HONG KONG INSTITUTE FOR MONETARY RESEARCH

# IS STERILIZED INTERVENTION EFFECTIVE? NEW INTERNATIONAL EVIDENCE

*Pierre L. Siklos and Diana N. Weymark*

*HKIMR Working Paper No.14/2007*

July 2007

*Hong Kong Institute for Monetary Research*

*(a company incorporated with limited liability)*

# Is Sterilized Intervention Effective?
# New International Evidence

**Pierre L. Siklos***
Wilfrid Laurier University
Viessmann European Research Centre
Hong Kong Institute for Monetary Research

and

**Diana N. Weymark**
Vanderbilt University

July 2007

*Please do not quote or cite without permission*

## Abstract

This paper applies a new measure of the effectiveness of sterilized interventions to data for 16 economies. The measure is defined as the difference between *ex ante* ($xa$EMP) and *ex post* exchange market pressure ($xp$EMP). $xa$EMP is calculated on the basis of a counterfactual that no intervention takes place and this is the rationally expected policy. $xp$EMP is the degree of exchange market pressure that remains based on the actual intervention policy in place. Based on a sample of 12 emerging markets, and Hong Kong, Korea, Japan, and Singapore, we conclude that sterilized interventions have persistent exchange rate effects. However, we also show empirically that this success also took place during a period of substantial growth in foreign exchange reserves.

Pierre L. Siklos
Department of Economics
and Viessmann European Research Centre
Wilfrid Laurier University
e-mail: psiklos@wlu.ca
Home page: www.wlu.ca/sbe/siklos

Diana N. Weymark
Department of Economics
Vanderbilt University
e-mail: diana.weymark@vanderbilt.edu

JEL classification: F31
Keywords: exchange market pressure, foreign exchange intervention, emerging markets

---

* Part of this research was carried out while Siklos was a Research Fellow at the Hong Kong Institute for Monetary Research (HKIMR) where an earlier draft was presented. Versions of this paper were also presented at Tilburg University and the 2007 Pacific Rim Conference, Beijing.

# 1. Introduction

Doubts persist about the advisability of a policy of foreign exchange intervention. In a recent survey, Sarno and Taylor (2001) reach no firm conclusions about the ability of such policies to persistently influence the exchange rate. Disyatat and Galati (2005), and Canales-Kriljenko (2004), have a more favorable view of the effectiveness of foreign exchange intervention, especially in emerging markets. Although intervention takes on many forms, it is commonly used to refer to the purchase or sale of foreign currencies which are then sterilized. Whereas unsterilized interventions clearly influence exchange rates, there is no broad consensus on the effectiveness of sterilized interventions.

In spite of a growing preference for floating exchange rate regimes (e.g., Fischer 2001, Babula and Ötker 2002), intermediate type regimes remain popular, particularly in emerging market countries, a reflection perhaps of a 'fear of floating' (Calvo and Reinhart 2004). Others have also expressed skepticism that the two corners solution, occasionally referred to as the hollowing out of the middle, that is, the phenomenon whereby exchange rate regimes gravitate either to the pure float or pegged exchange rate regimes, can explain the evolution of exchange rate regime choice over the past few decades (Willett 2003).

In this paper we propose a way of evaluating the impact of intervention on exchange rates that is applicable to a wide variety of exchange rate regimes. We measure the effectiveness of sterilized interventions by quantifying the proportion of exchange market pressure that is relieved through intervention. This requires, first, an estimate of the change in the exchange rate assuming there is no foreign exchange intervention, and the policy is correctly anticipated by economic agents. Obtaining such an estimate entails carrying out a counterfactual experiment that asks: what would have happened to the exchange rate under the hypothetical 'do no harm' policy of no intervention? Next, given the policy actually implemented, we estimate the impact of intervention on the exchange rate. The counterfactual refers to *ex ante* exchange market pressure ($xa\mathrm{EMP}$), while the impact of the actual intervention enables us to obtain an estimate of ex post exchange market pressure ($xp\mathrm{EMP}$). The difference between the two, when converted into index form, is defined as the Policy Induced Change in Expectations ($\mathrm{PICE}$). This index provides a quantitative measure of the effectiveness of intervention. Siklos and Weymark (2006) introduce the $\mathrm{PICE}$ and estimate it for Australia and Canada, two archetypical small open economies with a varied history of intervention policies.

We construct measures of the effectiveness of exchange market intervention for 12 emerging markets in Asia, Europe, Latin and South America, as well as for four developed economies, namely Hong Kong, Korea, Japan, and Singapore. The latter countries are usually placed at either end of the "bi-polar" range of exchange rate regime classifications (Fischer 2001) while Singapore adopted a 'basket, band, and crawl' version of a pegged exchange rate regime (Williamson 2000). It is also worthwhile noting that, according to the exchange rate regime classification schemes developed by Reinhart and Rogoff (2004), and Levy-Yeyati and Sturzenegger (2005), about half of the 16 countries in our sample that introduced inflation targets continue to permit only limited exchange rate flexibility, or adopted a floating exchange rate regime toward the end of our sample.[1] Finally, some of the countries in our study, such as Japan, have a long history of intervening in foreign exchange markets on a regular basis.

---

1 The introduction of this monetary policy strategy, in roughly half the countries in our sample, occurs throughout the 1990s. Moreover, there are substantive differences in how inflation targeting is actually implemented in the countries in question.

Asian economies, and emerging market economies more generally, are fertile ground for our approach for several reasons. First, the Asian crisis of 1997-1998, as well as similar financial crises that have afflicted other parts of the world (e.g., the "Tequila" crisis of 1994-1995), may have been predictable in hindsight, given the economic and financial policies then in place, but policy makers were clearly caught by surprise by the timing of such events (e.g., Bank for International Settlements 1998, Kochher, Loungani, and Stone 1998). Intervention practices, and the policy authorities' inability to remove exchange market pressure sufficiently through intervention, could not prevent a collapse of the existing exchange rate regime.

Briefly, we find that sterilized interventions have been effective in emerging markets, in the sense of producing persistent changes in the exchange rate. Nevertheless, there are also indications that this success has come at a time of large increases in reserves holdings of foreign exchange. Finally, there is also some evidence that $xa\mathrm{EMP}$ tends to be lower the closer the exchange rate regime is to a pure float.

The paper is organized as follows. In the following section, we define our indicator of exchange market pressure and address some of the issues, both theoretical and empirical, faced by researchers that seek to measure the effectiveness of sterilized interventions. A separate section outlines the model we propose to estimate for each economy considered, using quarterly data covering the period 1993-2005. This is followed by an outline of the model as well as a description of the data. Estimates of the $\mathrm{PICE}$ measure of the effectiveness of foreign exchange market intervention are then presented and discussed. The paper concludes in section 6 with a summary and some limitations are also noted.

## 2. Exchange Market Pressure: Definition and Measurement Issues

We construct two indices of exchange market pressure. The formal definitions are as follows (also see Siklos and Weymark 2006).

### 2.1 Ex ante Market Pressure (xaEMP)

Ex ante market pressure is the change in the exchange rate that would have occurred if the policy authority had refrained from exchange market intervention in a given period, under the assumption that this policy decision was correctly anticipated by economic agents.

### 2.2 Ex Post Exchange Market Pressure (xpEMP)

Ex post market pressure is the change in the exchange rate that would have occurred if the policy authority had unexpectedly refrained from intervening in the foreign exchange market, given the expectations generated by the exchange rate policy actually implemented.[2]

---

2 A detailed discussion of the theoretical foundation and the measurement of $xp\mathrm{EMP}$ is found in Weymark (1995, 1998).

### 2.3 Constructing Indicators of xaEMP and xpEMP

The exchange market pressure concepts described above are not directly observed and must be obtained from a structural model. Accordingly, our indicators of the effectiveness of exchange market pressure have the advantage of not being ad hoc. While the resulting PICE may be sensitive to the chosen structural model, we have taken care to ensure that the estimated model for each economy in our data set is reasonably congruent with the data, relying on specifications used widely in the extant literature. Moreover, we strive to ensure that the estimated specifications are able to pass model adequacy tests.[3]

An important feature of recent research that deals with the effectiveness of foreign exchange intervention is the shift in focus away from the resort to quarterly or monthly data toward studies that rely on data at higher frequencies (i.e., daily or even intra-daily), in large part because it has been widely documented (e.g., see Neely 2005) that exchange rates respond very quickly to news and other market events. The presumption is that the effects of news or interventions apparently lasts only a few hours, perhaps at most a few days, so this kind of policy has no macroeconomic relevance. Yet, many policy makers around the world persist in the belief that sterilized intervention is a potentially effective policy (e.g., see Neely 2005), or worry about the accumulated economic costs of sustained interventions that lead to a build-up of foreign exchange reserves (Ho and McCauley 2007).[4] Hence, exchange rate pressure ought to be measurable at a sampling frequency used to estimate standard macroeconomic models (i.e., quarterly or monthly). The challenge is that estimating the impact of foreign exchange intervention at the sampling frequency of interest requires both a counterfactual exercise, as well as a structural model of the economy. The former approach has generally been eschewed in the literature to date.[5] We argue that our *xa*EMP and *xp*EMP indicators are ideally suited for this purpose since decisions about intervention cannot be entirely divorced from the policy maker's knowledge of the macroeconomic environment in which such actions are undertaken.

Despite the potential appeal of the proposed procedure, rendering the two concepts of EMP operational, especially for data from emerging markets does present some obstacles. For example, central banks in emerging market countries have not yet followed the example of select industrial countries which have made available actual intervention data. It is not obvious, however, that estimates of the effectiveness of intervention are substantially different when actual intervention data, as opposed to official reserves data, are employed. One reason is that central banks intervene not just through the purchase or sale of foreign exchange on their own account. They also have facilities with other central banks, and can use off-balance sheet transactions to intervene, and act in foreign exchange markets as agents for the

---

3 Since the PICE indicator is evaluated as the difference between *xa*MP and *xp*MP, it is unclear whether agents or policy makers could have anticipated, for example, structural breaks. Hence, all we can aim for is to ensure that the estimated model fits the data reasonably well.

4 Japan is a case in point. Between 1991 and 2004, the Bank of Japan regularly intervened in foreign exchange markets. The Reserve Bank of New Zealand is another example of a central bank that decided not to exclude the possibility of intervening in foreign exchange markets in spite of a firm commitment to floating exchange rates. For example, see http://www.rbnz.govt.nz/finmarkets/foreignreserves/intervention/index.html.

5 Blundell-Wignall and Masson (1985) simulate a model under the condition of no intervention and contrast the results with the policy actually implemented. Bonser-Neal and Tanner (1996) rely on the volatility of foreign currency auction prices, but their focus alone is on what we term ex ante exchange rate volatility.

government.[6] Moreover, even when the central bank does not officially intervene as in, say, the currency board system adopted by Hong Kong, the banking sector may still react to attempts by the monetary authority to influence exchange rate expectations. In other words, it is not only the ability to intervene in foreign exchange markets that matters, it is the central bank's willingness to do so which will impact expectations (e.g., see Kasa 1999).[7] Nevertheless, since our sample includes Japan, we are able to contrast estimates of the PICE using reserves data as well as official intervention data for one of the countries in our sample.[8]

## 3. The Effectiveness of Foreign Exchange Intervention

The literature of foreign exchange intervention by central banks has only very recently turned its attention to the experience of emerging market economies (see Disyatat and Galati 2005, and references therein). The ability of intervention to influence foreign exchange rates in emerging markets relative to the experience in developed economies is even less well understood (e.g., Canales-Kriljenko 2004). Generally, this literature finds that foreign exchange intervention can be relatively more effective in emerging markets, either because central banks in these countries have an informational advantage over market participants, they do not completely sterilize interventions, or thanks to currency regulations that provide a comparative advantage to the monetary authority over foreign exchange market participants. In Asia, it is also claimed that intervention by different central banks tends to be undertaken is the same direction, and in a fashion that gives the appearance that they are coordinated.

The approach developed in this paper allows us to assess the suitability of our measure of the effectiveness of intervention in light of the foregoing debate. Partly for this reason, our sample includes five countries described as Asian crisis countries (Indonesia, Korea, Malaysia, Philippines, and Thailand), and four of the countries affected by the Tequila crisis (Argentina, Brazil, Chile, and Mexico). The four developed economies in our study, Hong Kong, Japan, Korea and Singapore, were not left untouched by the Asian crisis but their policy response throughout the period studied differs from the rest of the Asian group of countries in our sample. Finally, the European countries in our sample may have been sideswiped both by the Asian and Tequila crises, as well as the Russian crisis of 1998, and possibly the Argentine crisis of 2000-2001.

6 Siklos and Weymark (2006) point out that Canada and Australia are excellent examples of both phenomena. For example, official intervention data show that no intervention took place in September 2000, when the ECB engineered a coordinated intervention, even though the Bank of Canada announced that it had intervened through facilities at the US Fed and the Bank of England. Disyatat and Galati (2005) report that emerging markets overwhelmingly intervene in the spot market.

7 Yam (1998) refers to the Hong Kong Monetary Authority's (HKMA) policy, at least for a majority of the time covered in our sample, as one of 'constructive ambiguity', labeling it as being "…the only one of its kind in the world" (op.cit., p.23). Therefore, the HKMA reserves the right to intervene at unspecified levels of the exchange rate close to the declared pegged value to the US dollar. It can do so in the conventional manner (i.e., buying and selling of foreign exchange) or via foreign exchange swaps. Tsang (1999) identifies the HKMA's policy as being of the activist variety.

8 Official intervention data for Japan are available from the Ministry of Finance.

# 4. Model Specification

The estimated model for each economy is specified with a small open economy in mind. It consists of a Phillips curve with both backward and forward-looking elements,[9] an IS curve, and an uncovered interest rate parity equation that allows for a risk premium to capture the fact that financial instruments in emerging markets are not perfect substitutes for US securities. Consequently, all foreign variables in the model are expressed in terms of US aggregates. The model also includes a money demand equation based on a vector error correction specification. Four other equations describe the determinants of the money supply for each economy in our sample. The model is closed with an equation that describes the monetary authority's time-varying intervention policy. As shown below, this is characterized as a reaction function to contemporaneous exchange rate changes.

Solving the model under rational expectations requires that we obtain a numerical solution. The model is sufficiently complex to preclude a closed-form solution. Details of the procedure can be found in Siklos and Weymark (2006). The reduced form rational expectations solutions for the endogenous variables in our model are relegated to an appendix. The general structure of the model estimated for data from each economy considered is given by the following equations:

$$\pi_t = \alpha^{\pi}{}_0 + \sum_{i=-k_\pi}^{+k_\pi} \alpha^{\pi}_i \pi_{t-i} + \sum_{j=-k_{\tilde{y}}}^{+k_{\tilde{y}}} \alpha^{\pi}_j \tilde{y}_{t-k} + \sum_{l=-l_\xi}^{+k_\xi} \alpha^{\pi}_l \xi_{t-l} + \varepsilon_t \tag{1}$$

$$\tilde{y}_t = \beta^{\tilde{y}}_0 + \sum_{i=-k_{\tilde{y}}}^{+k_{\tilde{y}}} \beta^{\tilde{y}}_i \tilde{y}_{t-i} + \sum_{j=-k_\theta}^{+k_\theta} \beta^{\tilde{y}}_j \theta_{t-j} - \sum_{l=-k_\xi}^{+k_\xi} \beta^{\tilde{y}}_l \xi_{t-l} + \eta_t \tag{2}$$

$$i_t = \overline{c} + i^*_t + \mathrm{E}_t \Delta q_{t+1} + \mu \Delta d_t + \sigma_t \tag{3}$$

$$\Delta m_t = h^{\Delta m}_0 + \sum_{i=1}^{k_m} h^{\Delta m}_i \Delta m_{t-i} - \sum_{l=1}^{k_y} h^{\Delta m}_l \Delta y_{t-l} + h^{\Delta m}_1 \Delta \pi_t - h^{\Delta m}_2 ec_{t-1} + \chi_t \tag{4}$$

$$\Delta m_t = \Delta d_t + \Delta r_t \tag{5}$$

$$\Delta d_t = \Delta d^a_t + \Delta d^f_t \tag{6}$$

$$\Delta d^a_t = \overline{m} + \gamma_\pi \pi_t + \gamma_y y_t + \delta_t \tag{7}$$

$$\Delta d^f_t = -\lambda \Delta r_t \tag{8}$$

$$\Delta r_t = -\rho_t \Delta q_t \tag{9}$$

A few remarks about equations (1) through (9) are in order. Lead values in equations (1) and (2) are interpreted as expectations of future values. As a result, we resort to an instrumental variables approach

[9] While the New Keynesian literature holds that a 'hybrid' Phillips curve with both forward and backward-looking variables are essential, Rudd and Whelan (2005) cast serious doubt on this view and find that a Phillips curve with lagged inflation and lagged changes in inflation performs better and survives stability tests, at least for US data.

to estimate such relationships. The Phillips curve specification (1) also permits the real exchange rate ($\xi$) to influence domestic inflation. Small open economy considerations also explain the addition of a real exchange rate variable in the IS curve equation for the determinants of the output gap ($\tilde{y}$) given by equation (2). Several proxies for the real interest rate ($\theta$) were considered, and we briefly discuss these in the following section. The uncovered interest rate (UIP) specification (equation (3)) requires that the difference between the nominal domestic interest rate ($i_t$), and the foreign interest rate ($i_t^*$), be driven by current period expectations of next period's change in the nominal exchange rate ($q_t$). Since a foreign exchange market determined forward premium is available for only a subset of countries in our data set, and covers considerably less than the full sample considered, we also set $E_t \Delta q_{t+1} = \Delta q_{t-1}$ as a proxy (see the following section). The term $\mu \Delta d_t$ represents a risk premium, where $\Delta d_t$ is domestic credit growth. In other words, we do not assume that domestic and US financial instruments are perfect substitutes.

The vector error correction money demand specification given in equation (4) assumes that money supply growth ($\Delta m_t$) is possibly constrained in the long run by the error correction term ($ec_{t-1}$). As shown, the specification assumes that there is a single cointegrating vector, although this need not be the case, since the long-run money demand equation

$$m_t = \overline{h} + \vartheta_0 i_t + \vartheta_1 y_t + \upsilon_t \tag{10}$$

describes the cointegrating relationship between the (log of) money supply (real balances, $m_t$), the nominal interest rate level, and (the log of) real GDP ($y_t$) and this specification can obviously admit more than one cointegrating relation. It should be clear from equations (5) to (9) that the policy variable is assumed to be a monetary aggregate. While many countries now rely on an interest rate instrument this is only a feature of the last few years in the policy landscape of most emerging markets. Second, to evaluate the effectiveness of sterilized interventions it is useful to cast the analysis in terms of its impact on the money supply as the effects of intervention would immediately be reflected in liquidity changes. Third, at least at a theoretical level, there is an isomorphism between specifying an interest rate or a monetary aggregate as the instrument of policy.[10]

The intervention parameter, $\rho_t$, is time-varying. The sterilization parameter, however, is not. This is a simplifying assumption. Our prior is that intervention is more likely to respond to exchange rate developments than to the degree to which foreign exchange transactions are sterilized. The assumption is also consistent with established practice in the relevant literature. If $\rho_t = 0$, the central bank refrains from intervening altogether. A pegged exchange rate is then equivalent to setting $\rho_t = \infty$. Intermediate exchange rate regimes are, therefore, characterized by $0 < \rho_t < \infty$. If $\rho_t < 0$, this means that intervention produces a change in the exchange rate that either exceeds the change that would have occurred in the absence of intervention, or is of the opposite sign to the no intervention case.

[10] A McCallum type rule also relies on a monetary aggregate as the instrument of policy. Other models of exchange rate behavior (e.g., Engel and West 2005) also specify a reaction function in terms of the money supply. Siklos and Weymark (2006) explicitly show that equations (4) to (9) can be recast in the form of a Taylor rule with forward- and backward-looking elements, while also permitting the nominal interest rate to respond to changes in the nominal exchange rate.

To obtain the counterfactual $xa\mathrm{EMP}$, we first solve the model under rational expectations. Expectations enter the model in equations (1) through (3). The rational expectations solution (see a separate appendix for details) relies on the computational program of Sims (2001). Since we require a quarter by quarter estimate of $\rho_t$, and a closed-form solution is not tractable due to the complexity of our model, we instead set $\rho_t$ to be equal to the sample mean value, under the counterfactual. Hence, we avoid having to obtain a separate rational expectations solution for each quarter and each economy in our sample. Given that we are only failing to adjust the coefficients for a one-period deviation from the estimated policy rule, the approximation should not have a significant impact on the quantitative results obtained.

To assess the effectiveness of sterilized interventions, we compute an index that measures the policy induced change in expectations (PICE). The PICE is the difference between $xa\mathrm{EMP}$ and $xp\mathrm{EMP}$ that is computed on a quarterly basis. More formally,

$$PICE_t = 1 - \frac{xpEMP_t}{xaEMP_t} \tag{11}$$

To interpret the PICE , it is useful to think of three possible cases. When $xp\mathrm{EMP} < xa\mathrm{EMP}$, and both have the same sign, then $0 < \mathrm{PICE} < 1$. Since EMP is lower after intervention, this is interpreted as a successful intervention. In contrast, if $|xp\mathrm{EMP}| > |xa\mathrm{EMP}|$, PICE becomes negative, and this can only be viewed as an unsuccessful intervention since exchange market pressure is actually higher after intervention. Finally, if $xpEMP$ and $xaEMP$ are of the opposite sign, this can also be classified as a successful intervention since the course of the exchange rate has been reversed. Nevertheless, to the extent that such a result means that the central bank underestimated the impact of intervention this could conceivably be construed as an example of an unsuccessful intervention involved.[11]

# 5. Data and Parameter Estimates

## 5.1 Data and Parameter Estimates

Equations (1) through (9) describe the general structure of the model specified for each economy considered. Of course, parameter estimates are tailored to the data for individual countries, and the model outlined in the previous section is sufficiently flexible to permit differences in the specifications across countries. Our sample consists of 12 emerging market economies, plus Hong Kong, Korea, Japan, and Singapore. The Bank of Japan (BoJ) has a long history of regular intervention in spite of often being labelled a currency that floats independently (e.g., Fischer 2001, Levy-Yeyati and Sturzenegger 2005). Moreover, there exists an extensive literature that relies on actual Japanese intervention data. In contrast, Hong Kong has long maintained a peg through its currency board that has outlasted other economies that adopted this kind of policy regime. Finally, Singapore is said to offer a way to maintain a type of pegged exchange rate regime that is able to deliver inflation performance comparable to that

11 A Granger-causality test, for example, would not be helpful since $xa\mathrm{EMP}$ and $xp\mathrm{EMP}$ are estimated quarter by quarter.

of an inflation targeting central bank (Williamson 2000). Korea's central bank targets inflation. Hence, the industrialized economies in our sample offer an interesting contrast to the 12 emerging market economies considered in this paper.

As indicated previously, the chosen sampling frequency is quarterly, and generally covers the period 1993-2005. The starting date seems appropriate for the group of Central European, Latin and South American countries in our data set. In the case of the European countries in our study, it was not until the early 1990s that the command economy system was entirely abandoned. Similarly, reforms in Latin and South America during the 1980s would make the task of estimating a reasonably data coherent structural model rather hazardous prior to the early 1990s. It is likely that the same is true for the so-called Asian 'Tiger' economies in our sample (e.g., Thailand, Malaysia). Even in the case of Japan, the starting date for the data set encompasses much of the 'lost decade' of deflation and stagnant economic growth. An appendix provides details about the sources of data. The appendix also contains information about exchange rate and monetary regime classifications over the period studied as a means of contrasting our estimates of the effectiveness of foreign exchange intervention with alternative methodologies used to date changes in policy regimes. Plots of the key time series used to estimate the parameters of our model are also provided there.

Nevertheless, a few remarks concerning the time series used in this study are in order. Inflation is the annual rate of change in the CPI. The output gap is obtained via an H-P filter applied to the log of real GDP using the standard smoothing parameter (1600).[12] The real interest rate is estimated as the nominal interest rate, usually a money market rate, less contemporaneous inflation. We also tried versions using a one period lag in inflation, forecasts published by the IMF in the World Economic Outlook, as well as forecasts from Consensus Economics, and there were no significant improvements in our estimates of the IS or Phillips curves.

The nominal exchange rate is defined as the number of domestic currency units per US dollar and the quarterly data are period averages. Foreign exchange reserves are in US dollars and were converted into domestic currency units using the nominal exchange rate.[13] Turning to the real exchange rate variable, where possible, this is based on relative CPI. However, in some cases (Hong Kong, Indonesia, Korea, Thailand, Mexico, Slovenia, and Thailand), we were either unable to obtain comparable exchange rate data or the available sample was too short. In these instances we use the recently published BIS series on nominal effective exchange rates.[14] Next, we were faced with the choice whether to use the

---

12 The estimation of output gaps is controversial. Several variants were examined in Siklos and Weymark (2006), including regressing the log of real GDP on a constant, linear and quadratic trends (also see IMF 2005 where this filter was used in the context of an analysis of emerging markets) but results seem most plausible and consistent across equations when we rely on the conventional smoothing parameter used for an H-P filter. Plots showing alternative output gap estimates are also relegated to the appendix. Gerlach and Yiu (2004), and Darvas and Vadas (2005), are just two examples of studies of the impact of different filtering methodologies used in estimating the output gap for select emerging markets. While the H-P filter is not always preferred, and has well-known drawbacks, it tends to be the filter of choice under most circumstances.

13 This means that valuation effects are ignored. If these affect the total value of reserves then our estimates of $xpEMP$ will be subject to measurement error. However, if such valuation changes are confined to changes in reserves, then they correctly reflect the size of any change in the monetary base necessary to offset exchange rate changes.

14 These are made available at http://www.bis.org/statistics/eer/index.htm. We used the BIS's so-called broad index.

real exchange rate variable in rates of change form, to rid the levels data of their non-stationarity, or apply, say, an H-P filter to the log levels of the series. Both the size and sign of the estimated coefficients in the relevant equations were consistently more sensible when we resort the first log difference of the levels than when deviations from an H-P filtered estimate. Readers are again referred to the appendix for further details. Finally, the monetary aggregate used here is the IMF's definition of a narrow (seasonally adjusted) money supply measure (line 34A in *International Financial Statistics*) which essentially consists of currency outside banks and demand deposits. This proxy comes closest to the monetary base measure we would have preferred to use.

Table 1 provides a summary of key features of our parameter estimates while more detailed estimates and statistical tests are relegated to an appendix to conserve space, along with model diagnostics. We sought model estimates that were theoretically plausible, survived model adequacy tests, and are simple enough in form to be used in producing the *xa*EMP indicator.[15] We obtained a mix of forward-looking (FL) and backward-looking (BL) estimates. The choice of models is predicated on the need to obtain plausible estimates and the requirement that estimated equations pass model adequacy tests. In the case of forward-looking models, we used GMM to estimate the parameters. Given the perennial problem of weak instruments (e.g., see Stock, Wright, and Yogo (2002), we also experimented with alternative specifications that incorporated additional instruments, such as commodity prices. These may be economically important to some of the emerging market countries in our sample. For example, the price of tin was used for Thailand, rubber for Malaysia, coffee for Brazil, and copper for Chile. In the event, reliance on these alternative instruments generally did not improve estimates. Two lags of the variables in each equation, including lagged money growth and lagged oil price inflation, were used as instruments. Hansen's J-test cannot reject any of the over-identifying restrictions considered. We also generate Andrews' (1999) GMM information criterion (GMMIC), which is used to discriminate among estimates according to whether the orthogonality condition required in instrumental variable estimation is met.

Estimates of the Phillips curve reveal considerable variation in the degree of inflation persistence.[16] However, if we sum the lead and lag inflation terms in the FL model, there is no statistically significant difference across countries in the impact on current inflation. A forward-looking Phillips curve (FL) fits best for a slight majority of countries. For the most part, the reported persistence parameters for the backward-looking (BL) models are not unlike the values reported in studies that rely on data from industrial countries (e.g., see Siklos 2002).

Turning to estimates of the IS curve, we are able to fit a forward-looking type model for 7 of 16 countries in the sample. As with the Phillips curve, there is considerable output persistence in most countries. The real interest rate variable is often statistically significant but economically small (coefficients not shown). The same holds for the real exchange rate variable. Estimates of equation (3) clearly show that there is a lack of complete substitutability between domestic and US assets, as measured by the parameter $\mu$.

15 The rational expectations solutions were derived from the chosen estimates, regardless of their statistical significance or whether, as happened in a very few cases, the estimated sign was inconsistent with theoretical priors. This is the standard practice as it avoids prejudging either the size or the direction of the relationship between the variables of interest.

16 The estimates for Hong Kong and Singapore are not substantially different from those of Gerlach and Gerlach-Kristen (2006) who rely on a much longer sample than ours and only consider backward-looking Phillips curve and IS equations.

The risk premium is economically small or statistically insignificant for Hong Kong and Korea but, perhaps surprisingly, also for Argentina, Mexico, and Malaysia. Part of the difficulty in interpreting this coefficient is that the actual definition of domestic component of the money supply is not measured across countries in a perfectly comparable manner.

Estimates of the reduced form of equations (6) to (8), which rely on OLS estimation, generate the coefficient for $\lambda$, which gives the impact of changes in foreign exchange reserves on domestic credit is the sterilization coefficient based on official foreign exchange data. In the case of Japan, using actual intervention data yields an estimate of $\lambda$ = -0.17(0.05). This value is well within one standard error of the estimate shown using official reserves data, namely $\lambda$ = -0.25(0.11). Therefore, there seems to be little difference between estimates that use actual and official reserves data, at least in our specifications. All sterilization coefficients have the correct sign, although they are statistically insignificant for Korea, Malaysia, and the Philippines. Only Slovenia exhibits a sterilization coefficient that is not statistically different from one. Hence, for almost all economies considered, there is effectively incomplete sterilization, a feature of the data that is consistent with results elsewhere in the literature, as previously discussed.

## 6. Estimates of *xa*EMP, *xp*EMP and PICE

Figures 1 through 4 plot the PICE index for the 16 economies in our study against the rate of change in the nominal exchange rate. Figure 1 reveals that intervention was unsuccessful in Hong Kong toward the end of the Asian crisis, in the middle of the Asian crisis for Korea, and at the beginning of the same crisis for Singapore. The drop in the PICE index in 2000 may have indirectly reflected the world wide drop in stock prices after the bursting of the dot com stock market ‘bubble’. The Asian crisis hardly has any impact on Japan, except at the end of 1998 when intervention became temporarily unsuccessful. However, the unsuccessful intervention around early 1999 may have been due to the adoption of a zero interest rate policy while the rise in the effectiveness of intervention beginning around 2001 could be explained by the adoption of a policy of ‘quantitative easing’. Since Hong Kong successfully maintained its exchange rate peg against the US dollar one might think that all interventions were successful. However, the impact of intervention activities also reflects the macroeconomic environment. It should be noted that Hong Kong experienced a mild deflation lasting several years between 1998 and 2004, unlike the US to which the HK dollar was pegged. Indeed, Genberg and Pauwels (2005) report that foreign shocks in the form of declining prices for imported intermediate goods help explain the deflation. Exchange rate effects, coupled with wealth effects arising in part from the role of real estate prices were also found to play a role in Schellekens (2005).

Turning to the Asian ‘Tigers’, shown in Figure 2, there are some quarters with unsuccessful interventions in 1998 for the Philippines, while *xa*EMP is approximately equal to *xp*EMP throughout the entire crisis period for Thailand. There is also a marked change in the PICE for Malaysia after 2001 and this may be due to a change in Governorship at the central bank that was accompanied with a changed view about the intensity of interventions. Overall, intervention seems to have been relatively more successful in Malaysia than for Thailand (McCauley 2006).

If we now examine the four Latin and South American economies, as seen in Figure 3, there is little evidence of unsuccessful interventions except in the case of Mexico during the period of the Argentine crisis of 2000-2001. Finally, Figure 4 also reveals few instances of unsuccessful interventions. One exception is Hungary, shortly after the Russian default of 1998. Indeed, it is often the case for emerging market economies in our sample that intervention led to frequent reversals in the direction of change in the exchange rate. We view this as evidence of successful interventions.

Table 2 provides some summary statistics for the PICE index. It is notable that the fraction of unsuccessful interventions is highest among the industrial economies, at around 26% of the sample considered. A more detailed breakdown suggests that interventions are unsuccessful almost half the time for Singapore, followed by Hong Kong, and Japan. In a few countries, namely Indonesia, Malaysia, Argentina, Chile, the Czech Republic, Poland, and Slovenia, none of the quarters examined were consistent with unsuccessful interventions.

Turning to episodes of successful interventions, we break down the results according to whether the intervention led to a reversal in the direction of change in the exchange rate. In the vast majority of cases, interventions led to reversals in exchange rate changes. The only exceptions were Brazil, Chile, Mexico, and Slovenia.

Since Figures 1 to 4 plot our measure of the effectiveness of sterilized interventions against the rate of change in the nominal exchange rate, it is useful to consider the extent to which change in the PICE are correlated with exchange rate movements. In general, there seems to be no statistical link between these two variables. Exceptions are Indonesia and Slovenia, where the correlation is significantly negative, and Korea and Chile, where the same correlation is found to be significantly positive. This implies, for example, that increases in $xa$EMP, or decreases in $xp$EMP, are correlated with exchange rate depreciations in Korea and Chile, two inflation targeting economies, but result in appreciations for Indonesia and Slovenia. Neither country targets inflation. In the vast majority of cases, however, exchange rate expectations induced by sterilized interventions are unrelated to contemporaneous exchange rate changes.

The last column in Table 1 shows the average growth rate of foreign exchange reserves, and its standard deviation, over the sample considered. It is positive and fairly large for almost all economies, and it is possible that the relatively successful record of sterilizations may, at least partly, be explained by this phenomenon (also see Ho and McCauley 2007). Put differently, the absence so far of any negative economic consequences from sterilized interventions may, at least partly, be due to their success over the period considered. To investigate the connection between $xa$EMP, $xp$EMP and the nature of exchange rate regimes in the economies considered, or in the build-up of foreign exchange reserves, Table 3 considers the cross-sectional relationship between the type of exchange rate regime in place, or the growth of foreign exchange reserves, and the components of PICE. For exchange rate regimes we rely on the classifications developed by Levy-Yeyati and Sturzenegger (L-YS; 2005), and Reinhart and Rogoff (RR; 2004).

The results reveal that $xa$EMP is significantly lower the closer the exchange rate regime is to a pure float if the L-YS classification is used but not when the RR scheme is employed. There seems to be no statistical relationship between exchange rate regime classification schemes and *xp*EMP. Assuming that a pure float should translate into less *xa*EMP – after all, there is no threat of intervention expected if the policy is credible - our measure seems most compatible with Levy-Yeyati and Sturzenegger (2005). Hence, even if sterilized interventions can have persistent exchange rate effects, EMP appears lowest when the central bank is less likely to intervene, and agents expect this policy to be followed. The cross-sectional regressions reveal, however, a more reliable relationship between the growth of reserves and *xa*EMP. A rise in the former is actually found to increase *xa*EMP regardless of the exchange rate classification scheme used but there is no statistically significant link with *xp*EMP. Hence, a policy of foreign exchange reserves accumulation raises pressure on the exchange rate in the absence of an expectation of intervention. Presumably, this increases the incentive to intervene. Given the state of expectations, this ought to raise the incidence of successful interventions and this is what is essentially reported in Table 1. To the extent that the accumulation of foreign exchange reserves does not contribute to lowering *xp*EMP, this suggests a possible additional cost arising from sterilized interventions not usually considered in the intervention literature.

## 7. Conclusions

This paper has investigated exchange market pressure (EMP) for 16 economies that are a mix of the industrial and emerging varieties. We propose a measure of ex ante EMP (*xa*EMP) which, when combined with an indicator of *ex post* EMP (*xp*EMP), enables us to evaluate the effectiveness of sterilized interventions as the difference between the two measures. When converted into an index, the measure of the effectiveness of sterilized intervention is called the Policy Induced Changes in Expectations (PICE). The *xa*EMP is obtained by conducting a counterfactual experiment where the central bank does not intervene in foreign exchange markets and agents correctly anticipate this policy. Both the *xa*EMP and *xp*EMP require a properly specified small open economy with the *xa*EMP found by numerically solving the model under the assumption of rational expectations.

Our estimates of the PICE for emerging markets in Asia, Central Europe, Latin and South America suggest that sterilized interventions do have persistent effects on the exchange rate and, hence, can be effective in all the countries considered. There are, as usual, several caveats to this conclusion. First, the success of sterilized intervention is to a significant degree conditional on the fact that there have been frequent changes in the exchange regime in many of the countries examined, and this feature may not have been fully captured in our structural model. Second, even if sterilized intervention can be effective, *xa*EMP is smallest the more flexible is the exchange rate regime. Consequently, intervention in foreign exchange markets might be effective but it could also needlessly raise exchange market pressure relative to a float and the costs associated with such a policy. Third, our approach focuses on the impact of sterilized interventions on exchange rate changes only. Higher moment effects of foreign exchange intervention, which have lately attracted considerable attention in the literature, are not considered. Finally, in countries where inflation targeting has been adopted, typically late in our sample, there is the potential of a conflict between a policy of sustained intervention and the inflation objective, not to mention the difficulties inherent in communicating the advisability of intervention in foreign exchange markets for policy makers.

## References

Andrews, Donald W. K. (1999), "Consistent Moment Selection Procedures for Generalized Method of Moments Estimation," *Econometrica*, 67(3): 543-64.

Babula, Andrea and Ici Otker-Rober (2002), "The Evolution of Exchange Rate Regimes Since 1990: Evidence From De Facto Policies," IMF Working Paper No.02/155, Washington D.C.: International Monetary Fund.

Bank for International Settlements (2005), "Foreign Exchange Market Intervention in Emerging Markets: Motives, Techniques and Implications," BIS Paper No.24.

Bank for International Settlements (1998), 68th *Annual Report* (Basel, Switzerland: Bank for International Settlements).

Blundell-Wignall, A. and Paul R. Masson (1985), "Exchange Rate Dynamics and Intervention Rules," International Monetary Fund Staff Papers: 132-59.

Bonser-Neal, Catherine and Glenn Tanner (1996), "Central Bank Intervention and the Volatility of Foreign Exchange Rates: Evidence from the Options Market," *Journal of International Money and Finance*, 15: 853-78.

Calvo, Guillermo and Carmen Reinhart (2004), "Fear of Floating," *Quarterly Journal of Economics*, 117 (2): 379-408.

Canales-Kriljenko, Jorge I (2004), "Foreign Exchange Intervention in Developing and Transition Economies: Results of a Survey," IMF Working Paper No.04/04, Washington D.C.: International Monetary Fund.

Chang, Yuanchen and Stephen J. Taylor (1998), "Intraday Effects of Foreign Exchange Intervention by the Bank of Japan," *Journal of International Money and Finance*: 191-210.

Chiu, Priscilla (2003), "Transparency Versus Constructive Ambiguity in Foreign Exchange Intervention" BIS Working Paper No.144.

Darvas, Zsolt and Gábor Vadas (2005), "A New Method for Combining Detrending Techniques with Application to Business Cycle Synchronization of the New EU Members," MNB Working Paper 2005/5, National Bank of Hungary.

Disyatat, Piti and Gabriele Galati (2005), "The Effectiveness of Foreign Exchange Intervention in Emerging Market Countries," in *Foreign Exchange Market Intervention in Emerging Markets: Motives, Techniques and Implications.* (Basel, Switzerland: BIS): 97-113.

Engel, Charles and Ken West (2005), "Exchange Rates and Fundamentals," *Journal of Political Economy*, 113(3): 485-517.

Fischer, Stanley (2001), "Exchange Rate Regimes: Is the Bipolar View Correct?" *Journal of Economic Perspectives*, 15(2): 3-24.

Genberg, H. and L.L. Pauwels (2005), "Wage-Price Dynamics and Deflation in Hong Kong," *Pacific Economic Review*, 10(June): 191-216.

Gerlach, S. and P. Gerlach-Kristen (2006), "Monetary Policy Regimes and Macroeconomic Outcomes: Hong Kong and Singapore," BIS Working Paper No.204.

Gerlach, Stefan and Matthew Yiu (2004), "Estimating Output Gaps in Asia: A Cross-Country Study," *Journal of the Japanese and International Economies*, 18(1): 115-36.

Ho, Corrinne and Robert N. McCauley (2007), "Resisting Appreciation and Accumulating Foreign Exchange Reserves: Examining the Domestic Financial Consequences," BIS Working Paper.

Hodrick, Robert J. and Sanjay Srivastava (1984), "An Investigation of Risk and Return in Forward Foreign Exchange," *Journal of International Money and Finance*, 3: 5-29.

Kasa, Kenneth (1999), "Why Attack a Currency Board?" Federal Reserve Bank of San Francisco *Economic Letter*, 99-36, November.

Kochhar, Kalpana, Prakash Loungani and Mark R. Stone (1998), "The East Asian Crisis—Macroeconomic Developments and Policy Lessons," IMF Working Paper No.98/128, Washington D.C.: International Monetary Fund.

Levy-Yeyati, Eduardo and Federico Sturzenegger (2005), "Classifying Exchange Rate Regimes: Deeds vs. Words," *European Economic Review*, 49(6): 1603-35.

McCauley, R. (2006), "Understanding Monetary Policy in Malaysia and Thailand: Objectives, Instruments, and Independence," in BIS Paper No.31, Monetary Policy in Asia: Approaches and Implementation, Proceedings of a BIS/ HKIMR Conference, 21-22 November 2005, December: 172-98.

Neely, Christopher J. (2005), "An Analysis of Recent Studies of the Effect of Foreign Exchange Intervention," Federal Reserve Bank of St. Louis *Review*, 87(6): 685-717.

Pétursson, Thóarinn G. (2005), "Inflation Targeting and Its Effects on Macroeconomic Performance," SUERF Studies 2005/5.

Reinhart, Carmen and Kenneth S. Rogoff (2004), "The Modern History of Exchange Rate Arrangements: A Reinterpretation," *Quarterly Journal of Economics*, 119(1): 1-48.

Rennison, Andrew (2003), "Comparing Alternative Output-Gap Estimators: A Monte Carlo Approach," Bank of Canada Working Paper No.2003-8.

Rudd, Jeremy and Karl Whelan (2005), "New Tests of the New-Keynesian Phillips Curve," *Journal of Monetary Economics*, 52(6): 1167-81.

Sarno, L. and M.P. Taylor (2001), "Official Intervention in the Foreign Exchange Market: Is It Effective and, If So, How Does It Work?" *Journal of Economic Literature*, 39: 839-68.

Schellekens, P. (2005), "Deflation in the Hong Kong SAR," *Pacific Economic Review*, 10: 243-60.

Siklos, Pierre L. and Diana N. Weymark (2006), "Measuring the Impact of Intervention on Exchange Market Pressure," Working Paper, Wilfrid Laurier University and Vanderbilt University.

Siklos, Pierre L. (2002), *The Changing Face of Central Banking, Cambridge*: Cambridge University Press.

Sims, Christopher A. (2001) "Solving Linear Rational Expectations Models," *Computational Economics*, 20: 1-20.

Stock, James H., Jonathan H. Wright and Motohiro Yogo (2002), "A Survey of Weak Instruments and Weak Identification in Generalized Method of Moments," *Journal of Business and Economic Statistics*, 20(4): 518-29.

Tsang, Shuk-ki (1999), "The Currency Board Arrangement in Hong Kong, China," Working Paper, Hong Kong Baptist University.

Weymark, Diana N. (1995), "Estimating Exchange Market Pressure and the Degree of Exchange Market Intervention for Canada," *Journal of International Economics*, 39: 249-72.

Weymark, Diana N. (1998), "A General Approach to Measuring Exchange Market Pressure," *Oxford Economic Papers*: 106-21.

Willett, Thomas D. (2003), "Fear of Floating Needn't Imply Fixed Rates: An OCA Approach to the Operation of Stable Intermediate Currency Regimes," *Open Economies Review*, 14(1): 71-91.

Williamson, John (2000), *Exchange Rate Regimes for Emerging Markets: Reviving the Intermediate Option*, Washington, D.C.: Institute for International Economics.

Yam, Joseph (1998), "Hong Kong: Financing Asia's Development," keynote address at the Hong Kong Development Council Financial Roadshow, Tokyo, Japan, March.

**Table 1. Key Parameter Estimates**

| *Industrial Economies* | Phillips curve Model type | $\alpha_1^{\pi}: BL$ <br> $\alpha_{-1}^{\pi}: FL$ | IS curve Model type | $\beta_1^{\tilde{y}}: BL$ <br> $\beta_{-1}^{\tilde{y}}: FL$ | μ | λ |
|---|---|---|---|---|---|---|
| **HK** | BL | 0.92 | FL | 0.42 | 0.07 | -0.54 |
| **K** | FL | 0.41 | BL | 0.73 | *0.05* | *-0.23* |
| **J** | FL | 0.58 | BL | 0.86 | -1.38 | -0.25 |
| **SI** | BL | 0.69 | FL | 0.58 | 1.52 | -0.39 |
| ***Asia*** | | | | | | |
| **IN** | FL | 0.24 | BL | 0.84 | 1.36 | -0.56 |
| **MA** | BL | 0.89 | FL | 0.63 | *-0.17* | *-0.03* |
| **PH** | BL | 0.98 | FL | 0.62 | 0.36 | *-0.14* |
| **TH** | FL | 0.40 | FL | 0.66 | 1.45 | -0.39 |
| ***Latin and South America*** | | | | | | |
| **AR** | FL | 0.67 | BL | 0.93 | *-0.03* | -0.49 |
| **BR** | FL | 0.39 | BL | 0.30 | 0.24 | -0.40 |
| **CH** | FL | 0.74 | BL | 0.75 | -0.87 | -0.24 |
| **MX** | FL | 0.46 | BL | 0.73 | *0.01* | -0.19 |
| ***Europe*** | | | | | | |
| **CZ** | FL | 0.80 | BL | 0.95 | -0.16 | -0.30 |
| **H** | BL | 0.96 | BL | 0.56 | -0.63 | -0.16 |
| **PL** | BL | 0.94 | FL | 0.21 | -0.20 | -0.15 |
| **SL** | BL | 0.92 | FL | 0.64 | 0.49 | -0.97 |

Note: Coefficient values in *italics* are statistically insignificant; otherwise coefficients are statistically significant at least at the 10% level. FL = forward-looking model estimated via GMM with instruments discussed in the text and in the appendix. BL= backward-looking model estimated via OLS. The key parameters shown are the lagged or lead coefficient on inflation, in the case of the Phillips curve, and the lagged or lead coefficient on the output gap, in the case of the IS equation (see column headings). μ and λ are, respectively, the measure of substitutability between domestic versus foreign bonds (i.e., US investment; see equation (3)), and the sterilization parameter (see equation (8)).

**Table 2. PICE Summary Statistics**

| Economy/Region | Ineffective Interventions % of total sample | Effective Interventions Reversals (%) | Effective Interventions Same Direction (%) | Correlation $(\Delta q, \Delta PICE)$ | Reserves Growth (s.d.) |
|---|---|---|---|---|---|
| Industrial | 26 | 48.7 | 25.3 | -0.04 | 14.7 (14.7) |
| Asian 'Tigers' | 5.6 | 59 | 35.4 | -0.13 | 15.5 (23.1) |
| Latin & S. America | 6.9 | 35.1 | 58 | -0.03 | 22.2 (59.6) |
| Europe | 4.6 | 56.9 | 38.5 | -0.06 | 21.3 (25.9) |
| HK | 32.5 | 40.5 | 27 | -0.06 | 9.6 (11.9) |
| IN | 0 | 77.8 | 22.2 | -0.59* | 22.0 (34.8) |
| J | 22.5 | 42.5 | 35 | -0.17 | 18.7 (12.6) |
| K | 2.7 | 91.9 | 5.4 | 0.63* | 22.2 (20.4) |
| MA | 0 | 55 | 45 | 0.10 | 14.4 (23.9) |
| PH | 17.5 | 52.5 | 30 | -0.07 | 14.4 (14.9) |
| SI | 47.5 | 32.5 | 20 | -0.05 | 8.2 (4.6) |
| TH | 21.6 | 56.8 | 21.6 | 0.08 | 10.0 (9.2) |
| AR | 0 | 57.9 | 42.1 | 0.17 | 14.4 (29.8) |
| BR | 5.6 | 38.9 | 55.5 | 0.15 | 47.6 (105.6) |
| CH | 0 | 29 | 81 | 0.53* | 7.1 (11.3) |
| MX | 20 | 15 | 65 | -0.06 | 19.7 (40.0) |
| CZ | 0 | 75.7 | 24.3 | 0.10 | 19.4 (28.4) |
| H | 19.4 | 63.9 | 16.7 | 0.11 | 15.9 (22.7) |
| PL | 0 | 75 | 25 | 0.03 | 24.9 (29.0) |
| SL | 0 | 15 | 85 | -0.41* | 25.1 (22.3) |

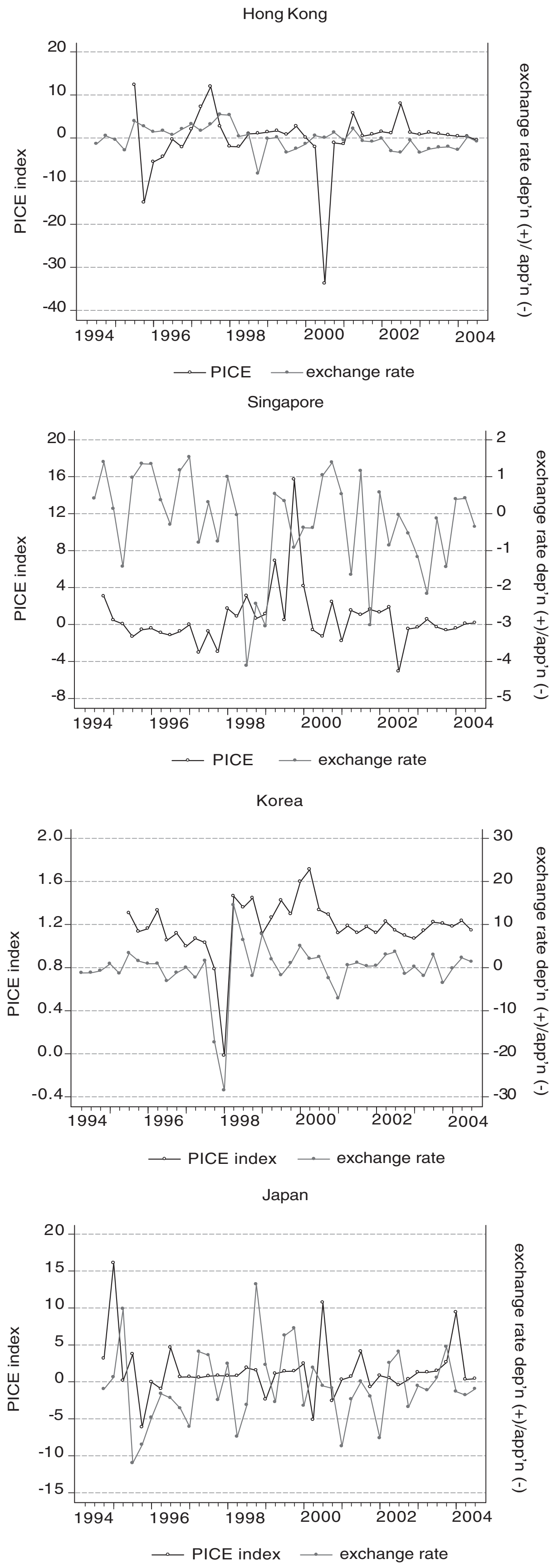
Note: The effectiveness of Intervention measures the percent of the sample the PICE is in the range where sterilized intervention was effective (i.e., PICE>0). A distinction is made between successful interventions that change the direction of the exchange rate (reversals) versus changes that reduce $xa$EMP in the same direction (i.e., a reversal means sign ($xa$EMP) ≠ sign ($xp$EMP)). The sum of the first three columns should add to 100%. The last column gives the simple correlation between realized exchange rate changes and changes in the PICE. * indicates that the correlation is statistically significant at least at the 5% level. Reserves growth based on quarterly data for the 1994-2005 period, inclusive, with standard deviations in parenthesis.

**Table 3. *xa*EMP, *xp*EMP, the Exchange Rate Regime, and International Reserves**

| Variable | *xa*EMP L-YS Coefficient (s.e.) | *xp*EMP L-YS Coefficient (s.e.) | *xa*EMP RR Coefficient (s.e.) | *xp*EMP RR Coefficient (s.e.) | L-YS *xa* Coefficient (s.e.) | L-YS *xp* Coefficient (s.e.) | RR *xa* Coefficient (s.e.) | RR *xp* Coefficient (s.e.) |
|---|---|---|---|---|---|---|---|---|
| Constant | 2214.6 | 357.7 | 3218.2 | 375.5 | 2993.8 | 332.8 | 3037.1 | 334.1 |
| | (468)* | (13.9)* | (1416)+ | (19.1)* | (93.74)* | (2.89)* | (89.65)* | (2.69)* |
| ER | -459.4 | 10.14 | -34.68 | 1.43 | – | – | – | – |
| regime | (229.7)+ | (6.73) | (724.4) | (9.70) | | | | |
| $\Delta \ln$ RES | – | – | – | – | 2.88 | 9.90 | 2.79 | 7.16 |
| | | | | | (0.16)* | (5.63)++ | (0.15)* | (5.37) |
| $\bar{R}^2$ | 0.96 | 0.35 | 0.99 | 0.37 | 0.74 | 0.71 | 0.75 | 0.72 |
| F.E. | 2790 | 21.8 | 4957 | 19.67 | 167.7 | 31.15 | 168 | 31.15 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| Obs. | 596 | 596 | 596 | 596 | 596 | 596 | 596 | 596 |
| Cross-sections | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |

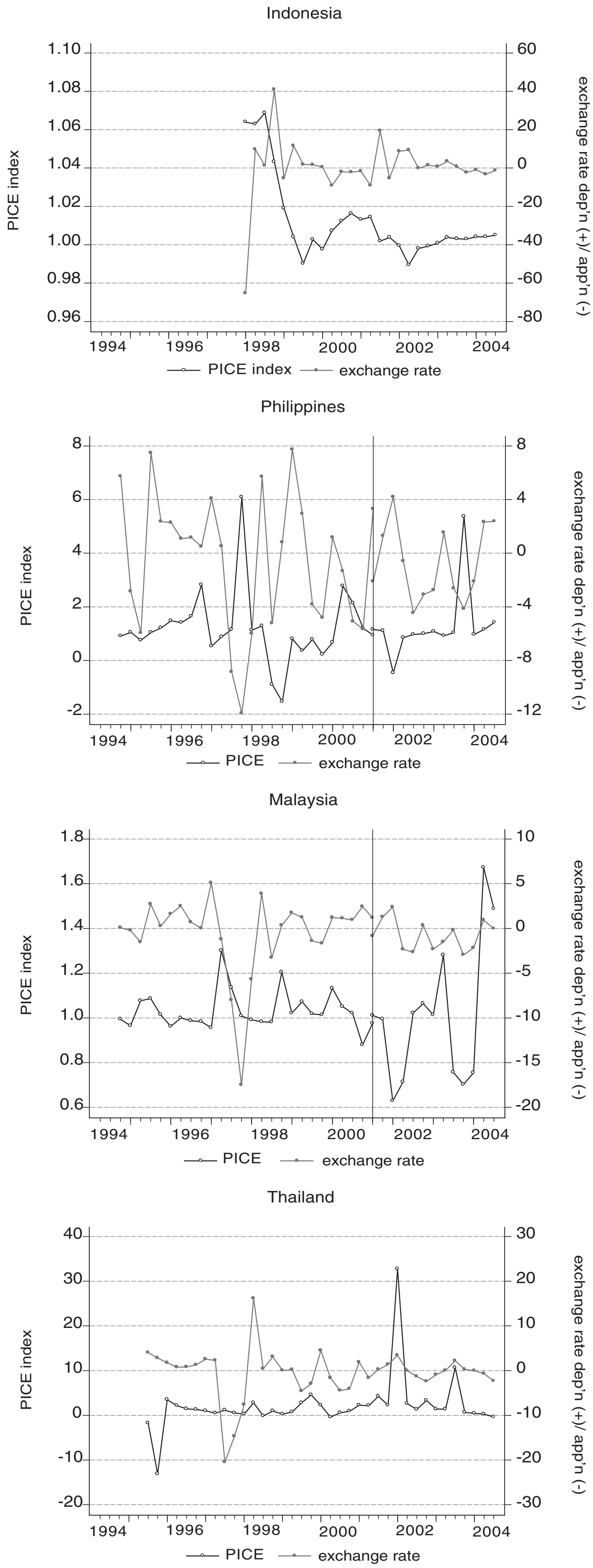
Note: For details about the timing of exchange rate regimes, see the appendix. RR is Reinhart and Rogoff's classification; L-YS is the Levy-Yeyati and Sturzenegger classification. Cross-section regressions estimated via weighted instrumental variable estimation with a constant, the rate of change in the exchange rate, inflation lagged one period, and the domestic-US interest rate differential as the instruments. In the case of the regressions on international reserves growth, the exchange rate regime classifications of L-YS and RR serve as additional instruments. The fixed effects are normalized so they add up to zero. Fixed effects coefficients and their standard errors available on request. Exchange rate regimes were coded as follows: (L-YS) Fixed = 0, dirty/crawl = 1, dirty = 2, float = 3; (RR) Pegged = 0, crawling = 1, managed float = 2, currency board/dual = 3, float = 4. The terms are the ones used by the respective authors. F.E. is the test for the null of redundant fixed effects, based on least squares estimation with cross-section weights; p-values are shown in parenthesis.

**Figure 1. Industrial Economies**



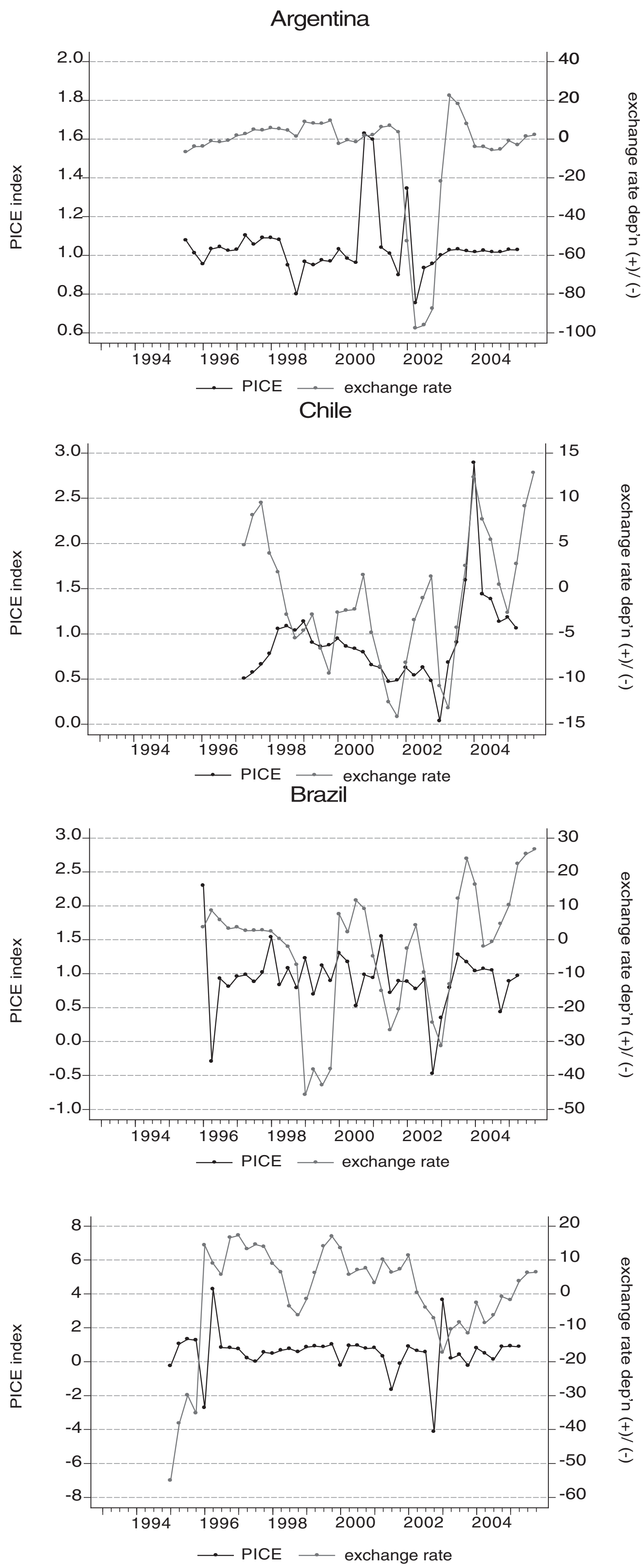

Note: For the definition of PICE, see equation (11). The right hand axis is defined as the 100 times the log difference in the nominal exchange rate.

**Figure 2. PICE Asian 'Tigers'**



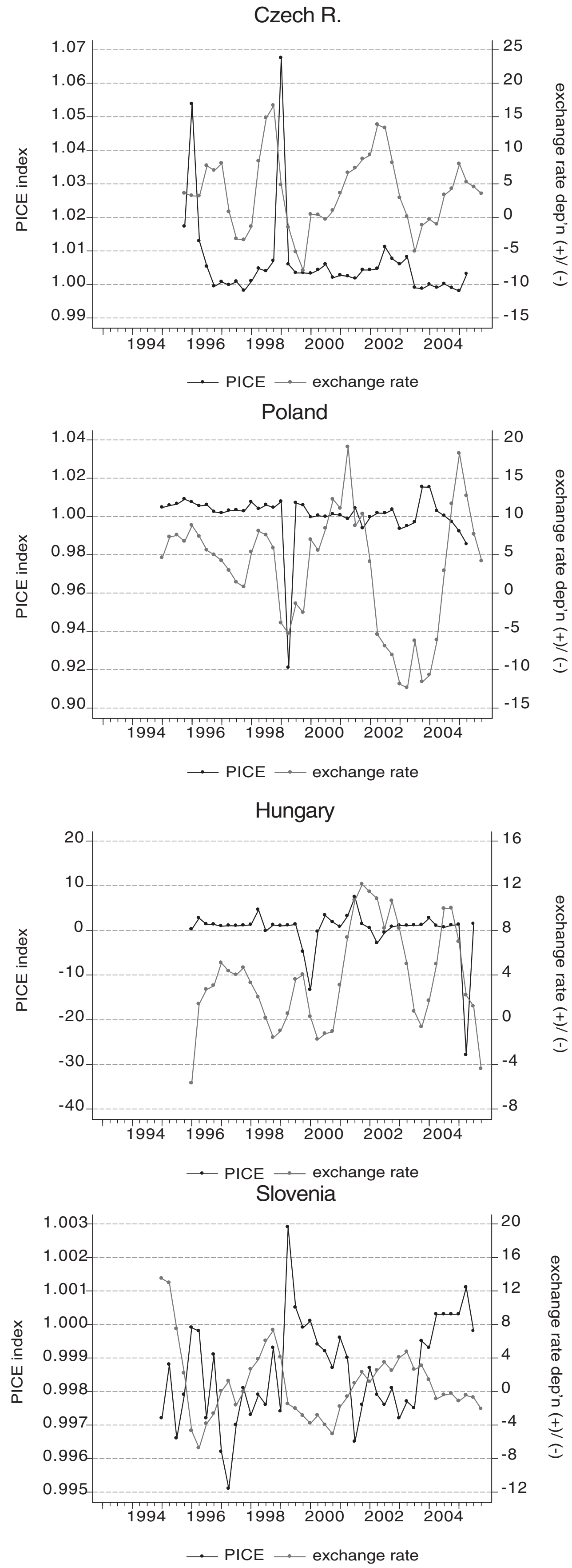

Note: See note to Figure 1. For Malaysia the value for 2001Q2 (=39.92) was excluded to avoid distorting the figure and is identified by the vertical line.

## Figure 3. Latin and South American Economies




Note: See note to Figure 1.

## Figure 4. PICE: European Economies




Note: See note to Figure 1.