The Role of Unobservable Fundamentals in Korea Exchange Rate Fluctuations: Bayesian Approach

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Recent literature emphasizes the role of unobservable fundamentals in exchange rate movements. Within the state-space model and the Bayesian approach, proposed by Balke et al. (2013), we find that unobservable fundamentals, such as the risk premium, the deviation from the purchasing power parity, and money demand shifters explain most of the Korea exchange rate fluctuations. In contrast, observed monetary fundamentals have much less effect. This result implies that Korean exchange rate movements are closely related to market expectations or sudden capital flows, rather than economic fundamentals.

JEL Classification: C11, F3

Keywords: Bayesian MCMC algorithm, Exchange rate, Unobservable fundamentals, Currency risk premium, Capital flows

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We are grateful for valuable comments to the editor and anonymous referees. We are responsible for any errors that may remain.

Received: 14 June 2017, Received in revised form: 2 August 2017, Accepted: 29 August 2017

Ⅰ. Introduction

Exchange rate fluctuations are a crucial issue in international finance and macroeconomics. Directly or indirectly, exchange rate forecasts are reflected in policy decisions of central banks all over the world. In particular, for an export-oriented economy, the exchange rate has been considered as one of the most important macro variables used to analyze the current and future economy. Since Meese and Rogoff (1983), however, the elusive link between the exchange rate and its theoretical economic fundamentals is referred to exchange rate disconnect puzzle. Even though some literature on exchange rate predictability finds evidence in favor of beating the random walk model (e.g, Mark, 1995; Mark and Sul, 2001; Molodtsova and Papell, 2009), it has been found that robustness of these results is influenced by the selection of predictor, forecast horizon, or sample period (e.g., Cheung et al. 2005; Kilian, 1999; Rossi, 2013).[1)]

Recent studies find the cause of the weak link between exchange rates and macro economic variables in unobservable fundamentals. Engel and West (2005) and subsequent literature state that the challenge in evaluating an exchange rate model is that not all the determinations are observable.[2)] To solve this problem, Balke et al. (2013) propose the state-space model, which enables us to quantify the contribution of observed fundamentals as well as unobserved fundamentals. One of the novelties of their approach is that additional data is involved to identify unobservable fundamentals, such as deviations from the uncovered interest rate parity and purchasing power parity, which allows us to better assess the impact of them on exchange rate movements. Using annual data for the UK-US exchange rates and their monetary fundamentals from 1880 to 2010, they show that observed

1) Rossi (2015) provides the survey of the exchange rate predictability literature.

2) Bacchetta and van Wincoop (2004, 2013) propose that the unstable relationship between exchange rates and observed fundamentals is caused by the shocks to unobservable fundamentals. Fratzscher et al. (2015) provide the empirical evidence of Bacchetta and van Wincoop (2013)'s model. Evans and Lyons (2002) use order flow and show that the failure of the exchange rate model results from omitting important variables. Chen and Tsang (2013) use yield curve factors as a proxy for the market expectation about future inflation and output growth, and success to show the systematical link between exchange rates and fundamentals.

monetary fundamentals as well as money demand shifters contribute most to UK-US exchange rate movements.

In this paper, we apply Balke et al. (2013) methodology to the short-run Korea-US exchange rates. We focus on the Korean exchange rates for several reasons. Korea has liberalized its financial market since the 1997 Asian crisis, and the Korean exchange rate has shifted to a free-floating exchange rate system since then. Thus, the value of the Korean won has been determined by the foreign exchange market since 1997, and is therefore suitable for investigating the impact of its economic determination. Unlike the UK pound, currencies in emerging countries are considered as investment currencies for carry trades, making them more vulnerable to sudden capital flows. For example, despite Korea’s relatively strong economic fundamentals and stable banking system, we witnessed sudden and large capital outflows and the sharp fluctuations of the Korean won during both the global financial crisis in 2008, and European debt crisis in 2010. Thus, the main determinant for the Korean won might differ from that of the UK pound. In addition, most interests for currency investors or policy makers is in short-run exchange rate movements rather than long-run. Hence, we adopt quarterly data for the Korea-US exchange rate and its monetary fundamentals from 1997Q1 − 2016Q4 periods, which includes the most recent financial crisis.

We find that the currency risk premium, money demand shifters, and the deviation from the purchasing power parity[3)], which bear a clear link to investors’ expectation rather than underlying fundamentals in FX market, explain most of the movements in the Korean won. In contrast, observed monetary fundamentals, such as money minus income differentials across countries, explain only small fraction of the movements in the Korean exchange rates. This result implies that non-fundamentals factors, such as sudden capital inflows or outflows driven by market expectation, play an important role in determining short-term Korean exchange rate fluctuations.

This paper is organized as follows. Section 2 presents the present value model

3) Menkhoff et al. (2017) show that the deviation from the PPP (i.e., real exchange rate) is driven by expectation, such as expected currency risk premium, the expected real interest rate differentials, and the long-run expected real exchange rates.

and state-space model developed by Balke et al. (2013). Section 3 explains the Bayesian approach conducted in this paper. Section 4 provides empirical results and discussion. We draw conclusions in Section 5.

Ⅱ. Exchange Rates and Monetary Fundamentals

1. The Present Value Model of Exchange Rates

As one of the asset prices, exchange rates can be expressed as the sum of the discounted value of expected future fundamentals. Within the present value model framework, fundamentals are implied by the various exchange rate models. In this paper, we focus on monetary fundamentals, which are derived from Mussa's (1976) monetary model of exchange rates and explored extensively in subsequent papers. Assume that the money market equilibrium in the home and foreign country is as below:

$$m_t - p_t = \phi y_t - \lambda i_t + v_{t,} \tag{1}$$

$$m_t^* - p_t^* = \phi y_t^* - \lambda i_t^* + v_t^* \tag{2}$$

where m_t is the log of money supply, p_t is the log of price level, i_t is the level of the interest rate, y_t is the log of output, and v_t is the shock to money demand. A variable with an asterisk denotes the foreign country.[4)]

Combining the purchasing power parity condition $s_t = p_t - p_t^* + r_t^{ppp}$, where r_t^{ppp} denotes the deviation from the PPP, and the uncovered interest rate parity condition $i_t - i_t^* = E_t s_{t+1} - s_t + r_t^{uip}$, where r_t^{uip} is the deviation from the rational expectation uncovered interest rate parity, the exchange rate solution is the present value relation as below:

$$s_t = (1-\psi)E_t(\sum_{j=0}^{\infty} \psi^j f_{t+j}) + E_t(\sum_{j=0}^{\infty} \psi^j R_{t+j}). \tag{3}$$

4) Following other literature, we treat US as the home country. The exchange rate is quoted as USD per KRW.

Here, $f_t = (m_t - m_t^*) - \phi(y_t - y_t^*)$ is directly observed fundamentals, and $R_t = \psi r_t^{uip} + (1-\psi) r_t^{ppp} - (1-\psi) r_t^{md}$ is unobservable fundamentals, where $r_t^{md} = v_t - v_t^*$. The discount factor in this equation is defined as $\psi = \dfrac{\lambda}{1+\lambda}$.

Many empirical studies examine the monetary fundamental contribution to exchange movements based on equation (3). Mark (1995) shows that deviations of the exchange rates from a monetary fundamentals are useful in predicting exchange rate changes over a long horizon (i.e., three to four years). Mark and Sul (2001) find that monetary fundamentals forecast exchange rates better than random walk by using the panel data techniques. The robustness of Mark's (1995) findings has, however, been attacked by Berkowitz and Giorgianni (2001), Groen (1999) and Faust et al. (2003). They found less exchange rate predictability even at long-horizon.

Recent literature suggests that these inconsistent results or the elusive link between the exchange rates and observed fundamentals is due to omitting unobservable fundamentals in empirical models. Engel and West (2005) state that the presence of unobserved fundamentals makes it difficult to predict exchange rates. Bacchetta and van Wincoop (2004, 2013) propose that the unstable relationship between exchange rates and macro fundamentals results from market participants who attach excessive weight to individual economic fundamentals when exchange rates are driven by unobservable shocks. Evans and Lyon (2005) use the order flows and Chen and Tsang (2013) employ yield curve factors as the proxies for unobservable fundamentals and find a significant relationship between those variables and exchange rate changes. Balke et al. (2013) show that using series with only two data inputs, exchange rates and monetary fundamentals, is insufficient to produce sharp inferences about the relative contribution of fundamentals. To resolve this problem, they propose a state-space model, which enables us to incorporate more observed fundamentals and to analyze the contribution of unobservable fundamentals to exchange rate fluctuations. Thus, in the next chapter, we first introduce Balke et al.'s (2013) framework and show how to conduct it using the Bayesian method.

2. A Decomposition of Exchange Rates

(1) State-Space Model

Balke et al. (2013) rearrange equation (3) as a form of the deviation of the exchange rates from the current observed fundamentals:

$$s_t - f_t = E_t[\sum_{j=1}^{\infty}\psi^j \Delta f_{t+j}] + [\sum_{j=0}^{\infty}\psi^j R_{t+j}]. \tag{4}$$

Note that R_t consist of unobservable fundamentals, r_t^{ppp}, r_t^{uip} and r_t^{md}. Assume each of the Δf_t and three component of R_t consists of both a predictable and unpredictable component as below:

$$\Delta f_t = g_{t-1} + \varepsilon_t^f, \qquad (1-\phi_g(L))g_t = \varepsilon_t^g, \tag{5}$$

$$r_t^{ppp} = \mu_{t-1}^{ppp} + \varepsilon_t^{ppp}, \qquad (1-\phi_{ppp}(L))\mu_t^{ppp} = \varepsilon_t^{\mu,ppp}, \tag{6}$$

$$\mathrm{r}_\mathrm{t}^\mathrm{uip} = \mu_{\mathrm{t}-1}^\mathrm{uip} + \varepsilon_\mathrm{t}^\mathrm{uip}, \qquad (1-\phi_\mathrm{uip}(\mathrm{L}))\mu_\mathrm{t}^\mathrm{uip} = \varepsilon_\mathrm{t}^{\mu,\mathrm{uip}}, \tag{7}$$

$$r_t^{md} = \mu_{t-1}^{md} + \varepsilon_t^{md}, \qquad (1-\phi_{md}(L))\mu_t^{md} = \varepsilon_t^{\mu,md}, \tag{8}$$

where $g_t = E_t[\Delta f_{t+1}]$, $\mu_t^{ppp} = E_t[r_{t+1}^{ppp}]$, $\mu_t^{uip} = E_t[r_{t+1}^{uip}]$, $\mu_t^{md} = E_t[r_{t+1}^{md}]$, and ε_t^g, $\varepsilon_t^{\mu,ppp}$, $\varepsilon_t^{\mu,uip}$, $\varepsilon_t^{\mu,md}$ are expectation shocks which can be contemporaneously correlated but are serially uncorrelated. Assuming lag operators $\phi_g(L)$, $\phi_{ppp}(L)$, $\phi_{uip}(L)$ and $\phi_{md}(L)$ to be AR(1), we can write the exchange rates relative to the observed current monetary fundamental as[5]:

$$\begin{aligned} s_t - f_t = {} & \frac{\psi}{1-\psi\phi_g}g_t + \frac{\psi^2}{1-\psi\phi_{uip}}\mu_t^{uip} + \psi\mu_{t-1}^{uip} + \frac{(1-\psi)\psi}{1-\psi\phi_{ppp}}\mu_t^{ppp} + (1-\psi)\mu_{t-1}^{ppp} \\ & - \frac{(1-\psi)\psi}{1-\psi\phi_{md}}\mu_\mathrm{t}^\mathrm{md} - (1-\psi)\mu_{\mathrm{t}-1}^\mathrm{md} + \psi\varepsilon_\mathrm{t}^\mathrm{uip} + (1-\psi)\varepsilon_\mathrm{t}^\mathrm{ppp} - (1-\psi)\varepsilon_\mathrm{t}^\mathrm{md}. \end{aligned} \tag{9}$$

Balke et al. (2013) demonstrate that in series with two observed fundamentals, Δf_t in equation (5) and $s_t - f_t$ in equation (9), not all the parameters are

5) Balke et al. (2013) specify g_t, μ_t^{ppp}, μ_t^{uip} and μ_t^{md} to be AR(1) process, and state that it keeps the model parsimonious. We also present the results of robustness check in next section.

identified. They resolve this problem by incorporating additional data, such as price differentials and the interest rate differential between two countries within the state-space model. Adjusting the money equilibrium equation and uncovered interest rate parity in terms of g_t and unobserved variables makes it possible to incorporate additional data in the state-space model.

$$f_t - (p_t - p_t^*) = -\frac{\psi}{1-\psi}(i_t - i_t^*) + r_t^{md}, \tag{10}$$

$$i_t - i_t^* = E_t(s_{t+1} - f_{t+1}) + E_t \Delta f_t - (s_t - f_t) + r_t^{uip}. \tag{11}$$

Then, we can construct the measurement equation in the state-space model by using equations (5), (9), (10), and (11). For the inference, the measurement equation is obtained as

$$y_t = H\beta_t \tag{12}$$

where

$$y_t = \begin{bmatrix} f_t - (p_t - p_t^*) \\ i_t - i_t^* \\ \Delta f_t \\ s_t - f_t \end{bmatrix}, \quad H = \begin{bmatrix} -\frac{\psi}{1-\psi}((h_{sf} + h_{df})G - h_{sf} + h_{uip}) + h_{md} \\ (h_{sf} + h_{df})G - h_{sf} + h_{uip} \\ h_{df} \\ h_{sf} \end{bmatrix},$$

$$h_{df} = [0 \quad 1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0 \quad 0],$$

$$h_{uip} = [0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0],$$

$$h_{md} = [0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0 \quad 0 \quad 1],$$

$$h_{sf} = [B_1 \quad 0 \quad B_2 \quad \psi \quad B_3 \quad 1-\psi \quad B_4 \quad -(1-\psi) \quad 0 \quad \psi \quad 1-\psi \quad -(1-\psi)],$$

$$B = [\psi(1-\psi\phi_g)^{-1} \quad \psi^2(1-\psi\phi_{uip})^{-1} \quad (1-\psi)\psi(1-\psi\phi_{ppp})^{-1} \quad -(1-\psi)\psi(1-\psi\phi_{ppp})]'.$$

B_i is i-th element of B vector, and the transition equation which portrays the evolution of the state variables is given by

$$\beta_t = G\beta_{t-1} + v_t, \quad v_t \sim N(0, \Omega), \tag{13}$$

where

$$\beta_t = \left[g_t \quad g_{t-1} \quad \mu_t^{uip} \quad \mu_{t-1}^{uip} \quad \mu_t^{ppp} \quad \mu_{t-1}^{ppp} \quad \mu_t^{md} \quad \mu_{t-1}^{md} \quad \epsilon_t^f \quad \epsilon_t^{uip} \quad \epsilon_t^{ppp} \quad \epsilon_t^{md} \right]',$$

$$G = \begin{bmatrix} \phi_g & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0_{1\times 4} \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0_{1\times 4} \\ 0 & 0 & \phi_{uip} & 0 & 0 & 0 & 0 & 0 & 0_{1\times 4} \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0_{1\times 4} \\ 0 & 0 & 0 & 0 & \phi_{ppp} & 0 & 0 & 0 & 0_{1\times 4} \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0_{1\times 4} \\ 0 & 0 & 0 & 0 & 0 & 0 & \phi_{md} & 0 & 0_{1\times 4} \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0_{1\times 4} \\ 0_{4\times 1} & 0_{4\times 1} & 0_{4\times 1} & 0_{4\times 1} & 0_{4\times 1} & 0_{4\times 1} & 0_{4\times 1} & 0_{4\times 1} & 0_{4\times 4} \end{bmatrix},$$

$$v_t = \left[\epsilon_t^g \quad 0 \quad \epsilon_t^{\mu,uip} \quad 0 \quad \epsilon_t^{\mu,ppp} \quad 0 \quad \epsilon_t^{\mu,md} \quad 0 \quad \epsilon_t^f \quad \epsilon_t^{uip} \quad \epsilon_t^{ppp} \quad \epsilon_t^{md} \right]',$$

and Ω denotes 8×8 variance-covariance matrix of v_t.

(2) Prior

We complete our econometric modeling by specifying our prior distributions for all model parameters. Let Φ be a set of all ϕ_j for $j=[g, uip, ppp, md]$. The set of model parameters is given by $\Theta = (\Phi, \psi)$ and Ω. Given the model parameters, the prior for β_0 has a normal distribution with unconditional mean $\overline{\mu}$ and variance $\overline{V}$ of β_t. The prior distributions for Θ, Ω and β_0 are summarized as

$$\phi_j \sim i.i.d.N(0.9, 0.1), \qquad \psi \sim i.i.d.N(0.9, 0.1),$$
$$\Omega \sim i.i.d.IW(20, 0.5I_k), \qquad \beta_0 \sim i.i.d.N(\overline{\mu}, \overline{V}),$$

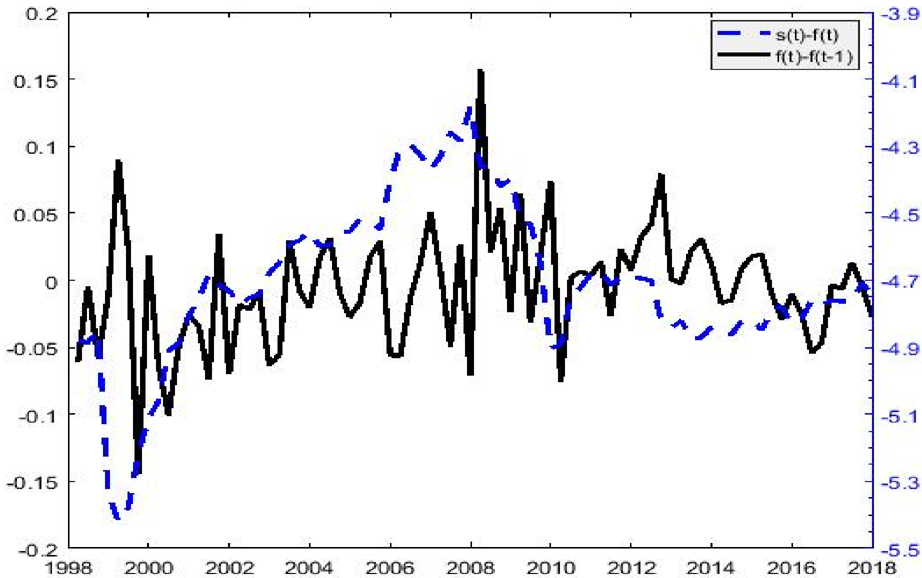
where IW denotes an inverse-Wishart distribution. For each of the models, our priors are fairly diffuse, which fully reflects the information of the data. In addition, we constrain the prior distributions on the autoregressive parameters for the stability condition.

III. Data and Estimation Strategies

1. Data Description

Asian currency crisis in 1997 ignited Korea to liberalize its financial market and

〈Figure 1〉 US-Korea Exchange Rates



Notes: This figure plots the US-Korea exchange rates from current observed monetary fundamentals, $(s_t - f_t)$ along with the fundamental growth, $f_t - f_{t-1}$.

open its capital account. In addition, the Korean exchange rates shifted to a free-floating exchange rate system since then.[6] Thus, our main sample consists of quarterly data from 1997Q1 to 2016Q4 for Korea and the United States.

Macro data-sets are from the Organization for Economic Cooperation and Development (OECD) via Federal Reserve Economic Data (FRED), and the exchange rate series are from Board of Governors of the Federal Reserve System (US) via Federal Reserve Economic Data (FRED). The exchange rate, s_t, is measured as the US dollar price per unit of Korean won. A lower number means a depreciation of the Korea won. The price level, p_t, is the consumer price index, and m_t is the seasonally adjusted money supply, M1. y_t is seasonally adjusted real GDP, and i_t is the 3-month Treasury bill rates for US and interest rates for government bonds for Korea. We convert all data apart from interest rates by taking logs.[7]

Figure 1 plots the deviation of the exchange rates from current observed

6) Lee (2007) points out that the Korean government announced a plan to liberalized all foreign exchange transaction in June 1998.

7) Since interest rates are annual rates and expressed as a percentage, we convert interest rate series by dividing by 400.

monetary fundamentals, $(s_t - f_t)$ along with the fundamental growth Δf_t. In this figure, $(s_t - f_t)$ shows very a persistent pattern, while Δf_t is much less persistent. This figure suggests that the unobservable fundamentals should have a persistent component, as emphasized in Colacito and Croce (2011).

2. Markov-Chain Monte Carlo (MCMC) Sampling

Given the conditional density of the data and the prior, we simulate the joint posterior distributions of the model parameters, factor, and contributions of each factor. To do this, we rely on a Bayesian estimation method. Our algorithm of the MCMC procedure can be summarized as follows.

Algorithm of the MCMC Procedure

Step 0: Initialize $\{\beta_t\}_{t=0}^{T}$, Ω and set the MCMC sample size.

Step 1: Sample Θ based on the tailored MH algorithm.

Step 2: Sample Ω from the full conditional distribution.

Step 3: Sample $\{\beta_t\}_{t=0}^{T}$ by using the Carter and Kohn method.

Step 4: Compute the contributions of each factors.

Step 5: Repeat Steps 2-4, discarding the burn-in samples.

To summarize the posterior distributions of the parameter and contributions, we run 150,000 iterations, 50,000 of them being the burn-in. Each of our MCMC cycles consists of four stages. The following sub-sections describe each stage in detail.

(1) Step 1: Sampling Θ

In the first stage, we are able to sample the parameters in the models by applying a tailored Metropolis-Hastings algorithm following Chib and Kang (2013). This method is more reliable than the standard Metropolis-Hastings (MH) algorithm, especially when the parameter structure of the model is nonlinear. For the technical details, refer to Chib and Ramamurthy (2010).

(2) Step 2: Sampling Ω

Conditioned on $\{\beta_t\}_{t=0}^{T}$ and Θ, we can generate Ω from the full conditional posterior distribution. The full conditional distribution for Ω is an inverse-Wishart distribution given an inverse-Wishart prior.

(3) Step 3: Sampling $\{\beta_t\}_{t=0}^{T}$

Given the Θ, Ω, and data, we sample from the conditional posterior distribution for the unobserved factors by using forward and backward recursion method of Carter and Khon (1994)'s method (see also Kim and Nelson (1999)).

(4) Step 4: Variance decomposition

By using the estimated parameters of the state-space model, we can determine the relative contributions of the economic fundamentals on Korean exchange rates through the effects of each factor on $s_t - f_t$ in the measurement equation.

Ⅳ. Empirical Results

1. Estimation Results

Table 1 presents the summary of the parameter estimation results from the model.8) It includes posterior means (mean) and 95 percent credibility intervals (95% C.I.) for each parameter. First, we should pay attention to the discount factor, ψ.

Engel and West (2005) propose that the exchange rates seem to be disconnected from the current value of macro variables when the discount factor is near unity. By using survey forecast data, Sarno and Solji (2009) find near unity discount factors for the Swiss franc, Euro, British pound, and Japanese yen. Similarly, we find that posterior mean of ψ, the discount factor for Korean won, is 0.9893 within Bayesian framework. It can be another supportive evidence of Engel and West's (2005) theorem.9)

8) We display histograms for the posterior distribution of main parameters only. Other histograms are available upon request.

9) Following Chib and Kang (2013), we compute the inefficiency factor for any sampled sequence of posterior draws. The sampled draws for all model parameters have low inefficiency factors.

〈Table 1〉 Parameter Estimates

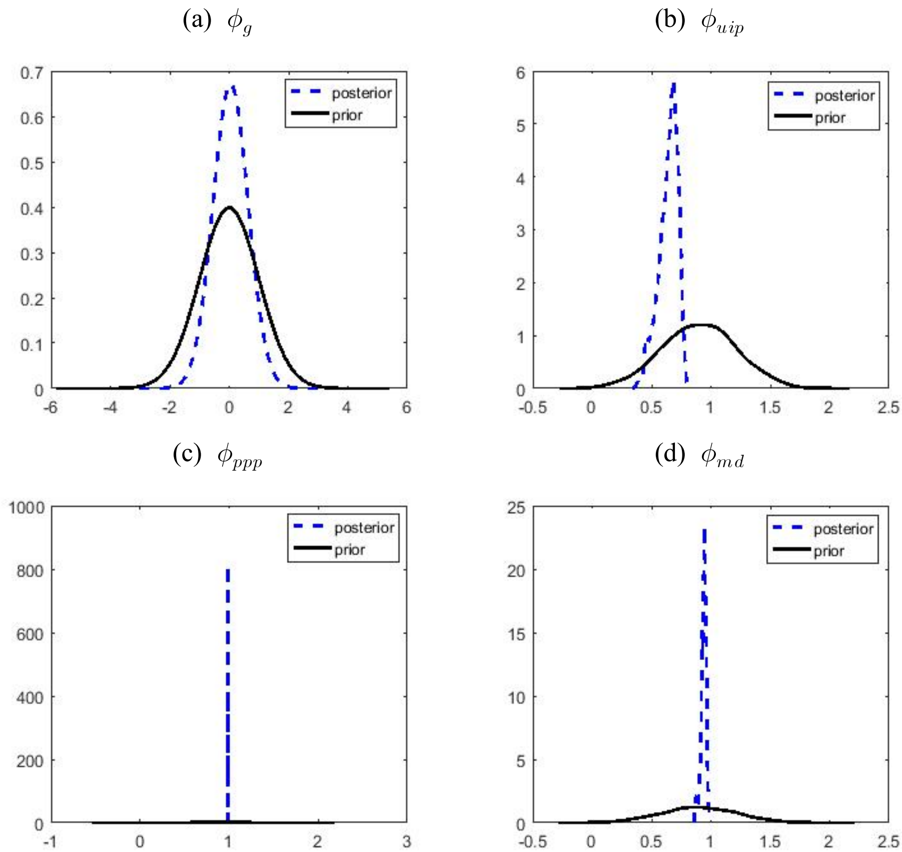
	Mean	S.E.	2.5%	97.5%
ψ	0.9893	0.0007	0.9872	0.9900
ϕ_g	-0.0938	0.3134	-0.7035	0.5338
ϕ_{uip}	0.6300	0.0510	0.5130	0.7292
ϕ_{ppp}	0.9892	0.0009	0.9864	0.9900
ϕ_{mds}	0.9351	0.0234	0.8719	0.9608

Notes: This table presents the posterior means and 95 percent credibility intervals based on 150,000 MCMC draws beyond a burn-in of 50,000 for the expended model.

In addition to Table 1, Figure 2 illustrates posterior distributions of autoregressive parameters in equations (5)-(8). The posterior distribution of the autoregressive parameters indicates that the predictable components of unobservable fundamentals, in particular the deviation from the purchasing power parity and money demand shifters are fairly persistent, whereas those of the observed fundamental are not. Persistent μ_t^{uip}, μ_t^{ppp} and μ_t^{md} are consistent with the theoretical and empirical findings in the previous literature. Colacito and Croce's (2011) theoretical model and Mark and Wu’s (1998) empirical results from the VAR construction consistently suggest that μ_t^{uip} contains fairly persistent pattern. As well documented by Rogoff (1996), consensus in exchange rate literature finds that the speed of convergence to the PPP is very slow and the deviation from the PPP is very persistent. Consistent to this view, our estimated ϕ_{ppp} is very high. Taylor and Taylor (2004) propose that because of structural and persistent differences between countries, the deviation from the PPP arise even in the long-run, especially when considering emerging markets. High ϕ_{md} supports the Engel and West (2005)’s conjecture that money demand shifters possibly consist of constant and trend terms, and could be serially correlated.

Figure 3 shows the posterior distribution of the variance decomposition of $(s_t - f_t)$. It shows clearly what best explains movements in the Korean exchange rates. We can see that the predictable component of directly observed monetary fundamentals, g_t explains only the small portion of the fluctuations in the Korean won. In contrast, most of the fluctuations is caused by the predictable component

〈Figure 2〉 Prior and Posterior Distributions

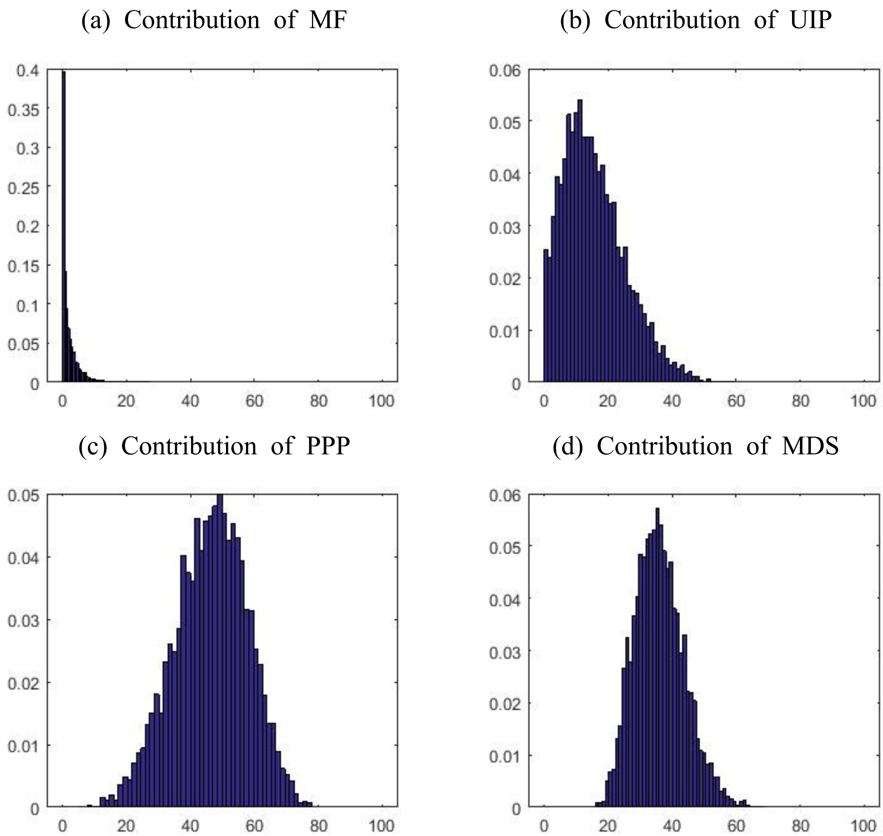


Notes: This figure plots the kernel density estimates of prior and posterior distributions for the autoregressive parameters. The subscripts g, uip, ppp, md indicate the monetary fundamentals, risk premium, purchasing power parity, and money demand shifter, respectively.

of unobservable fundamentals, μ_t^{uip}, μ_t^{ppp}, and μ_t^{md}.

Specifically, our findings show that on average, μ_t^{uip}, μ_t^{ppp}, and μ_t^{md} account for 15%, 50%, and 35% of Korea-US exchange rate fluctuations, respectively. We can see that information in the derivation from the PPP contributes the most to Korean won movements. Thus, from this results, we conclude that unobservable fundamentals, in particular, the risk premium, the deviation from the PPP, and money demand shifters which are typically not accounted for in observed fundamentals, are the driving variables for the Korean exchange rates.

〈Figure 3〉 Posterior Distribution of Variance Decomposition of $s_t - f_t$: M1

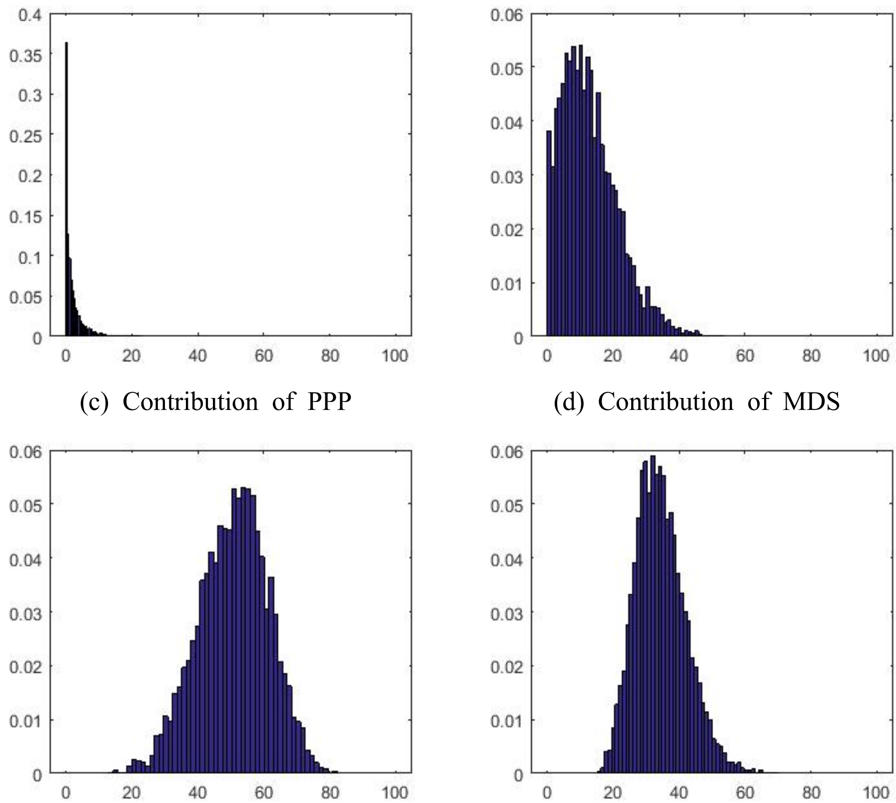


Notes: Histograms of posterior distribution of variance decomposition of $s_t - f_t$ based on 150,000 MCMC simulations beyond a burn-in of 50,000. The MF, UIP, PPP, and MDS indicate the observed monetary fundamentals, risk premium, purchasing power parity, and money demand shifter, respectively. We use M1 series as the money supply in this analysis.

2. Robustness Checks

In this section, we perform several additional robustness checks. First, we estimate the model with M2 and M3, as an alternative proxy for the monetary supply. Figure 4 and 5 display the posterior distribution of variance decomposition of $(s_t - f_t)$ when M2 and M3 series are employed, respectively. Similar to Figure 3, Figure 4 and 5 show that the most of the contribution come from the risk premium, the deviation from the PPP and money demand shifters. It confirms that unobservable fundamentals are an important contributor to fluctuations in $(s_t - f_t)$. The great similarities among Figures 3-5 imply that our results appear largely

〈Figure 4〉 Posterior Distribution of Variance Decomposition of $s_t - f_t$: M2



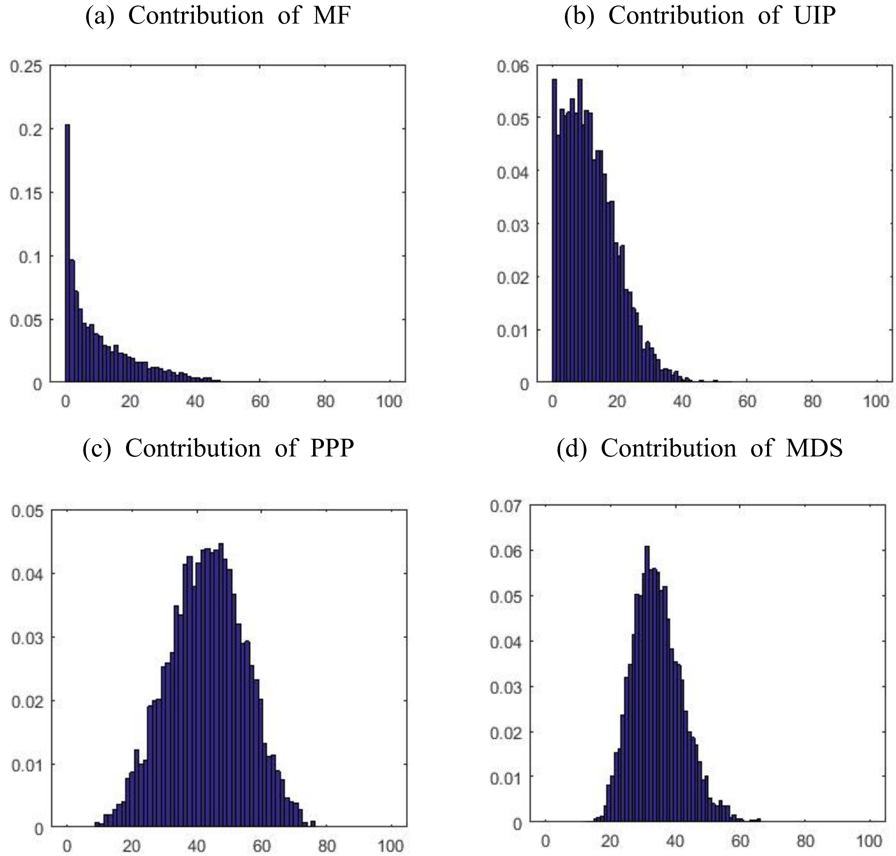
(a) Contribution of MF
(b) Contribution of UIP
(c) Contribution of PPP
(d) Contribution of MDS

Notes: Histograms of posterior distribution of variance decomposition of $s_t - f_t$ based on 150,000 MCMC simulations beyond a burn-in of 50,000. The MF, UIP, PPP, and MDS indicate the observed monetary fundamentals, risk premium, purchasing power parity, and money demand shifter, respectively. We use M2 series as the money supply in this analysis

robust for data set.

Second, we conduct a subsample analysis by excluding the time period of the 1997 Asia crisis. Abnormal movements in Korea-US exchange rates as well as macro fundamentals during the crisis period can potentially overestimate the contribution of risk premium or money demand shifters. We thus use the data covering from 1999Q1 to 2016Q4 and implement the same procedure as before. Even with the subsample period, we still find the strong impacts of unobserved fundamentals on Korean won movements. It shows that estimated parameters and results of the variance decomposition are robust to the sample period.[10)]

〈Figure 5〉 Posterior Distribution of Variance Decomposition of $s_t - f_t$: M3



Notes: Histograms of posterior distribution of variance decomposition of $s_t - f_t$ based on 150,000 MCMC simulations beyond a burn-in of 50,000. The MF, UIP, PPP, and MDS indicate the observed monetary fundamentals, risk premium, purchasing power parity, and money demand shifter, respectively. We use M3 series as the money supply in this analysis

Third, we check if the AR(1) specification in equations (5)-(8) is appropriate. Since g_t, μ_t^{uip}, μ_t^{ppp}, μ_t^{md} in equations (5)-(8) are unobservable, the growing the number of orders in AR(q) increases the number of parameters we should estimate within the state-space model. Instead of estimating high order of AR(q) process, we conduct the Ljung-Box Q test for checking whether the residuals from AR(1) process is serially correlated or white noise.

The Q-statistic computed from residuals is generally used to detect serial

10) To save the space, we do not report the histograms for the subsample analysis. Other histograms are available upon request.

〈Table 2〉 Q-statistics of Residuals

	ε_t^f	$\varepsilon_t^{\mu,uip}$	$\varepsilon_t^{\mu,ppp}$	$\varepsilon_t^{\mu,md}$
$Q(3)$	2.443	4.898	5.797	1.952
$Q^2(3)$	2.580	2.976	5.216	1.594

Notes: Ljung-Box Q-statistics based on the first three serial correlation coefficients of the levels and squares of residuals estimated within the model.

correlations in the data not captured by the estimated model. The intuition behind this test is that residuals would have serial correlation when AR(1) specification is inappropriate. We also conduct the test for serial correlations in the second moment. In Table 2, we can see that all these sample Q-statistics are insignificant with large p-values: that is, AR(1) model specification reasonably describes the dynamics of the unobserved fundamentals.

Fourth, we examine whether the estimated risk premium in our model properly reflects risk premium, by the survey forecast data. The survey forecast data are obtained from Economic Consensus Inc., covering from 1997Q1 to 2014Q3 period. We calculate the survey-based risk premium[11] as $rp_{t\to h}^s=(i_t-i_t^*)-(E_t^s s_{t+h}-s_t)$, where $E_t^s s_{t+h}$ is the survey forecast of 3-month, 12-month, and 24-month ahead exchange rates. To evaluate the linkage between the model-based and the survey-based measures of risk premium, we run the following regression:

$$\mu_t^{uip}=\beta_0+\beta_1 rp_{t\to h}^s+e_t, \qquad where\ \ h=1,4,8. \tag{14}$$

Table 3 reports the estimated results. We can see that β_1 coefficients for various horizons are statistically significant at a 5% level. The magnitude of the linkage between estimated μ_t^{uip} and survey-based risk premium are considerably high. It indicates that the risk premium estimated from our model contains the common information in the risk premium measured by survey forecast data.

11) The foreign exchange literature (i.e., Dominguez, 1986; Frankel and Froot, 1987; Frankel and Chinn, 1993; Bacchetta et al., 2009) investigates the exchange rates by using survey forecast data. Following Bacchetta et al. (2009), we calculate the survey-based currency risk premium.

〈Table 3〉 Relationship between Survey-Based and Estimated Risk Premium

$$\mu_t^{uip} = \beta_0 + \beta_1 rp_{t\to h}^s + e_t, \qquad where\ \ h = 1,4,8,$$

	Horizon		
	1-Quarter	4-Quarter	8-Quarter
β_0	-0.443***	-0.430***	-0.415***
(s.e.)	(0.011)	(0.012)	(0.011)
β_1	0.841**	0.612***	0.657***
(s.e.)	(0.377)	(0.186)	(0.124)
R^2	0.067	0.136	0.271

Notes: Asterisks denote significance at 1%(***), 5%(**), and 10%(*) respectively. $rp_{t\to h}^s = (i_t - i_t^*) - (E_t^s s_{t+h} - s_t)$ is survey-based risk premium, where $E_t^s s_{t+h}$ is the survey forecasts of h-quarter-ahead exchange rates.

3. Discussion

Although we do not explicitly test for any specific macroeconomic models, our results nevertheless have economic interpretations regarding the importance of capital flows in the Korean foreign exchange market. Balke et al. (2013) find that long-run (annual) British pound movements are mainly determined by observed monetary fundamentals as well as money demand shifters. On the contrary, our results provide evidence that the deviation from the UIP (or currency risk premium), the deviation from the PPP, and money demand shifters explain most of movements in the Korean won in the short run (quarterly). Our question is what causes this difference.

We note that first two factors (i.e., currency risk premium, and the deviation from the PPP) are closely related to market expectation. μ_t^{uip} is related to the market expectation by definition (i.e., $\mu_t^{uip} = E_t[r_{t+1}^{uip}]$). It can be due to the foreign exchange risk premium (see Engel, 2014), some sort of liquidity risk premium (Brunnermeir et al. 2009; Banti et al. 2012), infrequent portfolio decision (Bacchetta and van Wincoop, 2010) or systematic forecast error (Bacchetta et al. 2009). In this paper, assuming away systematic market expectation errors, we consider μ_t^{uip} as risk premium and that agents require a higher expected return on Korean deposit than on US deposits, because of the foreign exchange risk. Moreover, Menkhoff et al. (2017) demonstrate that the deviation from the PPP (i.e., real exchange rate) is driven by expectation, such as expected currency risk premium, the expected real interest rate differentials, and the long-run expected real exchange rates. In this line of reasoning, we infer that the huge contribution of the deviation from the PPP to Korean won movements also indicates the importance of market expectation in Korean FX market. Additionally, money demand shifters indicates factors that are not related with monetary fundamentals but affect country's money market equilibrium, such as sudden capital inflows or outflows. Thus, large impacts of the deviation from the UIP, the deviation from the PPP, money demand shifters on exchange rate fluctuations imply that market expectations or sudden capital flows in the FX market rather than economic fundamentals, have a large influence on short-run movements in the Korean exchange rates.

We saw sudden and large capital outflows and sharp fluctuations of Korean won's value during the global financial crisis in 2008 and the European debt crisis in 2010[12]. Recently, near zero interest rates adopted by many developed countries attracts large capital inflows in emerging markets as a result of carry trade. Our results suggest that since the Korean won is vulnerable to sudden capital flows, appropriate capital controls could be effective in stabilizing its short-run exchange rates.

V. Conclusion

In this paper, we use the state-space model and the Bayesian MCMC method developed by Balke et al. (2013) to analyze the contributions of the economic fundamentals on Korean exchange rates during 1997Q1-2016Q4 period. We find that unobservable fundamentals, such as the currency risk premium, money demand

12) It is also referred to as the Eurozone crisis or the European sovereign debt crisis.

shifters, the deviation from purchasing power parity play a key role in explaining short-run Korean won fluctuations. By contrast, observed monetary fundamentals cause only a small portion of the short-run movements in the Korean won. Our results imply that market expectation or sudden capital flows is an important contributor to Korean exchange rate movements in the short run.

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한국 환율 변동에 대한 비관측 요인들의 역할: 베이지안 접근법

김영민* · 이서진**

최근 국제금융 관련 연구에서는 환율을 결정 요소로서, 관찰 불가능한 변수들(unobservable fundamentals)의 중요성을 강조하고 있다. 이 논문에서는 Balke et al. (2013)이 제안한 상태공간 모형과 베이지안 접근법을 한국의 경우에 적용하여 추정하였다. 그 결과 관측 할 수 없는 변수 중에서도 특히 리스크 프리미엄이나 PPP, money demand shifters로 부터의 괴리와 같은 변수들이 한국의 환율 변동의 대부분을 설명한 다는 것을 알 수 있었다. 반면, 양국 간의 통화량과 소득의 차이와 같은 지표의 한국 환율 변동에 대한 기여도는 훨씬 낮은 것으로 분석 되었다. 이러한 결과는 한국의 단기 환율은 한국의 기초경제변수보다 외환시장 참가자들의 예상(expectation)에 따라 결정되는 것을 의미한다.

JEL Classification: C11, F3

핵심 주제어: 베이지안 MCMC 알고리즘, 환율, 환리스크 프리미엄, 현금흐름

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논문 투고일: 2017.6.14, 논문 수정일: 2017.8.2, 게재 확정일: 2017.8.29