Gauging Exchange Rate Targeting

Abstract

In this paper, we examine whether a monetary authority targets the exchange rate, *per se*, or instead simply appears to do so as it responds to the exchange rate and other variables in service to inflation and output targets. We combine data-rich estimation with a system of forward-looking equations in order to disentangle the possibilities. The combined approach reveals the potentially misleading nature of standard estimates of the extent of exchange rate and inflation targeting. We illustrate the approach by applying it to two *de jure* inflation targetters, Canada and Korea. In contrast to standard methods and much past work, we find that neither country targets its exchange rate; and, both are *bona fide* inflation targetters.

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

In an open economy, a monetary authority may respond to exchange rate changes and other related variables in order to insulate their effects on inflation and on economic growth. In this type of monetary policy, a response to the exchange rate is incidental to standard price and output targets. Such a policy differs fundamentally from a policy of exchange rate targeting (sometimes pejoratively referred to as exchange rate manipulation), where the monetary authority responds independently to changes in the exchange rate itself.[1] This paper provides an approach to help distinguish between the two types of policies. Specifically, the

[1] Engel (2009) provides a recent theoretical argument for managing the exchange rate in the presence of observed 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.

paper combines data-rich estimation with a system of forward-looking equations characterizing a small open economy. The combination addresses the simultaneity and informational shortcomings that plague many policy assessments. 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. The paper demonstrates the usefulness of the data-rich approach and clarifies the role of the exchange rate in the monetary policy rule. In doing so, it allows for a more accurate assessment of the extent of exchange rate targeting.

The paper builds on the work of Calvo and Reinhart (2002), Reinhart and Rogoff (2004), Levy-Yeyati and Sturzenegger (2005), Ilzetzki, Reinhart, and Rogoff (2008), and others who provide measures of countries' *de facto* exchange rate arrangements. These papers classify exchange rate arrangements using indicators such as exchange rate variability and monetary aggregates. Like these papers, ours is concerned with discerning a country's *de facto* arrangement.[2] What we do differently from these papers is that we assess the role of the exchange rate in the conduct of monetary policy itself. Once an economy opens its capital markets, exchange rate policy and monetary policy merge.[3] To discern the exchange rate arrangement, one must examine the behavior of monetary policy.[4] Thus, our focus is on the monetary authority's policy rule.

Our emphasis on monetary policy follows Shambaugh (2004), Ball and Reyes (2004, 2008), and Lubik and Schorfheide (2007). These papers all explicitly consider the conduct of monetary policy in their assessments of exchange rate arrangements. However, Shambaugh's classification ultimately depends on the

[2]Frankel, Fajnzylber, Schmukler, and Servén (2001) and Popper, Mandilaras, and Bird (2013) also look at *de facto* arrangements. However, rather than providing measures of exchange rate arrangements, the work of Frankel, Fajnzylber, Schmukler, and Servén is intended to use exchange rate behavior to examine the verifiability of the *de jure* arrangements; while Popper, Mandilaras, and Bird characterize exchange rate arrangements in terms of archetypes within the international macroeconomic trilemma.

[3]Exchange rate controversies often go hand in hand with foreign reserve concerns. Here, we focus on settings with open capital markets where the scope for successful foreign exchange intervention is diminished.

[4]While our approach has the advantage of a more general treatment of a country's exchange rate arrangement, it offers a complement, not a substitute for these earlier approaches that rely on a narrow range of indicators. Classifications that are tied to just a handful of indicators can be used to gauge policy changes as those indicators change. In contrast, our approach relies on estimation, so it requires that policy remain in place long enough to be estimated. The data-rich technique can make the task easier by allowing for estimation using data series of different lengths, but estimation nevertheless requires time.

behavior of the exchange rate exclusively; and Ball and Reyes focus on the monetary rule exclusively. Our work is closest to that of Lubik and Schorfheide, who examine the importance of the exchange rate in monetary policy in the context of a small, forward-looking open economy model; and our work builds on theirs by using data-rich estimation.

Bernanke and Boivin (2003) use the term 'data-rich' to describe an environment where relevant information may be contained in thousands of macroeconomic time-series. Econometrically, the challenge is how best to incorporate the information in such large data sets into empirical macroeconomic models consisting of only a few equations. In an important contribution, Stock and Watson (2002) show rigorously that one can reduce the dimensionality of a very large number of time series (large vis-à-vis the number of observations in time) to improve forecasts. They apply principal component analysis to extract just a few factors that summarize the common co-movements from a large macroeconomic dataset. Their factor-model framework makes it possible for an empirical macroeconomic model to incorporate a great deal of information while retaining a blend of variable parsimony and dynamic generality. Moreover, their approach does not require that one be able to precisely specify the correct macroeconomic model. Instead, it only requires that many of the observed series be linked to a smaller number of underlying variables, which themselves needn't even be observable.[5] More recently, Bai and Ng (2010) carefully demonstrate the superiority of the data-rich approach over standard GMM in terms of the consistency and distribution of the estimated parameters.[6] Bernanke and Boivin's contribution is to illustrate the usefulness of Stock and Watson's factor-model techniques in estimating a central bank's reaction function.

The data-rich approach is conceptually important in the forward-looking model that we use here. Forward-looking agents condition on the information available to them when making choices; and, the data-rich approach enables the econo-

[5]The requirement that the observed series be linked to a smaller number of underlying potentially unobservable variables is arguably met by all standard macroeconomic models.

[6]Among their contributions, Bai and Ng formally address the problem of weak instruments in the context of endogenous variables which have a factor structure. They show that as the number of instruments grows, the factor instrumental variable estimate is consistent and asymptotically normal even if each individual instrument is only weakly correlated with the endogenous explanatory variable. In earlier work (Bai and Ng, 2002), they also address the problem of generated regressors. There, they show that, when the number of instruments exceeds the number of periods, the factors can be treated as known.

metrician to correspondingly condition on much of the relevant variation.[7] As Bernanke and Boivin emphasize, the ability to econometrically capture the information available to forward-looking agents is particularly germane when modeling the actions of a central bank. Central banks are known to carefully track thousands of variables, which they actively acquire from a large variety of sources and observe at differing frequencies. Disregarding key elements of the central bank's information set has led to many empirical problems, including the well-know 'price puzzle.'[8] To the extent that central banks act in response to expectations about the future, failing to condition on the relevant information used by the central bank (for example, commodity price changes) results in misspecification. When the information from too few variables is included, estimates are left with omitted variable bias. While it is impossible to condition on all the series available to the central bank, the factor-model approach of Stock and Watson makes it feasible to condition on a large part of the informational content of the central bank's rich set of data.

We apply the data-rich, forward-looking approach to an open economy by assessing the extent of exchange rate targeting in two countries whose exchange rate policies have been the subject of some controversy. We focus on *de jure* inflation targetters that have been described instead as *de facto* exchange rate targetters. Specifically, we focus on Canada and Korea. The Bank of Canada, an early inflation targetter, officially began in 1991 with a stated policy first to reduce inflation, then to stabilize it. The Bank of Korea officially began targeting inflation in 1998, after its economy was badly battered by the Asian financial crisis. Despite their sustained official policies of inflation targeting, the policies of both countries have at times been characterized quite differently in the economics literature.

For example, Lubik and Schorfheide find that the Bank of Canada targets the exchange rate.[9] Likewise, in a far-reaching *de facto* classification study, Ilzet-

[7]Beyer, Farmer, Henry, and Marcellino (2008) use data-rich estimation to study a system of forward-looking equations describing a closed economy.

[8]The price puzzle refers to the finding in many empirical studies that an unexpected monetary policy tightening seems to be followed by a rise, not a fall, in prices. See Rusnak, Havranek, and Horvath (2013) for a recent summary and meta-analysis of the literature. Notably, they find that misspecification is a key piece of the resolution to the puzzle.

[9]In addition to Canada, Lubik and Schorfeide also examine Australia, New Zealand, and the United Kingdom; but it is their work on Canada that is of particular interest. They, themselves, focus most closely on Canada. Only for Canada do they find a *de facto* policy that diverges from a sustained official policy. In Australia and New Zealand, they find the exchange rate to be irrelevant to monetary policy; and, for the United Kingdom, they find some evidence of an exchange rate

zki, Reinhart and Rogoff (2008) categorize both Canada and Korea as having managed floats or crawling bands. While Levy-Yeyati and Sturzenegger (2005) classify Canada as floating, they classify Korea as having a fixed exchange rate from 1999 until their data end in 2004.[10] Eichengreen (2004) focuses solely on Korea and suggests that the exchange rate is important in Korea's monetary policy rule.[11] Additionally, various U.S. officials, including members of Congress, have criticized Korea for its exchange rate policies.[12] This paper's data-rich, system method provides a useful framework for re-examining the question of how much a country targets its inflation rate – as Canada and Korea each claims to do – and how much it instead targets its exchange rate.

Before using the data-rich, system methods, we first provide preliminary, single-equation estimates of the monetary policy rule of each country. The resulting preliminary estimates replicate the key findings of a number of previous studies. As in many earlier studies, the single-equation estimates obtained here would seem to suggest that each of the two countries has placed a significant weight on the exchange rate, and – relative to a *bona fide* inflation target – an insufficient weight on inflation. Such single-equation estimates, however, conflate evidence of actual exchange rate targeting with what may instead simply be evidence of an indirect exchange rate role. In contrast, the data-rich, system approach disentangles the two possibilities.

In our estimates of the fuller approach, the importance of the exchange rate diminishes, and the coefficients on inflation becomes both meaningfully large (greater than one) and significant. These results suggest that there was no independent role for the exchange rate *per se*, and the earlier apparent responses to the exchange rate occurred in service to inflation targeting in both countries. That is, the data-rich, system estimates indicate that neither the monetary policy of the

response, but that evidence is consistent with its period of semi-official shadowing of the mark and its subsequent (though brief) participation in the Exchange Rate Mechanism.

[10]Ball and Reyes (2008) provides a notable exception, classifying both countries as floaters or inflation targetters in what may be interpreted as the most important of the various classification methods they report.

[11]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 the Bank of Korea's monetary policy; however, he does suggest that its role does not merely reflect its usefulness in, say, forecasting inflation.

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

Bank of Canada nor the monetary policy of the Bank of Korea has been one of exchange rate targeting.

2. Open-Econony Model

We closely follow the small, open economy model of Lubik and Schorfheide (2007).[13] The model has three main parts: a new-Keynesian Phillips curve, an Euler equation-based expectational IS curve, and a monetary policy rule.[14] The Phillips curve is derived from the optimal behavior of suppliers in a model with Calvo pricing. It links inflation in period t, π_t, to expectations about inflation conditional on currently available information, Ω_t; to the economy's output gap, x_t; to the terms of trade, q_t, and to the expected change in the terms of trade , where a decline is akin to an unfavorable supply disturbance.[15] Specifically, the open-economy Phillips curve describes inflation as follows:

$$\pi = \beta E_t[\pi_{t+1}|\Omega_t] + \alpha\beta E_t[\Delta q_{t+1}|\Omega_t] - \alpha\Delta q_t + \frac{\kappa}{\gamma}x_t \tag{1}$$

Here, α is the country's import share, β is the discount factor, κ is a function of price rigidities and labor market elasticities, $\gamma = \tau + \alpha(2-\alpha)(1-\tau)$, and τ is the intertemporal substitution elasticity. Changes in the terms of trade are described by first order autoregressive processes: $\Delta q_t = \rho_q \Delta q_{t-1} + \upsilon_{q,t}$, where $\upsilon_{q,t}$ is a stationary, mean-zero, i.i.d. innovation.[16]

Next is a forward-looking, open-economy equation similar to a traditional IS curve. Like the standard, closed-economy version generalized from a representative consumer's Euler equation, the output gap is linked to expectations about its future, to the expected real interest rate, $r_t = i_t - E[\pi_{t+1}|\Omega_t]$, and to technology, z_t. In this open economy version, output is also linked to the foreign output gap, x^f, and to the expected change in the the terms of trade. Letting $\delta = \alpha(2-\alpha)\frac{1-\tau}{\tau}$, the open-economy IS curve is:

[13] Lubik and Schorfheide in turn rely on Galí and Monacelli (2005).

[14] We focus on estimating the parameters of the monetary policy rule, which – as emphasized by Favero and Rovelli (2003), among others – is a somewhat less ambitious task than untangling the deeper objectives of the monetary authorities.

[15] This work focuses on the output gap rather than a marginal cost measure. This facilitates a comparison with related work, and it ultimately relies on the argument of Galí and Gertler (1999, section 2.1.2), who show that the two measures are proportional in a setting with asynchronous pricing. Numerous other studies have used unemployment measures.

[16] This treatment of the terms of trade follows Lubik and Schorfheide's handling of the computational difficulties arising from determining it endogenously.

$$x_t = E_t[x_{t+1}|\Omega_t] - \gamma r_t - \rho_z z_t - \alpha\gamma E_t[\Delta q_{t+1}|\Omega_t] - \delta E_t[\Delta x^f_{t+1}|\Omega_t], \quad (2)$$

where the technology process is given by $z_t = \rho_z z_{t-1} + \upsilon_{z,t}$, and $\upsilon_{z,t}$ is a stationary, mean-zero i.i.d. innovation.

The definition of the terms of trade gives an expression for the depreciation in the nominal exchange rate, Δe_t, in terms of the domestic and foreign inflation difference, $(\pi_t - \pi^f_t)$.

$$\Delta e_t = (\pi_t - \pi^f_t) - (1-\alpha)\Delta q_t. \quad (3)$$

Finally, we include a monetary policy rule that allows for the possibility that the nominal exchange rate enters the rule.[17] Specifically, the interest rate rule is:

$$i^*_t = \bar{i} + \alpha_x(x_t - x^*_t) + \alpha_\pi(E[\pi_{t+1}|\Omega_t] - \pi^*_t) + \alpha_e(E[\Delta e_{t+1}|\Omega_t] - \Delta e^*_t), \quad (4)$$

where asterisks represent the targeted values; and, $\bar{i}$ is a benchmark interest rate. If monetary policy is used to target the nominal exchange rate *per se*, then α_e is nonzero.[18] Noting the renewed 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.

We also allow for partial adjustment of the interest rate to the target. We include two smoothing terms, rather than just one, to reflect the possibility of a

[17] 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.

[18] Note that this specification captures the role of nonsterilized intervention. Nonsterilized intervention does not provide an independent avenue for the implementation of monetary policy. So, it involves concomitant interest rate changes, which are accounted for in this framework. Sterilized intervention, however, is not captured here: given sufficient financial barriers, sterilized intervention could be used to target the nominal exchange rate in a way that is divorced in the short run from the domestic interest rate. We set aside this potential issue by focusing on situations with some degree of capital market openness and by relying on the extensive literature indicating that sterilized intervention is only effective in the very short run.

particularly gradual adjustment of the interest rate.[19]

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

Here, ε_t represents the unsystematic component of monetary policy, and it is assumed to have a mean of zero.

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

$$i_t = \tilde{\alpha}_0 + \tilde{\alpha}_x x_t + \tilde{\alpha}_\pi E[\pi_{t+1}|\Omega_t] + \tilde{\alpha}_e E[\Delta e_{t+1}|\Omega_t] + \varepsilon_t, \tag{5}$$

where we let x^* and Δe^* 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 5 involves only the parameter α_e, and the smoothing parameters, ρ_1 and ρ_2. In contrast, the exchange rate coefficient in a reduced form, single-equation version of a monetary policy rule would (misleadingly) also involve the other policy parameters, α_x, and α_π. The extra policy parameters would enter a reduced form coefficient through the terms of trade effects in Equations 1 and 2. That is, the terms of trade influences inflation and output. So, *even if the exchange rate itself were absent from the monetary policy rule*, a nonzero coefficient on the nominal exchange rate would appear in a single-equation, reduced form version of the interest rate equation.

That is, while the system estimates account for this simultaneity, single equation estimates do not. Single-equation estimates of the monetary policy rule conflate the direct effect of the exchange rate and the indirect effect of the terms of trade via other macroeconomic variables. In contrast, with sufficient data, system estimates allow the distinct effects to be discerned. In the next section, we estimate the monetary policy rule first by itself then as part of the full model, using both standard and data-rich techniques.

3. Estimation

This section describes the data and presents estimates of the monetary policy rule from a total of six alternative approaches. We initially use standard GMM to estimate the monetary policy rule as a single equation, as part of an unrestricted system, and as part of the system with the model's cross-equation restrictions

[19] Kim and Park (2006) suggest that this form of smoothing is important in the Korean call money rate.

imposed.[20] Then, we repeat the estimation using the data-rich approach. Specifically, we use Bai and Ng's factor-instrumental variables estimator.

3.1. Data

In all of the estimates, we use Canadian or Korean data from January, 1999 to April, 2008. This period begins after the Bank of Canada abandoned its use of a monetary conditions index (a weighted sum of changes in the interest rate and the exchange rate) as an operational guide, and it ends before the rapid move toward the Canadian overnight rate's lower bound. For Korea, the period encompasses much of the central bank's experience with its stated policy of inflation targeting. Over that period, Canada's overall CPI was targeted at two percent; and Korea's annual inflation target 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, and to 3.0 percent for the core afterwards. Correspondingly, we allow the Korean inflation targets to change over the sample period.

The estimates use the Canadian overnight rate and the Korean overnight call-money rate as the nominal interest rates.[21] To construct measures of 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 and terms of trade are measured bilaterally against the dollar, and we use U.S. data to construct the remaining foreign variables.[22] In all of the estimates, the expected values of future variables are instrumented, either through standard GMM or through factor instrumental variables.

For the data-rich estimation, we use a large and diverse set of variables that represents all of the categories that Stock and Watson (2002) used to forecast U.S. macroeconomic variables. The data are taken from DataStream and include thousands of variables for Canada and Korea. An online appendix to an earlier working paper provides a more detailed description of the data source, the selection, and the transformations that were used.

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[20] Our focus here is on the monetary policy rule, but the model's other equations also involve forward-looking agents, so it is important to capture agents' information in estimating those equations as well. So, we also report the estimates for those equations. They are provided in the Appendix Tables A1 and A2.

[21] The Bank of Canada shifted its target to the overnight rate in 1994. In Korea, the overnight call money rate has been used as the monetary policy operating target since 1999. See Bank of Korea (2008).

[22] 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.

3.2. Standard GMM

We start with standard GMM estimation. The set of instruments includes: a constant and lagged values of the interest rate, inflation, and the output gap; and we adjust for heteroskedasticity and serial correlation.[23] The results of the standard GMM estimation are given in the first three columns of tables 1 and 2. Table 1 reports the estimates for Canada, and table 2 reports the estimates for Korea.

The first column of each table provides the single-equation estimates. We find qualitatively similar results for both countries. In the single equation estimates of the monetary policy rules, the coefficients on output and the expected exchange rates are positive and statistically significant, but the coefficients on inflation are not. If mistakenly taken in isolation, this preliminary finding would suggest that the monetary authorities in both countries target exchange rates and output, rather than inflation. That is, by themselves, the results might seem to indicate that Bank of Canada and the Bank of Korea are inflation targetters in name only. However, as discussed above, the single-equation estimates conflate the effect of the terms of trade effect of equations 1 and 2 with the coefficient α_e in the monetary policy rule: the coefficients of the single-equation estimates are not identified.

System estimates are given in the next two columns of each table. Two different types of system estimates are provided. The first set of system estimates uses only the exclusion restrictions of the model, so it is linear, and there are no cross-coefficient restrictions. In contrast, the second set of system estimates imposes all of the model's nonlinear cross-equation restrictions. The two approaches differ in terms of how far they go in the tradeoff between identification and potential misspecification. The first approach provides only an unobtrusive structure for identification; and, while it does not impose any potentially invalid cross-coefficient restrictions, it must rely heavily on the instruments. The second approach imposes the potentially incorrect cross-coefficient restrictions, but those restrictions, if correct, allow for better identification. Column 2 provides the estimates from the simple, linear system of equations, while column 3 provides the restricted estimates that are fully consistent with the model specified in section 2.

In the system estimates without the cross-equation restrictions, we begin to see some whittling away at the notion that these countries are exchange rate target-

[23] 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.

ters. As shown in column 2 of table 1, the Canadian coefficient on expected inflation, while still small (and much less than one), is larger that the single-equation estimate, and it is statistically significant; and, the statistical significance of the exchange rate coefficient disappears. For the Korean estimates, shown in column 2 of table 2, the coefficient on the exchange rate is smaller, and its significance is diminished.

The estimates for the restricted system, which impose all of the model's cross-coefficient restrictions, are provided in column 3 of tables 1 and 2. Here, both the Canadian and the Korean estimated inflation coefficients become greater than one, as is required for inflation targeting; and, both are statistically significant at all standard confidence levels. As shown in column 3 of table 1, the estimated Canadian exchange rate coefficient, while somewhat larger numerically than the linear system one, is not statistically significant. However, as shown in column 3 of table 2, the Korean exchange rate coefficient remains statistically significant (and more so than the first system estimate). Overall, when the model's cross-coefficient restrictions are imposed, evidence of exchange rate targeting erodes even further for Canada, and there is greater evidence of inflation targeting for both countries.

3.3. Factor Instrumental Variables

In this subsection, we present estimates that reflect the fact that 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 all variables were observable by the econometrician. Moreover, standard GMM estimates using a large number of instruments are known to be biased, and they can be inconsistent as well. Bai and Ng (2010) combine GMM with the data-rich approach in their factor instrumental variables estimator, which we adopt here. This estimator incorporates more information than is used in the standard GMM estimate, and it has two important statistical 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.

The factor instrumental variables estimator is useful because of these statisti-

cal properties, but the factors also a have deeper macroeconomic interpretation.[24] The continued citation of the work of Burns and Mitchell (1946) reminds us that macroeconomic variables move together. Macroeconomic models of all types are designed to reflect the pervasive comovements exhibited by a wide range of economic time series. Models link a wide range of time series to a smaller number of underlying (often unobservable) fundamental determinants. So, in a modeling context, the factors represent the model's smaller number of underlying fundamental determinants.[25]

Here, we estimate the factors for Canada and Korea. As described in the *Data* section above, we use a panel of thousands of variables that reflect the categories in Stock and Watson (2002). Let Z_j, denote the NxT panel of observable variables, where $j = Canada, Korea$; and, let F_j denote a Txk matrix of k underlying factors.[26] Following Bai and Ng, we extract the factors using principal components. Specifically, the Txk matrix of estimated factors, $\widetilde{F}_j$, is the matrix of the largest k eigenvectors of $\frac{Z'Z}{TN}$, multiplied by $\sqrt{T}$. We then construct the factor instrumental variables estimators using two domestic factors and one foreign factor (constructed from U.S. data). The instruments also include lagged values of the interest rate, inflation, and the output gap.[27]

Using the factor-instrumental variables approach, we estimate the monetary policy rule using the same three approaches as above: single-equation estimation, linear system estimation, and restricted system estimation, which imposes the model's nonlinear cross-coefficient restrictions. The resulting estimates are given in the last three columns of tables 1 and 2.

The single-equation factor-instrumental variables estimates are given in column 4 in each table. These estimates weaken the earlier, single-equation support for the idea that the Bank of Canada and the Bank of Korea target their exchange rates in lieu of inflation. As shown in column 4 of table 1, the estimated coefficient

[24] This interpretation has also been given to many of the precursors of Bai and Ng's estimator.

[25] As noted by Bai and Ng, among others, the factor instrumental variables estimator also has another important, practical motivation. It can be thought of in terms of the mismatch between a model's conceptual variable and what can be measured. A model's conceptual variables rarely have perfect empirical counterparts. For any particular economic concept, there are usually many candidate measures, each with its own error, which introduces problems in standard estimates. The factor instrumental variables estimator takes advantage of the plethora of imperfect candidate measures, and the unobservable factors can be thought of as the model's conceptual variables.

[26] The estimator requires that N is much greater than T, as in our sample.

[27] We use the same lags described above in the standard GMM estimation.

on the exchange rate in the Canadian monetary policy rule is no longer statistically significant, as it was in the corresponding standard GMM, single-equation; and the estimated inflation coefficient, while small (and much smaller than one), is now positive and statistically significant at the ten percent confidence level. As shown in column 4 of table 2, while the Korean coefficient on the exchange rate remains significant, the point estimate of the coefficient on inflation, which was negative in the standard GMM, single-equation estimate, is now positive and greater than one, though it is not yet statistically significant.

The first set of the system estimates is given in column 5 of each table. While these linear, system estimates do not impose the model's cross equation restrictions, their use of factor-instrumental variables provides greater scope for identification than does standard GMM, and these linear system estimates contrast with their standard linear system counterparts. For both Canada and Korea, the estimated coefficients on the exchange rate are now statistically indistinguishable from zero; and, the estimated coefficients on inflation now exceed one (as they should for active inflation targeting) and are statistically significant at all standard confidence levels. Unlike the standard GMM linear system estimates, these data-rich, linear system estimates are consistent with inflation targeting, not exchange rate targeting.

The restricted system estimates of the monetary policy rule are given in the final column of each table. For both Canada and Korea, the nonlinear estimators, which impose the model's cross-equation coefficient restrictions, generate estimates that are very similar to the linear system estimates in column 5. Most importantly, the restricted coefficients on the exchange rate are again statistically insignificant. That is, for neither Canada nor Korea do we find evidence of *bona fide* exchange rate targeting. Likewise, in both countries, the coefficients on inflation are again indicative of active inflation targeting; they are greater than one and significant at all standard confidence levels. That is, in contrast to much earlier work, both sets of data-rich system estimates – which address the problems of simultaneity and data paucity– support the claim that both countries are *de facto* inflation targetters, as well as *de jure* ones.

We also note that the estimated Canadian coefficient on the output gap is large and statistically significant both here and in our earlier results. This finding may reflect the role of output in the Bank of Canada's current operating procedures. The output gap has replaced the Bank's earlier use of the monetary conditions index in guiding its actions. The Bank explains that the output gap plays an informational role that assists it in pursuing its official policy of inflation targeting. According to the Bank of Canada (2001): "... when demand presses against the

economy's capacity to produce, there will be upward pressure on inflation relative to the target, and the Bank will act to tighten monetary conditions. This, in turn, will moderate demand and activity and thus reduce the inflationary pressures."[28] However, the coefficient's consistent size and significance suggests that the output gap may in effect play more than a mere informational role in the pursuit of inflation targeting. That is, the central bank's operations may have the effect of making the output gap an implicit policy target.

3.4. Robustness

The next table provides two robustness checks on the factor-instrumental variables system estimators. We first re-estimate the systems replacing the expected values of inflation and depreciation with contemporaneous values in the monetary policy rule. Then, we re-estimate the system replacing the Hodrick-Prescott filter with the Baxter-King approach. The first four columns provide these alternative estimates for Canada, and the next four columns provide the estimates for the Korea.

The estimated output responses change (becoming very large for Canada and negative for Korea under Baxter-King). Yet, despite the changing output coefficients, the coefficients on the inflation terms remain greater than one and statistically significant in all cases. These estimates again support the argument that both countries are *de jure* inflation targetters. Likewise, the coefficients on exchange rate depreciation remain insignificant. This again suggests that neither central bank targets its exchange rate. Together, these additional estimates reinforce our earlier conclusion that exchange rate targeting does not drive policy in either of the two countries; instead, inflation targeting does.

4. Conclusions

This paper combines a small, open-economy model with data-rich estimation to study the exchange rate's role in monetary policy. The combination addresses problems of simultaneity and data insufficiency, and it enables us to disentangle exchange rate and inflation targeting in a monetary policy rule. We apply the approach to the question of whether the *de facto* monetary policies of Canada and Korea have been the same as their *de jure* policies of inflation targeting, or whether

[28] More recently (Bank of Canada, 2012), described this strategy in terms of easing: "When demand is expected to fall short of potential (negative output gap), the Bank will lower interest rates to boost demand and prevent inflation from falling below 2 per cent."

the central banks instead have followed policies of exchange rate targeting, as has been suggested by a number of past studies. Using the data-rich, system approach, we find that neither the Bank of Canada nor the Bank of Korea appear to be targeting its exchange rate. In both countries, the exchange rate influences monetary policy only indirectly. In contrast to what has been suggested by some past work, we find that both central banks appear very much to be following their *de jure* policies of inflation targeting.

The framework of this paper could be extended to other small open economies and used for a variety of purposes. It could be used to improve our understanding and assessment of other indicators of *de facto* exchange rate arrangements. It also could provide clearer insights into inflation targeting and central bank responses to financial conditions. In addition, it may be able to help give a sense of how monetary policy rules change in the face of institutional developments. For example, it could be used to gauge the extent of exchange rate targeting 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 of equations, and using a data-rich approach, as important elements in exploring the monetary policy rules of small, open-economies.

Table 1: Canada

	Standard GMM			**Data-Rich**		
	Single Equation (1)	System (2)	Restricted System (3)	Single Equation (4)	System (5)	Restricted System (6)
x_t	3.0450***	2.9368***	3.3051***	3.0562***	3.5472***	3.4467***
	(0.7068)	(0.7190)	(0.8491)	(0.7773)	(0.8876)	(08567)
$E[\pi_{t+1}\|\Omega_t]$	0.0982	0.1869**	1.2532***	0.1507**	1.0628***	1.2751***
	(0.0715)	(0.0825)	(0.1507)	(0.0638)	(0.2849)	(0.1443)
$E[\Delta e_{t+1}\|\Omega_t]$	0.6000**	0.2072	0.3598	0.1555	0.4277	0.2408
	(0.2602)	(0.2311)	(0.2845)	(0.3145)	(0.3301)	(0.2419)
i_{t-1}	1.1904***	1.1140***	1.1131***	1.0823***	1.0137***	0.9876***
	(0.0702)	(0.0955	(0.0958)	(0.0779)	(0.1161)	(0.1061)
i_{t-2}	-0.2398***	-0.1831**	-0.1750***	-0.1547**	-0.0886	-0.0658
	(0.0672)	(0.0916)	(0.0920)	(0.0754)	(0.1114)	(0.1010)

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 are reported in parenthesis beneath the estimates. The standard GMM instrument set includes lags 1-6, 9 and 12 of the Canadian overnight call money rate (monthly average), industrial production and the inflation rate. The data-rich instrument set includes the first six lags of the Canadian overnight money market rate as well as lags 1-6, 9 and 12 of the first two principal components obtained from the more than 4000 Canadian economic indicators data set extracted from DataStream, and the first principal component from the 93 variable data set of U.S. key economic indicators, also from DataStream (see online appendix). Asterisks denote significance at the ten (*), five (**), and one (***) percent levels.

Table 2: Korea

	Standard GMM			**Data-Rich**		
	Single Equation (1)	System (2)	Restricted System (3)	Single Equation (4)	System (5)	Restricted System (6)
x_t	0.1348***	0.1009***	0.4246***	0.1041***	-0.0090	-0.0682
	(0.0403)	(0.0305)	(0.1240)	(0.0393)	(0.0291)	(0.0575)
$E[\pi_{t+1}\|\Omega_t]$	-0.4767	0.8163	1.4244***	1.3669	3.7605***	1.5466***
	(0.8477)	(0.5169)	(0.1651)	(1.0818)	(0.9309)	(0.2158)
$E[\Delta e_{t+1}\|\Omega_t]$	0.3981***	0.1736*	0.0942**	0.2564***	0.0607	0.0218
	(0.1095)	(0.1001)	(0.0460)	(0.0953)	(0.0819)	(0.0690)
i_{t-1}	1.4868***	1.4201***	1.4857***	1.4503***	1.3403***	1.4085***
	(0.0653)	(0.0888)	(0.0720)	(0.0722)	(0.1144)	(0.0943)
i_{t-2}	-0.5380***	-0.5202***	-0.5152***	-0.5102***	-0.4522***	-0.4565***
	(0.0571)	(0.0785)	(0.0698)	(0.0573)	(0.1024)	(0.0915)

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 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 overnight rate as well as lags 1-6, 9 and 12 of the first two principal components obtained from the more than 2000 Korean economic indicators data set extracted from DataStream, and the first principal component from the 93 variable data set of U.S. key economic indicators, also from DataStream (see online appendix). Asterisks denote significance at the ten (*), five (**), and one (***) percent levels.

Table 3: Robustness of Data-Rich System Estimates

	Canada				**Korea**			
	Contemporaneous values of Δe and π		Baxter-King Detrending		Contemporaneous values of Δe and π		Baxter-King Detrending	
	Unrestricted	Restricted	Unrestricted	Restricted	Unrestricted	Restricted	Unrestricted	Restricted
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
x_t	3.6054***	3.5695***	14.0811**	3.4467***	0.0803***	0.1672	-0.4340***	-0.1098*
	(1.0138)	(0.8848)	(6.6206)	(0.8567)	(0.0295)	(0.1046)	(0.0861)	0.0615
π_t	1.8604***	1.2089***	–	–	3.4775***	1.5463***	–	–
	(0.4969)	(0.1561)	–	–	(0.7864	(0.2426)	–	–
Δe_t	0.5316	(0.5729*)	–	–	0.0815	-0.0260	–	–
	(0.3617)	(0.3289)	–	–	(0.0650)	(0.0952)	–	–
$E[\pi_{t+1}\|\Omega_t]$	–	–	5.0850***	1.2750***	–	–	2.3139***	1.5432***
	–	–	(1.9702)	(0.1443)	–	–	(0.5547)	(0.2180)
$E[\Delta e_{t+1}\|\Omega_t]$	–	–	0.1528	0.2409	–	–	0.0024	0.0368
	–	–	(0.4688)	(0.2419)	–	–	(0.0482)	(0.0646)
i_{t-1}	1.0210***	(0.9799***)	1.0748***	0.9877***	1.3676***	1.4991***	1.1951***	1.4034***
	(0.1227)	(0.0801)	(0.1153)	(0.1061)	(0.0872)	(0.0800)	(0.1167)	(0.0958)
i_{t-2}	-0.0945	(-0.0505)	-0.1226	-0.0659	-0.4729***	-0.5260***	-0.3824***	-0.4530***
	(0.1167)	(0.1070)	(0.1130)	(0.1010)	(0.0779)	(0.0772)	(0.0995)	(0.0929)

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 are reported in parenthesis beneath the estimates. The instrument sets include the first six lags of the each country's overnight rate as well as lags 1-6, 9 and 12 of the first two principal components obtained from the more than thousands of economic indicators data set extracted from DataStream for each country, and the first principal component from the 93 variable data set of U.S. key economic indicators, also from DataStream (see online appendix). Asterisks denote significance at the ten (*), five (**), and one (***) percent levels.

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Appendix: Data Selection for Factor Instrumental Variables

Because the factor instrumental variable methodology is designed to extract signals from large data sets, an expansive approach is used here. Specifically, all economic time series in DataStream for Korea and Canada for the time period 1985-2008:04 are in the dataset, though the estimation runs from 1999 through the first part of 2008. This yields 6,314 time series for Canada and 2,021 for South Korea. The only requirement then imposed is that there could be no more than ten years of missing data (120 monthly observations). This results in 4,026 economic time series for Canada and 1,810 for South Korea.

For the United States (the 'foreign' country), DataStream's set of 'key indicators' are used. This choice is dictated primarily because there are more than 12,000 economic time series in DataStream for the U.S., so the problem becomes unmanageable. The key indicator set includes 93 economic time series for the U.S. (considerably less for Canada and Korea).

The data transformations used to induce stationarity follow Stock and Watson (2002) as closely as possible: e.g., variables in percentage units received no transformation; variables with minimums less than zero were transformed using first differences; and the rest were transformed using log first differences. The principal components estimation was run for the full sample.

Table A.1: Canada – Other Coefficients and Parameters

		Standard GMM		Data-Rich	
		Singe Equation	System	Singe Equation	System
Unrestricted Estimates					
Equation					
π_t	$E[\pi_{t+1}\|\Omega_t]$	0.1886***	-0.6611***	0.4840***	0.2919***
		(0.0338)	(0.0934)	(0.0509)	(0.0640)
	x_t	0.0588	-0.0755	-0.0775	-0.0893
		(0.4076)	(0.5412)	(0.3911)	(0.2989)
	$E[\Delta q_{t+1}\|\Omega_t]$	0.1178	0.1716	0.3020	0.3097
		(0.2753)	(0.3512)	(0.2800)	(0.2539)
	Δq_t	-0.5991**	-0.1565	-0.4970*	-0.1649
		(0.2922)	(0.2975)	(0.2976)	(0.2347)
x_t	$E[x_{t+1}\|\Omega_t]$	0.9808***	0.9577***	0.9712***	0.9343***
		(0.0440)	(0.0487)	(0.0621)	(0.0547)
	r_t	0.0118	0.0441***	0.0066	0.0414***
		(0.0109)	(0.0098)	(0.0124)	(0.0100)
	$E[\Delta q_{t+1}\|\Omega_t]$	-0.0734	-0.0545	0.0308	-0.0061
		(0.0583)	(0.0434)	(0.0672)	(0.0501)
	$E[x^f_{t+1}\|\Omega_t]$	0.0026	0.0018	0.0011	0.0005
		(0.0039)	(0.0038)	(0.0035)	(0.0033)
Restricted Estimates					
Parameter	Starting Value				
α	0.11	–	-0.00005	–	0.02191*
		–	(0.00005)	–	(0.01322)
τ	0.31	–	-0.01740	–	-0.06332*
		–	(0.01506)	–	(0.03347)
β	0.99	–	0.99996***	–	0.99999***
		–	(0.00032)	–	(0.00033)
κ	0.32	–	-0.00001	–	-0.00001
		–	(0.00004)	–	(0.00004)

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 are reported in parenthesis beneath the estimates. The standard GMM instrument set includes lags 1-6, 9 and 12 of the Canadian overnight call money rate (monthly average), industrial production and the inflation rate. The data-rich instrument set includes the first six lags of the Canadian overnight money market rate as well as lags 1-6, 9 and 12 of the first two principal components obtained from the more than 4000 Canadian economic indicators data set extracted from DataStream, and the first principal component from the 93 variable data set of U.S. key economic indicators, also from DataStream (see online appendix). Asterisks denote significance at the ten (*), five (**), and one (***) percent levels.

Table A.2: Korea – Other Coefficients and Parameters

		Standard GMM		Data-Rich	
		Singe Equation	System	Singe Equation	System
Unrestricted Estimates					
Equation					
π_t	$E[\pi_{t+1}\|\Omega_t]$	0.4675***	0.2825***	0.5394***	0.7273***
		(0.0824)	(0.0891)	(0.0876)	(0.0840)
	x_t	-0.0117***	-0.0212***	-0.0069***	-0.0046**
		(0.0019)	(0.0021)	(0.0018)	(0.0022)
	$E[\Delta q_{t+1}\|\Omega_t]$	-0.0412**	-0.0463***	-0.0493.***	-0.0133
		(0.0203)	(0.0162)	(0.0145)	(0.0144)
	Δq_t	-0.0466*	-0.0072	-0.0082	-0.0134
		(0.0245)	(0.0187)	(0.0217)	(0.0133)
x_t	$E[x_{t+1}\|\Omega_t]$	0.6128***	0.9733***	0.3169 ***	1.0161***
		(0.1272)	(0.0685)	(0.1196)	(0.0955)
	r_t	0.4313	0.3596	0.7179	0.3527
		(0.5056)	(0.3211)	(0.6106)	(0.2997)
	$E[\Delta q_{t+1}\|\Omega_t]$	0.6782***	0.2705	0.2198	0.5765
		(0.2506)	(0.5665)	(0.5176)	(0.6352)
	$E[x^f_{t+1}\|\Omega_t]$	-0.0183***	-0.0326***	-0.0101***	-0.0275***
		(0.0016)	(0.0024)	(0.0017)	(0.0028)
Restricted Estimates					
Parameter	Starting Value				
α	0.11	–	-0.00000	–	-0.00006
		–	(0.00009)	–	(0.00011)
τ	0.31	–	0.10618	–	0.07242
		–	(0.09825)	–	(0.09974)
β	0.99	–	0.99405***	–	0.99560***
		–	(0.00815)	–	(0.00890)
κ	0.32	–	-0.00209	–	-0.00075
		–	(0.00199)	–	(0.00109)

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 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 overnight rate as well as lags 1-6, 9 and 12 of the first two principal components obtained from the more than 2000 Korean economic indicators data set extracted from DataStream, and the first principal component from the 93 variable data set of U.S. key economic indicators, also from DataStream (see online appendix). Asterisks denote significance at the ten (*), five (**), and one (***) percent levels.