A Small-Scale Monetary Policy Model for Korea[*]

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We analyze a small-scale new Keynesian open economy model to assess the BOK's monetary policy during the post crisis period.   The model is estimated by the Bayesian Markov Chain Monte Carlo (MCMC) method.   The results are largely consistent with the predictions of the new Keynesian model.   Most importantly, the forward looking behavior plays an important role in the IS curve as well as in the Phillips curve.   The estimates on the real exchange rate in the model show signs consistent with the theory.   The monetary feedback rule tells that inflation and output have been equally treated. The weight on the exchange rate is relatively small, but the exchange rate seems to be another important concern of the BOK.   The impulse response analysis confirms that the BOK tries to offset the impact of exchange rate shocks in a moderate but persistent way.   Our results indicate that even under the official inflation targeting regime, inflation is not the sole focus.   The BOK seems to put no less emphasis on stabilizing exchange rates as well as output.

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1. INTRODUCTION

The Bank of Korea (BOK, hereafter) has adopted inflation targeting since 1999, and has begun to pursue a single objective of stabilizing inflation. Now the BOK officially takes price stability as the primary objective of its monetary policy, and uses the short-term interest rate as policy instrument to achieve its goal.   In this new environment, the issues on the effectiveness and efficiency of the monetary policy have attracted the attention of many scholars.   Most researches extensively use the Keynesian-type structural models, which are either medium-scale or small-scale dynamic stochastic models, as well as the augmented structural vector autoregressive model. However, empirical evidences are still inconclusive.

Kim and Park (2006) report their findings that the BOK's inflation stabilization was forward-looking in nature and the short-term interest rate tended to move with the output gap.   Their estimates are largely consistent with the objective of the inflation-targeting regime.   However, according to their coefficient estimates of the monetary reaction function, the weight on inflation stabilization is remarkably larger than on the output gap.   Despite the difference in data spans, Marcelo (2009) obtained similar results. Marcelo (2009) presented his empirical evidence that the BOK seemed to place a negligible weight on stabilizing exchange rate, but was successful in stabilizing inflation.

However, Cho *et al*. (2006), Cho (2007), and Cho *et al*. (2007) showed different results.   Cho (2007) sets up a canonical New Keynesian model which consisted of three equations, namely the Keynesian Phillips Curve (NKPC), the aggregate demand curve, and the monetary policy rule (Taylor rule), and found that the stable inflation seems not the results of the BOK's monetary policy.   On the contrary, BOK has been quite successful in moderating fluctuations in the output gap.   Cho *et al*. (2007) also reported similar results that the BOK is more successful in stabilizing output than inflation.

The objective of this paper is to assess the monetary policy for Korea since

the inflation targeting regime was officially implemented. We assume a small open economy, and use a small-scale New Keynesian stochastic dynamic model, which is similar to that of Buncic (2008) and Soderstrom (2008). It consists of a hybrid NKPC, an aggregate demand equation, an uncovered interest rate parity condition, and a monetary policy feedback rule.

Furthermore, taking into account of small sample problem, we apply the Bayesian Markov Chain Monte Carlo (MCMC) algorithm to estimate our model parameters. One advantage of the Bayesian method is that it allows us to incorporate the prior knowledge into the model; that is, either subjective adjustment or economic theory. The prior can ease the small sample problem, since the prior can be considered as a weak calibration. According to An and Schorfheide (2007), the performance of MCMC method is better than that of other common methods, e.g., numerical method, especially for the case of insufficient data. For this reason, the Bayesian MCMC method has been extensively used in the New Keynesian model as well as the Real Business Cycles model.

The results obtained in our study are largely consistent with the predictions of the new Keynesian model. A puzzling finding from previous literatures was that that the relation between the call rate and the CPI inflation in the post crisis period is negative. If we use the interest rate in terms of log-deviation from its steady state, however, this anomaly disappears. In the monetary feedback rule, there is a high contemporaneous correlation between the inflation and the interest rate in terms of log-deviation. The estimates show that inflation and output have been equally treated in usual manner as dictated by the Taylor's principle. The weight on the exchange rate is relatively small, but the exchange rate seems to be another important concern of the BOK. The impulse response analysis as well as forecast error variance decomposition also show results consistent with the Keynesian theory.

The rest of the paper is organized as follows: we introduce a small-scale New Keynesian model in section 2. In section 3, we describe statistical relationships of the time series and empirical methods used. Estimated

results with some discussions are provided.   The section 4 shows impulse responses and variance decomposition.   The section 5 concludes.

2. THE MODEL

The New Keynesian model used in this paper is a well-known and simplified version of the dynamic stochastic general equilibrium (DSGE) model for a small open economy, which is a standard two-country model developed by Clarida (2002), Gali and Monacelli (2005), Soderstrom (2008), etc.   The basic assumption is that the world consists of two parts: a small open economy (domestic economy) and a large closed economy (foreign economy).   The world shares the same preferences and technology, as well as the traded consumption goods.   The New Keynesian model aims to provide the microeconomic foundations of aggregate demand and aggregate supply analysis.   Aggregate demand is the result of consumers' maximizing their intertemporal utility.   Aggregate supply is driven by the optimal behavior of firms, who set the prices for their products to maximize profits in monopolistically competitive markets.

The basic blocs of the model are the aggregate demand curve (IS), the aggregate supply curve (AS), the uncovered interest rate parity condition (UIP), and the monetary policy rue.   In modeling foreign sector, there are two issues considered in general: how to model the structure of foreign economy and what variables are used as the proxy of that.   For the first issue, there are two approaches commonly used: one is setting a symmetric structure for both domestic and foreign economy (Buncic *et al*., 2008), the other approach assumes that the foreign economy just follows a vector autoregressive process (Svensson, 2000; Lee *et al*.; 2010, etc.).   For the second issue, the macroeconomic variables of the U.S. or G7 are used as proxy foreign series (Lubik and Schorfheide, 2007; Justiniano and Preston, 2010, etc.).   In this paper, for simplicity, we use the U.S. series and assume these series follow simple autoregressive processes.

2.1. The Aggregate Supply Curve

The aggregate supply curve (AS curve) is described by an augmented hybrid NKPC, which contains both forward-looking and backward-looking component. Incorporating both behaviors into the equation is primarily due to an empirical motivation, but this can be theoretically justified from the model of staggered price setting. The output gap, real exchange rate, and cost-push shock also affect the current inflation. The NKPC (domestic inflation dynamics) takes the following form:

$$\pi_t = \mu E_t \pi_{t+1} + (1 - \mu) \pi_{t-1} + \lambda_1 y_t + \lambda_2 e_t + u_t^{AS} \tag{1}$$

where π_t presents the rate of inflation in the domestic goods sector; y_t is the output gap in the domestic economy (the log deviation from its steady state); e_t denotes the real exchange rate; and u_t^{AS} is a stationary cost-push shock that is specified as an autoregressive process.

$$e_t = s_t + p_t^* - p_t, \tag{2}$$

where s_t denotes the nominal exchange rate, p_t^* is the price level in the foreign economy and p_t is the domestic price level. All series are in terms of logarithm and refer to deviations from their steady states.

The equation (1), reflecting the new Keynesian perspective, tells that the current inflation depends on the lagged inflation the one period ahead expected inflation and the current real marginal cost. In our open economy setup, the real marginal cost is affected by the output gap and the real exchange rate. The real exchange rate affects the marginal cost through households' labor supply decision: households value their wage in relation to the consumer price index (which includes prices of imported goods), so the equilibrium wage depends on the real exchange rate.

2.2. The Aggregate Demand Curve

The aggregate demand curve (IS curve) is described as follows:

$$y_t = \alpha E_t y_{t+1} + (1-\alpha) y_{t-1} - \delta_1 \left[r_{t-1} - E_{t-1} \pi_t \right] + \delta_2 e_{t-1} + u_t^{IS}. \tag{3}$$

The equation (3) is a rational expectations augmented IS curve, which relates the current output gap to the lagged and the one period ahead expected output gap; the lagged real interest rate (as households substitute consumption over time); the lagged real exchange rate (as consumption is partly satisfied through imported goods); and demand shock.   The backward-looking component in the IS curve can be derived from the assumptions of consumption habits or costly adjustments of capital stock. The forward-looking component is framed by rational or bounded rational agents who maximize their intertemporal utility function.   The last term u_t^{IS} represents the demand shock that is specified as AR(1) process.

2.3. The Uncovered Interest Rate Parity Condition

The real exchange rate is adjusted in such a manner that the uncovered interest rate parity (UIP) condition holds, as presented in equation (4). Taking into account that the UIP equation does not completely hold in practice, we add an exchange rate shock that can also be interpreted as the risk premium, thus the exchange rate disturbance reflects the fact that domestic households pay a premium for foreign bond holding.   Additionally, we allow the exchange rate shocks to be serially correlated.

$$e_t = E_t e_{t+1} - \left[r_t - E_t \pi_{t+1} \right] + \left[r_t^* - E_t \pi_{t+1}^* \right] + u_t^{RER}, \tag{4}$$

where r_t^* and π_t^* denote the foreign short-term interest rate and inflation rate, respectively.   The UIP equation presents that the expected real depreciation is related to the real interest rate differential between the

domestic and foreign economies.   All foreign variables are assumed to be exogenous and follow AR(1) process.

2.4. The Monetary Policy Rule

The monetary policy rule needs an objective function from which an optimal monetary policy rule is derived.   Despite the fact that stabilizing inflation is the central bank's sole objective under inflation-targeting regime, it is commonly believed that the output gap, exchange rate fluctuations, and other macroeconomic conditions are also considered in reality.   Thus, we assume an open economy Taylor rule; this is a simple instrument rule, but an optimal monetary policy under some special conditions.   Taking Kim *et al.*'s (2006) findings into account, we specify a simple forward-looking rule for the BOK:

$$r_t = \rho_R r_{t-1} + (1 - \rho_R)\left[\rho_P E_t \pi_{t+1} + \rho_Y y_t + \rho_E e_t\right] + \varepsilon_t^R. \tag{5}$$

Under this specification the monetary authority responds to one period ahead expected inflation, the current output gap and the change in real exchange rate.   The autoregressive coefficient, ρ_R, represents the degree of instrument smoothing.   The idea is straightforward; the higher the volatility of the policy instrument, the lower the credibility of the policy.   Moreover, if the fluctuations in output and inflation are persistent, these may lead to "over responsiveness" of the interest rate due to the lack of the "instrument smoothing".   See Sack and Wieland (2000) for details.   A feedback on the exchange rate has been commonly used in the open economy model, and the performance of the exchange rate augmented Taylor rule is better than that of the standard one, which is consistent with our institution: the exchange rate is so influential that the central bank could not neglect it, especially in a highly open economy like Korea.

Also, considering the persistent characteristics of structural shocks, we assume that some innovations in our model follow AR(1) process as specified in equation (6), (7), and (8).

$$u_t^{IS} = \rho^{IS} u_{t-1}^{IS} + \varepsilon_t^{IS}, \qquad (6)$$

$$u_t^{AS} = \rho^{AS} u_{t-1}^{AS} + \varepsilon_t^{AS}, \qquad (7)$$

$$u_t^{RER} = \rho^{RER} u_{t-1}^{RER} + \varepsilon_t^{RER}, \qquad (8)$$

$$r_t^* = \rho^{R*} r_{t-1}^* + \varepsilon_t^{R*}, \qquad (9)$$

$$\pi_t^* = \rho^{AS*} \pi_{t-1}^* + \varepsilon_t^{AS*}. \qquad (10)$$

We assume that ε_t^{AS}, ε_t^{IS}, ε_t^{RER}, ε_t^{R}, ε_t^{AS*}, and ε_t^{R*} are independent and identically distributed with the standard deviations of σ^{AS}, σ^{IS}, σ^{RER}, σ^{R}, σ^{AS*}, and σ^{R*}, respectively. Thus the model includes 21 parameters:

$$\Theta = [\mu,\ \delta_1,\ \delta_2,\ \alpha,\ \lambda_1,\ \lambda_2,\ \rho_R,\ \rho_P,\ \rho_Y,\ \rho_E,\ \rho^{AS},\ \rho^{IS},\ \rho^{RER},\ \rho^{AS*},\ \rho^{R*},\ \sigma^{AS},\ \sigma^{IS},\ \sigma^{RER},\ \sigma^{R},\ \sigma^{AS*},\ \sigma^{R*}].$$

3. ESTIMATION

3.1. The Data

Lee (2009) reports that the stability of Korean structural parameters could not be statistically rejected even in the presence of the 1997 currency crisis. However, it seems more realistic to assume that there was a structural break around the 1997-1998. Furthermore, since our main concern is the new policy regime that has been officially implemented since 1998, we focus on the post crisis era only. The sample period covers through the first quarter of 1999 to the fourth quarter of 2009.

We use the consumer price index (CPI) and the rate of inflation calculated by the log difference; the measure of real output gap is the deviation of real

GDP from its steady state.   The short term nominal interest rate is measured by the uncollateralized overnight call rate, which can be considered the index of the monetary policy.   The real exchange rate is constructed using the nominal exchange rate between the Korean won and U.S. dollar and their price levels.   For the foreign price and interest rate, we use the U.S. CPI and federal funds rate respectively.   All series are drawn the BOK and measured in terms of log deviation from their trend means.

3.2. Preliminary Analysis

The interest rate as a monetary policy instrument, is represented by call rate.   However, we may use two different terms in the analysis: the level and the log deviation from the steady state.   The latter can be interpreted as an innovation rate around the trend.   The reason we try to take the latter measure is due to the Cho's (2007) puzzling finding that the relation between the call rate and the CPI inflation in the post crisis period is negative.   In figure 1, we plot the call rate in terms of level and log-deviation with inflation.

Figure 1   Inflation and Call Rate
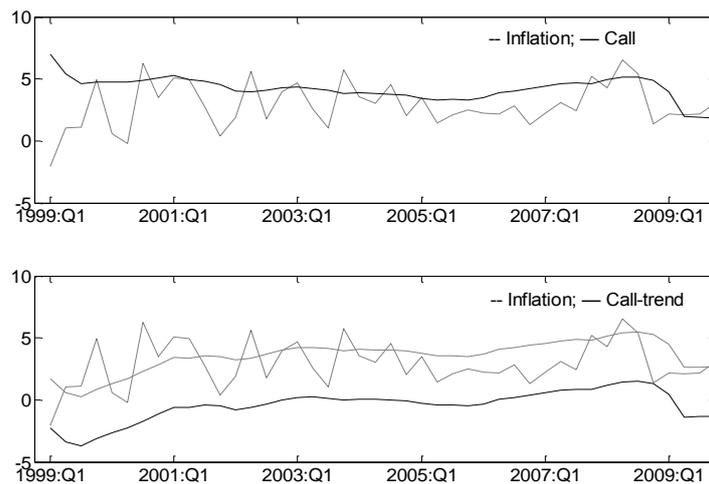
**Figure 2   Correlation between Call Rate and Inflation**
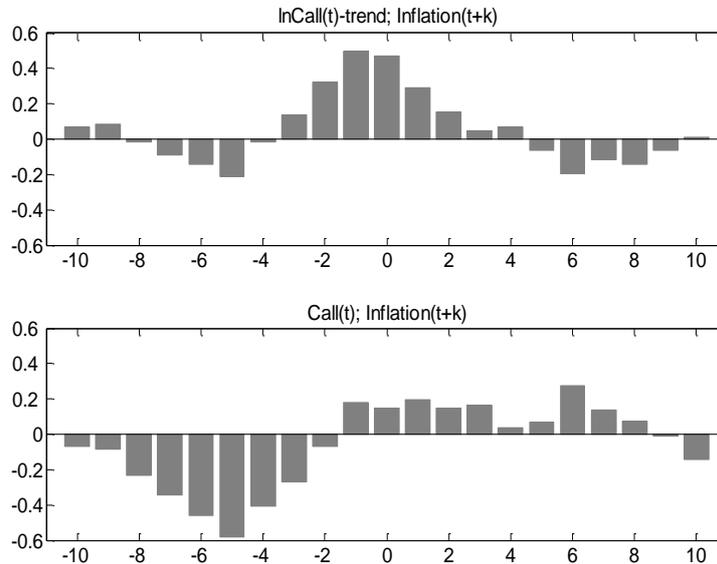
Cho (2007) reports that the inflation and call rate in terms of level seem to move in the opposite directions (the upper graph in figure 1); but the lower graph in figure 1 gives some hints to explain the puzzle. This may indicate that even though the BOK actively pursues the inflation stabilization, their operation is not based on the level of the interest rate itself but the deviation around the stationary trend. Figure 2 presents a more explicit relationship between inflation and the interest rate, by using two different terms.

As shown in the lower graph of figure 2, the contemporaneous correlation of the inflation and the interest rate in level is weak. In contrast, there is a high contemporaneous correlation between the inflation and the interest rate in terms of log deviation (the upper box in figure 2). The original interest rate is commonly used for industrial countries since the potential assumption is that the short-term rates are low and stationary. However, it seems not the case for Korea. Several papers including Moons *et al*. (2007) uses the log-deviation strategy, so we will take the same approach.

Figure 3   Correlation between Call Rate and Real Exchange Rate
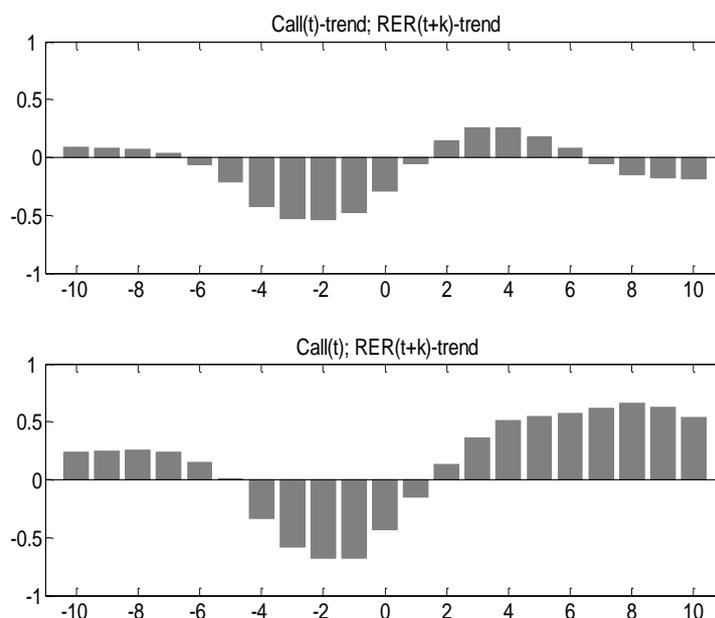
The correlation between the real exchange rate and the interest rate is presented in figure 3.   To our surprise, the contemporaneous correlation is negative and consistent with Marcelo (2009).   One possible explanation for this is that the BOK responds to the expected exchange rate or the rate of changes in the real exchange rate, not the observed current one.

The cross-correlation coefficients of the output gap and interest rate are plotted in figure 4.   The correlation of the output gap with the interest rate in terms of level is much higher than that in terms of deviation.   This can also help to understand Cho's (2007) finding that the BOK seemed to focus more on the output stabilization relative to inflation stabilization even in the period of inflation targeting.   However, if their operation is not just based on the level of the interest rate, inflation and output may have been equally treated in usual manner as indicated by Taylor's principle.

Figure 4　Correlation between Call Rate and GDP Gap
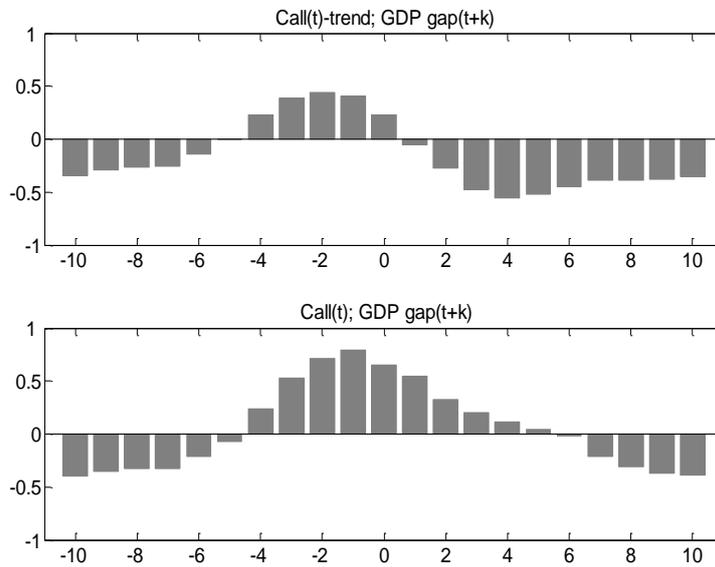
3.3. Empirical Strategy

The structural parameters of the model are estimated using the maximum likelihood function based on the Bayesian MCMC method, which combines prior information (prior density of structural parameters) and the information coming from observed data. Following An and Schorfheide (2007), let us denote the vector of structural parameters to be estimated as $\Theta = \begin{bmatrix} \mu, & \delta_1, & \delta_2, & \cdots, & \sigma^{R^*} \end{bmatrix}$ and the prior density of Θ as $f(\Theta)$. The prior density summarizes the knowledge about structural parameters before observing actual data, where the prior knowledge or comes from other similar research, or subjective judgments of the author, or the economic theory. In our study, we refer to other research. The likelihood function defined as $L(data \,|\, \Theta)$ represents the probability of data that is generated from the distribution with given parameters.

Using the prior distribution and likelihood function defined above, the posterior distribution can be represented as follows:

$$f(\Theta \mid data) = \frac{L(data \mid \Theta) f(\Theta)}{\int L(data \mid \Theta) f(\Theta) d\Theta},\qquad(11)$$

or more simply,

$$f(\Theta \mid data) \propto L(data \mid \Theta) f(\Theta),\qquad(12)$$

where $f(\Theta \mid data)$ denotes the posterior distribution of these parameters. Equation (11) is the Bayesian rule, showing that the posterior distribution is determined by the prior distribution and the likelihood function. Equation (12) says that the posterior distribution is proportional to the production of the prior distribution and the likelihood function, since the term $\int L(data \mid \Theta) f(\Theta) d\Theta$ is constant. In empirical studies, equation (12) is commonly used to construct posterior probability. The first step in the Bayesian inference is to setup the prior distribution over the structural parameters (a more detailed description is as follows: specifying the form of prior distribution, e.g., normal distribution, gamma distribution, etc., as if parameters of these prior distributions are given). The prior contains some implications in economic analysis: the prior setting means a weak restriction on these structural parameters, which is one of the reasons that we use the Bayesian method. Before estimation, we place weak restrictions on parameters under the theoretical framework through prior distributions.

Since our small-scale Keynesian model is rational expectations augmented, we solve the stochastic difference equations first. The solution consists of a policy rule and a law of motion of state variables, under the hypothesis of a unique stable solution. Several methods can be used to solve the model, e.g., undetermined coefficient method by Sims, etc. The Klein method is employed in this paper, and the solution can be presented by the following state-space form:

$$\xi_{t+1} = A \cdot \xi_t + C\omega_t, \quad \omega_t \sim N(0,\ Q),\qquad(13)$$

$$z_t = D \cdot \xi_t + v_t, \quad v_t \sim N(0, R). \tag{14}$$

Equation (13) is the transition equation (also called the state equation), representing the law of motion of the state variables; the equation (14) is the measurement equation, showing the relationship between state variables and observable variables (jump or control variables). In our case, $\xi_t = \{\pi_{t-1}, y_{t-1}, e_{t-1}, r_{t-1}, \pi_{t-1}^*, r_{t-1}^*, u_t^{AS}, u_t^{IS}, u_t^{RER}, u_t^{R}, u_t^{AS*}, u_t^{R*}\}$.

$z_t = \{\pi_t, y_t, e_t, r_t, \pi_t^*, r_t^*\}$, and $\omega_t = \{\varepsilon_t^{AS}, \varepsilon_t^{IS}, \varepsilon_t^{RER}, \varepsilon_t^{R}, \varepsilon_t^{AS*}, \varepsilon_t^{R*}\}$. The matrices A, B, C are functions of the structural parameters Θ. The vector v_t is the measurement error, including the discrepancies between theoretical variables and statistical variables, and the noise comes from incorrect data collection.

The transition equation and the measurement equation can be used to compute the likelihood function using the Kalman filter algorithm. The process is summarized as follows.

Let us define some notations.

$$\hat{\xi}_{t|t-1} \equiv E_t\left(\xi_t \mid I_{t-1}\right), \tag{15}$$

$$\hat{z}_{t|t-1} \equiv E_t\left(z_t \mid I_{t-1}\right), \tag{16}$$

$$\Sigma_{t|t-1} \equiv E_t\left[\left(\xi_t - \hat{\xi}_{t|t-1}\right)\left(\xi_t - \hat{\xi}_{t|t-1}\right)^T \mid I_{t-1}\right], \tag{17}$$

$$\Omega_{t|t-1} \equiv E_t\left[\left(z_t - \hat{z}_{t|t-1}\right)\left(z_t - \hat{z}_{t|t-1}\right)^T \mid I_{t-1}\right]. \tag{18}$$

3.3.1. Prediction

Assuming the initial state variables ($\hat{\xi}_{0|0}$) and their second moments ($\Sigma_{0|0}$) in hand, we can predict one-step-ahead state variables, and in turn the one-step-ahead observable variables.

$$\hat{\xi}_{t|t-1} = A\hat{\xi}_{t-1|t-1}, \tag{19}$$

$$\hat{z}_{t|t-1} = D\hat{\xi}_{t|t-1}. \tag{20}$$

Moreover, we can also obtain the predicted variance of the state and observable variables:

$$\Sigma_{t|t-1} = A\Sigma_{t-1|t-1}A^T + CQC^T, \tag{21}$$

$$\Omega_{t|t-1} = D\Sigma_{t|t-1}D^T + R. \tag{22}$$

The covariance between the predicted errors of the state variables and of the observable variables:

$$E_t\left[\left(z_t - \hat{z}_{t|t-1}\right)^T\left(\xi_t - \hat{\xi}_{t|t-1}\right) | I_{t-1}\right] = D\Sigma_{t|t-1}. \tag{23}$$

3.3.2. Updating

Once having a new observation, z_t^{obs}, we can update the state variable and their second moment by following two equations.

$$\hat{\xi}_{t|t} = \hat{\xi}_{t|t-1} + K(z_t^{obs} - D\hat{\xi}_{t|t-1}), \tag{24}$$

$$\Sigma_{t|t} = \Sigma_{t|t-1} - KD\Sigma_{t|t-1}, \tag{25}$$

where K is

$$K = \Sigma_{t|t-1}D^T\left[D\Sigma_{t|t-1}D^T + R\right]^{-1}. \tag{26}$$

Thus we can re-predict ahead state variable and observable variables, as done in the first step.

3.3.3. Formulating the log likelihood

Given sequence observation, z_t^{obs}, we can calculate the corresponding predicted variance series of observable variables, $\Omega_{t|t-1}$, using above algorithm.   In turn calculating likelihood value based on the prediction error and its variance, as in equation (27).

$$LL(z_t^{obs} \mid \Theta) = -0.5 \sum_{t=0}^{T} \left[p \ln(2\pi) + \ln |\Omega_{t|t-1}| + u_t^T \Omega_{t|t-1}^{-1} u_t \right], \tag{27}$$

where $u_t \equiv z_t^{obs} - \hat{z}_{t|t-1}$, and p presents the dimension of the observable series.   More detailed descriptions can be found in Kim and Nelson (1999), Ireland (2004), Hamilton (1994), Hansen and Sargent (2005), etc.

3.4. Parameters Estimated

We approximate the joint posterior distribution of structural parameters by employing Random-Walk-Metropolis-Hasting algorithm (RWMH) 100,000 draws.   To ensure convergence, we discard the first 50,000 draws as a burn-in sample.   Table 1 reports the estimation results.

The estimated forward-looking component in the AS equation, μ, equals 0.8975, which is remarkably larger than in Cho (2007).   The forward-looking component in the IS equation, α, equals 0.7764, which is also larger than Cho's estimate.   According to these estimates, the forward-looking behavior seems to be stronger in the determination of inflation than in the output gap.

The impact of the short-term interest rate on the output gap measured by δ_1 (0.0169) is smaller than the impact of the real exchange rate (measured by δ_2, that is 0.0294 in magnitude).   This means that it is hard to stabilize output with the short-term interest rate under the significant volatility of exchange rates, and this finding is consistent with the behavior of small open economy like Korea.

The impact of the real exchange rate on inflation measured by λ_2 equals 0.0042, and is much lower than that for the output gap (the estimated δ_2 equals

Table 1   Parameter Estimates

	Prior Distribution			Posterior Distribution			
	Distr.	Mean	S.D.	Mode	Mean	5%	95%
μ	Beta	0.50	0.25	0.9092	0.8975	0.7734	0.9854
α	Beta	0.50	0.25	0.7765	0.7764	0.6080	0.9341
ρ_R	Beta	0.50	0.25	0.9244	0.9216	0.8828	0.9487
ρ^{AS}	Beta	0.50	0.25	0.2109	0.2165	0.0453	0.4060
ρ^{IS}	Beta	0.50	0.25	0.8016	0.7765	0.5403	0.9099
ρ^{RER}	Beta	0.50	0.25	0.9423	0.9375	0.8789	0.9807
λ_1	Invgamma	0.07	0.50	0.0558	0.0618	0.0228	0.1200
λ_2	Invgamma	0.01	0.50	0.0036	0.0042	0.0017	0.0087
δ_1	Invgamma	0.06	0.50	0.0169	0.0196	0.0087	0.0395
δ_2	Invgamma	0.02	0.50	0.0294	0.0328	0.0042	0.0766
ρ_P	Normal	1.50	0.50	1.4006	1.4721	1.0472	2.0757
ρ_Y	Normal	1.50	0.50	1.5160	1.5303	0.9507	2.1656
ρ_E	Normal	0.50	0.50	0.0601	0.0781	0.0051	0.2336
σ_R	Invgamma	0.01	0.10	0.0032	0.0032	0.0027	0.0039
σ_P	Invgamma	0.01	0.10	0.0128	0.0129	0.0098	0.0159
σ_Y	Invgamma	0.01	0.10	0.0045	0.0046	0.0031	0.0064
σ_E	Invgamma	0.01	0.10	0.0057	0.0059	0.0035	0.0088
σ_R^*	Invgamma	0.01	0.10	0.0052	0.0053	0.0043	0.0064
σ_P^*	Invgamma	0.01	0.10	0.0322	0.0324	0.0272	0.0383
ρ^{R*}	Beta	0.65	0.07	0.7908	0.7914	0.7034	0.8693
ρ^{AS*}	Beta	0.65	0.07	0.3413	0.3398	0.2372	0.4388

0.0328).   The real exchange rate's influence on the output gap is stronger than that on inflation.   The parameters λ_1 and δ_1 are crucial elements in the interest rate transmission channel, through which monetary policy aims to stabilize inflation and output.   The estimated λ_1 and δ_1 are 0.0618 and 0.0196, respectively.

Finally, what does the monetary policy feedback rule look like? The degree of interest rate smoothing in the feedback is captured by ρ_R, which also represents the inertia of the short-term interest rate.   The estimated smoothing coefficient equals 0.9216, which is largely consistent with the estimates in related literature.   The estimated weights on inflation and the output gap are almost equal in size, which are 1.4721 and 1.5303, respectively.   The inflation stabilization is the objective of BOK, as they have formally announced; however it is not the sole focus, and the output stabilization is another important concern.   On the other hand, the weight of exchange rate stabilization is 0.0601 in size, which is much smaller than those of inflation and output gap.

It is again noteworthy that our estimates do not completely agree with previous literature, particularly with Cho (2007) and Cho *et al*. (2007). There are several possible explanations for this.   First of all, the parameters are unrestricted in Cho (2007) and Cho *et al*. (2007), but we have placed restrictions on parameters based on the microeconomic foundations, which is more common in the New Keynesian framework.   Moreover, our prior information in the Bayesian estimation may be responsible for some of the differences, although the prior does not lead to sensitive estimates in general.

4. IMPULSE RESPONSES

In this section, we analyze the effects of demand shocks, cost-push shocks, exchange rate shocks, and interest rate shocks (unanticipated monetary policy shocks) in our model.   In the process of impulse response analysis, all parameters are set to the estimates in the previous section.   The black solid

lines in the figures display the mean impulse responses and grey area represents the 95% confidence bands.

4.1. Effects of Demand Shock

Figure 5 presents the responses to a positive standard deviation of the demand shock occurred at time 0. A positive demand shock leads to mild increase in inflation, which lasts for about five quarters. The response of output gap is remarkable. It goes up and returns to its steady-state level within about eight quarters. A positive demand shock induces the sustained downward response of real exchange rate, which maintains over long period of time. The interest rate rises, peaks after five quarters, and finally returns to its steady-state level in about twenty quarters. The increase in the interest rate creates appreciation under the UIP condition, and gradually leads to the stabilization of the output gap.

**Figure 5   Effects of Demand Sock**
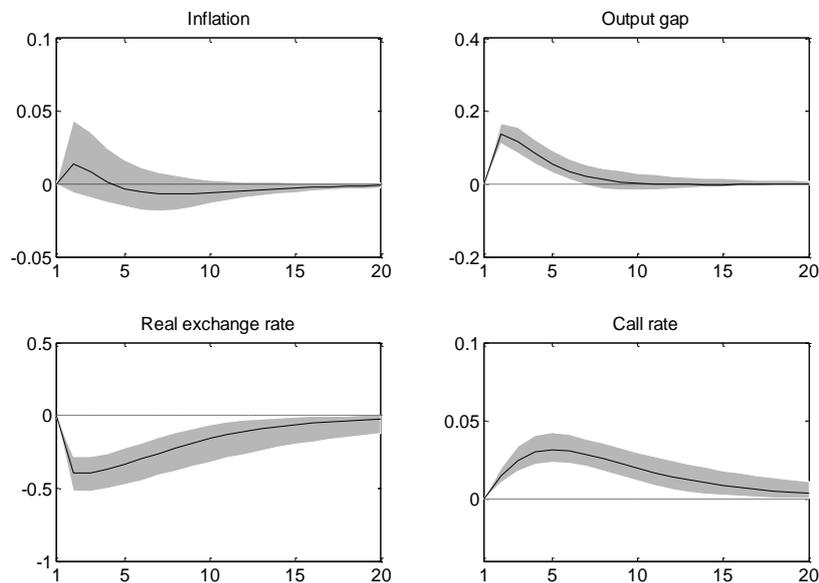
4.2. Effects of Cost Push Shock

The responses to a positive standard deviation of the cost-push shock are shown in figure 6. In reality, the cost-push shock may be more important and dangerous than other shocks since it is not only highly influential, but also persistent.

A positive cost-push shock leads to a significant jump in inflation and the impact lasts for about five quarters. The output gap declines and hits the ground at the fifth quarter. The real exchange rate experiences instant upward movement but goes down sharply as the domestic price level and interest rate begin to rise. The BOK instantly responds to the positive cost-push shock by raising interest rate, which depresses the demand for investment and consumption. This negative effect is reinforced by real appreciation. The cost-push shock on the output gap lasts for about ten quarters, but the effect looks mild in our case. Lowered real interest rate due to higher inflation may partially offset the negative effect on output.

Figure 6   Effects of Cost-push Shock
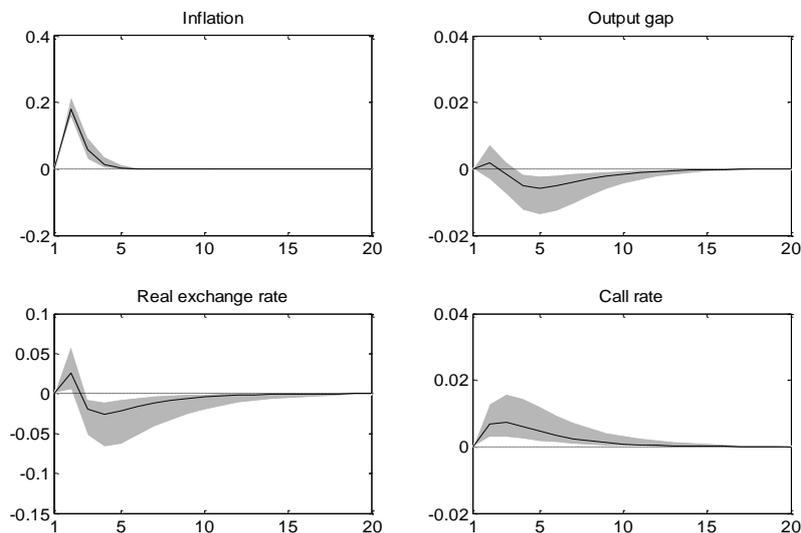
4.3. Effects of Exchange Rate Shock

Figure 7 displays the responses of the variables to a positive exchange rate shock. The real exchange rate is the only channel through which foreign shock is transmitted in our model. A positive exchange rate shock means instant real depreciation that directly raises both inflation and output gap. Its effects on both variables seem to be highly significant, which is similar to what Moon (2007) found in the Euro area. In response to an exchange rate shock, the inflation rises immediately, peaking and returning back to its steady-state level after about thirteen quarters. The output gap rises and reaches the maximum after three quarters, living for about ten quarters. The impact of the real exchange rate shock on itself lasts for more than twelve quarters. It is noteworthy that a positive real exchange rate shock triggers a sustained positive response in the interest rate, and this effect does not fade away even after twenty quarters. By raising interest rate, the BOK tries to offset the impact of depreciation in a moderate but persistent way, which does not agree with Marcelo's (2009) argument hat the BOK seems not to put any emphasis on stabilizing exchange rates.

Figure 7   Effects of Exchange Rate Shock
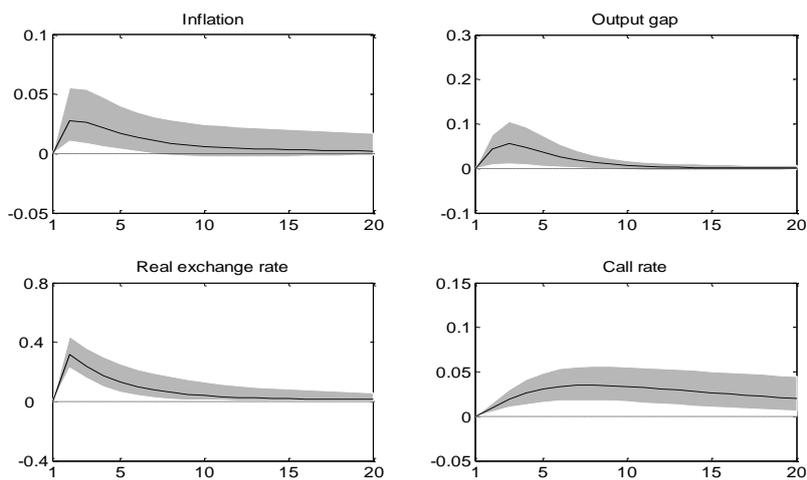
4.4. Effects of Monetary Policy Shock

Monetary policy consists of systematic and unsystematic parts. In our model, the anticipated policy is characterized by policy parameters and the unanticipated policy is represented by the error term in the feedback rule. The unanticipated monetary policy shock indicates that central banks have some other objectives which are not included in the policy rule. For instance, the monetary authority may react to equity and property price bubbles. Bubbles that inflate and then burst are particularly damaging because the wealth effects they create cause consumption to explode and then contract just as rapidly. Modern policy makers who have often experienced financial crises may care about asset prices or balance sheets of financial intermediaries not included in the standard feedback rule. In this sense, the error term in the feedback rule can be interpreted as "unanticipated."

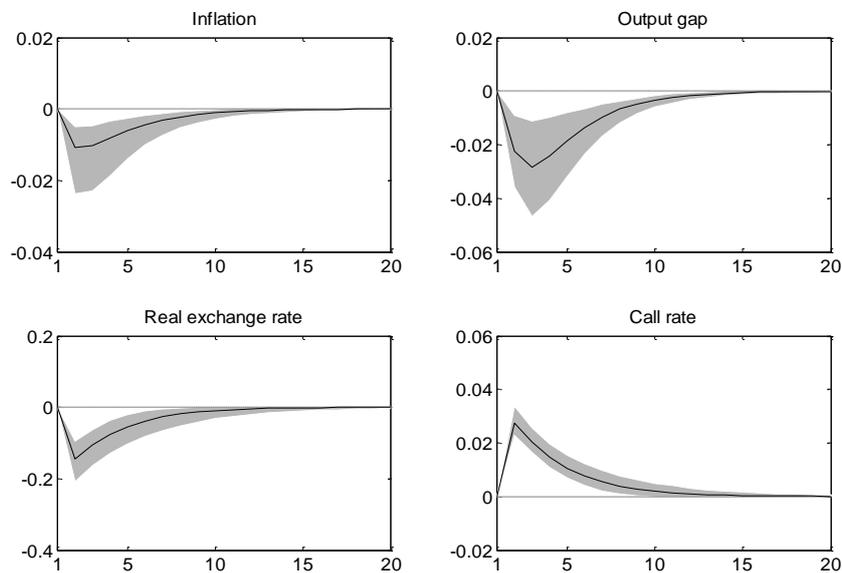**Figure 8   Effects of Monetary Policy Shock**

Figure 8 illustrates the effects of an unanticipated monetary policy shock that is a positive interest rate shock in our model.   In response to unanticipated interest rate shock, inflation falls down and lasts for about eleven quarters.   The effect is mild but there is no so called "price puzzle". The output gap decreases and reaches the lowest point after three quarters, finally returning back to its steady-state level in about fifteen quarters.   The response of output gap looks prominent and long-lasting.   Looking at the response of real exchange rates, there is an instant appreciation, which reaches its steady-state level in about ten quarters.

4.5. Variance Decomposition

Table 2 shows the forecast error variance decomposition for infinite horizons.   It is noteworthy that the variation in output gap is mostly affected by demand shock.   The monetary policy shock and real exchange rate shock seem to have some additional effects on output, while the supply shock plays no role.   For inflation, however, the impact of supply shock is very important.   Variations in inflation are mainly driven by supply shock and real exchange rate shock.   For interest rates and exchange rates, both demand shock and exchange rate shock seem important.

In summary, demand shock has large effects on output, interest rates, and exchange rates in our model.   Major real influences seem to come from demand shock. Exchange rate is another important source.   Most interestingly, however, the impact of supply shock is limited on inflation.

Table 2   Forecast Error Variance Decomposition (%)

Variable\Shock	ε_t^{IS}	ε_t^{AS}	ε_t^{R}	ε_t^{RER}
π_∞	8.28	59.64	11.13	20.94
y_∞	77.78	0.04	10.28	11.91
e_∞	77.44	0.04	8.70	13.82
r_∞	32.43	0.11	15.24	52.22

5. CONCLUSION

We analyzed a small-scale new Keynesian open economy model to evaluate the BOK's monetary policy during the post crisis period, when the inflation targeting regime was officially implemented. The parameters are estimated by the Bayesian MCMC method to ease some empirical difficulties. The results are largely consistent with the predictions of the new Keynesian model. First of all, the forward looking behavior, emphasized by the new Keynesian model, plays an important role in the IS curve as well as in the Phillips curve. The estimates on the real exchange rate included in both curves show signs consistent with the theory.

A puzzling finding in previous literatures is that that the relation between the call rate and the CPI inflation in the post crisis period is negative, which implies that BOK seemed to focus much heavily on the output stabilization even in the official inflation targeting regime. We also found that the contemporaneous correlation of the inflation and the interest rate in level is weak in our sample. If we use the interest rate in terms of log-deviation from its steady state, however, this anomaly disappears. In the monetary feedback rule, there is a high contemporaneous correlation between the inflation and the interest rate in terms of log-deviation. The estimates show that inflation and output have been equally treated in usual manner as dictated by the Taylor's principle.

The impulse response analysis also shows results consistent with the Keynesian theory. For example, there is no "price puzzle" found in our model. However, some sophisticated findings are to be noted. The cost-push shock seems to be less influential than the demand shock. Especially, the impact on the output seems to be mild in the Korean economy, which is not common in other countries. The impact of the real exchange rate is also noteworthy. In the monetary feedback rule, the weight on the exchange rate seems relatively small. However, a positive real exchange rate shock triggers a sustained positive response in the interest rate, and this effect does not fade away for a long time. The BOK tries to offset the impact of

exchange rate shocks in a moderate but persistent way. Overall, even though the official focus of the monetary policy is to stabilize domestic inflation, the BOK seems to put no less emphasis on stabilizing exchange rates as well as output gap.

REFERENCES

Berg, A., P. Karam, and D. Laxton, "Practical Model-Based Monetary Policy Analysis — A How-to Guide," IMF Working Paper, 2006.

Buncic, D. and M. Melechy, "An estimated New Keynesian Policy Model for Australia," *The Economic Record*, 84(264), 2008, pp. 1-16.

Cho, S., "An Empirical Assessment of the Korean Monetary Policy Since Foreign Exchange Crisis," *The Korea Economic Review*, 23(2), 2007, pp. 329-353.

Cho, S. and A. Moreno, "A Small-Sample Study of the New-Keynesian Macro Model," *Journal of Money Credit and Banking*, 38, 2006, pp. 1461-1481.

Cho, S., H. Hun, and H. Y. Woo, "A Test on the Efficiency of Monetary Policy in Korea," *Korea Development Review*, 29(2), 2007, pp. 117-133.

Christiano, L., M. Eichenbaum, and C. L. Evans, "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *Journal of Political Economy*, 113(1), 2005, pp. 1-45.

Chung, J., Y. Jung, and D. Y. Yang, "Optimal Monetary Policy in a Small Open Economy: The Case of Korea," *Journal of Asian Economics*, 18, 2007, pp. 125-143.

Clarida, R., J. Gali, and M. Gertler, "The Science of Monetary Policy: a New-Keynesian Perspective," *Journal of Economic Literature*, 37, 1999, pp. 1661-1707.

Gali, J. and T. Monacelli, "Monetary Policy and Exchange Rate Volatility in a Small Open Economy," *Review of Economic Studies*, 72, 2005, pp.

707-734.

Hodge, A., T. Robinson, and R. Stuart, "A Small BVAR-DSGE Model for Forecasting the Australian Economy," unpublished manuscript, 2008.

Hoover, K. D. and O. Jorda, "Measuring Systematic Monetary Policy," unpublished manuscript, 2001.

Hwang, Y., "Estimation of the Natural Output for Korea: A Bayesian DSGE Approach," *Korea Development Review*, 31(1), 2009, pp. 1-25.

Huh, Chan-Guk and Kwanghee Nam, "A Preview of Tale of Korea's Two Crises: Distinct Aftermaths of 1997 and 2008 Crises," *The Journal of the Korean Economy*, 11(1), 2010, pp. 1-29.

Ireland, P. N., "A Method for Taking Models to the Data," *Journal of Economic Dynamics and Control*, 28(6), Elsevier, pp. 1205-1226.

Karam, P. and A. Pagan, "A Small Structural Monetary Policy Model for Small Open Economies with Debt Accumulation," IMF Working Paper, 2006.

Kim, S. and Y. C. Park, "Inflation Targeting in Korea: A Model of Success?," *Monetary Policy in Asia: Approaches and Implement*, 31, 2006, pp. 140-164.

Klein, P., "Using the Generalized Schur form to Solve a Multivariate Linear Rational Expectations Model," *Journal of Economic Dynamics & Control*, 24, 2000, pp. 1405-1423.

Lee, J., "Are Structural Parameters of DSGE Models Stable in Korea," Bank of Korea Working Paper, No. 381, 2009.

Lee, M., "The Optimal Interest Rate Rule under Inflation Targeting in Korea?," *Review of Financial Studies*, 17(1), 2003, pp. 1-24.

Leiemo, K. and U. Soderstrom, "Robust Monetary Policy in a Small Open Economy," *Journal of Economic Dynamics & Control*, 32, 2008, pp. 3218-3252.

Li, B., "Evaluating Structural Vector Autoregression Models in Monetary Economies," unpublished manuscript, 2009.

Lippi, F., "Information Variables for Monetary Policy in an Estimated Structural Model of the Euro Area," *Journal of Monetary Economics*,

54, 2007, pp. 1256-1270.

Marcelo, S., "Characterizing the Inflation Targeting Regime in South Korea," Working Paper, Euro Central Bank, 2009.

Moons, C., H. Garretsen, B. V. Aarle, and Jorge Fornero, "Monetary Policy in the New-Keynesian Model: An Application to the Euro Area," *Journal of Policy Modeling*, 29, 2007, pp. 879-902.

Rotemberg, J. and M. Woodford, "An Optimization-based Econometric Framework for the Evaluation of Monetary Policy," *NBER Macroeconomics Annual*, 12, 1997, pp. 297-346.

Sack, B. and V. Wieland, "Interest-Rate Smoothing and Optimal Monetary Policy: A Review of Recent Empirical Evidence," *Journal of Economics and Business*, 52, 2000, pp. 205-228.

Smets, F., "An Estimated Stochastic General Equilibrium Model of the Euro Area," *Journal of the European Economic Association*, 1(5), 2003, pp. 1123-1175.

Soderstrom, U., "Robust Monetary Policy in a Small Open Economy," *Journal of Economic Dynamic & Control*, 32, 2008, pp. 3218-3252.

Uhlig, H., "A Toolkit for Analysis Nonlinear Dynamic Stochastic Models Easily," *Computational Methods for the Study of Dynamic Economics*, 1999, pp. 30-61.