

**MEASURING EXCHANGE RATE FLEXIBILITY:
A Two-Parameter Exchange Market Pressure Approach***

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Abstract

Recognition that official classifications of exchange rate regimes are often misleading has led to considerable interest in behavioral measures. Many of these measures are related to the concept of exchange market pressure that shows how policy interventions affect how much a given change in excess demand in the foreign exchange market shows up changes in reserves versus changes in the exchange rate. We argue that this is the correct conceptual approach to measuring the degree of exchange rate flexibility of a regime, but that several of the most popular applications of this approach use functional forms that destroy useful information. One important problem that has been overlooked is that the approach is clearly defined only for leaning against the wind intervention and we find that fairly often changes in reserves and exchanges don't fit with this type of intervention. A second important issue is that where there are trends the interpretation of these three types of measures becomes more difficult. We suggest that to deal with this issue a two parameter approach is needed rather than the one parameter measure that have been used in most of the previous literature. We illustrate the approach with an application to Japan.

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I. Introduction

There has been considerable recent interest in the classification of exchange rate regimes in order to investigate a wide range of hypotheses. These include the relationships of alternative exchange rate regimes with inflation, growth, and currency crises. It has become widely recognized that official classifications often can be quite misleading. This has led to a number of efforts to produce behavioral measures of exchange rate policies that capture what governments actually do rather than what they say they do. Advances have been made in the construction of such behavioral measures including the IMF measure that is based on staff judgments of the policies actually being followed [Bubula and Ötoker-Robe, 2002], Reinhart and Rogoff [RR, 2004]'s herculean "Natural" classification that puts emphasis on the behavior of black market or parallel rates, and a number of classifications based on the statistical behavior of exchange rates, international reserves, and in some cases also interest rates, such as those of Weymark [1995, 1997, and 1998], Calvo and Reinhart [CR, 2002] and Levy Yeyati and Sturzenegger [LYS, 2005].

A major limitation of the RR measure is that it looks only at the behavior of exchange rates, though the actual behavior of exchange rates is due to a combination of shocks and government policy, i.e. their reaction functions. Thus one can not tell from looking at small movements in exchange rates whether these are due primarily to government intervention or to an absence of large shocks. Likewise a large exchange rate movement needn't imply a freely floating rate since this could result from a large shock and leaning against the wind intervention. Such cases are not just theoretical possibilities. For example, there are important instances where countries like Japan and Korea have had large exchange rate movements while also having considerable intervention to keep these movements from being even larger. Looking at the behavior of exchange rates alone led RR to the conclusion that these were cases of freely floating rates when they were in fact managed floats.

In such cases to correctly identify the degree of flexibility of an exchange rate regime we need to consider both changes in exchange rates and the amount of exchange market intervention (usually

proxied by changes in international reserves)¹. We already have a concept based on the combination of these changes, that of Exchange Market Pressure (EMP) developed by Girton and Roper. In this approach the degree of exchange rate flexibility is measured by the proportion of exchange market pressure that is reflected in movements in the exchange rate relative to the proportion that is met through official intervention. The greater the former, the more flexible is the regime. This basic idea also underlies most other recent efforts at statistical classification of exchange rate regimes such as Calvo and Reinhart (2002) and Levy Yeyati and Sturzenegger (2005). We argue that the functional forms that have been used in many of such studies misses important information.

The exchange market pressure ratio has a clear conceptual meaning for the degree of exchange rate flexibility only for intervention that leans against the wind, i.e. where there is a positive correlation between changes in reserves and changes in the value of the currency. We find, however, that for many countries a substantial number of monthly observations display correlations between changes in exchange rates and reserves that are of the wrong signs for leaning against the wind intervention. This type of problem cannot be addressed by the popular method of looking at the ratios of variances of exchange rate and reserve changes. This approach also runs into problems when there are trends in reserves or exchange rates. We argue that such cases at least two parameters are necessary to classify exchange rate regimes as there is no clear theoretical basis for comparing the relative degree of flexibility of a more rapidly trending regime with a narrow band for allowable short term fluctuations with a more slowly trending regime with a wide band. Thus we need to distinguish trend behavior from behavior with respect to deviations from trend. We discuss operational issues involved in applying this approach along with uses concerning proxies for intervention and consider the role of interest rates in classifying exchange rate regimes. We then offer an illustration with respect to Japanese exchange rate policy where actual intervention data is available. While there are some differences from the reserve change proxy when using the actual intervention data the qualitative conclusions remain unchanged, supporting the view that reserve changes are a reasonable albeit imperfect proxy for actual intervention.

¹ Actual intervention data is publicly available for only a few countries.

II. Exchange Market Pressure (EMP)

1. The Propensity to Intervene and Exchange Market Pressure

The concept of exchange market pressure introduced by Girton and Roper [1977] is a measure of the gap between quantities demanded and supplied in the foreign exchange market at a particular exchange rate. It provides a way of comparing pressures under alternative exchange rate regimes by adding changes in reserves (as a measure of official intervention) and exchange rate changes.² This is illustrated in Figure 1 where a shift in the demand for foreign exchange can be taken all on the exchange rate with no intervention ($E_0 \Rightarrow E_1$) or all on intervention with no change in the exchange rate ($E_0 \Rightarrow E_2$) or any combination in between ($E_0 \Rightarrow E_3$). We can then define the degree of flexibility of an exchange rate regime as the inverse of the authorities' propensity to intervene to limit exchange rate fluctuations, with possible values running from zero to one. Thus under a fixed rate regime all the pressure is reflected in changes in reserves and the coefficient of flexibility is zero, while under a free float it would all be reflected in changes in the exchange rate with a flexibility coefficient of one.

With a managed float or some form of movable peg, the authorities follow a mixed response by intervening to take some of the pressure off of the exchange rate and the rest on reserves. Such leaning against the wind could be light or heavy and steady or sporadic. By looking at the ratio of percentage changes in the exchange rate to the sum of percentage changes in the exchange rate and reserves, we have a continuous index of the propensity to intervene in the foreign exchange market that varies between zero and one. One minus the index of the propensity to intervene gives the degree of exchange rate flexibility, i.e. the degree of exchange rate flexibility is the percentage change in the exchange rate divided by the percentage change in reserves plus the percentage change in the exchange rate.

This approach is superior to looking at the behavior of the exchange rate alone since it allows us to distinguish (at least conceptually) whether a low level of exchange rate volatility is due to a low level of shocks or to a high propensity of the authorities to intervene. Likewise, where changes in exchange

² Of course changes in reserves are far from a perfect proxy for exchange market intervention. See the analysis and references in Willett et al. (2011). For the analytic purpose of this paper, however, we will use the two terms as identical.

market pressure are substantial there may be considerable exchange rate changes even in the face of heavy intervention. Japan and Korea are important recent examples.³ Based only on the behavior of exchange rates, RR classified them as free floats at a time when they were also intervening heavily and should more appropriately be classified as a managed float. Several recent efforts at behavioral classifications have included changes in reserves as well as exchange rates, but have not paid sufficient attention to the theoretical foundations of the functional forms for their equations.

It is important to recognize that in the exchange market pressure approach an index of flexibility is clearly defined only when there are positive correlations between changes in reserves and currency values. For example the EMP approach is clearly defined only for intervention that leans against the wind, to slow down exchange rate movements. For many countries, however, a substantial minority of monthly observations have negative correlations. Measures based on ratios of variances do not distinguish between positively and negatively correlated observations.

If the authorities are leaning with the wind to accelerate exchange rate changes this is clearly a managed float, but it is not clear whether this should be considered as super flexibility or as an extreme case of heavy management.⁴ For testing many propositions such as the unstable middle and two-corners hypotheses these would have importantly different interpretations.⁵ Such behavior usually violates the codes of good behavior for monetary authorities, especially if they are forcing down the rate for competitive advantage. However, as will be discussed below, it is not uncommon for monthly changes in reserves and exchange rates to violate the leaning against the wind assumption. Thus this issue of ‘wrong signs’ is not trivial and presents a problem for the studies that have based their classification on the ratios of variances of changes in exchange rates, reserves, and sometimes interest rates since such measures do not distinguish between positive and negative signs of the relation of the changes in reserves to the

³ On the Korean case see Willett and Kim (2006). The Japanese case is considered in section four.

⁴ Weymark’s treatment of this issue will be discussed in Section II-3.

⁵ For discussions of testing these hypotheses see the analyses in Angkinand, Chiu, and Willett (2009).

changes of exchange rates in each period.⁶ This problem has generally not been acknowledged in the literature. As we will discuss below, trends can also present a problem for ratio of variances approach.

In interpreting the economic meaning of the propensity to intervene, one faces the same problem as for the relative weights of the variables in the construction of the indices of currency crises. In each case, what one would like to have is the slope of the excess demand curve for foreign exchange.⁷ Unfortunately reliable estimates for the slope and shift coefficients do not exist for a broad sample of countries and in addition are likely to be time-variant. Thus we should not interpret a coefficient of 0.5 on the propensity to intervene as being the true mid point on the scale except in particular models.⁸ The comparison of coefficients across countries makes the weaker but still heroic assumption that while the excess demand elasticity is unknown, it is the same across countries and time.

An advantage of this approach is that we can obtain a ratio of changes in the exchange rate to changes in reserves for each month, allowing us to investigate changes in regimes on an intra-year basis. Of course there may be a great deal of variability and/or noise in the monthly ratios. Typically we would look at an average over longer time periods (along with its variance) but plots of the ratios can be quite helpful in classifying shifts in regimes and are especially useful for investigating changes in operating rules within regimes such as changes in the slopes of crawling peg regimes or changes in the intensity of intervention under a managed float. While focusing on such short-run behavior will often be of limited relevance when attempting to make broad classifications of regimes such as managed versus free floats,

⁶ Examples include Calvo and Reinhart (2002), Hernandez and Montiel (2003) and Levi-Yeyati and Surtzenegger (2005). For summaries and critiques of these approaches see Willett et al. (2011).

⁷ See Eichengreen et al (1994), Weymark (1997), Nitithanprapas (2000), Willett et al (2005), and Frankel and Wei (2008). For interest rates the relevant measure is the size of the shift in the excess demand curve, (due to primarily to capital flows) for a unit changes in the interest rate. Recent studies by the IMF (2007) and Frankel and Wei (2008) make use of this concept. They weigh the changes in reserves (or interest rate) and exchange rates by the inverse of their standard deviations or precision weights as is frequently done in the construction of crisis indices. This is not a theoretically appropriate weighting approach for either purpose as precision weights reflect the government's reaction function rather than the slope of the excess demand in foreign exchange market. See Willett et al (2005).

⁸ In a strict monetary model such as Girton and Roper (1977) used to introduce the concept of exchange market pressure, the mid point of the degree of flexibility would be 0.5 because under the assumptions of that model sterilized intervention would have no effect. (Sterilized intervention occurs where the domestic monetary effects of the intervention are offset by government actions). With unsterilized intervention there will be an equivalent effect on the domestic money supply and prices in the strict monetary model. Despite some initial support, the weight of subsequent empirical research has shown that the pure monetary model is much too restrictive. (See for example, Isard (1995)).

few floats are truly free with no or only very occasional interventions. Many of the most interesting issues involve how heavily floats are managed and whether this is done in an asymmetric manner that contains mercantilist elements. Just as there has been considerable research on monetary policy reaction functions, the characterization of exchange rate policy reaction functions is also of interest. For such purposes, looking at behavior over fairly short time periods can be quite important.

2. Some Problems with the Ratio of Variances

A number of recent studies such as CR [2002], and Hernández and Montiel [2003] look at the ratios or the volatilities of exchange rates, international reserves and interest rates to characterize exchange rate policies.⁹ LYS also use this basic approach but in a more sophisticated form, using cluster analysis to divide countries into five groups based on three classifying variables: exchange rate volatility, volatility of exchange rate changes, and volatility of reserves. They divide each of the classifying variables into two categories, high volatility and low volatility using K-means filtering and find combinations to define four types of exchange rate regimes: fixed, crawling peg, dirty floating, and flexible.¹⁰ If all three classifying variables have low volatilities they are classified as inconclusive in this approach.

⁹ Hernández and Montiel compare the volatilities of each variable across countries separately rather than comparing their ratios. After the initial draft of this paper was completed, the IMF (2007, Ch. 3) published a study that directly used the idea of the proportion of exchange market pressure taken on the exchange rate versus reserves to classify exchange rate regimes by what was labeled an index of resistance. This study did not consider the issue of wrong signs as emphasized here.

¹⁰ LYS use the following criteria to characterize each regime: low exchange rate volatility, low volatility of exchange rate changes, and high volatility of reserves for fixed regimes; high exchange rate volatility, high volatility of exchange rate changes, and low volatility of reserves for flexible regimes; high exchange rate volatility, high volatility of exchange rate changes, and high volatility of reserves for dirty floating regimes; and high exchange rate volatility, low volatility of exchange rate changes, and high volatility of reserves for crawling peg regimes. The inclusion of these crawling band category is one method of dealing with the issue of trends that we discuss below. LYS state that, “k-means cluster analysis has the advantage of avoiding any discretion from the researcher except selection of the classifying variables and assignment of clusters to different exchange rate regimes and our method evaluates the deviations in the classifying variables relative to the world norm, rather than to some ad hoc reference cases”. This is attractive but has no clear economic rationale behind them.

LYS divide each classifying variable into two categories, which is not unreasonable but it isn't clear that more categories would not be useful. With LYS' two categories we have eight cases including their 5 cases and an additional 3 cases such as (i) low volatile exchange rate, highly volatile exchange rate changes, and low volatile reserves (ii) low volatile exchange rate, highly volatile exchange rate changes, and high volatile reserves (iii) highly volatile exchange rate, low volatile exchange rate changes, and low volatile reserves. The first and the second cases are not possible for practical purposes in the sense that exchange rates are very volatile with highly volatile exchange rate changes. However, the third case is possible implying LYS should have taken 6 groups into account.

Calvo and Reinhart (CR) note one problem with using ratio of variances is that variances may be distorted by outliers. Thus they advocate an approach based on the frequency with which classifying variables remain within a threshold limit, arguing that "... the probabilistic nature of the statistic conveys information about the underlying frequency distribution that is not apparent from the variance." [p 384].¹¹ As we will discuss in following sections using ratios of variances also does not deal with the problems of currency regimes and of trends.

3. Should the behavior of interest rates be included?

Some studies have argued that the behavior of interest rates should be included in measures of exchange rate regimes. Thus for example, Calvo and Reinhart (2002) include the variability of interest rates in their classification scheme. It is clearly appropriate to use changes in interest rates or other monetary variables such as money supplies or degrees of sterilization in classifying countries' overall monetary policies *cum* exchange rate regimes (see Willett et al. 2011), but it is not clear in what way the behaviors of these monetary policy variables should be related to the classification of the degree of flexibility of the exchange rate regime. Calvo and Reinhart are able to make a strong link only by making the assumption that interest rate changes are only used to limit exchange rate movements. They argue correctly that "such interest rate volatility is not the result of adhering to strict monetary targets in the face of large and frequent money demand shock..." [p 392]. However, they then jump directly from this statement to the conclusion that "Interest rate volatility would appear to be the byproduct of a combination of trying to stabilize the exchange rate through domestic open market operation and lack of credibility" [p 392]. This leaves out the possibility of the effects of other types of shocks and of

The third group could be regarded as flexible regime or inconclusive depending on whether episodes with the volatile exchange rate can be considered as having enough flexibility for the flexible regime.

LYS report minimum, centroid, and maximum values of each classifying variables. Values of each classifying variables are overlapped across exchange rate regimes. There are also several peculiar levels of classifying variables. For example, centroids of volatility of exchange rate, volatility in the change of the exchange rate, and volatility of reserves for the flexible regime are 2.3, 2.0, and 4.6. LYS describe them as high, high, and low. The volatility measures in the dirty float regime are 17.3, 8.5, and 6.98 and LYS describe them as high, high, and high. But the first two numbers are very different and the third numbers are similar. The maximum average monthly volatility in the exchange rate of the float regime and the fixed regime is the same, 7.22 percent. Therefore, LYS do not have clear-cut reference variables for each exchange rate regimes.

¹¹ RR also use the similar approach. For example, RR classify a case as a de facto peg if the probability that the monthly exchange rate change remains within one percent band over rolling 5-year period is 80 percent or higher.

domestically motivated monetary policy actions dictated by discretion rather than monetary rule. Interest rate changes can also be used to protect reserve levels. Thus we see no clear basis for a presumption that higher interest rate variability should be considered solely as an indicator of less flexibility in the exchange rate regime. This is certainly an issue worthy of further investigation, however.

4. Observations Undefined within the EMP Framework

As was discussed in the previous section, where government policies lean with rather than against the wind, i.e. where reserve declines occur during a period of currency appreciation or reserve increases during a period of depreciation, the concept of the propensity to intervene is not well defined in the EMP framework. A look at the data for several countries shows that these combinations occur fairly frequently. When the series are detrended, the frequency of these wrong sign months tends to decline, but they remain fairly common. One of the most striking examples is Uruguay during 1990-2001. Over this period there is a clear trend in both exchange rate and reserves. When those series are detrended, the number of wrong signs decreases but is still substantial, falling from 76 observations to 53, out of a total of 133.

One method of dealing with wrong signs has been provided by Weymark (1995, 1997, and 1998), who was the first to explicitly relate measures of the degree of exchange market intervention to the concept of exchange market pressure. Weymark uses a full range of estimates from plus to minus infinity rather than the zero to one bounds used in our formulations. She defines the degree of intervention as the proportion of exchange market pressure absorbed by exchange market intervention. When the sign of changes in exchange rate and reserves is correct for leaning against wind intervention, thus Weymark's index has a range from 0 to 1, with values closer to 1 indicating a higher degree of fixity. When the exchange rate and reserve changes have the same sign, but have a greater absolute magnitude than the changes that would have occurred in the case of no intervention, Weymark's index is negative. When the exchange rate appreciates (depreciates) with excess supply (demand) of domestic currency, Weymark's index is greater than one.

The interpretation of the degree of intervention in cases of wrong sign observations in Weymark's index is not straightforward. Consider two cases of domestic currency appreciation. For simplicity, assume the elasticity of excess demand in the foreign exchange market equals 1. In case A the domestic currency appreciates 0.5 % and reserves decline by 2.5 %. In case B the domestic currency appreciates 5% and reserves decline by 7%. With the same speculative pressure equaling to 2, case A and case B will have a measured degree of intervention of 1.25 and 3.5 respectively. From Weymark's definition, the higher the index, the higher is the degree of intervention. Therefore, case B would be interpreted as having a greater degree of intervention than case A. However, if one considers the ratio of speculative pressure taken on reserves versus on the exchange rates, case B has a lower degree of intervention than case A. From this perspective, the absolute value greater than one in Weymark's index could be interpreted as less intervention as the absolute values are closer to 1.

Weymark's benchmark for managed floats focuses on the speed of convergence to the free-float equilibrium, but Weymark does not explain how to relate the speed of convergence to how heavily the float is. In her framework there is no difference between adjustment speeds of 0.1 and 0.9 since both cases converge to the free-floating equilibrium. Thus we don't find Weymark's treatment of wrong signs to be satisfactory. It is not easy, however, to see how best to deal with them.

Wrong signs can be caused by imperfections in the reserve proxy. In these cases the best solution would likely be to drop these observations. Wrong signs may also be due to episodes of leaning with the wind. Actual leaning with the wind to increase depreciation is classic beggar thy neighbor policy and is discouraged by the IMF's guidelines except for cases where a currency is judged to be seriously overvalued. Leaning with the wind to accelerate appreciation may be justified during periods in which country's currencies are considered to have overdepreciated, such as during the Asian crisis.

In general, we will not be able to distinguish between wrong sign observations due to imperfect proxies and those due to leaning with the wind. Thus, at least initially, we propose comparing calculations with wrong signs included and excluded to see whether this makes a great difference in the particular case.

5. Issues of Trends

The use of our approach highlights issues of the time periods used for analysis and the problems of changes in trends. Consider the case of Singapore. Figure 2 presents exchange rates from January 1990 to December 2000. Looking at the behavior of the exchange rate over the whole 1990-2000 period, one would be likely to classify it as having a fairly flexible regime. However, we find only a small movement of exchange rate during 1996-1997 before the Asian crisis. From this perspective, Singapore seems to have abandoned a managed float before the crisis. However it could be that during 1996, Singapore had few shocks so that with no change in the propensity to intervene the nominal exchange rate did not move much. This is a type of question that our framework, with both trend coefficients and propensities to intervene, can help to address. As is shown in figure 2, after showing considerably greater flexibility immediately after the crisis, Singapore's degree of variability began to decline again. This is consistent with Calvo and Reinhart's general theme that there is considerable fear of floating. This analysis of Singapore and our earlier analysis of Asian exchange rate regimes prior to the crisis of 1997 [Willett et al, 2005] support Calvo and Reinhart's general conclusion that "it is often quite difficult to distinguish between [a soft peg and a managed float]." [p 405]

There has been considerable debate about the degree of post-crisis exchange rate flexibility in Asia.¹² While it is widely assumed that there has been a substantial increase in exchange rate flexibility, there has also been considerable accumulation of reserves. This has led some economists to argue that there has really been little change in exchange rate policies.¹³ We can help clarify this debate by distinguishing (conceptually at least) between intervention designed to accumulate reserves such as may be highly desirable after a period of reserve losses, intervention to hold down the average level of the

¹² See for example CR (2002), Hernández and Montiel (2003), McKinnon and Schnabl (2004), Cavoli and Rajan (2005), and Willett and Kim (2006).

¹³ See McKinnon and Schnabl (2004).

exchange rate for competitive advantage, and intervention to smooth out short-run fluctuations in the exchange rate.¹⁴

The first two motives will be observationally equivalent in terms of the statistical data during the early stages of recouping reserve losses. In the later stages of reserve accumulation distinctions would have to be based on judgments about whether reserve accumulations were becoming “excessive”. The appropriate level of reserves for a country can of course be a matter of considerable dispute.¹⁵

The third type of intervention – to limit short-term fluctuations in the exchange rate - is more easily identified. Indeed that is what our suggested methodology is designed to capture, once we detrend changes in reserves as well as changes in the exchange rate.

III. A Two-Parameter Exchange Market Pressure Framework

1. The Two-Parameter Approach

The use of one parameter to capture the trend rate of crawl and a second one to describe the policy toward fluctuations around the crawling parity are easily interpreted in terms of the institutional characteristics of exchange rate regimes. The coefficient of the country-specific time trend on the log of the bilateral exchange rate is a proxy for the rate of crawl. The minimum and the maximum of deviations from the trend is a proxy for a bandwidth.¹⁶ The traditional narrow band peg of the Bretton Woods system would have a zero rate of crawl and a narrow band width. A horizontal band would also have a zero rate of crawl but a substantial width. A narrow band crawling peg could have a substantial rate of crawl but a low value for band width, while a crawling band would have substantial parameters for both. It is clear that the first (narrow band) and fourth (crawling band) of these categories are more fixed and

¹⁴ Of course, there could also be the intervention to prop up the rate to avoid inflation. This is especially likely before elections.

¹⁵ For recent discussions of the high levels of reserve holdings in post crisis Asia, see Aizenman and Marion (2002), Bird and Rajan (2002), Kim et al (2004), and Li, Sula, and Willett (2007).

¹⁶ Since there frequently exist outliers in soft bands, we could substitute the maximum and the minimum of the deviations with other boundaries such as 95% frequency distribution.

more flexible respectively than the middle two, but the appropriate ranking of the middle two on institutional grounds is ambiguous¹⁷.

Note, however, that band widths defined either as announced limits or the maximum actual fluctuations around parity or trend are not fully adequate to describe a countries' propensity to intervene. What is needed is the propensity to intervene in the face of exchange market pressure that deviates from trend. Thus in our two-parameter characterization, we keep the trend rate of change of the exchange rate but replace the band width with the propensity to smooth fluctuations around trend.¹⁸ This characterization is straightforward, however, only when there is no trend in the level of reserves. In many cases there have been substantial increases in reserves, however, with the huge post crisis buildup of reserves in many Asian countries being an important case in point. In this section we present calculations of both detrended and non-detrended ratios. Thus we have both trend and deviation from trend propensities to intervene as measures of exchange rate flexibility

Propensities to intervene may change quite substantially over time depending on such factors as the interpretations of the causes of exchange market pressures, the state of the domestic economy, the nearness of elections, and the world view of the relevant policy officials. This raises the obvious problems of the appropriate time periods for calculations. Data limitations make monthly changes the shortest feasible unit for analysis for most countries, but the length of the time period over which observations should be averaged is far from clear and will likely vary with the purpose at hand. For example, we may want to distinguish between broad categories of exchange rate regimes and the specific operating strategies followed within these broader categories. Obviously, we would want to be more sensitive to possible shift in trends of exchange rates and/or reserves when investigating the second type of issue.

¹⁷ Of course there is a problem of changes in both stated and behavioral regimes over time. Both trends and propensities to intervene around trends can change. We will pay considerable attention to attempting to identify such shifts in our analysis.

¹⁸ For example, Singapore appears to have adopted a less flexible regime in 1996. (See figure 2). There is a change in trends in the exchange rate during August 1995. On average, Singapore had an intervention coefficient of 0.6 during 1996, with a downward trend of 0.001. In comparison, the intervention coefficient during 1994 was 0.4, with a downward trend of 0.004.

2. Two Parameter Indices

2-1. Trend Coefficients

The first step in calculating two parameter indices is to break down the two main variables, the exchange rate and policy instrument, into trend and deviations from trend components:

$$e_t = T_{e_t} + u_{e_t} \quad (1)$$

$$r_t = T_{r_t} + u_{r_t} \quad (2)$$

where e and r are exchange rate and policy instrument in logarithm, T and u are trend component and deviation from the trend component, and t denotes periods.

There are various ways to estimate trends. This paper uses a linear time trend as the main method. Since sub-periods are less than two years in most cases, there is no significant benefit of using more complicated methods such as a Hodrick-Prescott filter. The trend coefficient of the exchange rate reflects the average rate of the appreciation or depreciation over time. Under a crawling peg or band or a managed float operated as a de facto crawl, it would reflect the rate of crawling. Under a free floating rate it would just reflect the average rate of appreciation or depreciation. The trend coefficient of reserves gives the average rate of accumulation or loss in reserves.

2-2. Propensities to Intervene

Propensities to intervene measure the degree of intervention in our framework. They are based on the exchange market pressure equation,

$$EMP_t = \Delta e_t + \varepsilon_t \cdot \Delta r_t, \quad (3)$$

where EMP implies the exchange market pressure and ε is a conversion coefficient that relates intervention to changes in the exchange rate, i.e., it is the slope of the excess demand function in the foreign exchange market. In the monetary model used by Girton and Roper, this coefficient is one. Through the first order difference of equations (1) and (2), we have equations (4) and (5), which are decompositions of the terms on the right side of equation (3). Substitution of equation (4) and (5) into

equation (3) leads to equations (6), (7), and (8). They indicate that exchange market pressure (EMP_t^C) is composed of two sub-pressures: trend pressure (EMP_t^T) and detrended pressure (EMP_t^{DT}).

$$\Delta e_t = \Delta T_{e_t} + \Delta u_{e_t} \quad (4)$$

$$\Delta r_t = \Delta T_{r_t} + \Delta u_{r_t} \quad (5)$$

$$EMP_t^C = \Delta e_t + \varepsilon_t \cdot \Delta r_t = (\Delta T_{e_t} + \varepsilon_t \cdot \Delta T_{r_t}) + (\Delta u_{e_t} + \varepsilon_t \cdot \Delta u_{r_t}) \quad (6)$$

$$EMP_t^T = \Delta T_{e_t} + \varepsilon_t \cdot \Delta T_{r_t} \quad (7)$$

$$EMP_t^{DT} = \Delta u_{e_t} + \varepsilon_t \cdot \Delta u_{r_t} \quad (8)$$

It is not uncommon for governments who say that they are only intervening to smooth out temporary fluctuations in the exchange rate to have sustained increases or decreases in reserves. If continued over long periods this is a clear indication that the authorities are doing more than just smoothing. A run of reserve changes in the same direction may be quite consistent with purely smoothing interventions since in the short term it can be hard to distinguish changes in trends from movements around the trends. However, if authorities don't want there to be an appreciating trend for their currency, say for competitive reasons, they are likely to be slow to recognize a market-driven trend and continue for some time to smooth it away. Likewise, we could see asymmetric smoothing where governments are more concerned with movements in one direction than the other.¹⁹ Looking at monthly ratios and breaking them into trend and cyclical components allows us to investigate such issues in a way that cannot be captured by ratios of variances. Of course, as we will discuss below, even ex post there can be disagreement about what to consider as shifts in trends versus movements around them so application won't always be free from ambiguity.

We estimate trend propensities to intervene (TPI), and smoothing propensities to intervene around trend (SPI). For purposes of comparison we also calculate a simple combined index that combines the two (CPI). Under the common assumption of a unitary elasticity of the exchange rate with respect to

¹⁹ Building up depleted reserves may of course be a 'legitimate' reason for prolonged reserve accumulations.

intervention,²⁰ these indices are given by

$$TPI_t = \frac{-\Delta T_{r_t}}{\Delta T_{e_t} - \Delta T_{r_t}} \quad (9)$$

$$SPI_t = \frac{-\Delta u_{r_t}}{\Delta u_{e_t} - \Delta u_{r_t}} \quad (10)$$

$$CPI_t = \frac{-\Delta r_t}{\Delta e_t - \Delta r_t}. \quad (11)$$

For most applications, these are averages over the time periods of interest.

As discussed in section II, observations undefined within the EMP framework yield ambiguous information on the extent to which governments intervene to influence exchange rates. Some may be due to the imperfect proxy of official interventions, strong interventions, or super flexibility of exchange rates. The propensity to intervene based only on observations with the right sign is therefore our main index for characterizing foreign exchange policy. However, for comparative purposes, propensities based on all the observations are also calculated.

3. Intervention Proxies

One of the most difficult problems in applying the EMP approach is that few countries make data on their exchange market intervention publicly available. Most empirical studies use changes in reserves as a proxy but acknowledge that this is far from perfect. Reserves can change due to interest earnings, changes in valuation due to currency movements, and official borrowings as well as intervention. And interventions can include actions in forward, not just spot markets.²¹ These problems have led some researchers to give up using reserve measures altogether (see Ghosh et al). This seems too strong a reaction, however, since where reserve accumulations are very large, such as those at times by Japan and Korea, there can be little doubt that intervention was a primary cause.

²⁰ An exception is Weymark (1995, 1997, and 1998) who estimates the elasticity.

²¹ CR give a nice discussion of several of these issues.

One adjustment that can be made fairly easily is to subtract an estimate of interest earnings from the reserve figures.²² In section V, we adjust reserve changes for Japan for estimates of interest earnings, but just find that this makes little difference for our estimates. Both series fairly closely track the data on Japan's actual interventions over the period 1991 to 2005. Of course, this proxy may not work as well for other countries, but our results for Japan suggest that this approach is worth using in the absence of better information, while remembering that it is only a proxy.

A final problem is that a constant amount of intervention per period in the same direction would give rise to varying percentage changes as reserve levels rose or fell.²³ Likewise, initial reserve levels can make a substantial difference. Studies such as CR, and Hernández and Montiel [2003] characterize Japan as having a low volatility in foreign reserves. Although Japan intervened heavily in absolute terms in the foreign exchange market in the early 2000s, the percentage changes in reserves were fairly small due to the high initial levels of reserves.

There are several ways to deal with this problem. The most popular method has been to use scaling variables for intervention proxies. Holden et al [1979], Weymark [1997], Bayoumi and Eichengreen [1998], and LYS use the lagged money base, lagged narrow money, and the sum of export and import for 12 months as scaling variables. This problem is lessened in our framework because detrending the intervention proxies moderates it.

V. Exchange Rate Policies in Japan

Japan is one of the rare countries that releases data on its intervention in the foreign exchange market. We focus on the period, from January 1991 to September 2005, when Japan intervened actively in

²² Since dollar values of reserves are used in most cross national empirical studies, valuation changes due to exchange rate movements can also be important. Since exchange rate changes among reserve currencies are often much larger over short periods than interest rate differences, estimates of the currency composition of reserves are particularly important for such calculations. For many countries published figures or good estimates about the currency composition of reserves are not available, but efforts to take valuation changes into account have been made in some country studies. See, for example, Ouyang, Rajan, and Willett (2006). Where countries mark their reserve figures to market interest rate changes in reserve currency countries can also affect valuation for longer maturity assets.

²³ This problem can of course also apply to continued appreciation or depreciation.

the foreign exchange market. This data enables us to investigate how well the proxy reflects official intervention using official intervention data. Figure 3 shows the behavior of our intervention proxy and the actual data on official interventions from January 1991 to September 2005. The intervention proxy is the change in adjusted foreign reserves, i.e., foreign reserves minus interest earnings. Interest earnings are computed by multiplying the US Treasury bill rate with the level of foreign reserves lagged one period. There are periods when our intervention proxy shows intervention behaviors without any official intervention, such as between the middle of 1996 and the end of 1997, but in general the proxy follows the actual intervention figures fairly closely.

Figure 4 presents a scatter diagram between the official intervention and our intervention proxy. It shows that there is a very strong positive linear relation between them. The correlation coefficient of 0.9 confirms the graphical inference. The estimated coefficient of the intervention proxy in the regression of official intervention on the intervention proxy is 1.05, and is not significantly different from 1. Thus, at least for Japan, changes in reserves do seem to be a reasonable proxy for official interventions.

Japan has been classified by several studies as an example of a highly flexible or free floating exchange rate regime. The IMF, LYS, and RR all classified Japan into their most flexible categories since 1982, 1974, and 1978, respectively. The IMF uses the term “independently floating” and LYS use “flexible”. This leaves open however, the important issue of how heavily the floats are managed. The IMF classification attempts to deal with this issue by giving three types of float, independently, other managed float with no predetermined exchange rate path, tightly managed floats.²⁴ The analytic rationale offered for their distinctions lacks clarity, however, and in some cases the resulting classification seems questionable.²⁵ CR’s results imply that Japan had a more flexible regime than Canada, Australia, or New Zealand.²⁶

²⁴ In 2009 the IMF revisited its de facto classification, using only two categories of floating, i.e., floating and free floating, based on the degree of intervention. (See Habermeier et al., 2009) The IMF has classified Japan as free floating since 2008.

²⁵ See Willett and Kim (2006).

²⁶ In order to characterize foreign exchange rate policy CR estimate the probability that volatility measures of exchange rate, reserves, and interest rate fall within some prespecified bounds. They use the absolute value of the

This seems clearly wrong with respect to New Zealand, however, since their central bank did not intervene over this period. It also seems questionable with respect to Australia and Canada since neither is known for heavy intervention. Our two parameter EMP framework finds that prior to the cessation of intervention in 2004, Japan had substantially increased intervention during the post Asian crisis period relative to the precrisis period. Figure 5 suggests that while the broad category of flexible rates is an appropriate label for Japan's exchange rate regime over this whole period, there have been substantial changes in intervention behavior. For some issues such as the effect of exchange rate regime on economic growth, these changes in behavior are likely not of great importance. For the characterization of intervention reaction functions they are quite important.

During the Asian crisis the yen depreciated against the dollar. While the yen has an overall appreciation trend over the post Asian crisis, it is far from steady. We observe a number of rather sharp breaks in each rate behavior. Based on inspection of Figure 5 we divided our sample period into four sub-periods: (i) September 1999-November 2000, (ii) March 2001-August 2003, (iii) October 2003-April 2004, (iv) June 2004-September 2005 and estimated our two parameter EMP framework with the proxy (table 1).

Some have objected to this approach since it is based on observation and judgment rather than a rigorous statistical methodology that can test for the significance of break points. For some purposes this may be a valid criticism but for our current purpose which is to provide an analytic history of exchange rate policy such a formal approach runs the risk of throwing the baby out with the bath water. Other analysts are, of course, perfectly free to challenge our choice of break points and analyze alternative ones of their own choosing. Basically this judgmental approach allows us to make comments about fine grained changes in behavior during episodes shorter than would provide enough data points for formal

percent changes for the volatility measures of exchange rate and foreign reserves, and the absolute value of the change for the volatility measure for interest rates. Relative to these three countries, CR's probability measures of staying within a zone for the exchange rate and nominal interest rate for Japan are low, while the probability measure for reserves is high. CR estimate the probability over January 1984-November 1999, June 1970-November 1999, February 1973-November 1999, and March 1985-November 1999 for Australia, Canada, Japan, and New Zealand, respectively. (See table 8)

statistical testing to be useful. Were we just interested in establishing that Japan was practicing a managed float rather than a peg or a free float then there would be plenty of data for formal statistical testing.

The first column in Table 1 lists periods, the second, their time spans, and the remaining columns the indices: trend coefficients of exchange rates and intervention proxy, trend propensity to intervene, smoothing propensities to intervene, and combined propensities to intervene. Our benchmark propensities to intervene are TPI and SPI calculated with correctly-signed observations. The estimated exchange trends are depicted in Figure 5. During the pre-crisis period, the yen had a strong depreciation trend and small volatility around the trend, but this low volatility did not result from intervention policy. TPI was the wrong sign and SPI was quite low, 0.28.

The exchange rate policy changed after 1999. Japan intervened strongly in the foreign exchange market. Foreign reserves accumulated by 23% per year on average and the SPI rose to 0.53 from 1999 through 2005. Analysis of sub-periods helps clarify characteristics of Japanese foreign exchange policy. TPIs are correctly signed during subperiods with appreciation trends in the exchange rates. SPIs for all subperiods are higher than for the precrisis period. They are 0.49 and 0.68 for the first and third subperiods. After June 2004, the SPI fell to 0.38, but was still higher than for the precrisis period.²⁷

In order to investigate the usefulness of the reserve change proxy for intervention we also calculate the SPIs using the ratio of official intervention to adjusted foreign reserves in the previous period.²⁸ The first column in table 2 lists regime periods, and the second gives their time spans. The remaining columns report the smoothing propensities to intervene, and the combined propensities to intervene.

SPIs using actual intervention data are lower than SPIs using the proxy since there are many observations with zero intervention in actual data which are considered as having right signs. The estimators are 0.06 for the actual data and 0.28 for our proxy during the precrisis period. They are 0.26

²⁷ The variance index shows the same pattern although the individual level is different. (see table 7).

²⁸ We use foreign reserves without adjusting interest earnings as the base value for the ratio of the official intervention. However, there is no significant difference between the two cases since interest earnings are very small relative to foreign reserves.

and 0.69 for the first and third subperiods using the official intervention and 0.49 and 0.68 using the proxy. After June 2004, the SPI using the official intervention was 0.0 while using the proxy yielded 0.38.

However, graph 6 indicates that SPIs using the proxy and the actual data show very similar patterns of intervention behaviors. SPIs for all subperiods are higher than the precrisis period except the fourth subperiod during which there was no official intervention. They are highest during subperiod 3.

For robustness testing, reserve money and M1 are used as scaling variables for our intervention proxy and official intervention to take into account the problem of initial levels (table 3-6). These results also support the conclusion that intervention behavior in Japan during the postcrisis period became stronger than during the precrisis period. It was highest for the third subperiod.

Finally, it is notable that our SPIs and CPIs with all observations show inconsistent and implausible numbers in some cases. SPI and CPI during subperiod 3 in table 1 are negative while SPI during the postcrisis and CPI during subperiod 3 are larger than 1. Such cases can be found in the other intervention measures. This suggests the importance of paying attention to the signs of the correlations between reserve and exchange rate changes.

At least for Japan, our framework appears to effectively characterize foreign exchange rate policy in the sense that there is a very similar pattern in propensities to intervene using the reserve change proxy and actual official intervention. However, the gap between both propensities to intervene implies that the adjustment of interest earnings does not sufficiently reduce the discrepancy between foreign reserves and the actual intervention.

VI. Conclusion

This paper develops a methodology for classifying exchange rate regimes based on a more precise application of the concept of exchange market pressure than has been used in most other studies. We argue that the most appropriate way to measure the degree of flexibility of an exchange rate regime is to compare the degree to which exchange rate pressure results in changes in exchange rates versus the amount of intervention to limit exchange rate movements. This concept has a clear meaning, however,

only for intervention that leans against the wind. We find that a substantial number of monthly data points show changes in reserves and exchange rates having the wrong signs for leaning against the wind intervention. The extent to which these wrong signs are due to the imprecision of using reserve changes as a proxy for intervention is an important issue. For most countries actual intervention data is not published so such analysis would typically need to be undertaken by researchers within central banks. We argue that both this and issues of trends make popular approaches based on the ratios of variances in changes in reserves and exchange rates fail to take full advantage of the information in the data.

We highlight the issue of trends and argue that at least two parameters – coefficients for trend and for deviations around trend – are necessary for the general classification of exchange rate regimes since there is no clear theoretical basis for comparing the degree of flexibility associated with trend movements in exchange rates with those resulting from movements resulting from fluctuations around trend. We can think of this in terms of the problem of attempting to compare the degree of flexibility of a faster crawling narrow band regime with that of a slower crawling wide band regime.

Because of shifting trends, issues of changes in intervention strategies and the appropriate time periods for analysis become important. There is likely no single best answer to such issues and the best answer is often likely to vary depending on the question at hand. We agree with LYS that researchers should be willing to make use of the ambiguous category when classifying regimes. (Typically this will be ambiguous with respect to classification between two particular categories, not complete uncertainty about the regime).

We apply our framework to the behavior of the yen using both a reserve change proxy and actual intervention data. While these give somewhat different results, our analysis suggests that in the absence of actual intervention data, reserve changes are useful if imperfect proxies for official intervention. We also argue that the practice of using measures of interest rate behavior to help classify the degree of flexibility is questionable without being able to identify the portions of interest rate movements which are caused by domestic considerations and efforts to protect exchange rate and reserve levels respectively. For the analysis of exchange rate cum monetary regimes, however, analysis of the interrelationships among

changes in exchange rates, reserves, money supplies and interest rates are all of these importance. These relationships will in turn depend in part on the degree to which intervention in the foreign exchange market is sterilized.²⁹

²⁹ See Hernandez and Montiel (2001), McCauley (2001), Willett et al. (2009) and (2011).

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Figure 1 Propensity to Intervene and Exchange Market Pressure

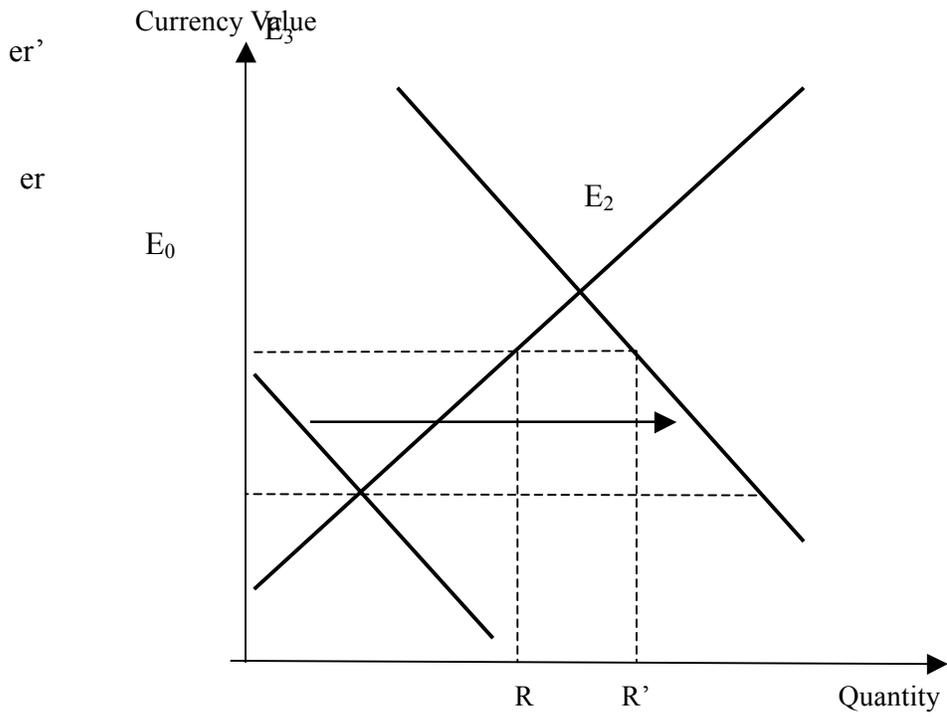
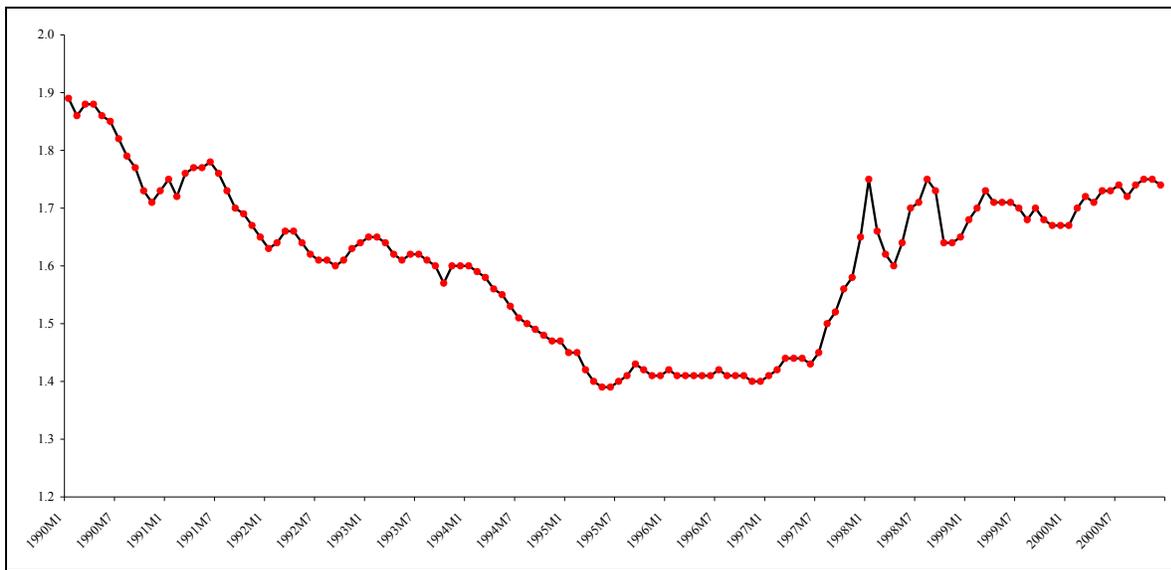
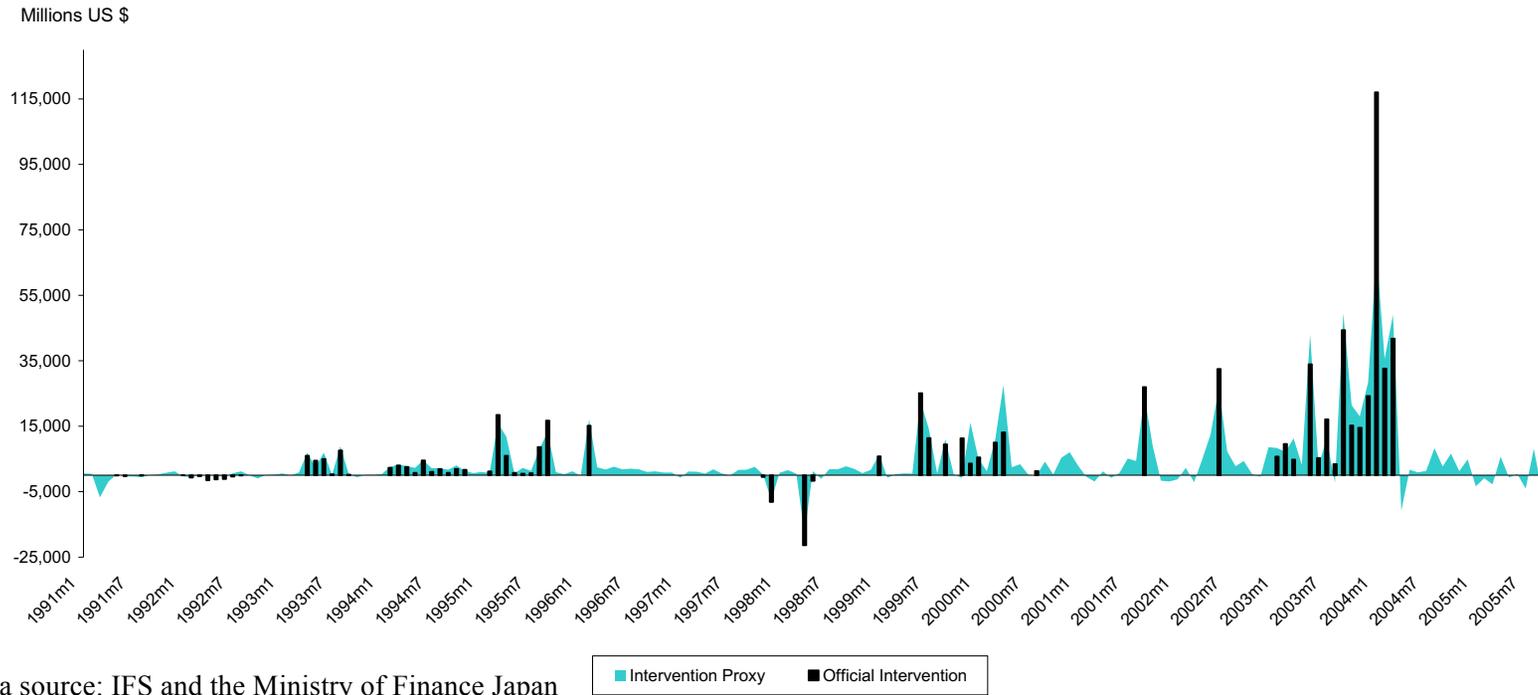


Figure 2 Singapore Exchange Rate against the Dollar 1990-2000



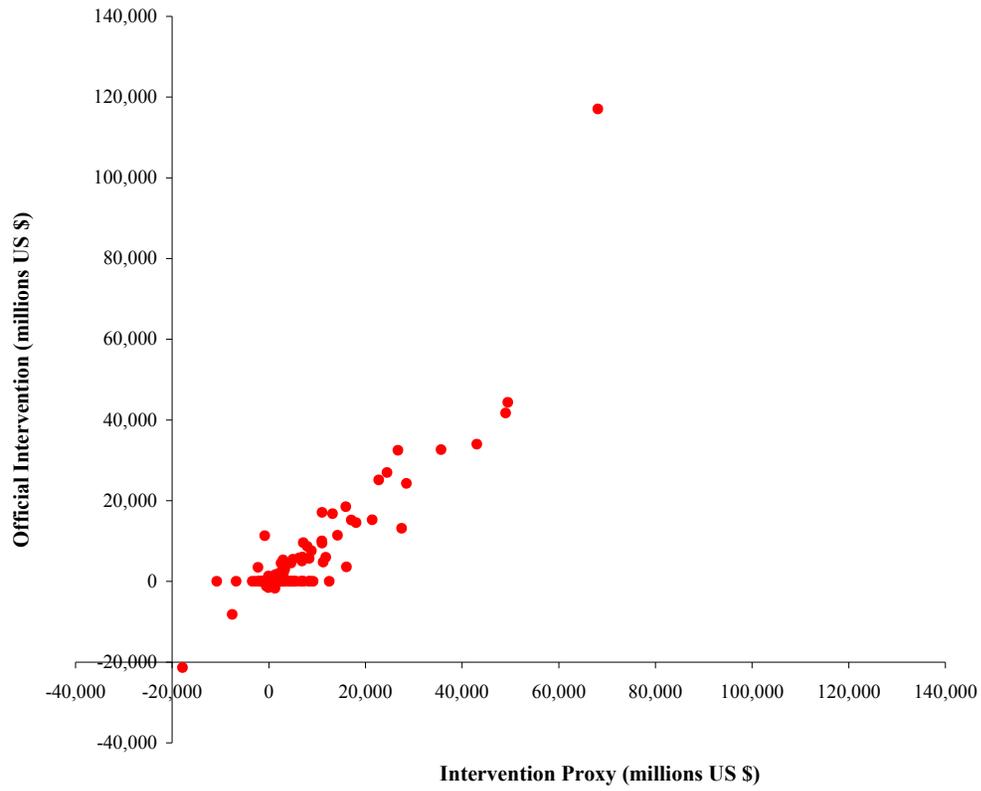
Data source: IFS

Figure 3 Official Intervention and Intervention Proxy for Japan



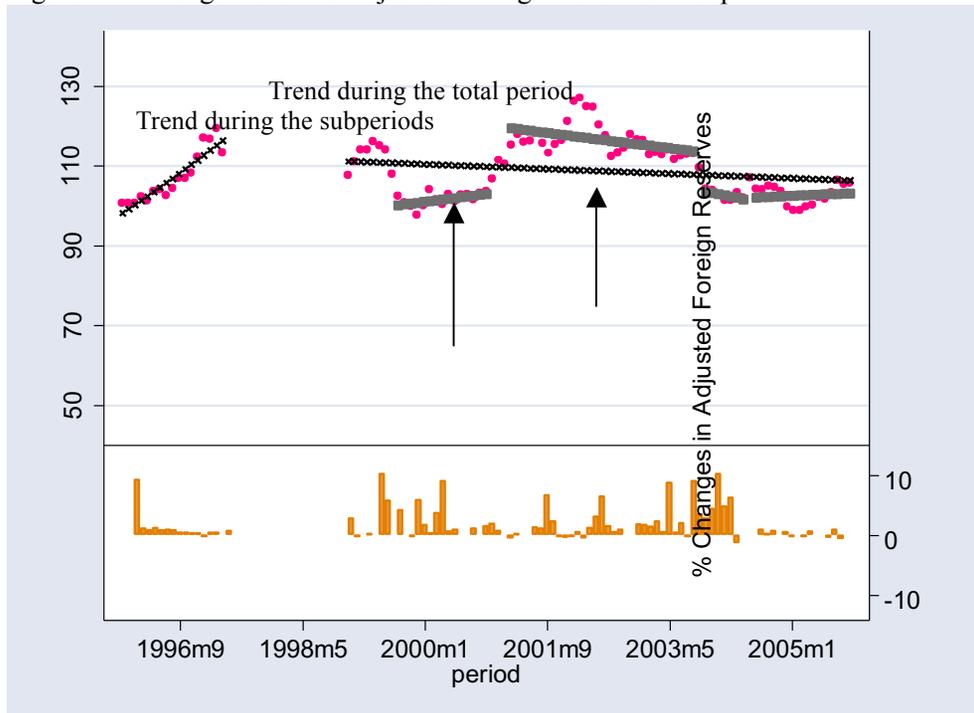
Data source: IFS and the Ministry of Finance Japan

Figure 4 Scatter Diagram between Official Intervention and Intervention Proxy for Japan



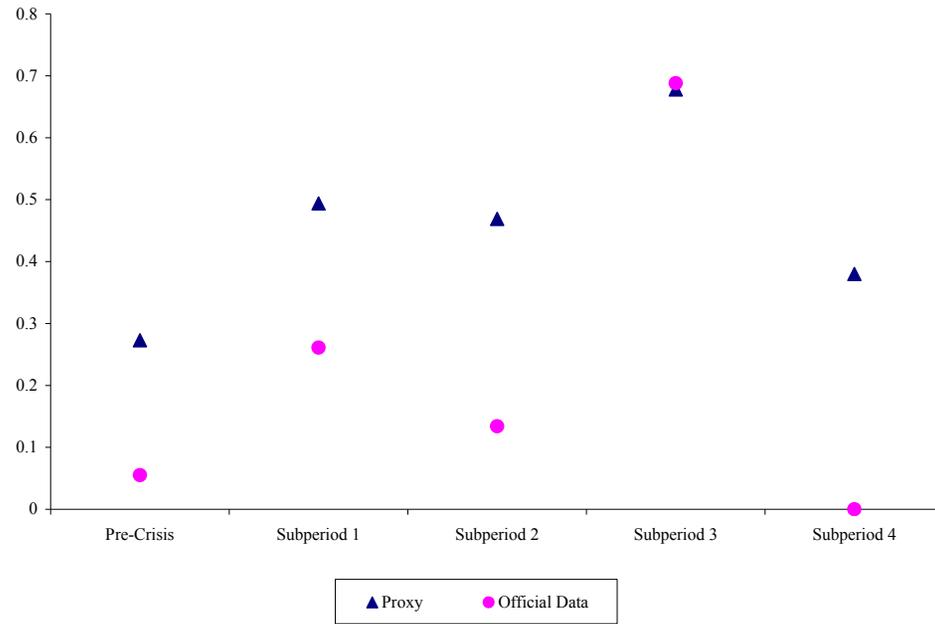
Data source: IFS and the Ministry of Finance Japan

Figure 5 Exchange Rate and Adjusted Foreign Reserves in Japan



Data source: IFS and authors' estimation

Figure 6 SPIs using Intervention Proxy and Official Data



Data source: Authors' estimation

Table 1 TPEMP Framework using the Intervention Proxy

	Time Span	TC_er	TC_int	TPI	SPI _A	CPI _A	SPI _B	CPI _B
Precrisis	1996:1-1997:5	0.135	0.097	WS	0.280 (12/16)	0.514 (7/16)	0.146	0.203
Postcrisis	1999:1-2005:9	-0.007	0.234	0.972	0.525 (54/80)	0.493 (44/80)	1.011	0.482
Sub 1	1999:9~2000:11	0.023	0.278	WS	0.494 (9/14)	0.470 (7/14)	0.931	0.067
Sub 2	2001:3~2003:8	-0.020	0.200	0.908	0.469 (23/29)	0.541 (14/29)	-0.173	-0.127
Sub 3	2003:10~2004:4	-0.037	0.832	0.957	0.678 (2/6)	0.854 (3/6)	0.739	2.271
Sub 4	2004:6-2005:9	0.008	0.020	WS	0.380 (11/15)	0.419 (11/15)	0.353	0.372

Note:

1. TC_er and TC_int: trend coefficients of exchange rates (local currency/US\$) and adjusted foreign reserves
2. TPI and SPI: trend propensity to intervene and smoothing propensity to intervene
3. CPI: combined propensity to intervene
4. A and B: right-signed data and all data
5. The numerator in parenthesis is the number of observations of leaning against the wind; the denominator is the total number of observations

Table 2 SPI and CPI using Proportion of the Official Intervention to Adjusted Foreign Reserves

	Time Span	SPI _A	CPI _A	SPI _B	CPI _B
Precrisis	1996:1-1997:5	0.055 (16/16)	0.062 (16/16)	0.055	0.062
Postcrisis	1999:1-2005:9	0.163 (72/80)	0.161 (72/80)	0.334	0.273
Sub 1	1999:9~2000:11	0.261 (13/14)	0.214 (12/14)	-0.248	0.013
Sub 2	2001:3~2003:8	0.134 (25/29)	0.129 (25/29)	-2.279	0.459
Sub 3	2003:10~2004:4	0.688 (4/6)	0.642 (4/6)	0.922	0.854
Sub 4	2004:6-2005:9	0.0 (15/15)	0.0 (15/15)	0.000	0.000

Note:

1. SPI: only exchange rate is detrended
2. A and B: right-signed data and all data
3. The numerator in parenthesis is the number of observations of leaning against the wind; the denominator is the total number of observations

Table 3 SPI and CPI using Proportion of the Intervention Proxy to Lagged Reserve Money

	Time Span	SPI _A	CPI _A	SPI _B	CPI _B
Precrisis	1996:1-1997:5	0.256 (9/16)	0.404 (7/16)	-0.313	2.899
Postcrisis	1999:1-2005:9	0.423 (44/80)	0.418 (44/80)	0.087	-0.121
Sub 1	1999:9~2000:11	0.371 (6/14)	0.348 (7/14)	0.156	0.270
Sub 2	2001:3~2003:8	0.428 (13/29)	0.458 (14/29)	0.177	-0.058
Sub 3	2003:10~2004:4	0.875 (3/6)	0.797 (3/6)	4.329	0.211
Sub 4	2004:6-2005:9	0.382 (11/15)	0.378 (11/15)	2.687	-1.089

Note:

1. SPI: only exchange rate is detrended
2. A and B: right-signed data and all data
3. The numerator in parenthesis is the number of observations of leaning against the wind; the denominator is the total number of observations

Table 4 SPI and CPI using Proportion of the Intervention Proxy to Lagged M1

	Time Span	SPI _A	CPI _A	SPI _B	CPI _B
Precrisis	1996:1-1997:5	0.118 (9/16)	0.254 (7/16)	0.014	0.198
Postcrisis	1999:1-2005:9	0.236 (44/80)	0.228 (44/80)	-0.063	0.516
Sub 1	1999:9~2000:11	0.181 (6/14)	0.171 (7/14)	-0.520	-0.010
Sub 2	2001:3~2003:8	0.237 (13/29)	0.252 (14/29)	0.134	1.173
Sub 3	2003:10~2004:4	0.706 (3/6)	0.55 (3/6)	0.191	-0.179
Sub 4	2004:6-2005:9	0.201 (11/15)	0.181 (11/15)	0.110	0.098

Note:

1. SPI: only exchange rate is detrended
2. A and B: right-signed data and all data
3. The numerator in parenthesis is the number of observations of leaning against the wind; the denominator is the total number of observations

Table 5 SPI and CPI using Proportion of Official Intervention to Lagged Reserve Money

	Time Span	SPI _A	CPI _A	SPI _B	CPI _B
Precrisis	1996:1-1997:5	0.047 (16/16)	0.061 (16/16)	0.047	0.061
Postcrisis	1999:1-2005:9	0.135 (72/80)	0.133 (72/80)	0.460	0.216
Sub 1	1999:9~2000:11	0.201 (13/14)	0.155 (12/14)	0.158	0.350
Sub 2	2001:3~2003:8	0.113 (25/29)	0.107 (25/29)	0.298	0.154
Sub 3	2003:10~2004:4	0.66 (4/6)	0.597 (4/6)	0.988	0.876
Sub 4	2004:6-2005:9	0.0 (15/15)	0.0 (15/15)	0.000	0.000

Note:

1. SPI: only exchange rate is detrended
2. A and B: right-signed data and all data
3. The numerator in parenthesis is the number of observations of leaning against the wind; the denominator is the total number of observations

Table 6 SPI and CPI using Proportion of Official Intervention to Lagged M1

	Time Span	SPI _A	CPI _A	SPI _B	CPI _B
Precrisis	1996:1-1997:5	0.029 (16/16)	0.057 (16/16)	0.029	0.057
Postcrisis	1999:1-2005:9	0.077 (72/80)	0.075 (72/80)	0.054	-16.252
Sub 1	1999:9~2000:11	0.113 (13/14)	0.077 (12/14)	0.096	0.013
Sub 2	2001:3~2003:8	0.058 (25/29)	0.053 (25/29)	0.477	-44.919
Sub 3	2003:10~2004:4	0.542 (4/6)	0.419 (4/6)	0.405	0.132
Sub 4	2004:6-2005:9	0.0 (15/15)	0.0 (15/15)	0.000	0.000

Note:

1. SPI: only exchange rate is detrended
2. A and B: right-signed data and all data
3. The numerator in parenthesis is the number of observations of leaning against the wind; the denominator is the total number of observations

Table 7 Variance Intervention Index for Japan

	Time Span	Var_index
Precrisis	1996:1-1997:5	0.464
Postcrisis	1999:1-2005:9	0.564
Sub 1	1999:9~2000:11	0.630
Sub 2	2001:3~2003:8	0.506
Sub 3	2003:10~2004:4	0.897
Sub 4	2004:6-2005:9	0.105

Table 8 Volatility of Exchange Rate, Reserves, and Nominal Interest Rate in Selected Countries

Country	Period	Exchange		Nominal Interest
		Rate ¹	Reserves ²	Rate ³
Japan	Feb. 1973-Nov. 1999	61.2	74.3	0.0
Canada	Jun. 1970-Nov. 1999	93.6	36.6	2.8
Australia	Jan 1984-Nov. 1999	70.3	50.0	0.0
New Zealand	Mar. 1985-Nov. 1999	72.2	31.4	1.8
United State \$/DM	Feb. 1973-Nov. 1999	58.7	62.2	0.3

Note:

1. Probability that the monthly change of exchange rate is within ± 2.5 percent band
2. Probability that the monthly change of reserves is within ± 2.5 percent band
3. Probability that the monthly change of nominal interest rate is greater than ± 4 percent band

Source: Calvo and Reinhart (2002)