}^{\infty} (\beta\theta_H)^s \lambda_{t+s} \left[\frac{\left(\frac{P_{t+s-1}^H}{P_{t-1}^H}\right)^{\gamma_H} (\pi_{t+1}^T \pi_{t+2}^T \dots \pi_{t+s}^T)^{1-\gamma_H}}{\left(\frac{P_{t+s}^H}{P_t^H}\right)} \right]^{\frac{\mu_{t+s}^H}{1-\mu_{t+s}^H}} Y_{t+s}^H P_{t+s}^H \\ \times \left[\frac{\left(\frac{P_{t+s-1}^H}{P_{t-1}^H}\right)^{\gamma_H} (\pi_{t+1}^T \pi_{t+2}^T \dots \pi_{t+s}^T)^{1-\gamma_H}}{\left(\frac{P_{t+s}^H}{P_t^H}\right)} \frac{P_{new,t}^H}{P_t^H} - \mu_t^H \frac{MC_{t+s}^H}{P_{t+s}^H} \right] = 0 \tag{53}$$

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

$$P_t^H = \left[\int_0^{\theta_H} \left(P_{t-1}^H (\pi_{t-1}^H)^{\gamma_H} (\pi_t^T)^{1-\gamma_H}\right)^{\frac{1}{1-\mu_t^H}} + \int_{\theta_H}^{1} \left(P_{new,t}^H\right)^{\frac{1}{1-\mu_t^H}} \right]^{1-\mu_t^H} \\ = \left[\theta_H \left(P_{t-1}^H (\pi_{t-1}^H)^{\gamma_H} (\pi_t^T)^{1-\gamma_H}\right)^{\frac{1}{1-\mu_t^H}} + (1-\theta_H)\left(P_{new,t}^H\right)^{\frac{1}{1-\mu_t^H}} \right]^{1-\mu_t^H} \tag{54}$$

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:

$$\hat{\pi}_t^H - \hat{\pi}_t^T = \frac{\beta}{1+\beta\gamma_H}(E_t \hat{\pi}_{t+1}^H - \rho_{\bar{\pi}} \hat{\pi}_t^T) + \frac{\gamma_H}{1+\beta\gamma_H}(\hat{\pi}_{t-1}^H - \hat{\pi}_t^T) \\ - \frac{\gamma_H \beta (1-\rho_{\bar{\pi}})}{1+\beta\gamma_H} \hat{\pi}_t^T + \frac{(1-\theta_H)(1-\beta\theta_H)}{\theta_H(1+\beta\gamma_H)}(\widehat{mc}_t^H + \hat{\mu}_t^H) \tag{55}$$

Retailers of imported good

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 good at price $S_t P_t^{F*}$. 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:

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

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:

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

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;

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

Monetary policy

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

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

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 inflation target is assumed to evolve according to the following stochastic process:

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

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:

$$Y_t^H = C_t^H + C_t^{eH} + I_t^H + C_t^{H*} + G_t \quad (66)$$

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 first quarter of 2000 to the third quarter of 2010 using 12 standard time series, some of which are shown in **Figure 3**. 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 (deviation from HP trend), 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. 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.

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 72, 27, 5, and 39 percent, respectively. The parameter β was fixed at 0.9963 implying an annual riskless real interest rate of approximately 3.5 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 corporate bond yield and the discount rate.[10] 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 310 basis points, and to achieve this steady state value, along with a leverage ratio of 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 2**.

Prior distributions of the estimated parameters

The remaining 43 parameters, shown in **Table 3**, 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 with Elekdag and other (2006). In line with the Taylor principle, the responsiveness to

[10] Specifically, IFS codes 54260...ZF... and 54260BC.ZF..., respectively for the discount and corporate bond rates, where 542 is Korea's IFS country code.

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 other (2007), whereas the investment adjustment cost parameter is relatively lower. Turning finally to the shocks, the persistence parameter was set at 0.8, lower than in Adolfson and other (2007) who use 0.85, but higher than Elekdag and other (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 3**. 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.[11]

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 the arguably most intense periods of the recent global financial crisis, while most (if not all) other studies do not. 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 (1.67 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 0.9 and 3.8, 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.

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

[11] 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.

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 0.9, which is on the higher end, but still in line with other studies. As for the responsiveness of inflation deviation from target, our estimate is 1.8, which is similar to the value of 1.6 found by Adolfson and others (2007). 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 an even lower value of 0.02.

Turning to the exogenous shocks, we start off by discussing persistence. The estimated persistence parameters lie within the range of 0.39 for the unit root technology shock, and 0.96 for the foreign demand shock. The 95th percentile of this shock's persistence parameter is estimated to be 0.98 indicating an absence of unit roots in these processes. As for standard deviations, the monetary policy shock is least volatile, whereas the variability of the preference and investment shocks are 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 11 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.

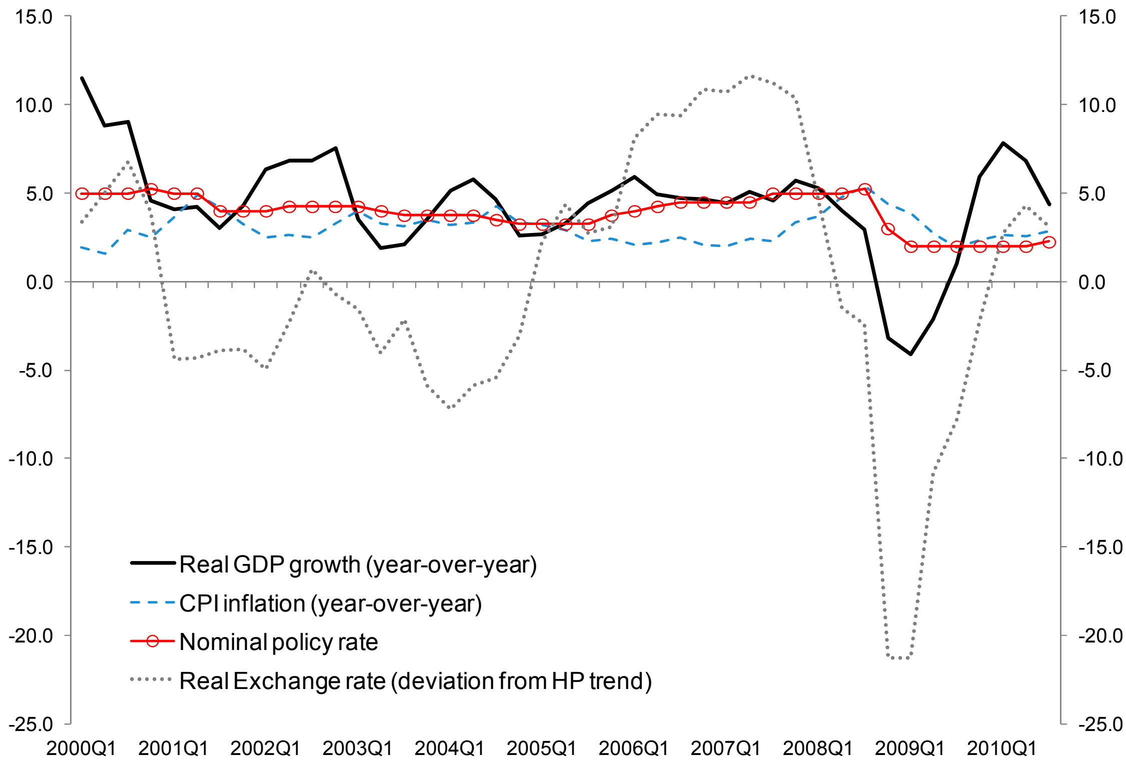
- First, the exclusion of the financial accelerator mechanism is decisively rejected in favor of the baseline model, which underscores the importance of incorporating such financial frictions in models, particularly when investigating emerging markets, a result also discussed extensively in Elekdag and 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 and real rigidities. In other words, as compared to the canonical real business cycle or New Keynesian models, other features 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, Smets and Wouters (2003) noted the role of labor supply shocks, and 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 of 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.

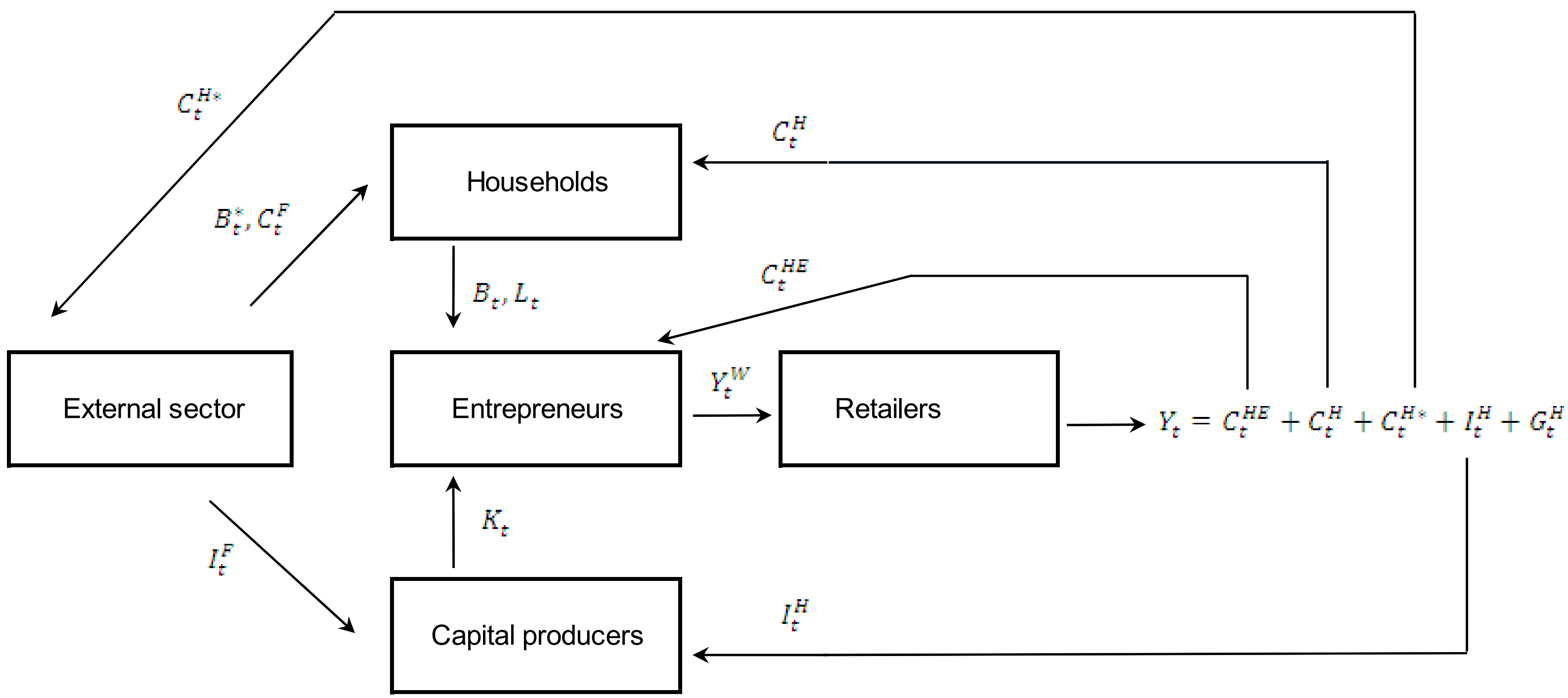
- Fourth, we consider five alternative monetary policy rules. In sum, the results are decisively in favor of the baseline specification. As shown in the table, the interest ate rule is altered by adding the change in output and the inflation rate, the nominal depreciation rate is dropped, or a combination thereof. We also consider cases without interest rate smoothing, strict inflation targeting, and lastly, a fixed exchange rate regime. Especially regarding the later, the results are decisively in favor of the model with a baseline interest rate rule.

Figure 1. Korea: Selected Macroeconomic Indicators



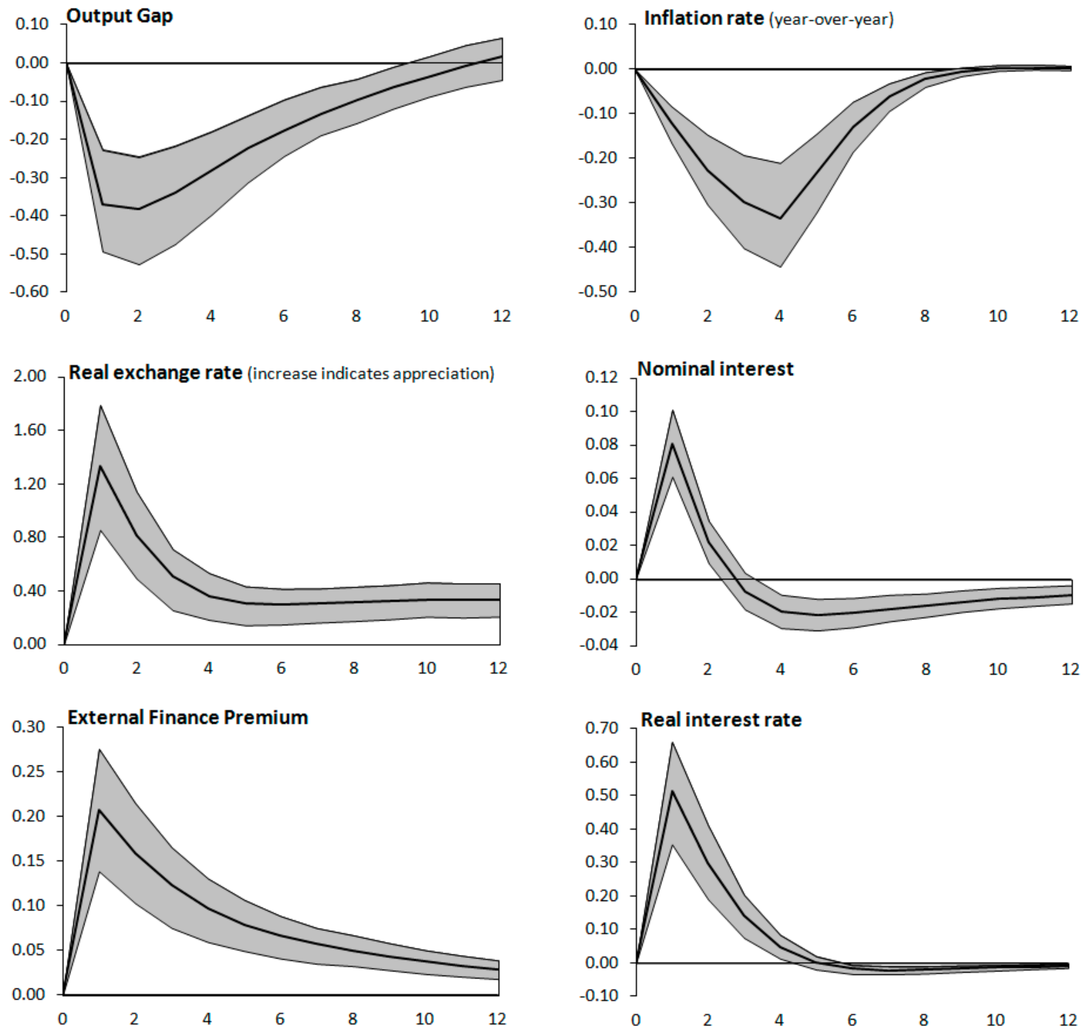
Source: IMF APDCore database and authors' calculations.

Figure 2. Model Schematic



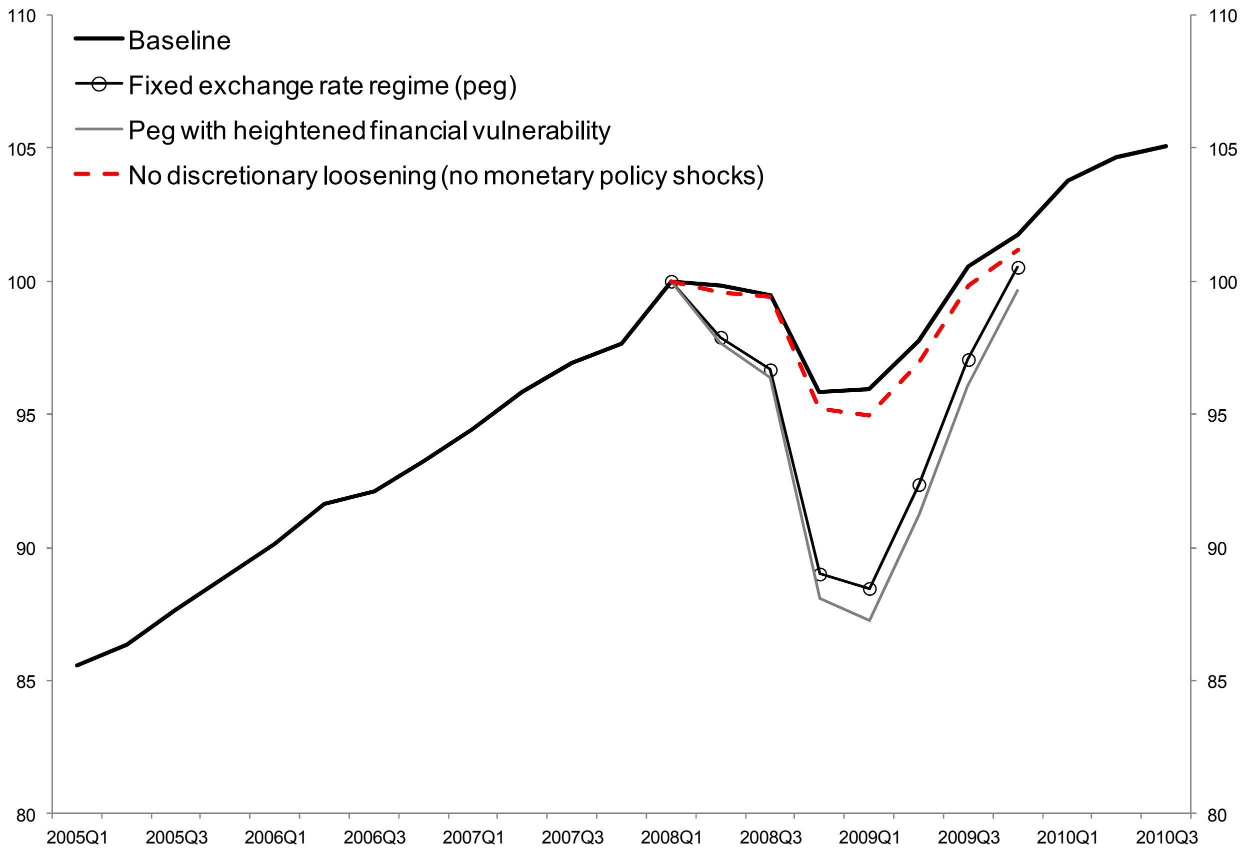
Source: Authors' calculations.

Figure 3. Korea: The Monetary Transmission Mechanism



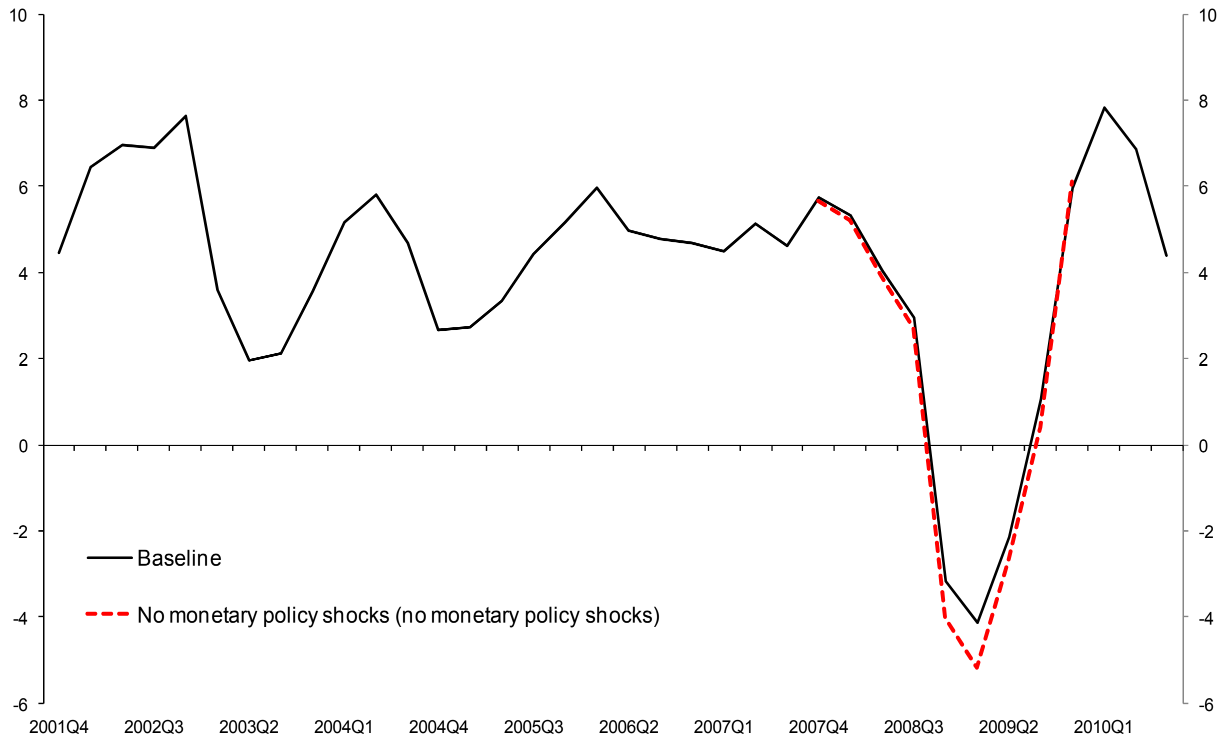
Source: Authors' calculations.
Note: Bayesian impulse response functions to a contractionary monetary policy shock. Interest rates, inflation rates, and the external finance premium are shown as absolute deviations from their steady states, while the other variables are percentage deviations from their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

Figure 4. Counterfactual Scenarios: The Role of Monetary Policy and Real GDP



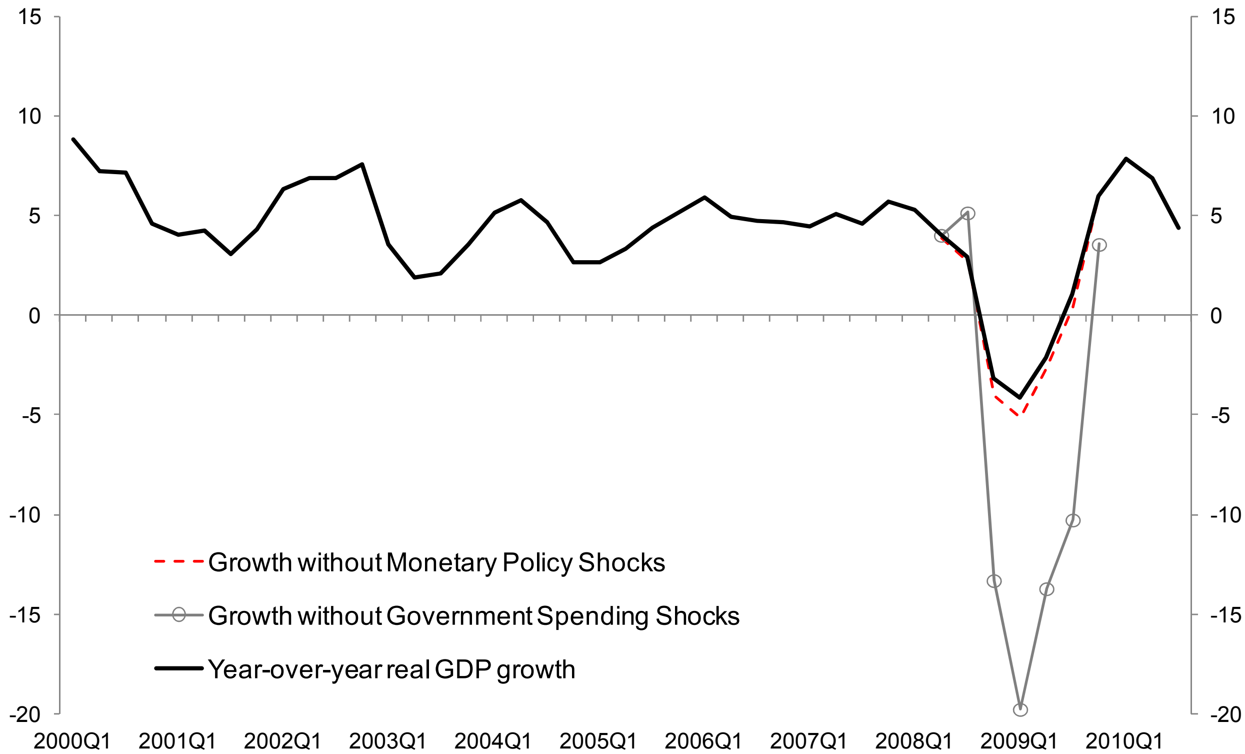
Source: Authors' calculations.
Note: Figure denotes the level of real GDP as an index with 2008Q1=100.
Baseline denotes the actual evoluation of Korean real GDP.

Figure 5. Counterfactual Scenarios: Monetary Policy and Real GDP Growth
(Year-over-year growth rates)



Source: Authors' calculations.
Note: Figure depicts year-over-year real GDP growth rates. Baseline denotes the actual evoluation of Korean data.

Figure 6. Counterfactual Scenarios: Any Role for Fiscal Policy?



Source: Authors' calculations.
Note: Figure depicts year-over-year real GDP growth rates. Baseline denotes the actual evoluation of Korean data.

Table 1. Calibrated Parameters

Parameter	Symbol	Value
Discount factor	β	0.9963
Consumption intra-temporal elasticity of substitution	ρ	1.00
Share of domestic goods in consumption	γ	0.575
Investment intra-temporal elasticity of substitution	ρ_i	0.25
Share of domestic goods in investment	γ_i	0.525
Inverse of the elasticity of work effort with respect to the real wage	σ_l	1.00
Share of capital in production function	α	0.625
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 interva 5%	95%
Calvo parameter							
Domestic prices	θ_H	Beta	0.50	0.10	0.419	0.286	0.550
Import prices	θ_F	Beta	0.50	0.10	0.511	0.426	0.597
Wages	θ_w	Beta	0.50	0.10	0.690	0.547	0.835
Indexation							
Domestic prices	γ_H	Beta	0.50	0.10	0.529	0.361	0.697
Import prices	γ_F	Beta	0.50	0.10	0.432	0.280	0.592
Wages	γ_w	Beta	0.50	0.10	0.524	0.360	0.683
Monetary policy							
Interest rate smoothing	ρ_i	Beta	0.70	0.10	0.892	0.856	0.932
Inflation reponse	τ_π	Normal	1.50	0.10	1.760	1.495	2.020
Output gap response	τ_y	Normal	0.20	0.10	0.019	0.002	0.036
Nominal exchange rate depreciation response	τ_s	Normal	0.10	0.10	0.099	0.033	0.163
Others							
Export demand elasticity	χ	Normal	1.00	0.20	-0.116	-0.215	-0.016
Export demand interia	ϖ	Beta	0.50	0.20	0.876	0.786	0.968
Habit formation	b	Beta	0.70	0.20	0.934	0.901	0.969
Invesment adjustment cost	ψ	Normal	4.00	0.50	3.795	2.990	4.664
Shock persistence							
Stationary technology	ρ_a	Beta	0.80	0.10	0.797	0.599	0.982
Unit root technology	ρ_ζ	Beta	0.80	0.10	0.386	0.290	0.485
Investment specific technology	ρ_{inv}	Beta	0.80	0.10	0.901	0.865	0.941
Domestic markup	ρ_{μ^h}	Beta	0.80	0.10	0.731	0.533	0.950
Import markup	ρ_{μ^f}	Beta	0.80	0.10	0.918	0.884	0.953
Foreign inflation	ρ_{π^*}	Beta	0.80	0.10	0.665	0.532	0.795
Foreign interest rate	ρ_{i^*}	Beta	0.80	0.10	0.770	0.654	0.893
Foreign demand	ρ_{y^*}	Beta	0.80	0.10	0.956	0.937	0.976
Country risk premium	ρ_{Φ}	Beta	0.80	0.10	0.576	0.448	0.709
Preference	ρ_c	Beta	0.80	0.10	0.756	0.634	0.882
Labor supply	ρ_l	Beta	0.80	0.10	0.813	0.666	0.951
Exogenous spending	ρ_g	Beta	0.80	0.10	0.807	0.719	0.896
Net worth	ρ_N	Beta	0.80	0.10	0.603	0.454	0.756
Inflation target	$\rho_{\bar{\pi}}$	Beta	0.80	0.10	0.695	0.563	0.829
Shock volatility							
Stationary technology	σ_a	Inverse gamma	0.05	1.00	0.013	0.009	0.017
Unit root technology	σ_ζ	Inverse gamma	0.05	1.00	0.037	0.029	0.043
Investment specific technology	σ_{inv}	Inverse gamma	0.05	1.00	0.126	0.103	0.149
Domestic markup	σ_{θ^H}	Inverse gamma	0.05	1.00	0.012	0.008	0.015
Import markup	σ_{θ^F}	Inverse gamma	0.05	1.00	0.022	0.014	0.030
Foreign inflation	σ_{π^*}	Inverse gamma	0.05	1.00	0.009	0.007	0.010
Foreign interest rate	σ_{i^*}	Inverse gamma	0.05	1.00	0.007	0.006	0.007
Foreign demand	σ_{y^*}	Inverse gamma	0.05	1.00	0.049	0.039	0.057
Country risk premium	σ_{Φ}	Inverse gamma	0.05	1.00	0.014	0.010	0.018
Preference	σ_c	Inverse gamma	0.05	1.00	0.183	0.091	0.277
Labor supply	σ_l	Inverse gamma	0.05	1.00	0.028	0.013	0.043
Exogenous spending	σ_g	Inverse gamma	0.05	1.00	0.026	0.022	0.031
Net worth	σ_N	Inverse gamma	0.05	1.00	0.038	0.022	0.053
Inflation target	$\sigma_{\bar{\pi}}$	Inverse gamma	0.05	1.00	0.018	0.011	0.025
Monetary policy		Inverse gamma	0.01	1.00	0.002	0.001	0.002

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	1,309	
	Sensitivity to frictions		
1	Financial accelerator	1,037	No
2	Low stickness including wages	1,192	No
3	Low habit persistence and investment costs	991	No
	Sensitivity to shocks		
4	Technology (all)	1,008	No
5	Preference and Government	992	No
6	Financial (uncertainty and UIP)	931	No
	Sensitivity to policy rules		
7	Add change in output and inflation	1,303	No
8	Baseline rule, but without ΔS rule	1,140	No
9	No interest rate smoothing	1,255	No
10	Strict inflation targeting	903	No
11	Fixed exchange rate regime	1,267	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 Korean won.

Table 4. The Role of Monetary Policy during the Global Financial Crisis of 2008–09

		Growth contributions of monetary policy owing to:			
		[1]	[2]	[3]	[4]
	Quarters	Monetary policy shocks	Flexible exchange rate regime	Reduced financial vulnerability	All factors ([1]—[3])
Average					
2008Q4—2009Q3	4	0.77	4.59	1.05	6.42
Christiano and others (2008)					
United States (2001Q2-2002Q2)	4	0.75			
Euro area (2001q4-2004q4)	13	1.27			
Cumulative					
2008Q4—2009Q3	4	3.09	18.38	4.20	25.67
Christiano and others (2008)					
United States (2001Q2-2002Q2)	4	3.00			
Euro area (2001q4-2004q4)	13	17.00			

Source: Authors' calculations.

Table 5. Summary of the Role of Monetary Policy

	2008Q4—2009Q3	Difference	Cumulative Difference
Baseline (actual)	–2.1		
No monetary policy shocks	–2.9	–0.8	–0.8
Fixed exchange rate regime (peg)	–7.5	–4.6	–5.4
Peg with heightened financial vulnerability	–8.5	–1.1	–6.4

Source: Authors' calculations

REFERENCES

Adolfson, Malin, Stefan Laseen, Jesper Linde, Mattias Villani, 2007, "Bayesian Estimation of an Open Economy DSGE Model with Incomplete Pass-Through," *Journal of International Economics*, Vol. 72, pp. 481–511.

Adolfson, Malin, Stefan Laseen, Jesper Linde, Mattias Villani, 2008, "Evaluating an Estimated New Keynesian Small Open Economy Model," *Journal of Economic Dynamics and Control*, Vol. 32, pp. 2690–2721.

Aguilar, Mark, and Gita Gopinath, 2007, "Emerging Market Business Cycles: The Cycle is the Trend," *Journal of Political Economy*, Vol. 115. No. 1, pp. 69–102.

Alp, Harun, and Selim Elekdag, 2011, "The Role of Monetary Policy in Turkey during the Global Financial Crisis," IMF Working Paper, No. 11/150 (Washington: International Monetary Fund).

Aydin, Burcu, and Engin Volkan, 2011, "Incorporating Financial Stability in Inflation Targeting Frameworks," IMF Working Paper, No. 11/224 (Washington: International Monetary Fund).

Bernanke, Ben, and Mark Gertler, and Simon Gilchrist, 1999, "The Financial Accelerator in a Quantitative Business Cycle Framework," *Handbook of Macroeconomics,* Vol. 1C, pp. 1341–93 (Elsevier: Amsterdam).

Calvo, Guillermo, 1983, "Staggered Prices in a Utility-Maximizing Framework," *Journal of Monetary Economics*, Vol. 12, pp. 383–98.

Calvo, Guillermo, Alejandro Izquierdo, and Luis. F. Mejia, 2004, "On the Empirics of Sudden Stops: The Relevance of Balance-Sheet Effects," NBER Working Paper, No. 10520 (Cambridge, Massachusetts: National Bureau of Economic Research).

Cardarelli, Roberto, Selim Elekdag, and Subir Lall, 2011, "Financial Stress and Economic Contractions," *Journal of Financial Stability*, Vol. 7, No. 2 (June), pp. 78–97.

Cespedes, Luis F., Roberto Chang and Andres Velasco, 2004, "Balance Sheets and Exchange Rate Policy," *American Economic Review*, Vol. 94, pp. 1183–93.

Christiano, Lawrence J., Roberto Motto, and Massimo Rostagno, 2003, "The Great Depression and the Friedmand-Schwartz Hypothesis," *Journal of Money, Credit, and Banking*, Vol. 35, No. 6, pp. 1119–97

Christiano, Lawrence J., Roberto Motto, and Massimo Rostagno, 2008, "Shocks, Structures, or Monetary Policies? The Euro Area and U.S. After 2001," *Journal of Economic Dynamics and Control*, Vol. 32, pp. 2476–2506.

Christiano, Lawrence J., Roberto Motto, and Massimo Rostagno, 2010, "Financial Factors in Economic Fluctuations," ECB Working Paper No. 1192 (Frankfurt, Germany: European Central Bank).

Curdia, Vasco, 2007, "Monetary Policy under Sudden Stops," FRBNY Staff Report No. 278 (New York: Federal Reserve Bank of New York).

Devereux, Michael B., and Charles Engel, 2002, "Exchange rate pass-through, exchange rate volatility, and exchange rate disconnect," *Journal of Monetary Economics*, Vol. 49, No. 5, pp. 913–40.

Dib, Ali and Ian Christensen, 2008, "The Financial Accelerator in an Estimated New Keynesian Model," *Review of Economic Dynamics*, Vol. 11, pp. 155–78.

Elekdag, Selim, Alejandro Justiniano, and Ivan Tchakarov, 2006, "An Estimated Small Open Economy Model of the Financial Accelerator," *IMF Staff Papers*, Vol. 53, pp. 219–41 (Washington: International Monetary Fund).

Elekdag, Selim and Ivan Tchakarov, 2007, "Balance Sheets, Exchange Rate Policy, and Welfare," *Journal of Economic Dynamics and Control*, Vol. 31, pp. 3986–4015.

Gali, Jordi, and Tommaso Monacelli, 2005, "Monetary Policy and Exchange Rate Volatility in a Small Open Economy," *Review of Economic Studies*, Vol. 72, No. 3, pp. 707–34.

Garcia-Cicco, Javier, 2010, "Estimating Models for Monetary Policy Analysis in Emerging Countries," Central Bank of Chile Working Paper No. 561 (Chile: Central Bank of Chile).

Gertler, Mark, Simon Gilchrist, Fabio Natalucci, 2007, "External Constraints on Monetary Policy and the Financial Accelerator," *Journal of Money, Credit and Banking,* Vol. 39, No. 2–*3*, pp. 295–330.

Justiniano, Alejandro, Giorgio E. Primiceri, and Andrea Tambalotti, 2007, "Investment Shocks and Business Cycles," Federal Reserve Bank of Chicago Working Paper 2008–12 (Chicago: Federal Reserve Bank of Chicago).

Jeffreys, Harold, 1961, Theory of Probability, 3rd Ed., Oxford: Clarendon Press.

Kiyotaki, Nobuhiro, and John Moore, 1997, "Credit Cycles," *Journal of Political Economy,* Vol. 105 (April), pp. 211–48.

Knight, Frank H., 1921, *Risk, Uncertainty, and Profit*. (Boston, MA: Hart, Schaffner & Marx; Houghton Mifflin Company)

Lubik, Thomas A., and Frank Schorfheide, 2007, "Do Central Banks Respond to Exchange Rate Movements? A Structural Investigation," *Journal of Monetary Economics*, Vol. 54, pp. 1069–87.

Mendoza, Enrique, 1991, "Real Business Cycles in a Small Open Economy," *American Economic Review,* Vol. 81, pp. 7973–818.

Schorfheide, Frank, 2000, "Loss Function-Bases Evaluation of DSGE Models," *Journal of Applied Econometrics*, Vol. 15, pp. 1–48.

Smets, Frank and Rafael Wouters, 2003, "An Estimated Stochastic General Equilibrium Model of the Euro Area," *Journal of the European Economic Association*, Vol. 1, pp. 1123–75.

Smets, Frank and Rafael Wouters, 2007, "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, Vol. 97, No. 3. pp. 586–605.

Taylor, John B., 1993, "Discretion versus Policy Rules in Practice," *Carnegie-Rochester Conference Series on Public Policy*, Vol. 39, pp. 195–214.

Taylor, John B., 1995, "The Monetary Transmission Mechanism: An Empirical Framework," *Journal of Economic Perspectives*, Vol. 9, No. 4, pp. 11–26.

Teo, Wing, 2009, "Estimated Dynamic Stochastic General Equilibrium Model of the Taiwanese Economy," *Pacific Economic Review*, Vol. 14, No. 2, pp. 194–231.