

# Evaluating Exchange Rate Management

An Application to Korea\*

David Parsley<sup>†</sup>

Helen Popper<sup>‡</sup>

Vanderbilt University

Santa Clara University

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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.

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<sup>†</sup>Owen Graduate School of Management, Vanderbilt University, dparsley@owen.vanderbilt.edu, 615-322-0649.

<sup>‡</sup>Department of Economics, Santa Clara University, hpopper@scu.edu, 408-554-6952.

# 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.<sup>1</sup> 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, Ilzetzi, 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

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<sup>1</sup>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.

rate plays an important role in Korean monetary policy;<sup>2</sup> and various U.S. officials, including members of Congress, have criticized Korea for its exchange rate policies.<sup>3</sup> 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 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 coun-

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<sup>2</sup>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.

<sup>3</sup>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."

try's *de facto* exchange rate management. What we do differently from the first five papers is that we assess the exchange rate arrangement in the context of monetary policy itself.<sup>4</sup> The extent of exchange rate management is reflected in the role of the exchange rate in the monetary authority's policy rule.<sup>5</sup> 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

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<sup>4</sup>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.

<sup>5</sup>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.

the consistency and distribution of the estimated parameters.

## 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,  $\pi_t$ , 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.<sup>6</sup> 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,  $\Delta q_{t-1}$ , as follows:

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

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

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<sup>6</sup>See especially pages 200-201. Numerous other studies have used unemployment measures.

$$s_t = \rho_s s_{t-1} + v_{s,t} \quad (2)$$

$$\Delta q_t = \rho_q \Delta q_{t-1} + v_{q,t} \quad (3)$$

where  $v_{s,t}$  and  $v_{q,t}$  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,  $i_t - E[\pi_{t+1}|\Omega_t]$ , and to a contemporaneous demand disturbance,  $d_t$ .<sup>7</sup> 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:

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

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:

$$x_t^f = \rho_{x^f} x_{t-1}^f + v_{x^f,t} \quad (5)$$

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

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

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<sup>7</sup>Our use of both lagged and expected output follows the hybrid approach of Fuhrer and Rudebusch (2002).

$$\Delta q_t = \Delta e_t - (\pi_t - \pi_t^f) \quad (6)$$

Note that this equation merely defines  $\Delta q_t$ ; 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.

$$\pi_t^f = \rho_{\pi^f} \pi_{t-1}^f + v_{\pi^f,t}. \quad (7)$$

Finally, we include a monetary policy rule.<sup>8</sup> 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 exception), we believe it is empirically important to allow for an exchange rate role.<sup>9</sup> Thus, the interest rate rule becomes:

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

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 mone-

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<sup>8</sup>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.

<sup>9</sup>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.)

tary policy is used to manage the behavior of the nominal exchange rate *per se*, then  $\alpha_e$  is nonzero.<sup>10</sup> 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).

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

Here,  $\varepsilon_t$  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:

$$i_t = \tilde{\alpha}_0 + \tilde{\alpha}_x x_t + \tilde{\alpha}_\pi E[\pi_{t+1}|\Omega_t] + \tilde{\alpha}_e E[\Delta e_{t+1}|\Omega_t] + \varepsilon_t, \quad (10)$$

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

Notice that the exchange rate coefficient in Equation 10 involves only the monetary policy parameter  $\alpha_e$ . 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,  $\alpha_e$ ,  $\alpha_x$ , and  $\alpha_\pi$ . The extra terms in the reduced

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<sup>10</sup>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.

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,  $\pi_t^*$  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.<sup>11</sup> 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 foreign variables, we use U.S. data.<sup>12</sup> 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.<sup>13</sup> The results of this estimation are given in the first column of Table 1.<sup>14</sup> 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

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

<sup>12</sup>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.

<sup>13</sup>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.

<sup>14</sup>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.

gap, while the real exchange rate is only mildly significant.<sup>15</sup> 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 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,

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<sup>15</sup>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).

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 rate coefficient is even larger and is still highly significant.<sup>16</sup>

### 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.<sup>17</sup> 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

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<sup>16</sup>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.

<sup>17</sup>Stock and Watson (2002) use 215 series in their forecasting exercise. Bernanke, Boivin, and Elias (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.

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.<sup>18</sup> 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.<sup>19</sup>

The single-equation, factor-instrumental variables estimates are given in the third column of Table 1.<sup>20</sup> The Phillips curve again is given in the top panel of the table. We now find a larger, and more precisely 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 .78 on expected inflation, .23 on lagged inflation, and -.07 on the output gap, compared with our corresponding point estimates of .58, .26, and -.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.

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

<sup>19</sup>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.

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

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  $\alpha_\pi$ , the response to inflation, exceeds one; and the estimate of  $\alpha_e$ , 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  $\alpha_x$ , the response to the output gap, also remain positive and significant, Korea's *de facto* policy nevertheless is largely in keeping with its 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.

Table 1: Model Estimation

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

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

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## 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 Service Activities 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 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