

Central bank foreign exchange market interventions, exchange rate fundamentals and monetary policy

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Preliminary, please do not quote!

Abstract

This paper extends the standard reaction function of the central bank when deciding to intervene or not in the foreign exchange market. Probit estimation of a reaction function using indicators of real exchange rate misalignments and monetary policy considerations indicate that the Bank of Japan have taken such considerations into account in intervention decisions. Omission of such variables are shown to have caused biased estimates in the standard formulation. The empirical evidence further suggests that the BOJ may have used such interventions as a supplementary monetary policy tool in the near zero interest rate environment since 2001.

Key words: exchange rates, interventions, reaction function

JEL classification: E52, E58, F31, G15

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1 Introduction

Although many countries are characterized by official floating exchange rate regimes many of these conduct interventions in the foreign exchange market.

¹ The monetary authorities conduct these interventions either using the international currency reserve to buy domestically denominated assets or buying foreign currency denominated assets with domestic currency. Further, interventions can either take the form of being unsterilized, which would change the monetary base and have similar effects as interest rate monetary policy, or sterilized where the effect of the monetary base is offset by buying or issuing bonds. The evidence appears to indicate that most countries mostly sterilize their interventions leaving the monetary base unchanged. The possible efficacy of interventions in moving the (nominal) exchange rate in any desired direction are mixed. The theoretical underpinnings of sterilized interventions being able to move the exchange rate mentioned in the literature are the portfolio balance channel, where the change in relative supplies of domestic and foreign bonds would lead to changes in the exchange rate², and the expectations/signalling channel indicating that interventions might signal information on future monetary policy stances. Empirical studies testing these two channels of influence on the exchange rate have been unable to produce a consensus on the mechanism of exchange rate effects of interventions. Another issue in the literature is why central banks (CB) at times intervene officially and at other times secretly and related to that why central banks up until recently have not been willing to make publicly available the intervention data, date and direction/size. This in turn is related to what channels of influence one believes is at work.³

Overall, the extent to which some central banks engage in interventions seem to be somewhat of a puzzle but clearly there must be good reasons for doing so and a belief that for whatever reason interventions are likely produce some desired outcome. So the natural question then arises: what are the determinants for interventions? The usual motivation of the studies in this area in to investigate whether the CB has pursued actions consistent with notions of "leaning against the wind". This is equivalent to saying that the CB would only care about nominal exchange rate movements *per se* or possibly that the CB regards the nominal rate as a good proxy of other objectives. The purpose of this paper is to make a case of the CB having other ulterior motives than exchange rate stabilization only. This paper will argue that interventions plausibly could have been carried out with other objectives in mind such as real exchange rate misalignments from fundamentals and monetary policy considerations. The empirical results of the paper indicate that the BOJ under the time period 1991-2004 have in deed made such considerations when deciding on intervening in the foreign exchange market.

¹The countries cited in the literature are USA, Germany, Australia, Japan, UK, Norway, Switzerland, Turkey and Sweden

²If domestic and foreign assets are not perfect substitutes and Ricardian equivalence does not hold.

³For a review of foreign exchange interventions see Sarno and Taylor (2002).

The paper is organized as follows: in section 2 the data for estimation is described in section 3 we will present the motivation of the paper along with some previous studies and intermediary results and section 4 compares estimates across different specifications of the BOJ reaction function. Section 5 concludes.

2 Data

Japan daily data on intervention amount, sign and date is provided by the authors of Ito and Yabu (2004).⁴ This data covers the period 4/01/1991 to 3/31/2003.⁵ Monthly data on prices (CPI excluding food and energy, seasonally adjusted), total production in industry (seasonally adjusted) and the BOJ uncollateralized overnight interest rate are collected from the SOURCE OECD database available online. The monthly data are converted to daily for reaction function estimation assuming that the monthly data is what is available to the authorities at each date throughout the month.⁶ The time series of the spot rate and BOJ interventions are displayed in the Appendix.

3 Previous studies and motivation of paper

The bulk of the empirical literature on determinants of interventions focuses on the central bank trying to smooth (nominal) exchange rate deviations from some target level. Estimation is usually carried out using standard ordered choice as described in Greene (2003) or friction models as pioneered in Rosett (1959). These models take into account the truncated nature of interventions around zero allowing for a no-intervention band around zero. Ordered choice models are most appropriate for predicting probability of interventions, friction models if one is interested in the size of interventions. A particular form of the reaction function can be derived by assuming that the central banks objective function is quadratically decreasing in deviations of the spot rate from the target rate and that the spot rate follows a random walk.⁷

$$INT_t^* = \beta_0 + \beta_1 (s_{t-1} - s_{t-1}^T) + v_t \quad (1)$$

where s_t^T , the target rate, is simply a weighted combination of the lagged nominal spot exchange rate, s_t , at different lag lengths and v_t is assumed to be of some known distribution. INT_t^* is the optimal intervention at time t , which not need to be the same as the observed intervention because of some fixed costs

⁴Data is also publicly available on the Japan Ministry of Finance home page: <http://www.mof.go.jp/english/e1c021.htm>

⁵Daily data for Australia covers the period 12/12/1983 through 3/31/2003. In this version, however, only Japan is covered. Comparable data should also be available for Turkey.

⁶This assumption is unrealistic in that some forecast could and probably should be used for taking a decision on monetary policy. Essentially, no informational advantage on the art of the BOJ is thus given. In a future version we are thinking about including forecast variables in the estimated reaction function.

⁷See Almekinders and Eijffinger (1996) for seminal contribution.

in intervening and simply observing that over long time periods no interventions are carried out. Thus, what we observe is:

$$\begin{aligned}
INT &= -1(INT_t^* - \beta_0 - \beta_1(s_{t-1} - s_{t-1}^T) - v_t < \mu_1) \\
&= 0(\mu_2 < INT_t^* - \beta_0 - \beta_1(s_{t-1} - s_{t-1}^T) - v_t > \mu_1) \\
&= 1(INT_t^* - \beta_0 - \beta_1(s_{t-1} - s_{t-1}^T) - v_t > \mu_2)
\end{aligned} \tag{2}$$

A version of this allowing for dynamics in the *observed intervention indicator variable* is estimated in Ito and Yabu (2004). Including lagged interventions in the estimated reaction function is obvious from the observation that interventions tend to come in series with long periods in between of no interventions. However, it is obvious to ask the question of whether there are not some other plausible independent variables that need to be included. If indeed there are some other determinants of interventions other than lagged realized interventions and deviations of the spot rate from the target rate then equation (2) is misspecified, the discrete choice analysis without taking proper account of this is flawed and moreover, some of the estimates may be biased.

Only a few previous studies have tried to look into possibilities of how more fundamental variables such as interest rate differentials, inventory considerations, profitability, trade volume and fundamental exchange rate deviations could effect the probability of central bank interventions. Most notably, Kim and Sheen (2002) and Kim and Sheen (March 2005) have employed the recently released daily intervention data for Australia and Japan to study the determinants of interventions in a friction model setting.

In this paper ⁸ we will make the general case that there are omitted variables in the usually estimated reaction function of the central bank. More specifically we will argue that interventions could have played a role as an alternative monetary policy instrument at times where interest rate changes were not sufficient to offset macroeconomic misalignments from the authorities target. This is especially relevant for a country like Japan which under a long period found itself in a situation where further target rate cuts were unfeasible due to the zero lower bound on nominal interest rates. In a sense, this paper then sets out to see if the intervention behavior of the BOJ have been consistent with getting Japan out of the "liquidity trap". In fact, this is what is argued in Svensson (2003) as the "foolproof way" among many other alternatives. The author argues that by depreciating the currency inflation expectations will arise and this will jump-start the economy back onto track. Our objective is thus not to study if such a policy has been effective or not, even if such a policy was indeed carried out, but merely if the intervention behavior during the low interest rate environment seem to have been consistent with such a policy recommendation.

⁸Actually, this paper will be part of ongoing joint paper by me and Assistant Professor Matias Eklöf at Uppsala University not mainly trying to unravel the "true" reaction function of the BOJ and the Reserve Bank of Australia (RBA) but developing a simulation based dynamic probit/friction model to account for omitted variables and/or serial correlation in the latent variable triggering interventions.

The other thrust of the paper is to take more seriously the issue of exchange rate deviations from fundamentals. Much quoted in the literature is the "target" or "fundamental" exchange rate. However, no studies seem to take this target level seriously. Modelling a fundamental rate necessitates a theory for exchange rate. Moreover, the target level of the CB need not to be identical to the fundamental rate since we cannot control for the preferences of the central bank other than noting that the CB chair changes occasionally. In this paper we will not get into the issue of the relation between the two but rather assume that the target is the same as the fundamental value.

3.1 Exchange rate target deviations

The background of foreign exchange rate interventions as reactions to misalignment in the nominal exchange rate have in recent papers been mostly occupied with high-frequency issues. The reasons for this has to our understanding been the high-frequency data on interventions released by some central banks. The basic idea is that for periods of time chartist speculators in the market have moved the exchange rate away from the equilibrium value implied by fundamentals. This could happen for a number of reasons but arises partly because of investors imperfect information on the proper fundamental rate which requires costly information processing. So, instead the investors resort to chartist techniques to forecast future spot rates. Moreover, in the absence of a clear idea on what the fundamental rate is investors are prone to overreact to "news" which could result in large short-run fluctuations. These misalignment can persist even under longer time periods if chartist views dominate fundamental beliefs on the proper exchange rate level. Eventually the currency bubble will inevitably collapse and the sudden realignment of the exchange rate can then have some serious real effects. Overall then, the central banks intervening in the market are likely to do so to counteract short-run misalignment from fundamentals or reinforce movements back toward the equilibrium value. Referring to the above described possible channels of influence of interventions on exchange rates interventions can serve the tool of signalling information on the fundamental value to investors so that misalignments do not grow too large or to smooth short-run movements to reduce the degree of uncertainty of the proper exchange rate level. So then, what is this fundamental value?

The specification of the fundamental exchange rate and the deviations from it depends on one's beliefs of what variables that affect this fundamental rate. Here, making the case as easy as possible, we focus on long-run purchasing power parity (PPP) deviations. More serious modelling of the fundamental exchange rate would require taking a stand on first of all at what time horizon and secondly on what theory to be guided by after having done so. Various models of exchange rate determination, such flexible price models, portfolio balance models, VAR-models and DSGE models, would obviously imply different determinants. Obviously, what we would need to pin down the nominal fundamental exchange rate at various horizons would include some measure of prices in the economy. Surely, some measure of the domestic and the foreign price level would

PPP relation 1973-2005		
Variable	Coefficient	Std.
c	7.28	0.23
p_t	0.52	0.10
p_t^*	-1.08	0.06
$R^2 : 0.82$		

Table 1: PPP estimation

play a central role since it the real exchange rate that matters for aggregate output in the economy. Thus, modelling the target exchange rate only as some kind of weighted average levels of the past realized spot rates would be flawed. However, this might not be that bad of an approximation given that the inflation levels of the economy and the world have been reasonably similar. In the case of Japan, however, it is easy to realize that with Japanese price levels increasing at a lower rate than foreign price levels one would expect the nominal exchange rate to appreciate. This paper tries to model this long-run misalignment more seriously than recent studies have by using a general form of PPP⁹. Define the price-exchange rate relation as:

$$AQ = S_t \frac{(P_t^*)^{\beta^*}}{(P_t)^\beta} \quad (3)$$

where S_t is the spot exchange rate and P_t and P_t^* are the price levels at home and abroad respectively. Q_t is the real exchange rate which should equal unity for PPP to hold. The constant A , however, recognizes the fact that due to index problem it need not be the case that $\frac{S_t^T P_t^*}{P_t}$ fluctuates around unity but instead around some other constant. The terms β and β^* allows for pass-through through changes in price levels to differ. Taking logarithms of the above and rearranging yields:

$$s_t = \alpha + \beta p_t - \beta^* p_t^* \quad (4)$$

where lower-case letters denote logs of variables. The residuals from estimation of equation (4) is our preferred measure of long-run deviations from the fundamental rate. A positive value of the residual means that the yen at the time was undervalued with respect to its PPP-implied value and a negative that it was overvalued. Estimation of equation (4) for the full post Bretton-Woods (BW) sample period 1973-2005 yields the results displayed in Table 1 and Figure 1.

On basis of Table 1 we can see that the coefficients are of expected signs, but hardly of the same magnitude which, without further testing, would seem to indicate that the weak version of PPP does not hold throughout this period.¹⁰

⁹This is a general version of the absolute purchasing power relation. Weak absolute PPP would impose that $\beta = \beta^*$, strong absolute PPP that $\beta = \beta^* = 1$. The relative versions would

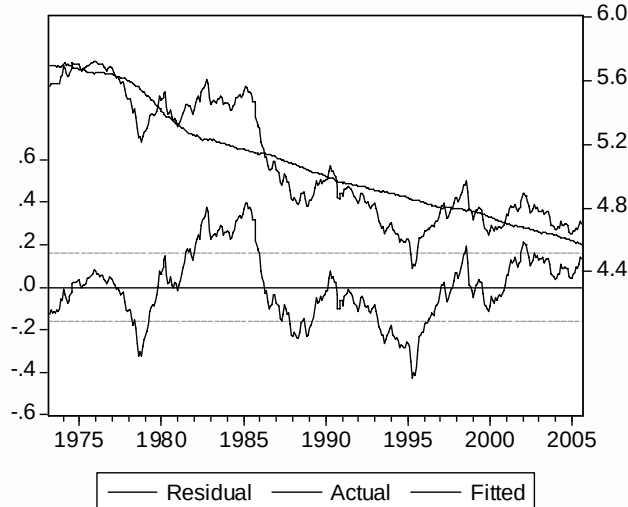


Figure 1: Fundamental rate deviations 1973-2005

The estimated residuals from the long-run price relation in (4) are used as possibly determinants of intervention behavior in the estimation section below.¹¹ It would seem plausible that overvaluation of the yen would tend to increase the probability of the BOJ interventions selling yen and buying dollar to move the rate back towards fundamentals and vice versa.

3.2 Monetary policy considerations

Considering the weak evidence on the possibilities of the authorities influencing the exchange rate through interventions and its dubious effect on output and inflation it should come as no surprise that it is not seen as a major policy instrument of the central bank in engineering monetary policy. It here warrants mentioning that the official stance of the Bank of Japan is formulated as to "stabilize the external value of the yen by taking necessary measures including foreign exchange transactions."¹² Nevertheless, large interventions have at times

imply that the same hold, but in first differences only.

¹⁰If we were interested in PPP per se, then estimation of a first difference version, weak PPP, would be more appropriate. Here we are essentially only trying to find a reduced form long-run relation between prices and spot rate.

Imposing that $\beta = \beta^*$ gives close to identical results, but imposition of $\beta = \beta^* = 1$ highly unreasonable results.

¹¹Applying the Johansen testing procedure of cointegration on the exchange rate and prices indicate that the variables are separate unit roots and that there exists one cointegrating vector for the three. Hence we need not to worry about spurious regression problems in estimation.

¹²Source: Bank of Japan home page at <http://www.boj.or.jp/en/about/basic/etc/faqkainy.htm>

been recommended as a policy option when the main policy instrument of the central bank, the target rate, is constrained by the infeasibility of negative nominal interest rates. In Svensson (2003) the author claims that such interventions aimed at creating inflationary expectations can be an indispensable tool in such an environment. Even the current Swedish central bank chair, Lars Heikensten, has written a paper on the possibility of using interventions during such times. Citing Borg and Heikensten (2002):

"In addition to adjusting the interest rate, the Riksbank can resort to interventions in the foreign exchange market and a number of other measures for the purpose of maintaining price stability. The most obvious case for a central bank with an inflation target considering interventions is when the interest rate instrument no longer functions effectively. One such situation is when the steering interest rate is zero and the real interest rates are nevertheless unjustifiably high as a result of the economy being in a deflation process, with a general and persistent fall in prices. Interventions with the aim of achieving more expansionary monetary conditions through a weakening of the exchange rate would be a possible measure here. The fact that there is a possibility, which is not negligible, of getting into a situation where the interest rate is zero and thereby constitutes a restraint for monetary policy, is a strong reason for having interventions in the monetary policy arsenal. It is also a reason for establishing firm principles for how interventions should be used."

p.31

To our knowledge no study yet has investigated if BOJ under the near zero nominal rate environment seem to have followed such an advice. In this paper we try to shed some light on this issue by considering the periods during the intervention sample period for which such a constraint on further nominal interest rate cuts have arisen. Furthermore, we consider the possibility that the BOJ during the last couple of decades could have used interventions as a supplementary monetary policy instrument. For this purpose we employ an estimated Taylor rule¹³. The Taylor rule as originally proposed in Taylor (1993) is formulated as:

$$i_t = i^* + \alpha(y_t - y_t^*) + \beta(\pi_t - \pi_t^T) \quad (5)$$

where $i_t = i^*$ if the output gap¹⁴ equals zero, $y_t - y_t^* = 0$ and inflation is at target, $\pi_t - \pi_t^T = 0$.¹⁵ For the USA during 1987-1992 Taylor suggests a target

¹³See Kuttner and Posen (2004) for an overview on the applicability of Taylor rules for Japan during this period.

¹⁴The real production trend is measured by the HP-filter, with a smoothing parameter of 126400 recommended for monthly data.

¹⁵A more realistic version of the Taylor rule would include forward looking behaviour of the BOJ. This could be considered in a future version of this paper.

inflation rate of two percent and $i^* = 5$ consistent with a real neutral rate of three percent.

Instead of taking these numbers as granted for Japan during our sample period we estimate a version of (5) allowing for a time-varying real neutral interest rate by inclusion of a deterministic trend as proposed in Plantier and Scrimgeour (2002)¹⁶ During this time period Japan has experienced a prolonged downturn of the economy with decreasing trend growth and the inclusion of the trend is motivated by the possibility that during the time period of prolonged recession either the real neutral interest rate has decreased and/or the inflation target of the BOJ could have decreased. Just an indication of the first would be that for the early observations in the sample, around 1991, the ex-post real interest rate¹⁷ was around six percent (8-2) whereas for the last observation of the sample at 0.5 percent (0-(-0.5)). We therefore estimate:

$$i_t = i^* + \gamma t + \alpha (y_t - y_t^*) + \beta (\pi_t - \pi_t^T) \quad (6)$$

where t is the deterministic linear time trend. The fitted values and the residuals from estimation of equation (5) and (6) are used to evaluate if the BOJ have had too tight of a monetary policy during the sample period and in turn these are used as possible determinants of interventions. The basic idea is that if the BOJ would have wanted to lower interest rates lower but was constrained in general or more specifically by the zero lower bound on nominal interest rates then it would seem more likely that they intervene in the forex market.

Another issue that needs to be approached is the possibility that the BOJ during the near zero interest rate environment have not tried to follow the Taylor rule at all. Since March 2001 the BOJ have pursued a policy of "quantitative easing", using different means other than the target rate to stimulate the economy by expanding liquidity through purchases of other assets. For this purpose we estimate the Taylor rule over 1986-2001m2 and use the estimates for this period in forecasts for 2001m3-2003.¹⁸

¹⁶ Obviously there are alternatives to this modelling of the time-varying real neutral interest rate such as using a HP-filter for the actual real rate or structural modelling as described in Wu (2005).

¹⁷ The real rate is measured as the uncollateralized overnight call rate minus inflation where inflation is measured as the past 12 months percentage price increase. The price index is CPI, excluding food and energy.

¹⁸ An indication of the Taylor rule not being applicable for this time period is seen in the Asahi shimbun internet edition 2005/10/24 where it is said that "Once the easing policy is lifted, the BOJ would revert to its old policy of targeting interest rates".

In fact, estimating throughout 1991-2005 and obtaining the fitted values and residuals out of these yield the same qualitative results as presented below for the time trend case.

Est. sample 1986-2001		
Variable	Coefficient	Std.
c	4.24	0.33
t	NA	NA
$y_t - y_t^*$	0.07	0.07
$\pi_t - \pi_t^T$	1.88	0.19
$R^2 : 0.66$		

Table 2: Taylor rule estimation without time trend

Est. sample 1986-2001		
Variable	Coefficient	Std.
c	6.16	0.43
t	-0.026	0.006
$y_t - y_t^*$	0.16	0.06
$\pi_t - \pi_t^T$	1.04	0.28
$R^2 : 0.79$		

Table 3: Taylor rule estimation with time trend

Estimation¹⁹ of (5) and (6) for Japan 1986-2001²⁰ yields the results displayed in Table 2, Table 3, Figure 2 and Figure 3.

The estimated coefficients are of the expected sign and interest rate setting can be described as stabilizing in that the coefficient for inflation deviations from target is greater than unity in both specifications. It further seems that also on statistical grounds the time trend should be included since it enters the Taylor rule with a significant coefficient.

For the estimation section below we will use the estimated residuals from these two specifications along with the corresponding dummy variable for those episodes where the fitted interest rate value from the Taylor rule estimation takes negative values. The residuals will then possibly capture the willingness of the BOJ to use interventions as a supplementary policy instrument when they are somehow constrained not to set the optimal interest rate. The fitted variable dummy will capture the possibility that the BOJ have used interventions as a complementary policy instrument when the zero bound restricts further decreases of the target interest rate. The indicator is defined as $1(jpnuncollf < 0)$ where $jpnuncollf$ is the fitted value for the interest rate in the Taylor rule.

¹⁹No spurious regression problem arises since the output gap measure is stationary and thus cannot be co-integrated of any order.

²⁰The motivation of extending the sample to 1986 is to avoid estimation in an economical downturn and instead capture a full cycle. In 1991 the Japanese economy is experiencing a bust in asset prices and the slump continues throughout the 1990's with short periods of temporary recovery.

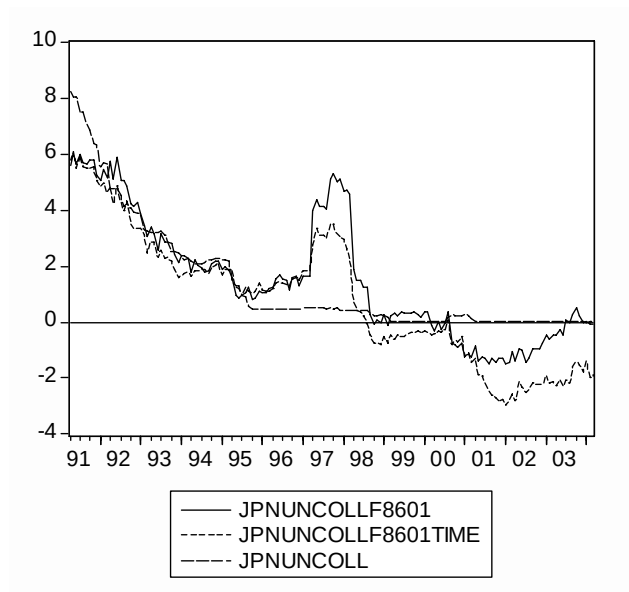


Figure 2:

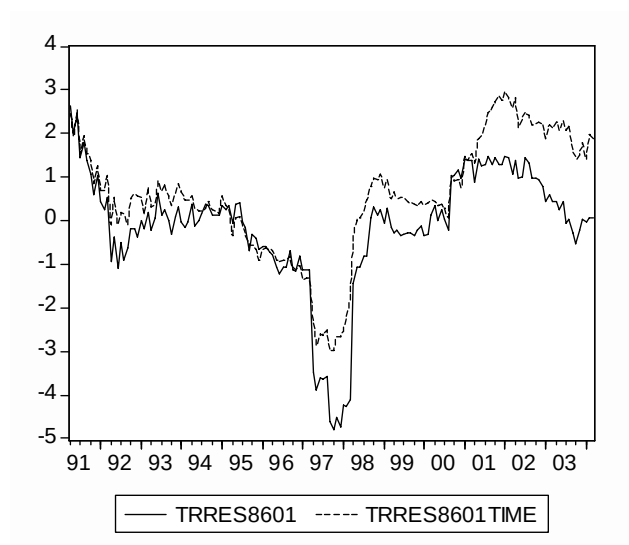


Figure 3:

4 Estimation of the reaction function of the BOJ

In this section we will firstly try to replicate the central results in Ito and Yabu (2004) relevant for this paper. Instead of only reporting the estimated coefficients in the ordered probit models we will also present the marginal effects evaluated at the mean of the covariates. Refraining to do so makes interpretations of the coefficients not meaningful. Then we will extent their model in two dimensions: firstly by simply estimating over the entire sample period available, then by inclusion of the variables discussed above along with changes in the overnight uncollateralized call rate. Inclusion of these variables will hopefully give some insight into weather the BOJ have used interventions as a means of a supplementary monetary policy instrument.

4.1 Non-fundamental specifications

The reaction function estimated with ordered probit model in Ito and Yabu (2004) is

$$INT_t = \begin{cases} -1 & \text{if } INT_t^* < \mu_1 \\ 0 & \text{if } \mu_1 < INT_t^* < \mu_2 \\ 1 & \text{if } \mu_2 < INT_t^* \end{cases} \quad (7)$$

$$INT_t^* = X_t\beta + v_t \quad (8)$$

$$v_t \sim i.i.d.N(0, \sigma^2) \quad (9)$$

$$\begin{aligned} X_t\beta &= \beta_1(s_{t-1} - s_{t-1}^T) + \beta_{lag}INT_{t-1} \\ &= \beta_{12}(s_{t-1} - s_{t-2}) + \beta_{121}(s_{t-1} - s_{t-21}) + \beta_{1MA}(s_{t-1} - s_{t-1}^{MA}) + \beta_{lag}INT_{t-1} \end{aligned} \quad (10)$$

where the last line follows from the authors assumptions of the fundamental rate. Estimation with ordered probit is valid under the assumption of normality of the residual term $v_t \sim i.i.d.N(0, \sigma^2)$ and no omitted relevant variables.²¹

In Table 4 the results in Ito and Yabu (2004) is replicated and the sample period is extended with 15 months of daily data. The estimates correspond closely to those reported in their paper. An interesting result just by extending the sample period is the decreased effect of past three weeks movement in the nominal exchange rate. It also appears that long-run determinants are getting more important. The marginal effects of changes in the independent variables are reported in parentheses and evaluated at the means of the independent variables. These coefficients are to be interpreted as the following: a hundredth of a unit of increase in the independent variable (for example an approximate one percent change in the exchange rate from the day before yesterday to yesterday)

²¹The second of these two issues is addressed here. The first requires a more general model in that it would allow for dependence of the residual term, such as serial correlation, due to omitted variables. The mitigation of such a problem is one of the purposes of the future full version of this paper. Surely, if the model was correctly specified in that no relevant variables are omitted the normality assumption seem innocuous, but since we will never really be able to control for all these this approach is validated. The set-back is high computational costs.

Table 4: Ordered probit estimates and marginal effects for ItoYabu-model

Var.	Full sample Est. (Mfx)	ItoYabu sample Est. (Mfx)
lag12	20.1976*** (-1.8274) (4.2557)	20.0627*** (-1.2404) (4.5468)
lag121	1.8187 (-.1645) (1.1163)	3.2686*** (-.2021) (1.2257)
lag1ma	3.5676*** (-.3228) (.6172)	2.9646*** (-.1833) (.6533)
int101lag	2.0525*** (-.1857) (.0841)	1.9135*** (-.1183) (.1026)
-cut1	-1.9315*** (.0497)	-2.0462*** (.0561)
-cut2	2.5261*** (.0754)	2.5000*** (.0758)
obs	4/1/1991-03/31/2003	4/1/1991-12/31/2002
LRIndex	0.3657	0.3152

NOTE:Standard errors are below estimates in parentheses.

One star indicates 10 percent, two stars indicate 5 percent and three stars indicate 1 percent significance level of the estimate.

Mfx=dProb(INT=-1)/dx evaluated at the means of x-variables

decreases the probability of a negative intervention (buying US dollars by selling Japanese yen) with approximately two percent. This behavior is consistent with the "leaning against the wind" behavior reported in the literature. The other effects are smaller of about one tenth in magnitude. The *LRIndex* indicates the goodness-of-fit of the specification.

4.2 Fundamental specifications

In the extended versions of the reaction function other factors than deviations from a nominal spot rate target are considered. As in some of the previous studies we consider the actual interest rate changes (*djpnuncoll*) to be a possible determinant (see Kim and Sheen (March 2005)). This could be the case because the CB perceives interventions as a possible remedy to temporary "over-shooting" of the market or alternatively a reinforcement of regular monetary policy. The other factors considered are those described, motivated and estimated above as deviations from fundamental exchange rate level (*pppdev**), general reinforcement of monetary policy when for some reason the interest rate is "unoptimally" set (*trres**) and the zero-bound constraint on interest rates (*trapindex**).

From the results in Table 5 one can infer that the variables considered above should indeed enter the specification of the BOJ reaction function. In both specifications, with and without time trend, the change in the interest rate along

Table 5: Ordered probit estimates and marginal effects for ItoYabu-model

Var.	Old model Est. (Mfx)	New model 1 Est. (Mfx)	New model 2 Est. (Mfx)
lag12	20.1976*** (-1.8274) (4.2557)	20.8944*** (-1.8383) (4.2755)	21.9059*** (-1.7868) (4.3332)
lag121	1.8187 (-0.1645) (1.1163)	1.9292* (-0.1697) (1.1288)	2.6196** (-0.2137) (1.1522)
lag1ma	3.5676*** (-0.3228) (0.6172)	3.2755*** (-0.2882) (0.6735)	1.2854* (-0.1048) (0.7666)
int101lag	2.0525*** (-0.1857) (.0841)	2.0443*** (-0.1799) (0.0842)	2.0077*** (-0.1638) (0.0845)
djpnuncoll		-2.0452** (0.1799) (.8125)	-2.0350** (0.1660) (0.8245)
pppdev7305		0.7313** (-0.0643) (0.3045)	2.1672*** (-0.1768) (0.4433)
trres8601		-0.0024 (0.0002) (0.0339)	
trres8601time			-0.1105*** (0.0090) (0.0391)
trapindex8601		-0.3113*** (0.0309) (0.1087)	
trapindex8601time			-0.5474*** (0.0490) (0.1309)
LRIndex	0.3657	0.3692	0.4152
Obs: 4/1/1991-03/31/2003			

NOTE: Standard errors are below estimates in parentheses.

One star indicates 10 percent, two stars indicate 5 percent and three stars indicate 1 percent significance level of the estimate.

Mfx=dProb(INT=-1)/dx evaluated at the means of x-variables

with exchange rate deviations from PPP level and the dummy for constraint on monetary policy enter significantly with the "correct" sign. As for the Taylor rule residual, the coefficient is only significant in the specification allowing for a deterministic time trend in the interest rate. Here should be duly noted that the regressors have been generated by OLS estimation and that the significance level of the estimates in Table 4 and 5 are conditional on this first estimation stage. However, inclusion of the arguments in the Taylor rule directly into the estimated reaction function yield significant and "correct sign" estimates of the effect on probabilities of interventions. E.g. a negative output gap or inflation below target increase the probability of BOJ selling yen which would be consistent with the notion of forex interventions as a supplementary monetary policy instrument.

Focusing on the third column the interpretation of the coefficient are the following: a ten point decrease in the interest rate decreases the probability of the BOJ selling yen with around two percent; a 0.1 percent positive deviation from the fundamental rate decreases the probability of the BOJ selling yen with around two percent; the Taylor rule residual being one point above target increases this probability of about one percent and finally: at times of the fitted value of the Taylor rule falling below zero the probability increases with five percent.

What is also worth noting is the way that the estimates of the effect of medium to long run changes in the nominal rate change with inclusion of the fundamental variables. The medium change (*lag121*) increases from close to insignificantly differing from zero and the long run change (*lag1ma*) decreases from strongly significant to close to insignificantly differing from zero. The estimated marginal effect (of *lag1ma*) further decreases from 0.3 to 0.1 indicating that there might have been a strong upward bias in the estimate of this coefficient in the absence of the fundamental variables. The intuition is that if these fundamental variables are not included the coefficient of *lag1ma*, the variable itself being positively correlated with the long run fundamental deviation (*pppdev7305*), will exhibit a positive bias.²²

The overall ability of the specification being able to explain the variation in interventions increase substantially in the second specification from 0.37 to 0.42.

We believe that the results indicate that although nominal considerations, deviations from the past nominal exchange rate levels, matter for interventions by the BOJ throughout the period other factors have also played a non-trivial role. This is especially true at longer time horizons for which nominal and real movements in the exchange rate are non-identical. This claim is corroborated by the non-robust coefficients on *lag121* and *lag1ma*. After all, at a longer time horizon it seems more consistent with central bank behavior that real considerations should also matter for intervention considerations. Perhaps the previous literature has been to preoccupied with high-frequency issues and short-run considerations to consider such possibilities in the past. Another possible reason

²²The correlation of *lag1ma* and *pppdev7305* is 0.38 in our sample.

for the focus on non-fundamental issues in the literature could be the difficulties that arise if trying to address the questions investigated in this paper. *Firstly*: one needs to take a stand on proper exchange rate modelling. Considering the difficulties in such modelling with theoretical underpinnings and the failure of such models to beat the random walk out of sample it is tempting to resort to non-fundamental modelling and to focus on the stabilization of chartist short-run misalignments and trends. *Secondly*: how does one model the constraint of the CB in interest rate setting? This becomes especially cumbersome if such rule-of-thumb behavior as the Taylor rule is inappropriate under certain circumstances. In this paper we have used as simple as possible of an approach in constructing exchange rate misalignments and CB constraints; more elaborate modelling of these issues could be an interesting issue for future work in the area.

5 Conclusions

In this paper we have shown that some economically relevant variables are missing in the standard formulation of the BOJ reaction function in intervening in the forex market. The results further indicate that the omission of such variables can result in biased estimates in the standard econometric model. Although we do not claim to have found "the correct specification", controlling for all possible determinants of intervention behavior there are reasons to believe that the ones we have studied have mattered for BOJ intervention behavior throughout the period in question. An interesting finding of the paper is that the zero-bound on the nominal target interest rate have seem to have made the BOJ more likely to intervene in the direction that for stabilization purposes would seem most appropriate during such periods. This finding is interesting in that theoretical work and the business press have suggested such behavior but nevertheless to my knowledge not empirically investigated up until now. Although not stated by the BOJ as a reason for interventions the data tells us otherwise.

6 Appendix

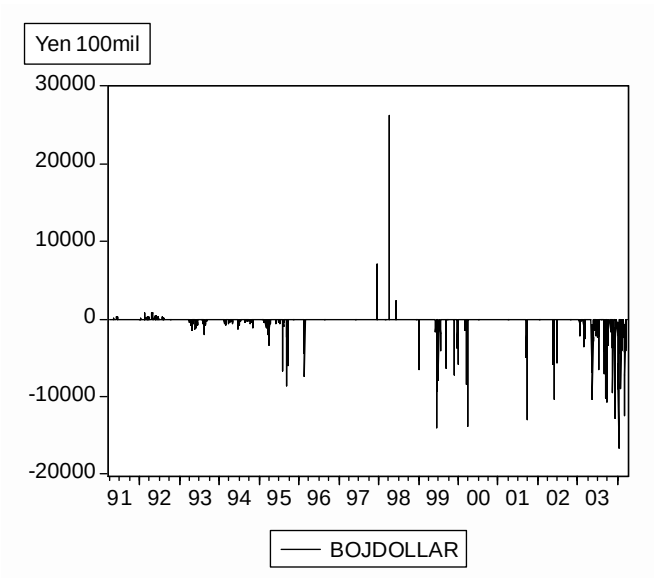


Figure 4: BOJ interventions 1991-2004

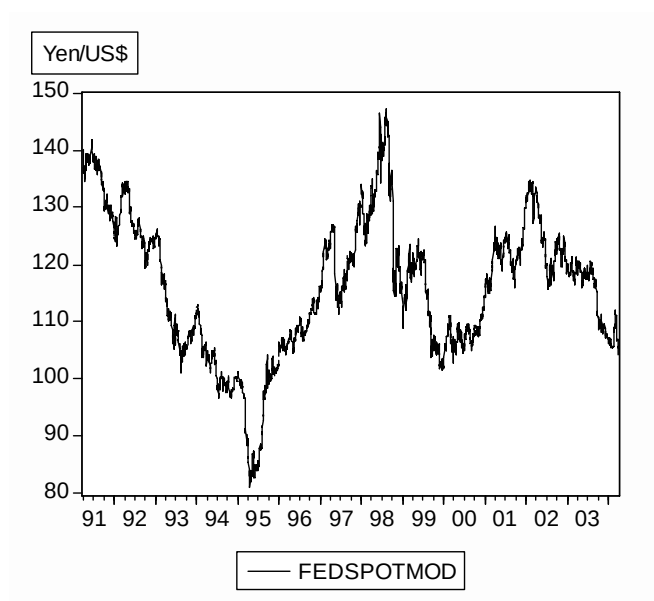


Figure 5: Yen/dollar spot rate 1991-2004

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