FOREIGN EXCHANGE INTERVENTION AND MONETARY POLICY IN JAPAN: EVIDENCE FROM IDENTIFIED VARS

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Abstract

Several researchers and commentators have argued that Japan should intervene in the foreign exchange market to weaken the yen and generate inflation. Such policy prescription only works if foreign exchange intervention has an economically significant impact on the exchange rate. This paper empirically analyzes the impact of foreign exchange intervention on the nominal yen-U.S. dollar exchange rate using an identified vector autoregression (IVAR). In contrast to previous work in this area, this paper explicitly allows intervention to contemporaneously respond to the exchange rate. Using data for the 1990s, the results show that intervention has a significant, albeit relatively small, impact on the exchange rate. The results of this paper cast doubts on claims that foreign exchange intervention could be effectively used to depreciate the yen and help solve the deflation problem.

Keywords: Japan, Monetary Policy, Foreign Exchange Intervention.

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I. INTRODUCTION

Recently, several researchers and commentators have argued that Bank of Japan's answer to the deflation problem lies (partly) in the depreciation of the yen (Svensson, 2003 and McCallum, 2003). It appears that the Japanese authorities may have been listening: in May 2003 alone, it spent over US$30 billion in an attempt to stem yen appreciation pressures (*Financial Times* June 6, 2003). As reported in the specialized media, most of these purchases of foreign exchange were aimed at stemming excessive volatility and appreciation pressures against the U.S. dollar.[2]

Several papers have analyzed the effectiveness of foreign exchange intervention, generally with mixed results - see Sarno and Taylor (2002) for a survey. Nevertheless, most of the papers focus on the experience of the U.S. Federal Reserve, and on the period comprising the second half of 1980s through early 1990s. The are several reasons for this, including data availability – daily data on intervention is available for the U.S., Germany, and Switzerland – and relatively intense period of foreign exchange intervention episodes. That period also includes major exchange rate swings (dollar depreciation following the Plaza Accord) and two major international accords that explicitly involved the major G-7 exchange rates (Plaza and Louvre).

The availability of intervention data for Japan (1991-present) is likely to stimulate another wave of research on the effects on foreign exchange intervention. Like the U.S. dollar during the 1980s, throughout the 1990s the value of the yen-dollar exchange rate has fluctuated sharply, from 80 yen per dollar in March 1995 to 147 yen per dollar in May 1998.

[2] The experience of Japan contrasts sharply with that of the U.S. and other European countries throughout the 1990s. The U.S. Federal Reserves has intervened on its own behalf only twice during the period 1995-2001, and the European Central Bank intervened reportedly intervened four times since the launch of the Euro (September 22, 2000, and November, 3, 6, and 9, 2000).

Perhaps not surprisingly to some, these two periods coincide with major interventions by both the Japanese and U.S. authorities. Two other factors make the Japanese case particularly interesting: in contrast with the U.S., in the 1990s the Japanese monetary authorities have maintained a relatively active presence in the foreign exchange market;[3] secondly, since the BOJ cannot rely on lowering short term interest rates to fight deflation, several researchers (McCallum, 2003, Svensson, 2001, 2003) have suggested that now is the time for less conventional monetary policy, including purchases of foreign exchange aimed at bringing down the value of the domestic currency. Baig (2003) argues that deflation in Japan reflects weaknesses in the economy, particularly stagnant demand. In this case, high real interest caused by expected deflation and (or close to) zero nominal interest rates impose costs by hampering the scope for a sustainable recovery. Therefore, initiatives to re-inflate the economy could be successful if they generate a sustainable increase in aggregate demand.

This paper analyzes the impact of foreign exchange intervention by the Japanese authorities[4] on the dollar-yen exchange rate. In contrast with previous studies, this paper uses an identified VAR (IVAR) to estimate the impacts of intervention on the exchange rate, allowing at the same time for the exchange rate to contemporaneously affect intervention (leaning-with or against the wind). The IVAR modeling strategy also allows one to gauge the degree of sterilization, which is given by the impact of intervention on the interest rates and money base calculated through the estimated impulse response functions.

The main advantages of using IVARs to study the effects of intervention on exchange rate are the following. First, the simultaneity problem that plagues regression based studies is dealt with directly. In addition, one can determine the type of simultaneity between the

[3] The heavy presence of the Japanese authorities is also felt on the magnitude of its interventions. For instance, on Monday, April 3, 2000, it purchased US$13.2 billion in an attempt to fend off a sharp appreciation of the yen which had taken place during the preceding week.

[4] In practice, the BOJ conducts foreign exchange intervention on behalf of the Ministry of Finance. A description of the institutional details of foreign exchange intervention in Japan can be found in Ito (2002).

exchange rate and intervention.[5] Second, the effective degree of sterilization can be studied, i.e. one can determine the impacts of intervention on interest rate and money base. Third, a VAR model allows one to estimate the short term and longer term effects of intervention using the same model (e.g. by looking at cumulative impulse responses). Finally, the VAR model allows a direct comparison of the effects of conventional monetary policy versus intervention on the exchange rate.[6]

The main disadvantages of using the IVAR to study the impacts of intervention include the use of monthly data, the degrees of freedom problem (small sample and too many parameters), the validity of identifying restrictions, and the plausibility of structural shocks. Most of the criticism is directed at the VAR approach to econometrics and shall not be discussed here.[7] The use of monthly data may be seen as one of the main weaknesses of the approach employed in this paper. Monthly data are used mainly for two reasons: first, to estimate a "macroeconomic" VAR model, the highest available frequency is monthly, especially if one wants to include variables such as industrial production; second, if intervention is a useful macroeconomic policy tool, then it should have effects that are beyond the daily/weekly horizon.[8] Obviously, one could estimate daily VARs a subset of variables, but at the potential cost of model misspecification, which may be particularly acute in the VAR framework.[9]

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[5] Obviously, the estimated degree of simultaneity is likely to change over time. But its is not obvious that this would be a more serious problem for the VAR approach.

[6] Kim (2003) extends the framework of Kim and Roubini (2000) to study the impacts of U.S. Fed interventions in an IVAR framework. He discusses some of the advantages of the IVAR framework.

[7] See Favero (2001) for an excellent review of these issues.

[8] Lyons (2001) argues that it may be useful to concentrate on the permanent component of shocks to the exchange rate, however small they might be. He uses daily data to "integrate out" the effects of intra-daily shocks. Our approach could be seen as equivalent, except that here we are integrating out the effects of daily shocks.

[9] Lewis (1995) uses VAR models to analyze the impacts of intervention on monetary policy. Guimarães (2003) also estimates daily VARs to gauge the effects of intervention. The results weakly support the effectiveness of intervention.

Empirical tests uncover significant, but small, impacts of intervention on the exchange rate. The results also show, in addition to smoothing volatility, interventions by the Japanese authorities are of the "leaning against the wind" type, i.e. the they have sold yen following yen depreciations. The findings also indicate that intervention has had very small effects on the short term interest rate and base money, which is consistent with sterilization.

The remainder of the paper is organized as follows. Section II reviews the academic literature on the conditions under which intervention may be effective in achieving its objectives and discusses the findings of the empirical literature of the actual effectiveness of intervention. Section III presents the empirical methodology used to assess the effectiveness of intervention. Section IV contains the main empirical findings and policy implications. Section V concludes.

II. Literature Review

Theory

The literature on the effectiveness of intervention is based mainly on three channels: (i) the signaling channel, (ii) the portfolio balance channel, and (iii) the microstructure channel. According to these channels, intervention may affect the exchange rate even when it is sterilized.

The *signaling channel* theory states that intervention can be effective if it is perceived as a credible signal on the future stance of monetary policy (Mussa, 1981). The exchange rate is treated as an asset price and it is a function of the expected path of the money supply. To the extent that intervention, even when sterilized, influences market expectations on *future* money supply, then it can influence the exchange rate. As argued by Lewis (1995), if foreign exchange intervention were only used as a signaling device of future policy actions, the signaling power of interventions would ultimately depend on whether there is a systematic relationship between intervention and future monetary policies.

The *portfolio balance channel* states that intervention can be effective by altering the currency composition of agents' asset portfolios. The model key assumptions are that domestic and foreign currency denominated government bonds are imperfect substitutes and market participants are risk averse, and hence demand a risk premium on the assets denominated in the riskier currency[10]. In this framework, a sterilized intervention operation alters the relative supply of domestic versus foreign currency bonds, causing agents to rebalance their portfolios to equalize risk-adjusted returns through a change in the exchange rate. The exchange rate serves as the adjustment mechanism for risk-adjusted returns because money supply and interest rates are assumed to remain unchanged following a sterilized intervention in the foreign exchange market.[11] This channel would imply that uncovered interest rate parity would not hold because of the existence of a risk premium.[12]

Under the *microstructure approach*, intervention's effectiveness focus on the extent to which central bank trades affect aggregate order flow. Intervention can cause market participants to change their expectations on the future path of the exchange rate and lead them to modify their desired net open foreign exchange positions, triggering a change in aggregate order flow well in excess of the central bank's contribution. Official intervention's impact on order flow and exchange rates can be greater in the presence of noise traders,

[10] The large literature on the violation of uncovered interest parity gives some support to the portfolio balance channel, see Obstfeld (1990), and Frankel and Dominguez (1993).

[11] Consider the case in which the Federal Reserve targets a more appreciated U.S. dollar against the Japanese yen. The Fed would sell the Japanese currency by liquidating its yen-denominated bonds and simultaneously buy domestic dollar-denominated bonds, leaving the domestic money supply and interest rates unaffected. These operations would increase the ratio of foreign debt relative to domestic debt held by the market, making the underlying currency (in this case the yen) more risky. This, in turn, increases the yen risk premium, triggering an immediate appreciation of the U.S. dollar.

[12] The appendix contains a simple model that generates a risk premium.

which follow recent trends, and often trade in a correlated fashion (Hung, 1997). Central bank intervention, even in small amounts, can trigger a tide of buy or sell order by trend-chasing traders.

Empirical Evidence

The empirical literature on intervention's effectiveness is vast.[13] They typically try to asses the impact of one of the channels above usually relying a regression framework. Tests for validity of the signaling channel have found mixed evidence in its favor. Dominguez and Frankel (1993a) estimate the effect of intervention on contemporaneous exchange rate movements and on forecasts of future exchange rates. Using survey data to measure exchange rate expectations, they find a significant effect of intervention on market expectations, especially if interventions are announced and coordinated. Evidence on the portfolio balance channel is also mixed. Obstfeld (1990) finds that portfolio balance effects are statistically significant, but small in size.[14] The consensus in the literature until recently was that the portfolio effect gives a limited role for intervention to influence the exchange rate. One exception is a study that found a significant and potentially large portfolio effect during the 1984-88 period, using *survey data* to measure exchange rate expectations and risk premium (Dominguez and Frankel, 1993b).

More recent research using data on order flow, however, identifies permanent price effects through the portfolio balance channel. Evans and Lyons (2001, 2002) found that order

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[13] See Edison (1993) for a survey of the results from the 1980s through early 1990s and Sarno and Taylor (2001) for the more recent empirical evidence.

[14] There is a vast literature, surveyed in Engel (1996), showing that there is a sizeable (and time-varying) risk premium, which is a necessary, though not sufficient, condition for intervention to have an effect on the exchange rate through the portfolio balance channel. Most of the evidence on the existence of a risk premium is concentrated on advanced economies. The limited evidence for emerging markets suggests that the risk premium may be substantial, but the supporting studies are plagued by problems such as sample size and structural changes (caused for example, by exchange rate regime changes).

flow and intervention have a significant “price impact.” Evans and Lyons (2001) also argue that private order flow, which could be seen as equivalent to sterilized and secret foreign exchange intervention that provides no policy signal, have the largest impact on the exchange rate when the flow of macroeconomic announcements is high.

Evidence for Japan is generally more favorable to the effectiveness of intervention. Using the same intervention data used in this paper, Ito (2002) finds that intervention has small but significant effects on the U.S. dollar-yen nominal exchange rate. Nonetheless, the impact of intervention on the exchange rate depends on the subperiod analyzed. For instance, Ito (2002) shows that for the period 1995-2001 a US$1 billion dollar purchase of yen by Japanese authorities led to a yen appreciation of about 15 basis points. Ito (2002) also shows that intervention has been caused by exchange rate movements (leaning against the wind) and attempts to “target” the exchange rate.[15] Ramaswany and Samiei (2000) also document significant effects of interventions by the Japanese authorities on the yen-dollar exchange rate. Using daily data for 1995-1999, they uncover small but rather persistent effects of intervention. Finally, Ramaswamy and Samiei (2000) also find that interventions are caused by excessive exchange rate movements, in a leaning against the wind fashion.[16]

Empirical studies of intervention’s effectiveness have also analyzed the impacts of intervention on exchange rate volatility. Most studies find that central banks’ ability to smooth exchange rate volatility may be limited.[17] Both Dominguez (1998) and Hung (1997)

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[15] The latter is also pointed by market participants as one of the determinants of interventions. For instance, throughout the first half of 2003, market participants were reported asserting that they expected dollar purchases by the Japanese authorities whenever the yen-dollar rate approached 117 (from above).

[16] Ramaswany and Samiei (2000) use *reports* of interventions by the Japanese authorities instead of actual intervention data.

[17] The measurement of exchange rate volatility is typically based on two approaches. The first method is to use a statistical model, such as generalized autoregressive conditional volatility (GARCH), to measure volatility. This approach has the advantages of being simple and increasingly used in the market to estimate asset price volatility. Several market participants use GARCH based models of

(continued)

provide evidence that following the Plaza Accord (September 1985) intervention tended to reduce exchange rate volatility among the G-3 currencies, but when the post-Louvre (1987-1989) period is examined, intervention increased volatility. Bonser-Neal and Tanner (1996) use implied volatilities from currency option prices and find that intervention increased exchange rate volatility. Cheung and Chinn (1999) conducted a survey with foreign exchange traders, 60 percent of whom view intervention as increasing exchange rate volatility. Beine et.al. (2002) show that interventions by the Japanese authorities have led to increases in exchange rate volatility during the 1990s.

III. DATA AND METHODOLOGY

This section empirically tests the impacts of foreign exchange intervention on the exchange rate. The first subsection discusses the data; the second subsection discusses the estimation method, identifying restrictions, and tests of the model. The last subsection discusses the empirical results along with some policy implications based on the numerical estimates.

Data Considerations

The data used in this paper are sampled monthly and taken from IMF's International Financial Statistics (IFS) and Datastream, with the exception of the intervention series, which comes from the Ministry of Finance of Japan's website. The variables used in the estimations are: industrial production, call money rate, the yen-dollar exchange rate, the consumer price index, commodity price index, FX intervention by the Japanese authorities, and money supply. The sample period covers 1991:01-2001:03. The exchange rate, expressed in yen per dollar, is the 12 p.m. close in NY, and the intervention is positive for yen purchases (in

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volatility, such as *Riskmetrics,* to help monitor their positions and calculate value at risk. Another approach is to use options-based measures of volatility. Options pricing models can be "inverted" to yield implied volatilities of the underlying asset.

billions of yen). The money base and industrial production series are seasonally adjusted. All variables are expressed in the form of logarithms (multiplied by 100) except the interest rate and the intervention series.

The variables included in the VAR are standard in monetary policy benchmark model. The commodity price index is included to address the price puzzle[18] uncovered by Sims (1992). Finally, intervention is included along with the exchange rate to allow an integrated analysis of the effects of monetary policy shocks and intervention on the exchange rate. Miyao (2002) notes that the call money rate (the overnight rate in the interbank money market) is the best indicator of monetary policy in Japan.

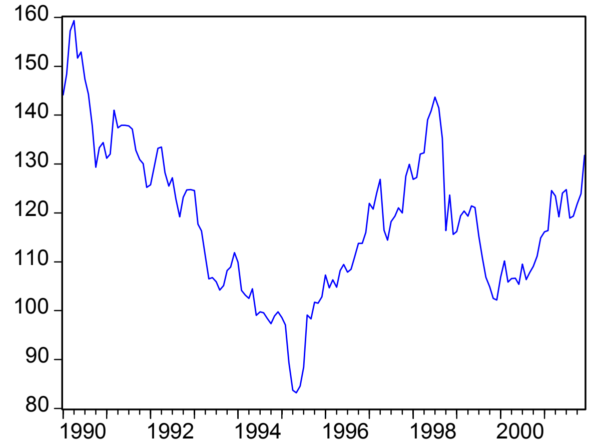
The main objective of intervention by the Japanese authorities has been to smooth volatility of the yen,[19] despite the fact that its reaction function can be reasonably described by a leaning-against the wind policy. Yen depreciations were followed by yen purchases by the Japanese authorities (e.g. Summer 1998), and yen appreciations were followed by sales (of yen). Most of the sample is characterized by yen sales against the U.S. dollar.

Figures 1 and 2 show the yen-dollar exchange rate and the intervention by the Japanese authorities (against the U.S. dollar) from 1990-2001. Ito (2002) presents a very comprehensive narrative and econometric analysis of Japan's case. Following the strong appreciation of the yen against the dollar that ended in March 1995, the dollar appreciated during the first half of the sample period, followed a subsequent depreciation during the second half of he sample (after the Summer of 1998).

[18] According to Sims (1992) the commodity price index controls for inflationary pressures (expectations) that are not captured by the other variables, but that monetary authorities may react to on a systematic basis.

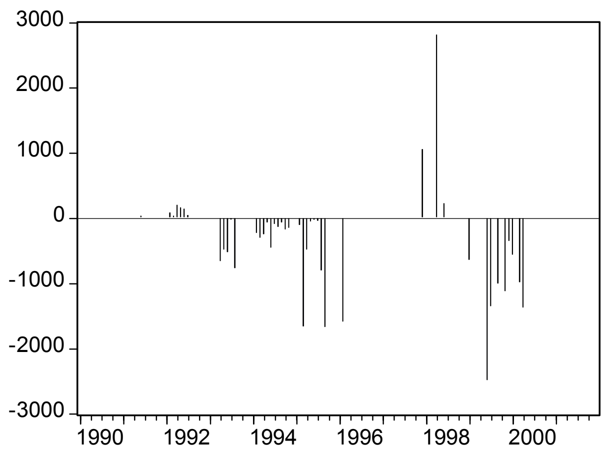
[19] Several market commentators have suggested that Japanese authorities appear to target the level of the yen-dollar exchange rate.

Figure 1. Nominal Exchange Rate (in yen per dollar)



Source: Datastream.

Figure 2. Foreign Exchange Intervention (in billions of yen)



Source: Ministry of Finance, Japan.

Estimation and Testing

This paper extends the framework of Kim and Roubini (2000) to incorporate foreign exchange intervention in what has become the "standard empirical monetary policy model" (Favero, 2001). The model is based on an identified VAR (IVAR), which was introduced in the VAR literature by Bernanke (1986) and Sims (1986) to analyze the impacts of monetary policy shocks. The IVAR model of Kim and Roubini (2000) is aimed at solving the empirical difficulties uncovered by Sims (1992) and others.[20]

The main thrust of the IVAR modeling strategy is to impose contemporaneous restrictions on the data to identify "structural" shocks, instead of the data-driven recursive restrictions imposed by, e.g., the Cholesky identification put forward by Sims (1980). The identifying restrictions imposed should ideally come from economic models and timing assumptions, and can be tested by standard testing procedures.

More specifically, the identified VAR model utilized in this paper assumes that the model economy can be represented by:

$$B_0 y_t = k + B_1 y_{t-1} + ... + B_p y_{t-p} + u_t$$

where $y_t = [p_t^c \quad I_t \quad r_r \quad m_t \quad p_t \quad q_t \quad s_t]'$ is the n x 1 data vector containing commodity price index (p^c), foreign exchange intervention (I),[21] interest rate (r), monetary base (m),

[20] Those include the price puzzle (Sims, 1992) and the foreign exchange puzzle (Eichenbaum and Evans, 1995), and are discussed in more detail in Kim and Roubini (2000) and Favero (2001).

[21] As in Kim (2003), the intervention measure is normalized by the money supply. The results below are qualitatively unchanged if actual intervention is used instead.

price index (p), industrial production (q), and the exchange rate (s); k is a vector of constants, B_i is an n x n matrix of coefficients (i = 1, ..., p), and u_t is a white-noise vector of "structural" shocks, with diagonal variance-covariance matrix D. The model can be rewritten as:

$$y_t = c + C_1 y_{t-1} + ... + C_p y_{t-p} + e_t$$

where $e_t = B_0^{-1} u_t$ is also white-noise vector process, with variance-covariance matrix given by $\Omega = B_0^{-1} D (B_0^{-1})'$. The matrix Ω can be rewritten as Ω = ADA' where D is diagonal. In this case, since $u_t = A^{-1} e_t$, with A = B_0^{-1}, then E($u_t u_t'$) = $E(A^{-1} e_t e_t' (A^{-1})')$ = $A^{-1}(ADA')(A^{-1})'$= D, i.e. the vector u_t is orthogonal and can now be interpreted as "structural" shocks[22]. In practical terms, identification amounts to finding (imposing restrictions on) the matrix A (B_0^{-1}) that orthogonalizes the reduced form errors, "soaking up" their contemporaneous correlation[23]. A widely-used identification scheme is the recursive ordering (Cholesky) proposed by Sims (1980), which assumes that A has a lower triangular structure. This is equivalent to saying that the ordering of the variables follows a hierarchical structure, with the most exogenous variable ordered first.

The model is estimated by maximum likelihood. The reduced form model can be used to estimate the matrix Ω, then the structural parameters may be obtained by solving the non-linear system given by $\Omega = B_0^{-1} D (B_0^{-1})'$, or alternatively, the log-likelihood function that relates Ω and D:

$$\ell(B_0, D, \hat{\Omega}) \propto (T/2)(\ln |B_0|^2 - \ln |D| - tr[B_0^{-1} D^{-1} B_0 \hat{\Omega}])$$

[22] Since e = B_0^{-1}u and u = A^{-1}e, the equality A = B_0^{-1} follows immediately.

[23] Alternatively, note that the matrices B_0 and D cannot have more unknowns than Ω. In this case, since D has n parameters (it is diagonal) and Ω has n(n+1)/2 parameters (it is symmetric), this constrains B_0 to have at most n(n-1)/2 free parameters.

The advantage of the latter is that inference based on the likelihood ratio and Wald tests can be conducted directly based on the estimated log-likelihood. If there are n* estimated parameters in B_0, the number of overidentifying restrictions (r) is given by $r = (n(n-1)/2) - n^*$. The likelihood ratio test is given by:

$$LR = 2[-(T/2)\ln|\hat{\Omega}| - (T/2)n - \ell^*]$$

where ℓ^* is the maximized value of the log-likelihood and LR has a chi-square distribution with r degrees of freedom. The model is estimated in levels[24] and the lag structure is also determined according to a log-likelihood based statistic (here the BIC is used). Finally, the standard errors for the impulse response functions are calculated according to the procedure outlined in Sims and Zha (1999).[25]

Identification

To identify the structural shocks, the following contemporaneous restrictions are imposed:[26]

- The commodity price index is exogenous with respect to all the variables in the system.

[24] The intervention series (normalized by base money) is the only stationary series at 5 percent. Sims (1992) recommends against differencing on grounds that differencing does not lead to efficiency gains, at a possible cost of inconsistency. Miyao (2002) and several other papers estimate VAR models in first-differences to account for non-stationarity. Most of the results reported below are robust to differencing, including the impacts of intervention on the exchange rate. Another possibility would be to estimate the model in levels and impose cointegrating restrictions. In addition to the fact that this might lead to potential inconsistency (in an econometric sense), the impacts of foreign exchange intervention and the monetary policy transmission mechanism are short to medium term phenomena, which can be adequately captured with unrestricted VARs (Favero, 2001).

[25] More specifically, the probability bands are calculated from at least 10,000 draws using a Bayesian method which employs a Gaussian approximation to the posterior of the matrix A.

[26] No coefficient restrictions are imposed on the lagged structural parameters of the model.

- Foreign exchange intervention responds contemporaneously only to exchange rate changes. However, intervention and monetary policy are linked since interest rates respond contemporaneously to intervention (see restriction 4 below). Also note that monetary policy shocks affect the exchange rate, which, in turn, is allowed to affect foreign exchange intervention contemporaneously.

- The call money rate responds and base money do not contemporaneously react to output and price level shocks (within a month, timing assumption), consistent with Sims and Zha (1995).

- The call money rate responds contemporaneously to the monetary aggregate, the commodity price index, and foreign exchange intervention. In addition, the effects of intervention on the interest rate are allowed since non-sterilized intervention affects domestic liquidity conditions;

- There is a money demand equation since nominal base money depends on the price level, industrial production, and the call money rate. In addition, money demand does not react contemporaneously to intervention nor the exchange rate.

- Given the monthly frequency, industrial production is sluggish and does not respond contemporaneously to shocks in the other variables (except commodity prices), an assumption justified by Kim and Roubini (2000) on the grounds that firms do not adjust output unexpectedly in response to policy shocks or financial market shocks.

- According to the "arbitrage equation", the exchange rate responds contemporaneously to shocks to all the variables in the VAR.

The above restrictions imply that the "structural model" can be written as:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & b_{27} \\ b_{31} & 0 & 1 & b_{34} & 0 & 0 & b_{37} \\ 0 & 0 & b_{43} & 1 & b_{45} & b_{46} & 0 \\ b_{51} & 0 & 0 & 0 & 1 & b_{56} & 0 \\ b_{61} & 0 & 0 & 0 & 0 & 1 & 0 \\ b_{71} & b_{72} & b_{73} & b_{74} & b_{75} & b_{76} & 1 \end{bmatrix} \begin{bmatrix} p_t^c \\ I_t \\ r_t \\ m_t \\ p_t \\ q_t \\ s_t \end{bmatrix} = B(L) \begin{bmatrix} p_t^c \\ I_t \\ r_t \\ m_t \\ p_t \\ q_t \\ s_t \end{bmatrix} + \begin{bmatrix} u_{pc} \\ u_I \\ u_r \\ u_m \\ u_p \\ u_q \\ u_s \end{bmatrix}$$

where $B(L) = \sum_{i=1}^{p} B_i(L^i)$, and consistent to the notation above, u_t is the vector of "structural" shocks. In this case the LR statistic is distributed as chi-square(5). According to the model above, the magnitude of the contemporaneous impact of intervention on the exchange rate is given by the coefficient b_{72}, since in the structural model the exchange rate equation is $s_t = -b_{72} I_t + b'_{-1} Z_t + B(L) y_t + u_t$, where the vector Z contains all the variables in the VAR except intervention. Conversely, the "leaning against the wind" coefficient which measures the contemporaneous impact of the exchange rate on intervention is given by b_{27}. The dynamic impacts (multipliers) are given by the impulse response functions described below.

IV. Empirical Findings

The estimations results of the baseline specification are presented in Table 1. The number of lags included in each model is determined by the likelihood ratio test of lag exclusion. According to the lag selection criteria (multivariate BIC), 2 lags are sufficient to accommodate the dynamics present in the data.[27] The first noticeable feature of the results is the number of insignificant (at the 5 percent level) coefficients of B_0. This result, although not particularly encouraging, is not uncommon in the IVAR literature. The estimated model yields significant impulse response functions for most of the variables and shocks studied in this paper. As in Kim and Roubini (2000), the large standard errors found might be due to the high correlation among the variables rather than over-identifying restrictions imposed on the model. The test for over-identifying restrictions show that they cannot be rejected at any conventional significance level; the statistic is LR = 6.45 with a p-value of 0.27.

[TABLE 1 (coefficients) HERE]

The estimated sign of the coefficient that gives the impact of intervention on the exchange rate is consistent with the effectiveness of intervention, i.e. yen purchases have a

[27] Residual tests reveal mild forms of autocorrelation (but not of heteroskedasticity) that can be reduced by adding more lags to the baseline model. Given the large model vis-à-vis sample size, the 1 lag structure was preserved.

negative impact on the value of the U.S. dollar ($b_{72} > 0$), nonetheless, the estimated b_{72} is not statistically significant at the 5 percent level. In any case, according to the estimated coefficient, a US$1 billion dollar purchase depreciates the Japanese yen (against the U.S. dollar) by 0.28 percent.[28] As noted above, the IVAR methodology also allows one to control for the simultaneity between intervention and exchange rates. In fact, this turns out to be quite important since it is found that interventions can be characterized as leaning against the wind. The coefficient b_{27} shows that yen depreciations have led to yen purchases by the Japanese authorities (i.e. $b_{27} < 0$), possibly in an attempt to stem the exchange rate movement or smooth volatility. In either case, single-equation methods or VAR models that do not properly account for the simultaneity are likely to find wrongly signed coefficients due to the simultaneity bias, a problem explained in detail in Dominguez and Frankel (1993).[29]

Figure 3 shows the impact of one standard deviation foreign exchange intervention *shock* on the exchange rate (panel A) and the impact of a one standard deviation shock to the latter on intervention (panel B). The impulse response functions are computed over a horizon of 24 months. The dashed lines are 90 percent probability bands estimated according to the bootstrapping method of Sims and Zha (1999) described in the previous section. According to the IRFs, the intervention shock has a negative impact on the exchange rate that lasts about one month. More specifically a one standard deviation intervention shock (Yen purchase) depreciates the dollar by about 0.93 percent.[30] The effect is reversed in the following months but is present at the long term horizon (after 10 months). The results also show that about one third of the effect of the shock (0.30 percent) remains after 24 months (although it is not

[28] This number is not directly comparable with those from daily reduced-form estimates (e.g. Ito, 2002), but it indicates that intervention might have a substantial effect beyond the daily horizon. The figure in dollars is calculated based on the average exchange rate during the estimation period.

[29] Dominguez and Frankel (1993), in single equation framework, discuss the difficulties of overcoming the simultaneity bias. Furthermore, the solutions may weaken the estimated impact of intervention on the exchange rate, even with daily data.

[30] The impact of the shock is about 0.21 percent per US$1 billion (using average exchange rate).

statistically significant different from zero), which suggests that intervention may have small, albeit persistent, effects on the exchange rate. Obviously, the impact of intervention on the exchange rate is consistent with the theories reviewed in this paper, although it is not possible to distinguish between them.

The dynamic impact of the exchange rate on intervention is also significant, but it dies out much faster: after one month it is not significantly different from zero, and the median response (point estimate) approaches zero after 12 months. This confirms that "leaning against the wind" is a short term phenomenon in the sense that the authorities only consider recent past exchange rate changes when deciding the intervention amount.

[FIGURE 3 (impacts of I on s, and s on I) HERE]

The results of the variance decomposition exercise (VDE) are shown in Table 2. In the case of the exchange rate, the VDE shows that intervention accounts for a very small fraction of the variance of the exchange rate (always less than 10 percent), which is consistent with the small impact of intervention on the exchange rate. The results also show that interest rate shocks account for a similar (but higher) percentage of the variance of the exchange rate. In contrast, the VDE shows that the exchange rate accounts for up to 20 percent of the variance of the forecast error of intervention, consistent with leaning against the wind by the monetary authorities (up to 24 months).

[TABLE 2 (variance decomposition – exchange rate, intervention) HERE]

The estimated IRFs are also consistent with most of the predictions of standard monetary policy models (Christiano, et.al. 1998 and Miyao, 2002). For example, a contractionary monetary policy shock, which leads to an unexpected increase in the call money rate, has a negative impact on industrial production after 24 months (hump-shaped), as predicted by the models of the monetary transmission mechanism (MTM). Nonetheless, a contractionary monetary policy shock does *not* lead to a gradual decrease in the price level, consistent with the liquidity effect (as the real interest rate rises on impact). Although explaining such anomalous behavior is beyond the scope of this paper, it is possible that the low interest rate-inflation environment might be partly responsible for this finding. Also note that there is no price puzzle in the model, although the impact of the call money rate on the yen-dollar rate suggests that the model cannot account well for the dynamics of the exchange rate and the interest rate associated with uncovered interest parity, since an increase in the yen interest rate leads to a depreciation of the yen against the U.S. dollar.[31] The IRFs are shown in Figure 4.[32]

[FIGURE 4 (impacts of r shocks p, q) HERE]

Sterilization

Another advantage of the VAR model is that it allows one to determine empirically the effective degree of sterilization. This is done simply by looking at the estimated impact of shock to intervention on the interest rate and money supply. The impulse response function showing the impact of a one standard deviation shock to intervention on the interest rate and money supply is shown in Figure 5. According to the IRF, the impact (on both money and interest rate) is rather small and not statistically significant, except for the money supply after 1 month. This finding is consistent with the hypothesis that interventions by the Japanese authorities are routinely sterilized.

[FIGURE 5 (impacts of I on r, m) HERE]

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[31] If the model is estimated with the interest rate differential (using the U.S. federal funds rate), the UIP puzzle emerges, although the impact of the interest differential shock on the exchange rate is not statistically significant.

[32] The impacts of monetary policy shocks on the exchange rate are less interesting since it is usually the interest differential that matters. The impacts of conventional monetary shocks on exchange rates is examined in detail by Kim and Roubini (2000). They note that it is important to control for the effects of U.S. monetary policy shocks in empirical models of small open economies in the G-7 context. The results reported here are robust to the inclusion of the interest rate differential (using the U.S. federal funds rate).

The degree of sterilization can also be gauged by inspecting the variance decomposition of the interest rate and money supply, presented in Table 2 above. The results show that at the 1-24 month horizon intervention explains only a very small fraction of the variance of the interest rate (less than 4 percent) and money supply (less than 1.1 percent).

Some Policy Implications for the Japanese Case

Several researchers have argued that one feasible approach to escape from a liquidity trap involves generating expectations of a higher future price level (and expected inflation). This will reduce the real interest rate and stimulate the economy, even if initially short term nominal interest rates are near or at zero. The key issue is to *credibly* generate expectations of a higher future price level. Some proposals rely on the effectiveness of foreign exchange intervention to affect the exchange rate (depreciate the yen).[33] The results uncovered in this paper suggest that the impacts of FX intervention on the yen may be quite small. Obviously, this does not rule out completely the scope for using intervention in conjunction with other measures, such as monetary quantitative easing, to depreciate the yen and inflate the economy. Furthermore, research on the impacts of foreign exchange intervention has shown that its impact may be quantitatively significant when it is coordinated with other central banks (Dominguez and Frankel, 1993, and Beine, et.al. 2002).

Finally, the results presented in this paper might understate the impacts of intervention on the exchange rate for other reasons. For instance, if the authorities decides to deploy large-scale intervention to target a depreciated yen, it can do so with credibility since it has an unbounded supply at its disposal to "attack" its own currency. According to this argument, which is developed more fully in Svensson (2001), a (credible) threat by the

[33] See, for example, McCallum (2003).

Japanese authorities may suffice to move the exchange rate in the desired direction, and it may not even require actual intervention in the foreign exchange market.[34]

V. Conclusions

This paper presents some empirical estimates of the impacts of foreign exchange intervention on the yen-dollar nominal exchange rate for the period 1991-2001. The estimations are based on the identified vector autoregression (IVAR) framework that allows the effects of intervention to be jointly estimated with the impacts of conventional (interest rate) monetary policy shocks. The model may also be used to estimate the effective degree of sterilization by the monetary authorities by looking at the impacts of intervention on the interest rate and the impacts of conventional monetary policy shocks on the exchange rate.

The results are consistent with previous assertions that, albeit intervention may be effective, its effects on the exchange rate are economically small (see Sarno and Taylor, 2002) The results also show that interventions have been effectively sterilized (has left interest rates and money supply virtually unchanged), and that there is considerable "leaning against the wind" by the Japanese authorities, i.e. yen appreciations are followed by yen sales. The latter underscores the importance of carefully estimating the impacts of intervention on the exchange rate while controlling for the effects of exchange rate on intervention (policy reaction function).

The results presented in this paper also highlight the challenges faced by the Japanese authorities to engineer a depreciation of the yen since short term interest rates cannot fall

[34] McCallum (2003) argument does not rely on the credibility of intervention. Instead, it depends on the impact of intervention on the exchange rate through a portfolio balance argument. In his model, uncovered interest parity does not hold, and intervention may affect the risk premium (interest differential adjusted for expected exchange rate change).

below zero. As suggested by several authors, the solution to the deflation problem lies in convincing market participants that efforts to generate inflation are credible.

APPENDIX

This appendix contains a model of exchange rate determination that is used to illustrate the effects of sterilized intervention in the presence of a risk premium. The model draws heavily on Grinols and Turnovsky (1994). The model is presented under two assumptions about the interaction of fiscal and monetary policies: in the first, there is no exchange rate risk premium and uncovered interest parity holds (accounting for the Jensen's inequality term); in the second, there is a non-neutrality in the model that that arises from the assumed fiscal policy rule, which allows the exchange rate to affect government spending. The effect of the exchange rate on spending comes from the fact that domestic currency denominated liabilities generate stochastic seigniorage flows. This, in turn, creates an exchange rate risk premium to induce the representative agent to hold domestic currency assets. From the discussion of the portfolio balance channel above, the violation of uncovered interest parity creates a potential role for sterilized intervention to affect the exchange rate.

The Model

The model is composed of a representative agent who chooses his rate of consumption (C), and allocates his portfolio among 4 assets: domestic money (M), non-traded domestic bonds (B), foreign bonds (B*), and claims on capital, both of which are traded in the international market.

Assets

Following Merton (1990, chapter 15), it is postulated that the prices in the model follow diffusion processes given by:

$$dP / P = pdt + du_p \qquad (1a)$$

$$dQ / Q = qdt + du_q \qquad (1b)$$

$$dE / E = edt + du_e \qquad (1c)$$

where P is the domestic price of the traded good, Q is the foreign price of traded good Q, E is the nominal exchange rate E, expressed in domestic currency per foreign currency, and the du terms are Brownian motions (i.i.d. with zero means) and variances $\sigma_i^2 dt$, with $i = p, q, e$.[35] In addition PPP holds, which implies:

$$P = EQ \quad (2)$$

and

$$p = q + e + \sigma_{qe} \quad (3)$$

with $du_p = du_q + du_e$ and $E(du_q du_e) = \sigma_{eq} dt$.

Given the exogeneity of the foreign price level (small open economy assumption), monetary policy determines P and E. As in Grinols and Turnovsky (1994), if E is the target of monetary policy target, then E can be viewed as being exogenously determined by the diffusion (3) – with the instantaneous rate of change depending on the structural parameters in equilibrium, while P is "endogenously" determined by the PPP condition. Furthermore, the monetary growth rate has to be consistent to accommodate the target rate of exchange rate depreciation/appreciation.

The assets' *real* rates of return are given by:

$$dR_M = r_M dt - du_p \qquad (4a)$$

$$dR_B = r_B dt - du_p \qquad (4b)$$

$$dR_F = r_F dt - du_q \qquad (4c)$$

where the nominal interest rates are (i, i*) and applying Itô's Lemma one obtains $r_M = -p + \sigma_p^2$, $r_B = i - p + \sigma_p^2$, and $r_F = i - q + \sigma_q^2$. The flow of output is assumed to follow:

$$dY = \alpha K dt + \alpha K dy \qquad (5)$$

[35] Unless otherwise noted, stochastic disturbances are regular Brownian motions.

where α is the constant MPK and dy is the stochastic disturbance (i.i.d. with mean zero and variance $\sigma_y^2 dt$). The real return on capital is:

$$dR_K = r_K dt + du_k \qquad \text{(4d)}$$

Budget Constraints and Optimization

The representative consumer maximizes expected utility subject to a wealth accumulation equation. The wealth constraint is:

$$W = M / P + B / P + EB^* / P + K \qquad \text{(6)}$$

where W is real wealth. It can be re-written in differential form as:

$$dW = W[n_M dR_M + n_B dR_B + n_K dR_K + n_F dR_F] - Cdt - dT \qquad \text{(8)}$$

where (n_i) is the vector of portfolio shares, with i = M, B, K, F; and dT represents the flow of taxes paid, and C is the flow of consumption.

The utility function is given by:

$$E\int_0^\infty \gamma^{-1}[C^\theta (M / P)^{1-\theta}]^\gamma \exp(-\rho t)dt \qquad \text{(7)}$$

with $\gamma < 1, 0 \le \theta \le 1$, where θ gives the relative importance of money, and $1-\gamma$ denotes the coefficient of relative risk aversion.

Taxes are endogenously determined to satisfy the government budget constraint:

$$dT = \tau W dt + W dv \qquad \text{(9)}$$

As before, in equilibrium the terms τ and dv depend on the underlying parameters of model so as to ensure that the government budget constraint holds with probability one. It is worthwhile to point out that this "residual" character of taxes is an important aspect of the model, and partly responsible for the neutrality of sterilized foreign exchange intervention.

With these assumptions the optimization problem may be recast as:

$$Max_{C,M,K,B} E\int_0^\infty \gamma^{-1}[C^\theta (M / P)^{1-\theta}]^\gamma \exp(-\rho t)dt \qquad \text{(7')}$$

$$dW = W[n_M r_M + n_B r_B + n_K r_K + n_F r_F - C / W - \tau]dt + W dw \qquad \text{(10a)}$$

(10b)

with $n_M + n_B + n_K + n_F = 1$, $dw = -(n_M + n_B)du_p + n_K du_K + n_F du_q - dv$, and the vector (i, i*, p, q) is taken as given by the representative agent.

The first order conditions are rather standard and are given by:

$$C / W = \theta(1-\gamma\theta)^{-1}[\rho - \beta\gamma - .5\gamma(\gamma-1)\sigma_w^2] \qquad (11a)$$

$$n_M = (1-\theta)\theta^{-1}(C / W) / i \qquad (11b)$$

$$(r_K - r_B)dt = (1-\gamma)\,\mathrm{cov}(dw, du_k + du_p) \qquad (11c)$$

$$(r_F - r_B)dt = (1-\gamma)\,\mathrm{cov}(dw, -du_q + du_p) \qquad (11d)$$

where $\beta = n_M r_M + n_B r_B + n_K r_K + n_F r_F - \tau$, and $\sigma_w^2 = E(dw)^2 / dt$.

Government

The government budget constraint may be written in real terms as:

$$d(M / P) + d(B / P) = dG - dT + (M / P)dR_M + (B / P)dR_B \qquad (12)$$

where dG is the rate of real government expenditure, which is assumed to follow $dG = g\alpha K dt + \alpha K dz$. In this case, the expected level of public spending is a fraction g of the expected level of output. The monetary authority sets the mean growth rate μ directly (to meet policy targets) and the money balances follow:

$$dM / M = \mu dt + dx \qquad (13b)$$

Debt policy is assumed to maintain a fixed ratio of domestic bonds to money:

$$B / M = \lambda \qquad (13c)$$

where λ is set by the government. This is consistent with Grinols and Turnovsky (1994) and Foley and Sidrauski (1971), and reflects sterilization policy. As argued by Grinols and Turnovsky (1994), once the optimal debt to money ratio is chosen, it is equivalent to choosing the tax rate, hence the treatment of taxes as the residual budget item is less economically significant. It also corresponds to what Kumhof and Nieuwerburgh (2002) refer to as the fiscal neutrality case.

The *real* rate of accumulation of traded assets is given by:[36]

[36] Note that net exports are given by dY - dC – dK - dG.

$$d(B^*/Q) = (dY - dC - dK - dG) + (B^*/Q)dR_F \qquad (14)$$

Equilibrium

In equilibrium all real components of wealth must grow at the same stochastic rate:

$$\frac{d(M/P)}{M/P} = \frac{d(B/P)}{B/P} = \frac{d(B^*/Q)}{B^*/Q} = \frac{dK}{K} = \frac{dW}{W} \equiv \psi dt + dw \qquad (16)$$

To solve for the equilibrium, it is assumed that the consumer chooses a time-invariant portfolio wealth allocation. The optimality conditions and budget constraints specified above yield the following:

$$\omega \equiv n_K/(n_K + n_F) = \frac{\alpha - (i^* - q + \sigma_q^2)}{(1-\gamma)(\alpha^2\sigma_y^2 + \sigma_q^2)} + \frac{\sigma_q^2}{\alpha^2\sigma_y^2 + \sigma_q^2} \qquad (17a)$$

$$\psi = \omega[\alpha(1-g) - n_K^{-1}C/W] + (1-\omega)(i^* - q + \sigma_q^2) \qquad (17b)$$

$$C/W = \theta(1-\gamma\theta)^{-1}\{\rho - \beta\gamma - .5\gamma(\gamma-1)[\alpha^2\omega^2(\sigma_y^2 + \sigma_z^2) + (1-\omega)^2\sigma_q^2]\} \qquad (17c)$$

$$\beta = \psi + C/W \qquad (17d)$$

$$n_M = \theta^{-1}(1-\theta)(C/W)/i \qquad (17e)$$

$$(1+\lambda)n_M + n_K/\omega = 1 \qquad (17f)$$

The equilibrium conditions can also be used to determine nominal quantities, which are expressed in terms of the variances of exogenous variables, and the covariance of these variables with money supply. For instance, the PPP equation can be rewritten as:

$$p = q + e - \omega\sigma_q^2 + \sigma_{xq} \qquad (18)$$

Grinols and Turnovsky (1994) show that government policy affects the consumption wealth ratio through its impact on the domestic interest rates (i and r_B). In this sense, interest rate targeting, exchange rate targeting, or stochastic intervention (open market operations, dx) are equivalent.

Initial Exchange Rate

As in any standard rational expectations equilibrium, the model needs to be "closed" by an appropriate initial condition (jump). Since asset supplies and the foreign price level follow diffusion processes, the variables $M_0, B_0, B_0^*, K_0, Q_0$ are predetermined. The initial exchange rate is given by:

$$E_0 = \left(\frac{n_K + n_F}{n_M + n_B}\right)\left(\frac{M_0 + B_0}{Q_0 K_0 + B_0^*}\right) \qquad (20)$$

with $\Upsilon \equiv \left(\frac{n_K + n_F}{n_M + n_B}\right) = \left(\frac{n_K}{\omega(1+\lambda)n_M}\right)$.

Note that any policy that generate a change in the ratio Υ, the relative portfolio share of traded to non-traded assets, will have an impact on the nominal exchange rate (initial jump in E_0). The equilibrium must also satisfy some feasibility conditions, including transversality conditions for each asset[37] and a non-negative initial exchange rate. The later condition is met if and only if the share of traded assets in the agent's portfolio is positive, i.e. $0 < n_K / \omega = n_K + n_F < 1$.

In this model, it is easy to see that sterilized intervention has no impact on the exchange rate, since any change in the money supply offset by an open market operation requires a constant λ in equation (13c). Furthermore, real allocations remain the same, since these two operations only represent a change of both the assets and liability sides of the central bank's balance sheet, and a new allocation of domestic versus foreign currency bonds (which are perfect substitutes) in the agent's portfolio.

Fiscal Non-Neutrality

As in Kumhof and Nieuwerburgh (KN, 2002), suppose that the government uses stochastic seigniorage shocks to adjust real spending. For example, when the exchange rate depreciates, the additional seigniorage proceeds is spent by the governments on goods.

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[37] For example, $\lim_{t\to\infty} E[(M/P)J_W \exp\{-\rho t\}] = 0$, where J_W is the marginal utility of wealth.

Similarly, exchange rate appreciations are followed by reductions in spending[38], making more goods available to the representative agent.[39]

To account for this non-neutrality of government spending, equation (13c) is dropped from the model, since money and domestic bonds need no longer to be issued in the same proportion. In addition government spending now depends on the stochastic seigniorage flows and the tax rule is now:

$$dT = \tau W dt \qquad (21)$$

Since the government transfers all non-stochastic net revenues on its portfolio to households (through lump-sum taxes) and adjusts spending in response to unanticipated shocks (see KN), one can use the government's budget constraint to solve for the drift component of taxes and the diffusion process for government spending (assuming a balance budget):

$$dG = W(n_M + n_B + n_K)(-\sigma_e^2 dt + \sigma_e du_e) \qquad (22)$$

Note that now (expected) government spending depends negatively on the volatility of the exchange rate, which creates a risk premium. This can be seen more easily by writing the optimality condition for domestic currency assets:

$$n_M + n_B + n_K = (-J_W / J_{WW} W)\left(\frac{i + \sigma_e^2 - i^* - e}{\sigma_e^2}\right) \qquad (23)$$

Since feasibility requires $n_M + n_B > 0$, the government has to pay a risk premium on its assets. Or alternatively, the household will only hold positive amounts of domestic currency assets if there is a positive risk premium. Moreover, note that by (22), government spending affects the risk premium. In this case, fiscal policy generates non-diversifiable risk

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[38] The correlation between exchange rate depreciation and government consumption is about 15 percent (annual data, 1970-2002).

[39] Alternatively, expectations of higher future budget deficits (caused by higher government spending), may increase the risk premium in a portfolio balance model. The government speding-induced risk premium works in a similar fashion and creates a potential role for sterilized intervention. As other papers have shown, these channels assume that Ricardian Equivalence does not hold.

for domestic currency assets, while foreign currency denominated asset is not subject to this type of risk.

As emphasized by KN, the magnitude of the exchange rate adjustment (initial exchange rate) required to create a given government spending adjustment depends on the government's net domestic currency exposure to households. For example, when the government issues domestic currency debt the exchange rate appreciates to reduce spending, offsetting the increase in the real value of government liabilities.

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Table 1. Identified VAR Estimates (baseline specification)

Coefficients (matrix B)

1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	**-8.519746**
0.013970	0.000000	1.000000	-27.37857	0.000000	0.000000	5.948763
0.000000	0.000000	0.413524	1.000000	2.203345	-0.364055	0.000000
5.39E-05	0.000000	0.000000	0.000000	1.000000	0.031544	0.000000
-0.000584	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000
0.002299	**0.024419**	-0.044193	0.545081	2.148208	0.633049	1.000000

Standard errors

2.779132	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.512431	0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.568881	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.068990	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.003485	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000	0.013392	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.035748

Likelihood ratio test for overidentification of the pattern matrix

Chi-Square(5) = 6.7561 Signif. Level = 0.2394

Table 2. Variance Decomposition

Intervention:

Period	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5	Shock6	Shock7
1	2.7	1.1	73.9	2.5	0.2	1.0	0.8	20.5
2	2.8	1.3	71.7	3.0	1.0	1.1	1.9	20.1
3	2.8	1.2	71.0	2.9	1.0	1.1	2.7	20.1
4	2.8	1.2	70.4	3.2	1.0	1.1	2.9	20.2
5	2.8	1.2	69.8	3.3	1.0	1.1	3.2	20.4
6	2.8	1.2	69.3	3.5	1.0	1.1	3.5	20.5
7	2.8	1.2	68.8	3.5	1.0	1.1	3.9	20.5
8	2.9	1.2	68.3	3.6	1.0	1.1	4.2	20.5
9	2.9	1.2	67.9	3.7	1.0	1.2	4.5	20.6
10	2.9	1.2	67.5	3.7	1.0	1.2	4.8	20.5
11	2.9	1.3	67.1	3.8	1.0	1.2	5.1	20.5
12	2.9	1.3	66.8	3.8	1.0	1.3	5.4	20.5
13	2.9	1.4	66.5	3.8	1.0	1.3	5.6	20.4
14	2.9	1.5	66.2	3.8	1.0	1.4	5.8	20.4
15	2.9	1.6	65.9	3.8	1.0	1.4	6.0	20.3
16	2.9	1.7	65.7	3.8	1.0	1.5	6.2	20.2
17	2.9	1.8	65.4	3.8	1.0	1.5	6.3	20.1
18	2.9	2.0	65.2	3.8	1.0	1.6	6.4	20.1
19	2.9	2.1	65.0	3.8	1.0	1.6	6.5	20.0
20	2.9	2.3	64.8	3.8	1.0	1.6	6.6	20.0
21	2.9	2.4	64.7	3.8	1.0	1.7	6.6	19.9
22	2.9	2.5	64.5	3.8	1.0	1.7	6.7	19.9
23	2.9	2.7	64.3	3.7	1.0	1.8	6.7	19.8
24	2.9	2.8	64.2	3.7	0.9	1.8	6.7	19.8

Note: Shock 1,...,7 refers to the order of the variables in the vector y_t. For example, shock 2 refers to the intervention shock.

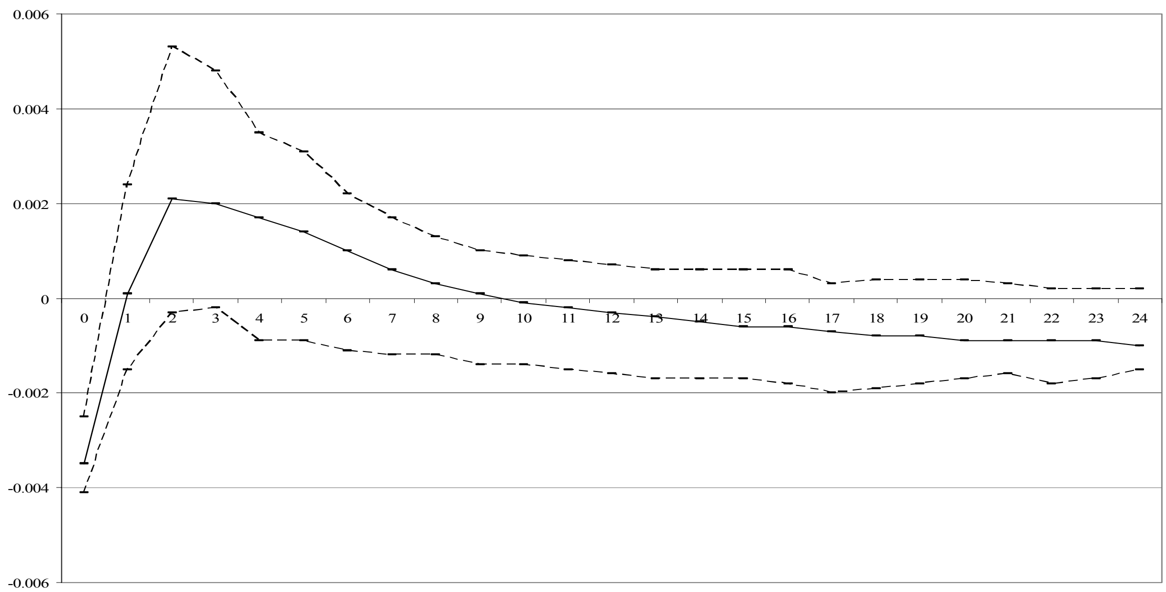
Table 2. Variance Decomposition (continued)

Exchange Rate:

Period	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5	Shock6	Shock7
1	0.0316	4.0	6.8	8.8	0.7	3.7	2.8	73.1
2	0.0451	6.6	3.4	8.0	0.6	10.8	1.5	69.2
3	0.0557	8.0	3.0	7.4	0.4	13.8	1.1	66.4
4	0.0627	8.4	2.9	7.3	0.3	14.4	1.2	65.5
5	0.0675	8.3	2.8	7.5	0.3	13.9	1.7	65.5
6	0.0710	8.0	2.8	7.8	0.3	13.1	2.4	65.6
7	0.0738	7.6	2.7	8.1	0.4	12.4	3.5	65.3
8	0.0762	7.2	2.5	8.3	0.5	11.8	4.9	64.8
9	0.0784	6.9	2.4	8.4	0.6	11.3	6.5	64.0
10	0.0803	6.5	2.3	8.4	0.6	10.9	8.2	63.0
11	0.0822	6.2	2.2	8.4	0.6	10.7	9.9	61.9
12	0.0839	6.0	2.1	8.3	0.7	10.5	11.6	60.8
13	0.0855	5.9	2.0	8.2	0.7	10.4	13.1	59.6
14	0.0869	5.9	2.0	8.1	0.7	10.3	14.5	58.5
15	0.0883	5.9	1.9	8.0	0.7	10.3	15.8	57.3
16	0.0896	6.0	1.9	7.8	0.7	10.4	17.0	56.2
17	0.0908	6.3	1.9	7.6	0.8	10.4	18.0	55.1
18	0.0919	6.6	1.9	7.5	0.8	10.5	18.9	54.0
19	0.0930	6.9	1.8	7.3	0.8	10.6	19.7	52.9
20	0.0940	7.3	1.8	7.1	0.8	10.7	20.3	51.9
21	0.0950	7.8	1.9	7.0	0.8	10.8	20.8	50.9
22	0.0959	8.3	1.9	6.9	0.8	10.9	21.2	50.0
23	0.0968	8.9	1.9	6.8	0.8	11.0	21.5	49.1
24	0.0976	9.4	1.9	6.7	0.9	11.2	21.7	48.3

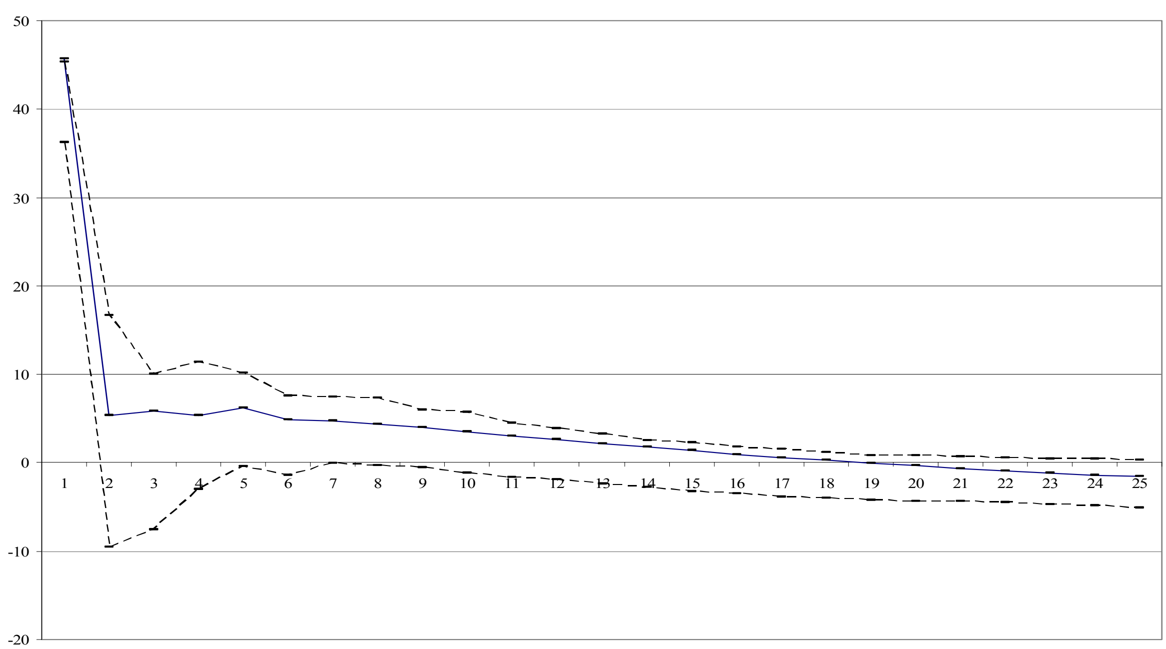
Note: Shock 1,...,7 refers to the order of the variables in the vector y_t. For example, shock 2 refers to the intervention shock.

Figure 3A. Impact of Intervention on the Nominal Exchange Rate (in yen per dollar)



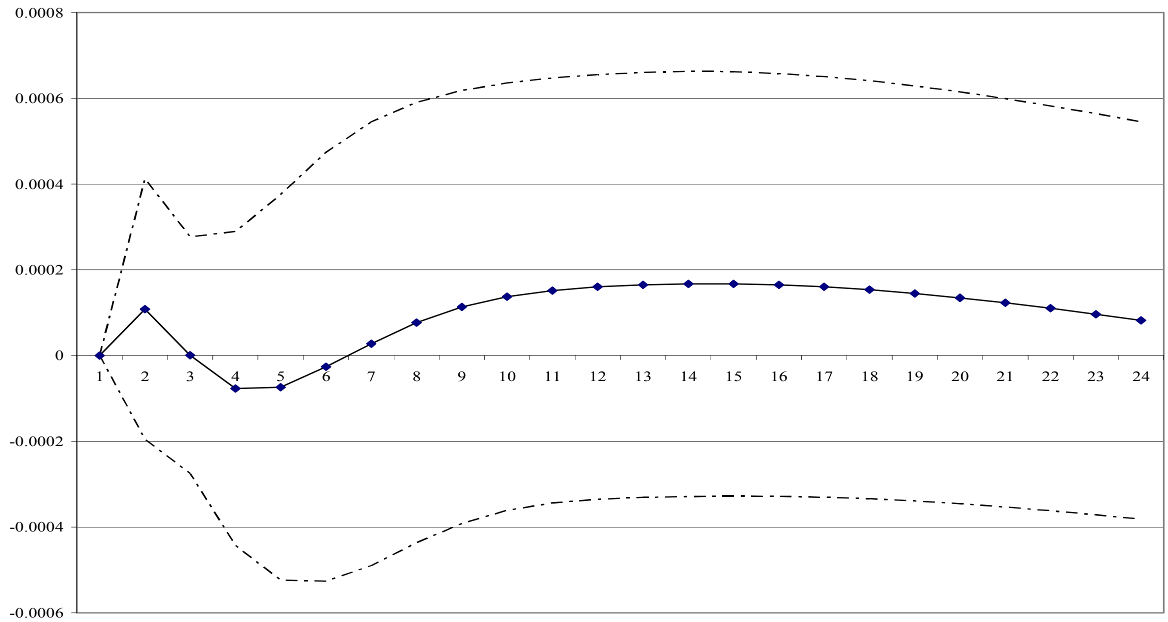
Notes: Median and probability bands calculated according to Sims and Zha (1999).

Figure 3B. Impact of the Nominal Exchange Rate on Intervention



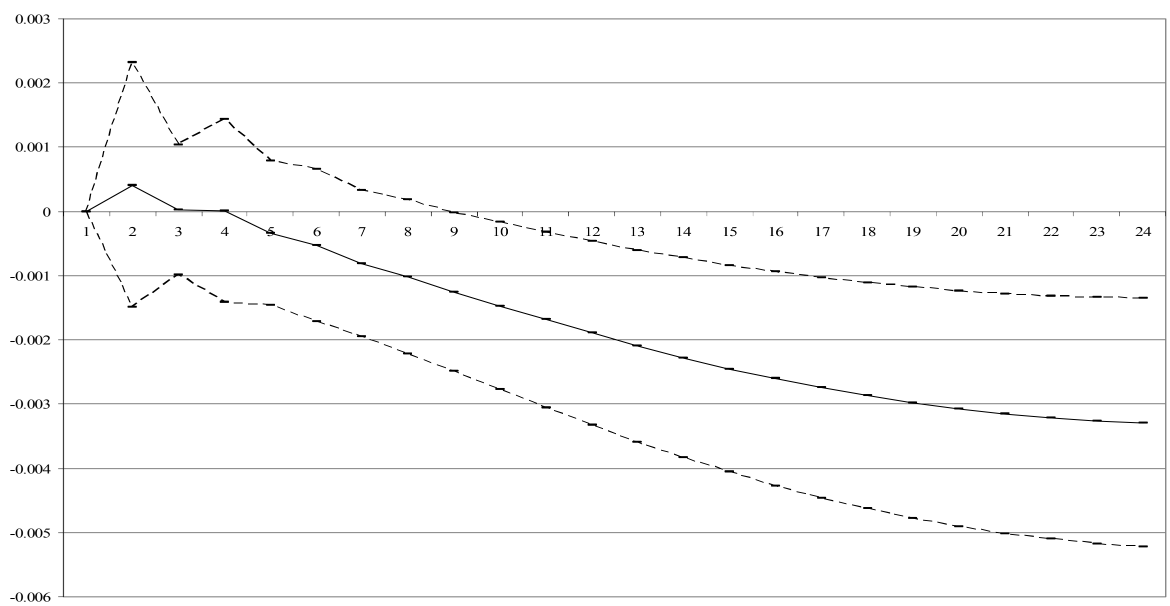
Notes: Median and probability bands calculated according to Sims and Zha (1999).

Figure 4A. Contractionary Monetary Policy Shock on CPI



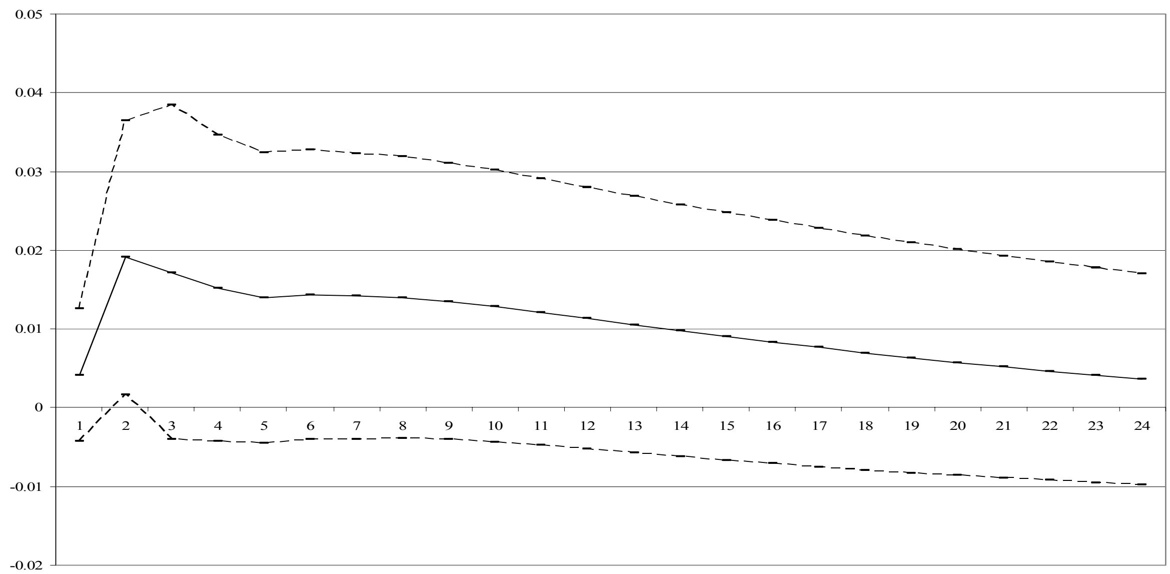
Notes: Median and probability bands calculated according to Sims and Zha (1999).

Figure 4B. Contractionary Monetary Policy Shock on Industrial Production



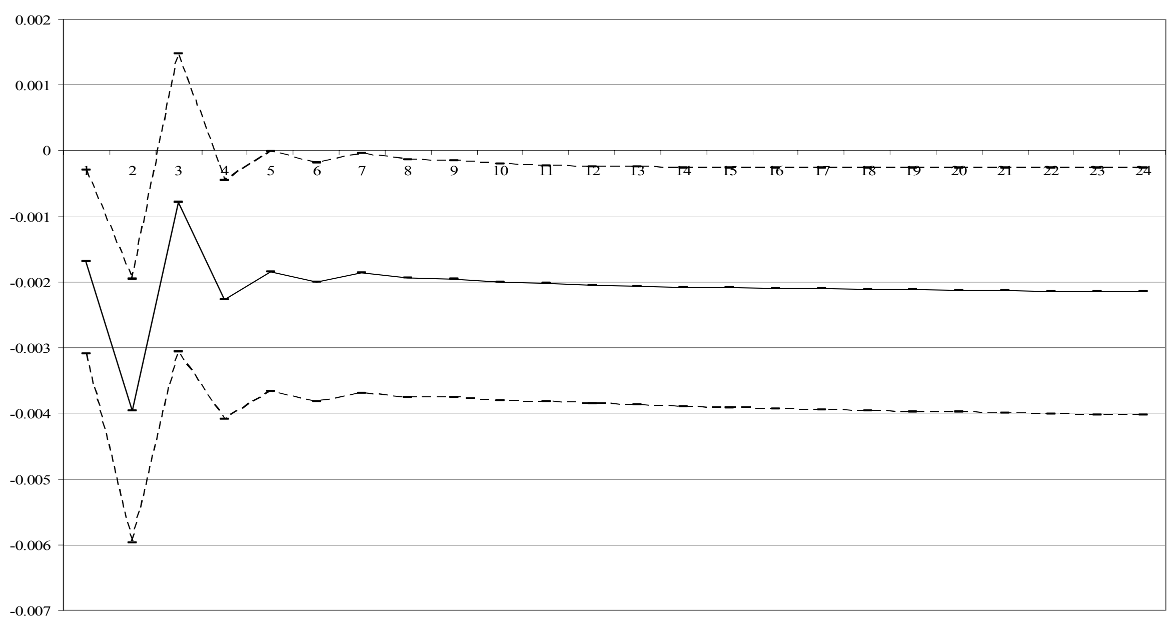
Notes: Median and probability bands calculated according to Sims and Zha (1999).

Figure 5A. Impact of the FX Intervention on the Call Money Rate



Notes: Median and probability bands calculated according to Sims and Zha (1999).

Figure 5B. Impact of the FX Intervention on Money



Notes: Median and probability bands calculated according to Sims and Zha (1999).