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EVALUATING EXCHANGE RATE MANAGEMENT
AN APPLICATION TO KOREA

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Abstract

This paper uses data-rich estimation techniques to study monetary policy in an open economy. We apply the techniques to a small, forward-looking model and explore the importance of the exchange rate in the monetary policy rule. This approach allows us to discern whether a monetary authority targets the exchange rate *per se*, or instead simply responds to the exchange rate in order to achieve its other objectives. The approach also removes a downward bias on the estimate of the extent of inflation targeting. We find that this bias is important in the case of Korea, a *de jure* inflation targeter. In contrast to previous studies, our findings suggest that the Bank of Korea actively targets inflation, not the exchange rate. Apparently, the exchange rate has been only indirectly important in Korea's monetary policy.

Keywords: Exchange Rates, Exchange Rate Management, Monetary Policy Rule, Inflation Targeting, Exchange Rate Regimes, Exchange Rate Classification, Factor Instrumental Variables

JEL Classification: F3, F4

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1. Introduction

In an open economy, a monetary authority may respond to exchange rate changes in order to insulate their effects on inflation and on economic growth. In this type of monetary policy, a monetary response to the exchange rate is merely a means to achieving standard price and output objectives. Such a policy differs fundamentally from a policy of exchange rate management (sometimes pejoratively referred to as exchange rate manipulation) where the exchange rate is itself an objective.[1] This paper provides a framework for distinguishing between the two types of monetary policies. The key elements of the framework are: the use of a simple, forward-looking model of a small open economy that includes an explicit open-economy monetary policy rule; and, the use of a data rich estimation approach that can encompass the full model. To our knowledge, this paper is the first to extend the data-rich approach to the analysis of monetary policy in an open economy framework. In addition to clarifying the role of the exchange rate, the approach has the added benefit of enabling one to more accurately assess the extent of inflation targeting.

We show how this framework can be used by applying it to the case of Korea. Korea is a relatively small, open economy, whose exchange rate policies have been a subject of some controversy. While the Bank of Korea officially has targeted inflation since April 1, 1998, several authors have characterized Korea's *de facto* monetary policy differently. For example, Ilzetzki, Reinhart, and Rogoff (2008) classify Korea as having a crawling band or managed float; and Levy-Yeyati and Sturzenegger (2005) classify Korea as having a fixed exchange rate from 1999 until their data end in 2004. In addition, Eichengreen (2004) suggests that the exchange rate plays an important role in Korean monetary policy;[2] and various U.S. officials, including members of Congress, have criticized Korea for its exchange rate policies.[3] The approach of the paper allows us to sort out empirically the question of whether Korea has targeted inflation or managed its exchange rate.

By using a data-rich approach to estimate a full model, as we do here, we can interpret the Bank of Korea's responses to exchange rate changes in terms of its overall monetary objectives. Before estimating the entire model, however, we begin by providing a standard single-equation estimate of the monetary policy rule. The single-equation estimate, by itself, indicates that there has been a heavy weight

1 Engel (2009) provides a clear theoretical argument for including an exchange rate objective in a model of optimal monetary policy. What he shows is that an exchange rate objective can become optimal once a model permits law of one price deviations. Other rationales sometimes given for a *de facto* policy of exchange rate management include concerns about the relative condition of the economy's traded sector, related concerns about export-led growth, and concerns about financial stability.

2 Eichengreen is careful to point out that his results do not distinguish between the indirect and independent roles that the exchange rate may play in Korean monetary policy; however, he does suggest that its role does not merely reflect its usefulness in, say, forecasting inflation.

3 U.S. Senator Lieberman, for example, re-introduced the "Fair Currency Enforcement Act" in 2005 to require the U.S. government to act against South Korea and other countries that are "engaged most egregiously in currency manipulation."

on the exchange rate during the inflation-targeting period. However, the single-equation estimate conflates what may be simply an indirect exchange rate role with what may be exchange rate management. In contrast, the data-rich estimate of the full model disentangles the two possibilities. Estimating the complete model, we see clearly that the Bank of Korea's apparent response to the exchange rate was in service to its inflation and output objectives. It was not a reflection of the importance of the exchange rate *per se*. That is, the full-model estimates indicate that the Bank of Korea's monetary policy has not been directed at exchange rate management.

The paper builds on the work of Calvo and Reinhart (2002), Reinhart and Rogoff (2004), Shambaugh (2004), Levy-Yeyati and Sturzenegger (2005), Ilzetzki, Reinhart, and Rogoff (2008), and others who provide measures of countries' *de facto* exchange rate arrangements; and it closely follows the work of Lubik and Schorfheide (2007), who examine the importance of the exchange rate using a small, forward-looking open economy model. Like these papers, ours is concerned with discerning a country's *de facto* exchange rate management. What we do differently from the first five papers is that we asses the exchange rate arrangement in the context of monetary policy itself.[4] The extent of exchange rate management is reflected in the role of the exchange rate in the monetary authority's policy rule.[5] This is also the method used by Lubik and Schorfheide. Our work builds on theirs by using a data-rich estimation approach. The data-rich approach is particularly useful for the forward-looking model that we use here. Forward-looking models are intended to capture the notion that agents condition on the information available to them when making choices; the data rich approach enables the econometrician to correspondingly condition on much of the relevant variation in the large information set that is available.

We rely on the recent work applying data-rich techniques to examine monetary policy in closed economies. Such techniques have helped to address a common criticism of many empirical versions of closed-economy macroeconomic models: that because they include so few variables, they are left with omitted variable bias. The data-rich approach makes it possible to use a great deal of information while retaining a blend of variable parsimony and dynamic generality. Building on the factor-model framework developed by Stock and Watson (1999, 2002), Bernanke and Boivin (2003) illustrate the usefulness of data-rich techniques in estimating a central bank's reaction function. Beyer, Farmer, Henry, and Marcellino (forthcoming) have combined the data-rich approach with generalized method of moments (GMM) estimation to study a system of forward-looking equations describing a closed economy. Bai and Ng (2008) carefully lay out the benefits of the GMM approach in terms of the consistency and distribution of the estimated parameters.

[4] Shambaugh (2004) explicitly considers the link between monetary policy and the exchange rate, but his classification of the exchange rate arrangement depends only on the behavior of the exchange rate.

[5] While our approach has the advantage of a more general treatment of a country's exchange rate arrangement, it offers a complement to the earlier approaches, not a substitute for them. Treating the exchange rate arrangement as part of monetary policy requires estimating countries' policies over a period of time. So, it is a useful framework only for countries with relatively stable exchange rate arrangements, or for those with a small number of regime changes that can be parameterized. The earlier approaches require data only from an individual time period; so, they can yield a useable gauge even when a country's exchange rate arrangements change from year to year.

2. A New Open-Economy Model

This section describes a pared-down model of a small, open economy that relies heavily on Lubik and Schorfheide (2007). Like its predecessors, the model has three main parts: a new-Keynesian Phillips curve, an Euler equation-based expectational IS curve, and a monetary policy rule. While our focus will be on the monetary policy rule, we illustrate below that it is important to embed the monetary policy rule in the full model of the economy.

The first piece of the model relies on Galí and Gertler's (1999) forward-looking Phillips curve equation, which they derived from the optimal behavior of suppliers in a model with Calvo pricing. Our open-economy version of the equation links inflation, π_t, to expectations about future inflation, $E[\pi_{t+1}|\Omega_t]$, to the economy's output gap, x_t, and to a real depreciation of the home currency, which, following Lubik and Schorfheide (2007), is modeled as being akin to an unfavorable supply disturbance. We focus on the output gap rather than a marginal cost measure primarily to facilitate a comparison with related work. In doing so, we rely on Galí and Gertler, who argue that these two measures are proportional in a setting with asynchronous pricing.[6] Specifically, the open-economy Phillips curve links inflation to its expected value, to the output gap, to a contemporaneous supply disturbance, s_t, and to the lagged real exchange rate depreciation, Δq_{t-1}, as follows:

$$\pi_t = \gamma_0 + \gamma_{E\pi} E[\pi_{t+1}|\Omega_t] + \gamma_\pi \pi_{t-1} + \gamma_x x_t + \gamma_q \Delta q_{t-1} + s_t \tag{1}$$

The supply disturbance and real exchange rate depreciation, are themselves described by first order autoregressive processes:

$$s_t = \rho_s s_{t-1} + \upsilon_{s,t} \tag{2}$$

$$\Delta q_t = \rho_q \Delta q_{t-1} + \upsilon_{q,t} \tag{3}$$

where $\upsilon_{s,t}$ and $\upsilon_{q,t}$ are taken to be stationary, mean-zero, i.i.d. innovations.

The second piece of the model is the forward-looking, open-economy version of an IS-like curve. Like the standard, closed-economy version generalized from a representative consumer's Euler equation, this one links the output gap both to its past and to expectations about its future, to the real interest rate,

6 See especially pages 200-201. Numerous other studies have used unemployment measures.

$i_t - E[\pi_{t+1}|\Omega_t]$, and to a contemporaneous demand disturbance, d_t.[7] In the open-economy version, the change in the real exchange rate and the foreign output gap, x^f, also play a role, as follows:

$$x_t = \beta_0 + \beta_{Ex}E[x_{t+1}|\Omega_t] + \beta_i(i_t - E[\pi_{t+1}|\Omega_t]) + \beta_x x_{t-1} + \beta_q \Delta q_t + \beta_{x^f} x_t^f + d_t \tag{4}$$

Here, the demand disturbance is assumed to be stationary, mean-zero i.i.d.; and the foreign output gap is modeled as a stationary, AR(1) process:

$$x_t^f = \rho_{x^f} x_{t-1}^f + \upsilon_{x^f,t} \tag{5}$$

where $\upsilon_{y^f,t}$ is a stationary, mean-zero i.i.d. innovation.

Next, we note that real exchange rate depreciation reflects both nominal exchange rate depreciation, Δe_t, and the domestic and foreign inflation difference, $(\pi_t - \pi_t^f)$.

$$\Delta q_t = \Delta e_t - (\pi_t - \pi_t^f) \tag{6}$$

Note that this equation merely defines Δq_t; it does not constrain it. That is, we do not impose purchasing power parity here, either in its absolute or relative form.

Foreign inflation, like foreign output, is modeled as a stationary, AR(1) process.

$$\pi_t^f = \rho_{\pi^f} \pi_{t-1}^f + \upsilon_{\pi^f,t} \tag{7}$$

Finally, we include a monetary policy rule.[8] Here, we adapt Clarida, Galí, and Gertler's (2000) interest rate rule to allow the central bank to target the expected change in the exchange rate. In their baseline rule, Clarida, Galí, and Gertler include the contemporaneous output gap and the expected difference between inflation and its target. While there are as yet few theoretical inroads to support the additional inclusion of an exchange rate term in the monetary authority's objective function (Engel, 2009, is a notable and recent

[7] Our use of both lagged and expected output follows the hybrid approach of Fuhrer and Rudebusch (2002).

[8] In some countries, the Ministry of Finance influences the monetary authority and is officially responsible for exchange rate policy. However, in this paper, we attribute the policy decisions to the monetary authority. We believe this is appropriate for two, related reasons. First, sustained exchange rate policies require the cooperation of the monetary authority. Second, we are interested in the monetary policy that goes into effect, regardless who might influence it.

exception), we believe it is empirically important to allow for an exchange rate role.[9] Thus, the interest rate rule becomes:

$$i_t^* = \bar{i} + \alpha_x\left(x_t - x_t^*\right) + \alpha_\pi\left(E\left[\pi_{t+1}\middle|\Omega_t\right] - \pi_t^*\right) + \alpha_e\left(E\left[\Delta e_{t+1}\middle|\Omega_t\right] - \Delta e_t^*\right) \tag{8}$$

where asterisks represent the targeted values; and, $\bar{i}$ is a benchmark interest rate. This specification allows the exchange rate to matter for its own sake: if monetary policy is used to manage the behavior of the nominal exchange rate *per se*, then α_e is nonzero.[10] Noting the controversy over whether a monetary authority should respond to contemporaneous variables or to forecast variables, the estimation section also includes a specification that allows the authority to respond to the contemporaneous exchange rate change, instead of its expected value.

Like Clarida, Galí and Gertler, we also allow for partial adjustment of the interest rate to the target. Empirically, we allow for two periods of adjustment, rather than just one, to accommodate the gradual adjustment of the Korean call money rate described by Kim and Park (2006).

$$i_t = \left(1 - \rho_1 - \rho_2\right) i_t^* + \rho_1 i_{t-1} + \rho_2 i_{t-2} + \varepsilon_t \tag{9}$$

Here, ε_t represents the unsystematic component of monetary policy, and it is assumed to be normally distributed with mean zero and unit variance.

Substituting the interest rate target into the partial adjustment equation gives:

$$i_t = \tilde{\alpha}_0 + \tilde{\alpha}_x x_t + \tilde{\alpha}_\pi E\left[\pi_{t+1}\middle|\Omega_t\right] + \tilde{\alpha}_e E\left[\Delta e_{t+1}\middle|\Omega_t\right] + \varepsilon_t \tag{10}$$

where we let x^* and Δe^* be constants; and, $\tilde{\alpha}_0 = \left(1 - \rho_1 - \rho_2\right)\bar{i} - \alpha_x x^* - \alpha_\pi \pi^* - \alpha_e \Delta e^*$, $\tilde{\alpha}_x = \left(1 - \rho_1 - \rho_2\right)\alpha_x$, $\tilde{\alpha}_\pi = \left(1 - \rho_1 - \rho_2\right)\alpha_\pi$, and $\tilde{\alpha}_e = \left(1 - \rho_1 - \rho_2\right)\alpha_e$.

9 Theoretical findings rejecting the importance of the exchange rate have relied on the assumption of purchasing power parity. That assumption, which is empirically unsupported, leaves no room for the exchange rate: because the assumption implies that the nominal exchange rate and prices cannot move independently, any change in the exchange rate can be expressed equivalently through a change in the inflation rate. (See Engel, 2009.)

10 Note that this specification captures the role of nonsterilized intervention: since nonsterilized intervention does not provide an independent avenue for the implementation of monetary policy, it involves concomitant interest rate changes, which are observed here. Sterilized intervention, however, is not captured here: given sufficient financial barriers, sterilized intervention could potentially be used to implement exchange rate policies that are divorced in the short run from the domestic interest rate. We set aside this potential issue by relying on the extensive literature indicating that sterilized intervention is only effective in the very short run.

Notice that the exchange rate coefficient in Equation 10 involves only the monetary policy parameter α_e. If we were to combine the equations of the model into a reduced form version of equation 10, then the exchange rate coefficient would involve all of the policy parameters, α_e, α_x, and α_π. The extra terms in the reduced form coefficient come from two sources. First, the real exchange rate change enters the Phillips curve expression for inflation, and inflation enters the policy rule. Second, the real exchange rate change enters the Euler equation describing output, and output enters the policy rule. That is, because the real exchange rate influences inflation and output, the nominal exchange rate would appear in a reduced form interest rate equation *even if the exchange rate itself is not an object of policy*. As we discuss below in the context of the model's estimation, it is important to keep this observation in mind when interpreting the coefficients on single-equation estimates of monetary policy rules.

3. Estimation

In this section, we present estimates from four alternative approaches. We first use standard GMM to estimate the forward-looking Phillips curve, Euler equation, and policy reaction function described by equation 1, 4, and 10. We estimate these equations both singly and as a system; these initial, standard GMM estimates are useful in comparing our findings to those of existing studies. Next, we follow Bernanke and Boivin (2003) in augmenting the GMM estimation with a data-rich approach. Bernanke and Boivin emphasize the importance of the data-rich approach in estimating a forward-looking policy rule. They note that such a modeling approach captures the fact that the monetary authority conditions on a great deal of information in constructing its forecasts. (Bernanke and Boivin, in turn, build on the macroeconomic forecasting work of Stock and Watson, 1999 and 2002.) Bernanke and Boivin focus their attention on the United States in a closed economy framework, but their insights are equally applicable to estimates of a policy reaction function in an open economy. The same insight is also important in the estimation of the model's other equations, given that they too involve agents' expectations. So, we use the data-rich approach both to estimate the equations singly and as a system.

In all of the estimates described below, we use Korean data from January, 1999 to April, 2008. This period encompasses most of the Bank of Korea's experience with its stated policy of inflation targeting. During that time, the annual inflation target, π_t^* moved from 3.0 percent for overall CPI in 1999, to 2.5 percent for core inflation (CPI less petroleum and agricultural products) in 2000, to 3.0 percent for the core afterwards. We use those official year-ahead targets and corresponding year-ahead inflation rates in the estimation. The overnight call-money rate is used as the interest rate.[11] For the output gap, we first detrend industrial production using a Hodrick-Prescott filter. However, we also report estimates using the Baxter-King filter. The nominal exchange rate is measured bilaterally against the dollar, and for the

[11] The overnight call money rate has been used as the monetary policy operating target since 1999. See Bank of Korea (2008).

foreign variables, we use U.S. data.[12] In all of the estimates, the expected values of future variables are instrumented, either through standard GMM or through factor instrumental variables.

3.1 Standard GMM

We begin with a standard, single-equation GMM estimates. We use as instruments: a constant and lagged values of the interest rate, inflation, and the output gap; and we adjust for heteroskedasticity and serial correlation.[13] The results of this estimation are given in the first column of Table 1.[14] The first panel gives the estimates of equation 1, the forward-looking Phillips curve. We find strongly significant coefficients on both expected inflation and lagged inflation, as well as on the output gap, while the real exchange rate is only mildly significant.[15] The second panel gives the Euler equation estimate. There, we find that both expected and lagged output are strongly significant. While the significance of expected output contrasts with the findings of Fuhrer and Rudebusch (2002), it is predicted by Euler equation for consumption. We also find that the lagged change in the real exchange rate appears to be important as well.

The third panel gives the equation that interests us most: the interest rate equation. Broadly speaking, the estimates of this single-equation are similar to those of Eichengreen (2004), who estimates a Korean policy reaction function for the early part of the period, ending in May, 2003. There is evidence of substantial smoothing; and, the estimated inflation, output gap, and expected exchange rate depreciation coefficients are all positive, as might be expected. The estimated coefficients on the output gap and on the exchange rate are both significantly different from zero. In contrast, the estimated coefficient on the inflation rate is small and is not significantly different from zero. If interpreted as a monetary policy rule, rather than as a reduced form, the estimated exchange rate coefficient would suggest that the interest rate target would be lowered in response to an expected currency appreciation. In contrast, the inflation coefficient estimates would seem to suggest that there is little, if any, response to expected inflation. Such an interpretation would be strongly at odds with a presumption of inflation targeting.

The second column gives the standard GMM estimates of the full system. The Phillips curve estimates are largely unchanged, as are most -- but not all -- of the Euler equation estimates. The exception is the

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12 As noted by Eichengreen (2004), both McKinnon and Schnable (2003) and Oh (2004) show that the won is more closely linked to the U.S. dollar than to other currencies.

13 We use the first through sixth lags, along with the ninth and twelfth lags, as is used in so many other studies. We note that correcting for serial correlation is particularly important here since there are overlapping observations of forward-looking expectations.

14 The J test (not reported) of the joint hypothesis of correct model specification and valid instruments is not significant for any of the estimated single equations.

15 The negative coefficient on the output gap is in keeping with many earlier results. Galí and Gertler (1999) attribute this surprising finding primarily to the fact that movements in output tend to lead the changes in marginal costs that underlie the theoretical relationship (page 204).

coefficient on the real interest rate, which has moved from positive and insignificant to negative (as predicted by theory) and mildly significant. We see a few changes in the interest rate equation. First, the estimated coefficient on output is somewhat larger than the single equation estimate, but it is less significant. Second, while the estimated coefficient on inflation has changed sign, it remains very small in absolute value. Finally, the exchange rte coefficient is even larger and is still highly significant.[16]

3.2 Factor Instrumental Variables

As discussed above, the expectations of agents, including the central bank, are formed using a multitude of economic indicators. In standard GMM estimation, it would be impossible to condition on all the information available, even if the information were observable by the econometrician. Standard GMM estimates using a large number of instruments are known to be biased, and they can be inconsistent as well. To incorporate more information than is used in the GMM estimate, we rely on the results of Bai and Ng (2008). Bai and Ng combine GMM with the data-rich approach in their "factor instrumental variables estimator." This estimator has two important properties. First, it is consistent even when the number of instruments exceeds the sample size. Second, it is consistent even when the instruments themselves are invalid, as long as the unobserved factors driving the economy are valid instruments. These two properties mean that we can condition on the informational content of a very large number of variables.

To construct the Bai and Ng estimator, we use 151 monthly, Korean economic series. The list includes a diverse set of variables, representing all of the categories that Stock and Watson (2002) used to forecast U.S. macroeconomic variables.[17] For the foreign variables, we use all of the series in DataStream's "key indicators" grouping that are available on a monthly basis for the United States; this leaves us with 59 U.S. variables. We then transform all of the domestic and foreign series to induce stationarity. The appendix lists the variables and the transformations that were used.[18] Next, we calculate the principal components of the entire set of variables to use as instruments. We use sixteen domestic and sixteen foreign factors, along with six lags of the interest rate.[19]

The single-equation, factor-instrumental variables estimates are given in the third column of Table 1.[20] The Phillips curve again is given in the top panel of the table. We now find a larger, and more precisely

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16 We also note that -- in this one instance -- the J test rejects the joint hypothesis of correct model specification and valid instruments. This rejection is not found in any of the subsequent estimations, which use factor instrumental variables.

17 Stock and Watson (2002) use 215 series in their forecasting exercise. Bernanke, Boivin, and Eliasz (2005) use a subset of that -- a balanced panel of 120 variables. Our set of 151 variables also comprise a balanced panel, though -- as Stock and Watson (2002) point out -- a balanced panel is not necessary.

18 The transformations largely follow Stock and Watson (2002), except for prices and money, which were first differenced (as in Bernanke, Boivin, and Eliasz, 2005), not twice differenced.

19 The Bai and Ng (2002) criteria suggest that at least thirteen factors are needed to capture the variation in the series used here for each country.

20 In this and all of the remaining estimations the J test does not reject the joint hypothesis of correct model specification and valid instruments.

estimated coefficient on expected inflation than on lagged inflation. This result echoes that of Beyer, Farmer, Henry, and Marcellino (forthcoming) in their study using a closed-economy model of U.S. data. Like them, we also find (as before) a negative coefficient on the output gap. Given the myriad of differences between the U.S. and Korean economies, the point estimates are remarkably close. In their single equation estimates, Beyer, Farmer, Henry, and Marcellino report U.S. coefficients of 0.78 on expected inflation, 0.23 on lagged inflation, and -0.07 on the output gap, compared with our corresponding point estimates of 0.58, 0.26, and -0.01.

The data-rich estimates of the single-equation version of the open-economy Euler condition are given in the second panel. The point estimates are all of the expected sign: all of the estimated coefficients on output (lagged, expected, and foreign) and the exchange rate are positive; and the estimated coefficient on the interest rate is negative. In addition, the output coefficients are all statistically significant, including foreign output. This latter finding is consistent with Lubik and Schorfheide's (2007) finding for Canada, where foreign output also seems to be important in the Euler equation specification.

The interest rate equation is given in the bottom panel. The estimated coefficient on output is slightly larger, but less statistically significant. As before, the coefficient on the exchange rate is positive and statistically significant, though somewhat less so. The estimated coefficient on the inflation rate remains less than one and is again insignificant. If we were viewing this reduced form estimate of the interest rate equation as being indicative of the Bank of Korea's policy objectives, we still might be misled into thinking that their inflation objectives were trumped by exchange rate objectives. As we shall see, the multiple equation, factor-instrumental variable estimation that follows strongly contradicts this interpretation.

Using the full model is important because it allows us to address head-on the obvious potential for simultaneity bias in the single equation GMM estimates. It is only here that we are able to clearly interpret the estimates in terms of the underlying parameters. Specifically, only when we estimate the interest rate rule in the context of the full system, are we able to discern whether or not the exchange rate is a distinct objective of policy. The system estimation also provides a clearer interpretation of the coefficient on inflation in the interest rate equation. To estimate the complete model, we again use the Bai and Ng factor instrumental variables approach. Using the same instruments, we now estimate the equations simultaneously. The resulting system estimates are given in the final column.

The top panel gives the new estimate of the Phillips curve. Our system results are similar to the other Phillips curve estimates in many respects. As before, both recent inflation and expectations of future inflation are important determinants of current inflation. The point estimates of the coefficients on recent and forecast inflation are statistically significant, and the point estimates of the coefficient on forecast inflation is somewhat greater than that on lagged inflation. The estimated coefficient on the output gap is again negative and significant. The exchange rate again matters little.

The next panel gives the Euler equation. By and large, the system estimation has little impact on the coefficient estimates, except past output gets a larger weight relative to expected output. All of the output variables, including foreign output, are again positive and statistically significant, while the estimated coefficients on the interest rate remains statistically insignificant, though the exchange rate becomes mildly significant. Overall, the use of the full system does not appreciably affect our understanding of the workings of either the Phillips curve or the Euler equation, except for the somewhat higher weight on past output.

Striking differences do arise, however, in the third panel, which gives the estimates of the monetary policy rule. Here, the estimated coefficient on the exchange rate shrinks and loses its statistical significance entirely. At the same time, the estimated coefficients on the output gap and on inflation rise. Both are significant at the one percent level; and the inflation coefficient is large. Most importantly, the inflation estimate exceeds one, which suggests that the Bank of Korea does not accommodate inflation.

Two robustness checks are provided in the next table. Here, we first re-estimate the system using the contemporaneous exchange rate change in lieu of the expected change in the policy equation. Then, we re-estimate the system replacing the Hodrick-Prescott filter with the Baxter-King approach. As shown in the first column, using the contemporaneous exchange rate has little effect on the estimates except that the inflation coefficient becomes somewhat larger. As shown in the second column, the change in the detrending method also has little impact on the results, with the only notable change involving the domestic output variables in the Euler equation. There, point estimate on lagged output falls somewhat; and the estimate on expected output becomes somewhat less statistically significant.

Overall, we again find that the estimate of α_π, the response to inflation, exceeds one; and the estimate of α_e, the response to the exchange rate change, is essentially zero. Together, these findings reinforce our earlier conclusion that Korea's inflation targeting has not taken a back seat to exchange rate management. While the estimates of α_x, the response to the output gap, also remain positive and significant, Korea's *de facto* policy nevertheless is largely in keeping with it's official one: inflation targeting.

4. Conclusions

This paper combines a small, open-economy model with a data-rich estimation technique to study the exchange rate's role in monetary policy. The combination enables us to infer the underlying exchange rate policy of a country's monetary authority. We apply the approach to the question of whether Korea's recent *de facto* monetary policy has been the same as its *de jure* policy of inflation targeting, or whether it has been one of exchange rate management. Single equation estimates are unable to answer this question because they conflate the two ways that the exchange rate can influence monetary policy. Policy can respond to the exchange rate because of the exchange rate's influence on output or inflation; or it can respond to the exchange rate because the exchange rate, itself, is an objective of policy. By ignoring the indirect role, single-equation estimates are left with omitted variable bias. In contrast, our data-rich, system equation estimates are designed to address both this particular omitted variable bias and the omitted variable bias that arises from a lack of conditioning on available information. Using a data-rich, system approach, we are able to discern that, in Korea, the exchange rate influences monetary policy only indirectly, through its effect on output and inflation. Korea appears very much to be following its *de jure* policy of inflation targeting.

The framework of this paper can be applied to a broad range of industrialized and emerging economies, especially small, open economies, for a variety of purposes. It can be used to improve our understanding of other indicators of *de facto* exchange rate arrangements. It also can provide a clearer insight into a small, open economy's use of inflation targeting. In addition, it may be able to help provide a sense of how monetary policies change in the face of institutional developments. For example, it could be used to gauge the extent of exchange rate management undertaken by EU periphery countries in advance of possible EU membership. We regard both pillars of this approach, i.e., considering the monetary policy reaction function in the context of a system, and using a data-rich approach, as steps forward in exploring the monetary policies of small, open-economies.

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Table 1. Model Estimation

		Standard GMM		Data-Rich GMM	
		Single Equation	System	Single Equation	System
Equation	Variable	(1)	(2)	(3)	(4)
π_t	$E[\pi_{t+1}\|\Omega_t]$	0.4818***	0.5726***	0.5780***	0.6275***
		(0.1019)	(0.0343)	(0.1071)	(0.0657)
	π_{t-1}	0.4815***	0.5373***	0.2595*	0.4544***
		(0.1125)	(0.0321)	(0.1277)	(0.0806)
	x_t	-0.0069***	-0.0074***	-0.0069***	-0.0042***
		(0.0017)	(0.0011)	(0.0018)	(0.0013)
	Δq_{t-1}	0.0072*	-0.0026	0.0071	0.0032
		(0.0043)	(0.0038)	(0.0046)	(0.0030)
x_t	x^e_{t+1}	0.5729***	0.5565***	0.4315***	0.1882**
		(0.1076)	(0.1106)	(0.0683)	(0.0863)
	$i_t - E[\pi_{t+1}\|\Omega_t]$	0.9256	-1.3873*	-0.3649	0.2427
		(0.9242)	(0.8083)	(0.6876)	(0.4117)
	x_{t-1}	0.4822***	0.4680***	0.5574***	0.9602***
		(0.1578)	(0.1103)	(0.0949)	(0.0773)
	Δq_t	0.9027***	0.7150**	0.2597	-0.3514*
		(0.2353)	(0.2988)	(0.1890)	(0.2078)
	x^f_t	0.0087	0.0097***	0.0087**	0.0200***
		(0.0057)	(0.0035)	(0.0038)	(0.0034)
i_t	$x_t - x^*$	0.0284***	0.0475**	0.0587*	0.0936***
		(0.0066)	(0.0225)	(0.0339)	(0.0329)
	$E[\pi_{t+1}\|\Omega_t] - \pi^*$	0.1258	-0.0118	0.4003	2.1037***
		(0.5168)	(0.5884)	(0.9064)	(0.7797)
	$E[\Delta e_{t+1}\|\Omega_t] - \Delta e^*$	0.0863***	0.1087***	0.0591**	0.0196
		(0.0213)	(0.0260)	(0.0286)	(0.0244)
	i_{t-1}	1.2279***	1.2267***	1.3416***	1.2491***
		(0.0427)	(0.1172)	(0.0459)	(0.0915)
	i_{t-2}	-0.3578***	-0.3731***	-0.4411***	-0.3727***
		(0.0356)	(0.1011)	(0.0347)	(0.0810)

Notes: All variables are observed monthly from January 1999 through April 2008 and are transformed following the procedures in Stock and Watson (2002) except as noted in the text. HAC standard errors allowing for the MA(12) error structure of the model are reported in parenthesis beneath the estimates. The standard GMM instrument set includes lags 1-6, 9 and 12 of the Korean overnight call money rate (monthly average), industrial production and the inflation rate. The Data-rich instrument set includes the first six lags of the Korean call money rate as well as lags 1-6, 9 and 12 of the first two principal components obtained from the 151 variable Korean economic indicators data set, and the 59 variables data set of U.S. economic indicators. Only in column 2 is the J statistic large enough to reject at any standard confidence level; there, the statistic, which is $\chi^2(58)$, equals 89.3 and is significant at the one percent level. Asterisks denote significance at the ten (*), five (**), and one (***) percent levels.

Table 2. Robustness Tests

		Data-Rich System GMM	
		Contemporaneous Exchange Rate	Baxter-King Detrending
Equation	Variable	(1)	(2)
π_t	$E[\pi_{t+1}\|\Omega_t]$	0.6488***	0.6425***
		(0.0685)	(0.0626)
	π_{t-1}	0.4163***	0.4191***
		(0.0838)	(0.0761)
	x_t	-0.0044***	-0.0090***
		(0.0014)	(0.0018)
	Δq_{t-1}	0.0027	0.0006
		(0.0032)	(0.0030)
x_t	x^e_{t+1}	0.2263***	0.2192**
		(0.0850)	(0.1090)
	$i_t - E[\pi_{t+1}\|\Omega_t]$	0.2786	0.2867
		(0.4108)	(0.3587)
	x_{t-1}	0.9396***	0.7787***
		(0.0767)	(0.0982)
	Δq_t	-0.3225	-0.2704
		(0.2006)	(0.1970)
	x^f_t	0.0186***	0.0189***
		(0.0033)	(0.0032)
i_t	$x_t - x^*$	0.1119***	0.0975***
		(0.0296)	(0.0317)
	$E[\pi_{t+1}\|\Omega_t] - \pi^*$	2.5727***	2.2061***
		(0.6082)	(0.7471)
	$\Delta e_t - \Delta e^*$	0.0255	–
		(0.0174)	–
	$E[\Delta e_{t+1}\|\Omega_t] - \Delta e^*$	–	0.0272
		–	(0.0214)
	i_{t-1}	1.2397***	1.2623***
		(0.0917)	(0.0932)
	i_{t-2}	-0.3653***	-0.3941***
		(0.0830)	(0.0824)

Notes: The J-statistics are $\chi^2(76)$ and equal to 88.1 in column 1 and 87.3 in column 2; neither is significant at any standard confidence levels. For other notes, see Table 1.

Appendix. Data Description

The data, their sources, and their transformations (None, Log, First Difference, First Difference of Logs) are listed below. All of the data are monthly, from 1999:01 to 2008:04.

Korean Variables

Sources:
NSO: Korean National Statistical Office
MOL: Ministry of Land, Transport and Maritime Affairs
KCS: Korea Customs Service
KE: Korea Exchange
BOK: Bank of Korea
IFS: International Monetary Fund

Manufacturing

Industrial Production Index (IPI), NSO, Log Diff
IPI: Mining and Quarrying (MQ), NSO, Log Diff
IPI: Manufacturing, NSO, Log Diff
IPI: Mfg: Intermediate Goods, NSO, Log Diff
IPI: Mfg: Consumer Goods: NSO, Log Diff
IPI: Mfg: Consumer Goods: Durable, NSO, Log Diff
IPI: Mfg: Consumer Goods: Non-durable, NSO, Log Diff
Manufacturing Production Capacity Index (MPCI), NSO, Log Diff

Employment

Agriculture, Forestry and Fishery (AF), NSO, Log Diff
AF: Agriculture and Forestry, NSO, Log Diff
AF: Fishing, NSO, Log Diff
Mining and Manufacturing (MM), NSO, Log Diff
MM: Mining, NSO, Log Diff
MM: Manufacturing, NSO, Log Diff
Social Overhead Capital and Other Services (SO), NSO, Log Diff
SO: Construction, NSO, Log Diff
SO: Wholesale, Retail Trade, Restaurants and Hotels (WR), NSO, Log Diff
SO: WR: Wholesale, Retail Trade, NSO, Log Diff
SO: WR: Hotels and Restaurants, NSO, Log Diff
SO: Electricity, Transport, Storage and Finance (ET), NSO, Log Diff

SO: ET: Electricity, Gas and Water Supply, NSO, Log Diff
SO: ET: Transport, NSO, Log Diff
SO: ET: Post and Telecommunications, NSO, Log Diff
SO: ET: Financial Institutions and Insurance, NSO, Log Diff
SO: Business, Personal and Public Services (BP), NSO, Log Diff
SO: BP: Real Estate and Renting and Leasing, NSO, Log Diff
SO: BP: Business Activities, NSO, Log Diff
SO: BP: Public Adm and Defense, Compulsory Social Security, NSO, Log Diff
SO: BP: Education, NSO, Log Diff
SO: BP: Health and Social Work, NSO, Log Diff
SO: BP: Recreational, Cultural and Sporting Activities, NSO, Log Diff
SO: BP:Other Community,Repair and Personal ServiceActivities, NSO, Log Diff
SO: BP: Private Households with Employed Persons, NSO, Log Diff
SO: BP: Extra Territorial Organizations and Bodies, NSO, Log Diff
Employment, NSO, Log Diff
Unemployment Rate, NSO, Log
Unemployment Rate: Age 15 to 19, NSO, Log
Unemployment Rate: Age 20 to 24, NSO, Log
Unemployment Rate: Age 25 to 29, NSO, Log
Unemployment Rate: Age 30 to 34, NSO, Log
Unemployment Rate: Age 35 to 39, NSO, Log
Unemployment Rate: Age 40 to 44, NSO, Log
Unemployment Rate: Age 45 to 49, NSO, Log
Unemployment Rate: Age 50 to 54, NSO, Log
Unemployment Rate: Age 55 to 59, NSO, Log
Unemployment Rate: Age 60 and Over, NSO, Log
Monthly Earnings: All Industries, MOL, Log Diff
Labour Force (2 week search), NSO, Log Diff
Avg Monthly Man Days: Total, MOL, Log
Avg Monthly Man Days: Manufacturing, MOL, Log
Avg Monthly Hours Worked: Overtime: All Industries, MOL, Log
Avg Monthly Hours Worked: Overtime: Manufacturing, MOL, Log
Bldgs Authorized for Construction: Total, MLT, Log Diff
Bldgs Authorized for Construction: Dwelling, MLT, Log Diff

Miscellaneous

Producers' Inventory Index (PII), NSO, Log
LDCI: Consumer Expectation Index, NSO, Log
Consumer Expectation Index (CEI), NSO, Log

Imports cif, KCS, Log Diff
Exports fob, KCS, Log Diff
Trade Balance, KCS, Log Diff

Equities

Index: KOSPI, KE, Log Diff
Index: KOSPI 200: Composite, KE, Log Diff
Index: KOSPI 200: Manufacture, KE, Log Diff
Index: KOSPI 200: Electricity and Communication, KE, Log Diff
Index: KOSPI 200: Construction, KE, Log Diff
Index: KOSPI 200: Circulative Service, KE, Log Diff
Index: KOSPI 200: Financial Service, KE, Log Diff
Index: KOSPI: Manufacturing Industry Index, KE, Log Diff
Index: KOSPI: Food and Beverages, KE, Log Diff
Index: KOSPI: Textile and Wearing Apparel, KE, Log Diff
Index: KOSPI: Paper and Wood Products, KE, Log Diff
Index: KOSPI: Chemicals, KE, Log Diff
Index: KOSPI: Medical Supplies, KE, Log Diff
Index: KOSPI: Non Metallic Mineral Products, KE, Log Diff
Index: KOSPI: Iron and Metal Products, KE, Log Diff
Index: KOSPI: Machinery, KE, Log Diff
Index: KOSPI: Electrical and Electronic Equipment, KE, Log Diff
Index: KOSPI: Transport Equipment, KE, Log Diff
Index: KOSPI: Distribution Industry, KE, Log Diff
Index: KOSPI: General Construction, KE, Log Diff
Index: KOSPI: Transport and Storage, KE, Log Diff
Index: KOSPI: Financial Institutions, KE, Log Diff
Index: KOSPI: Financial Institutions: Banks, KE, Log Diff
Index: KOSPI: Financial Institutions: Securities, KE, Log Diff
Index: KOSPI: Financial Institutions: Insurance, KE, Log Diff
Dividend Yield: Mth Avg: Weighted: KOSPI: Total, KE, Log
PE Ratio: KOSPI: Mth End: Weighted: Total, KE, Log
PE Ratio: KOSPI: Mth Avg: KOSPI 200, KE, Log

Exchange Rates

Forex: Korean Won To USD, BOK, Log Diff
Forex: Korean Won to Swiss Franc, BOK, Log Diff
Forex: Korean Won to Japanese Yen, BOK, Log Diff
Forex: Korean Won to British Pound, BOK, Log Diff

Forex: Korean Won to Canadian Dollar, BOK, Log Diff

Interest Rates

Discount Rate (End of Period) IFF De-meaned
Money Market Rate, IFS, De-meaned
Corporate Bond Rate, IFS, De-meaned
Time Deposit at DMB: 1 Yr. or More, IFS, De-meaned
Lend Rate on DMB Loans: Minimum, IFS, De-meaned
Yield on Nat'l Housing Bonds, 1, 2, IFS, De-meaned

Money Supply

Reserve Money: Month Avg, BOK, Log Diff
New M1: Month Avg, BOK, Log Diff
New M2: Month Avg, BOK, Log Diff
Liquidity Aggregates of Financial Institutions:Mth Avg, BOK, Log Diff
New M1: Month Avg: sa, BOK, Log Diff
New M2: Month Avg: sa, BOK, Log Diff
Liquidity Aggregates of Financial Inst: Mth Avg: sa, BOK, Log Diff
New M2: Month Avg: Currency in Circulation, BOK, Log Diff
New M2: Month Avg: Demand Deposits, BOK, Log Diff
New M2: Month Avg: Transferable savings Deposit, BOK, Log Diff
New M2: Month Avg: MMF, BOK, Log Diff
New M2: Month Avg: Short Term Time and Savings Deposits, BOK, Log Diff
New M2: Month Avg: Certificate of Deposit, BOK, Log Diff
New M2: Month Avg: Bills Sold, BOK, Log Diff
New M2: Month Avg: CMA, BOK, Log Diff
New M2: Month Avg: Beneficial Certificates (BC), BOK, Log Diff
New M2: Month Avg: Short Term Money in Trust, BOK, Log Diff
New M2: Month Avg: Bills Issued, BOK, Log Diff
New M2: Month Avg: Securities Investment Savings, BOK, Log Diff
New M2: Month Avg: Short Term Foreign Currency Deposit, BOK, Log Diff
New M2: Month Avg: Short Term Financial Debentures, BOK, Log Diff
New M2: Month Avg: Repurchase Agreement, BOK, Log Diff
New M2: Month Avg: Central Bank, BOK, Log Diff
New M2: Month Avg: Other Depository Corporations (OD), BOK, Log Diff
New M2: Month Avg: OD: Commercial and Specialized Banks, BOK, Log Diff
New M2: Month Avg: OD: Merchant Banking Corporations, BOK, Log Diff
New M2: Month Avg: OD: Investment Trust companies, BOK, Log Diff
New M2: Month Avg: OD: Trust Accounts of Banks, BOK, Log Diff

New M2: Month Avg: OD: Mutual Saving Banks, BOK, Log Diff

New M2: Month Avg: OD: Mutual Credits, BOK, Log Diff

New M2: Month Avg: OD: Credit Unions, BOK, Log Diff

New M2: Month Avg: OD: Postal Savings, BOK, Log Diff

New M2: Month Avg: OD: Community Credit Cooperatives, BOK, Log Diff

New M2: Month Avg: OD: The Export-Import Bank of Korea, BOK, Log Diff

Prices

PPI: All Commodities and Services, BOK, Log Diff

PPI: Commodities, BOK, Log Diff

PPI: Commodities: Agricultural, Forestry and Marine Products (AF), BOK, Log Diff

PPI: Commodities: Mining Products (MP), BOK, Log Diff

PPI: Commodities: Manufacturing Industry Products (MI), BOK, Log Diff

PPI: Commodities: Mining Products (MP), BOK, Log Diff

CPI: Overall, NSO, Log Diff

CPI: Food and Non-Alcoholic Beverages (FB), NSO, Log Diff

CPI: Alcoholic Beverages and Cigarettes (BT), NSO, Log Diff

CPI: Clothing and Footwear, NSO, Log Diff

CPI: Housing, Water and Fuels (HW), NSO, Log Diff

CPI: Furnishings and Household Equipment (FH), NSO, Log Diff

CPI: Health, NSO, Log Diff

CPI: Transportation, NSO, Log Diff

CPI: Communication, NSO, Log Diff

CPI: Culture and Recreation, NSO, Log Diff

CPI: Education, NSO, Log Diff

CPI: Miscellaneous Goods and Services, NSO, Log Diff

CPI: Agricultural Products and Oils, NSO, Log Diff

CPI: Core, excl Agricultural Products and Oils, NSO, Log Diff

U.S Variables

Source: Datastream

Average hourly earnings per worker in manufacturing industry, Log Diff

Avg hourly real earnings - private nonfarm industries, Log Diff

Avg hrly earn - total private nonfarm, Log Diff

Avg wkly hours - total private NONFARM, None

Capacity utilization rate - all industry, None

Chain-type price index for pce less food and energy (core), Log Diff

Chain-type price index for personal consumption expenditure, Log Diff

Chicago purchasing manager business barometer (sa), None

Commercial bank assets - commercial and industrial loans, Log Diff

Commercial bank assets - loans and leases in bank credit, Log Diff

Construction expenditures - total (ar), Log

Consumer confidence index, None

Consumer credit outstanding, Log Diff

CPI - all items less food and energy (core), Log Diff

CPI - all urban sample: all items - annual inflation rate, Log Diff

CPI - all urban: all items, Log Diff

Disposable personal income (monthly series) (ar), Log Diff

Dow jones industrials share price index (ep), Log Diff

Employed - nonfarm industries total (payroll survey), Log Diff

Export price index - all commodities (end use), Log Diff

Exports f.a.s., Log Diff

Federal funds rate (monthly average), Diff

Federal funds target rate (ep), Diff

Federal government budget balance, Diff

Foreign net long term flows in securities, Log Diff

Foreign reserve assets, Log Diff

Import price index - all commodities (end use), Log Diff

Imports f.a.s., Log Diff

Index of help wanted advertising, None

Industrial production - manufacturing (naics), Log Diff

Industrial production - total index, Log Diff

ISM purchasing managers index (mfg survey), None

Monetary base, Log Diff

Money supply M1, Log Diff

Money supply M2 (BCI 106), Log Diff

New passenger cars - total registrations, Log Diff

New private housing units authorized by building permit (ar), Log
New private housing units started (ar), Log
Personal consumption expenditures (monthly series) (ar), Log Diff
Personal income (monthly series) (ar), Log Diff
Personal saving as % of disposable personal income, None
Philadelphia fed outlook survey - diffusion index manufacturing, None
Population (estimates used in national accounts), Log Diff
PPI - Finished goods, Log Diff
PPI - Finished goods less foods and energy (core), Log Diff
Prime rate charged by banks, Diff
Sales of new one family houses (ar), Log
Terms of trade rebased to 1975=100, Log Diff
The conference board leading economic indicators index, None
Total civilian employment, Log Diff
Total treasury securities outstanding (public debt), Log Diff
Trade-weighted value of us dollar against major currencies, Log Diff
Treasury bill rate - 3 month (ep), Diff
Treasury yield adjusted to constant maturity - 20 year, Diff
Unemployed - (16 yrs and over), Log Diff
Unemployment rate, None
University of michigan consumer sentiment index, None
US 3 Month interbank rate (london) (mth.avg.), Diff
Visible trade balance f.a.s.-f.a.s., Diff