

# Do Interventions in Foreign Exchange Markets Modify Investors' Expectations? The Experience of Japan Between 1992 and 2003

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## ABSTRACT

*The purpose of this paper is to analyze the impact of the Bank of Japan's official interventions on the JPY/USD parity during the period 1992-2003. The novelty of our approach is to combine two recent advances of the empirical literature on foreign exchange interventions: (i) drawing on over-the-counter option prices to characterize more precisely the distribution of market expectations; (ii) redefining interventions in terms of events as they tend to come in clusters. Moreover, in order to deal with the features of the data (small sample size, non-standard distribution), we use bootstrap tests.*

*We show that interventions have a significant impact on the mean expectation (the forward rate). The results are more ambiguous for variance. Additionally, we find that the effect of interventions on skewness is significant, robust to different definitions of skewness, and consistent with the direction of interventions. On the contrary, our results clearly show that kurtosis is not affected by interventions. We finally show that: (i) coordination increases effectiveness of interventions; (ii) results are not altered when controlling for other economic and political news.*

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Key words: FX interventions, risk-neutral density, event study, bootstrap, Bank of Japan.

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## 1- Introduction

The effectiveness of central banks' foreign exchange (FX) interventions has given rise to an important debate. Theoretically, a sterilised intervention is likely to affect agents' expectations and the level of the exchange rate according to three channels (Sarno and Taylor [2001]): portfolio equilibrium (Dominguez and Frankel [1993]), the signal channel (Mussa [1981]), and the microstructure and noise-trading approaches (Lyons [2001], Hung [1997], De Grauwe and Grimaldi [2003]). From an empirical point of view, the effectiveness of FX interventions has been far more controversial since the Jurgensen report (Jurgensen [1983]). It could even be argued that, until recently, there was a contradiction between the attitude of central banks and conclusions reached by academics. On the one hand, academics have often been highly skeptical about the effects of FX interventions with the exception of the periods surrounding the Plaza Accord and the Louvre Accord, or under very specific conditions, mainly interventions that are announced publicly, coordinated and consistent with monetary and fiscal policies (see the surveys of Edison [1993] and Sarno and Taylor [2001]). On the other hand, central banks have always made use of this tool of economic policy, thereby suggesting that — from their point of view — interventions do have an impact (Obstfeld and Rogoff [1996]). This point appears in fact quite markedly in the survey of central banks carried out by Neely (2001): while motivations to intervene are heterogeneous and there is no consensus about the horizon when the maximum effect is likely to be observed, no central bank believes in the ineffectiveness of interventions on exchange rates. Nevertheless, it is true that the monetary authorities of the main industrialized countries have significantly reduced their interventions since the nineties. A noteworthy exception is Japan as it has constantly intervened in foreign exchange markets, often massively and alone. Its presence was a well-known fact among currency traders and frequently reported by the financial press. However, information remained vague, as the Bank of Japan (BoJ) maintained secrecy about its interventions<sup>1</sup>. This changed when, in July 2001, the BoJ

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<sup>1</sup> Unlike the Fed and the Bundesbank that have gradually made their intervention data available for the academic community, all the more easily as they have become less interventionist.

decided to publish the track record of its interventions (dates, currencies concerned and amounts) since April 1991. Since then, the BoJ has steadily published information, with a slight lag, about its interventions.

Undeniably, the publication of this information has led to a renewed interest in empirical studies about the effectiveness of FX interventions. To our knowledge, the first to have used this database is Ito (2002). From a detailed analysis of the BoJ's interventions and its motivations, Ito reaches the conclusion that interventions have apparently not only been effective (notably since 1995), but also profitable. This conclusion has been broadly confirmed by other studies drawing on the same dataset<sup>2</sup>. Among these studies, we can note the one of Fatum and Hutchison (2003b) which analyzes the effectiveness of BoJ's interventions by means of an event study approach, along the lines of Fatum (2000) and Fatum and Hutchison (2003a)<sup>3</sup>. Such a methodology is attractive because, in contrast with the usual approaches based on time series, it is adapted to the sporadic and clustered nature of interventions. In particular, this methodology is well suited to incorporate the fact that there are separate intervention phases corresponding to separate intervention decisions based on a particular economic and market environment but that each phase can be characterized by different length. Furthermore, it is more flexible than standard time-series approach and allows testing in an easier way particular hypotheses such as reversals or smoothing tests of FX interventions (Fatum [2000]). In practice, the event study consists in isolating intervention phases and to analyze moves in exchange rates around these phases. While we also rely on an event study, our work differs significantly from Fatum and Hutchison (2003b). Notably, we broaden the analysis to the second to fourth moments (variance, skewness and kurtosis) whereas Fatum and Hutchison (2003b) restrict their analysis to the first moment with the JPY/USD returns.

The overwhelming majority of empirical studies have restricted themselves to the analysis of the impact of FX interventions on the first two moments (Sarno and Taylor [2001]). Such approach is

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<sup>2</sup> See notably Chaboud and Humpage (2003), Hillebrand and Schnabl (2003) and Beine and Szafarz (2003).

<sup>3</sup> See also Fatum and King (2004) for an application to CAD/USD exchange rate with ultra-high frequency data.

limited for several reasons. First, market expectations description obviously does not amount to the first two moments only, except in the Gaussian world. Secondly, there is a practical interest both for authorities and market participants to have information for instance on asymmetry and the tails of the distribution after an intervention in FX markets: authorities may more precisely estimate intervention impact on the basis on such informations whereas investors can exploit them for risk management or asset valuation purposes (option pricing notably). Few studies have looked at higher moments of the distribution. The analysis of the BoJ's interventions has not been an exception to this rule<sup>4</sup>. To the best of our knowledge, there are only two exceptions. Beine, Laurent and Palm (2004) analyze the impact of the BoJ's interventions, jointly with those carried out by the Fed and the Bundesbank, from so-called "realized" measures of moments and cross-moments<sup>5</sup>. Note however that the authors focus on the first three moments and primarily on the DEM/USD parity whereas the BoJ has mainly intervened on the JPY/USD (see below). Following the previous studies carried out by these authors (Galati and Melick [1999]), Galati, Melick and Micu (2004) have proposed an analysis of the impact of the BoJ's interventions on the four first moments of the risk-neutral distribution (RND) drawn from the observation of option prices. The deduction of the RND from options has imposed itself as a major tool for monitoring the market's perception of forthcoming changes in asset prices due to their informative and forward-looking nature<sup>6</sup>. At the end of a very detailed study (taking into account the endogeneity bias, the impact of other macroeconomic news, etc.), Galati et al. (2004) come to the conclusion that there is no significant impact from the BoJ's

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<sup>4</sup> In addition to the studies quoted previously that analyse the impact on the first moment, several studies have analysed the second moment, i.e. variance/volatility. In the literature, the impact of interventions on volatility has been carried out via two separate measures of volatility: econometric measures drawn from GARCH/FIGARCH specifications (Baillie and Osterberg [1997], Beine, Bénassy-Quéré and Lecourt [2002]) and implicit measures drawn from at-the-money currency options (Bonser-Neal and Tanner [1996], Dominguez [1998]). In the case of the BoJ's official interventions, both cases are treated respectively by Hillebrand and Schnabl (2003) or Beine and Szafarz (2003) and by Frenkel, Pierdzioch and Stadtmann (2005).

<sup>5</sup> Realized moments are constructed from the aggregation at a daily frequency of intraday observations. This method, which allows less noisy moments to be constructed, was introduced for variance by Andersen and Bollerslev (1997) (see also Andersen, Bollerslev, Diebold and Labys [2003]).

<sup>6</sup> This literature is now very large. See Söderlind and Svensson (1997) for a founding and introductory text. See section 3 for a reference list in the case of exchange rates.

interventions on the first four moments of the RND. Our study naturally extends that carried out by Galati et al. (2004).

The novelty of our approach is to combine two recent advances of the empirical literature on foreign exchange interventions<sup>7</sup>: (i) drawing on options data to characterize more precisely the distribution of market expectations; (ii) redefining interventions in terms of events, and carrying out an event study which is more appropriate given the nature of interventions, instead of an approach drawing on regressions (the reader should note that this extension is encouraged by Galati et al. themselves). Moreover, (i) to deal with features of the data (small sample size, non-standard distribution), we extend the basic methodology by judging significance through a bootstrap ; the bootstrap is a very general re-sampling technique that allows to construct, under the null hypothesis, an empirical distribution of a statistic and its attractiveness when dealing with small samples and/or non-standard distributions (i.e. asymmetrical or with fat tails), as is the case for exchange rates, is widely acknowledged<sup>8</sup> (ii) we adopt a technique for the deduction of RND that is probably better adapted to the nature of the option data available in over-the-counter (OTC) FX markets ; (iii) we consider the period 2001-2003 that led to an acceleration in the BoJ's interventions.

Our results significantly point to the effectiveness of the BoJ's interventions. In line with Fatum and Hutchison (2003b), we show that dollars purchases (sales) are reflected by an appreciation (depreciation) of the dollar or, equivalently, an increase (decrease) in the first moment — the JPY/USD forward rate. In consistency with Fatum and Hutchison (2003b) study but contrary to Galati et al. (2004), we find that dollars purchases (sales) provoke an increase in skewness in the direction of a greater likelihood granted to a future rise (decline) in the dollar than to a fall (rise). We also show that interventions can sometimes lead to a decrease in variance, meaning they display stabilizing features in the medium term but that this result is ambiguous and depends on

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<sup>7</sup> More generally, one should note that the framework here proposed could be adapted to other economic and financial topics.

<sup>8</sup> The bootstrap was introduced by Efron (1979). See among others McKinnon (2002) for a discussion of the use of this technique in economics and finance.

circumstances. Conversely, kurtosis seems insensitive to interventions. Furthermore, we also show that: (i) coordination increases effectiveness of interventions; (ii) the impact of interventions on moments is apparently not linked to the presence of major economic and political news (such as reflected by stock market volatility).

The rest of the paper is organized as follows. The next section carries out a general overview of the BoJ's interventions since the early nineties. Section three presents our methodology and the data. Section four presents the basic results, in other words the impact of interventions on the moments of the JPY/USD RND. Section five considers various extensions, that is the impact of coordination and the sensitivity to the simultaneous dissemination of news. Finally, the last section concludes our study.

## **2 - The Bank of Japan's interventions**

Among the major central banks, the BoJ undeniably has intervened the most in foreign exchange market since the early nineties. This was confirmed when it released in July 2001 intervention data going back to 1st April 1991. Since then, the BoJ "reports" every quarter details about its interventions<sup>9</sup>. In this study, because of constraints in options data (see section 3), we concentrate on the period April 1992-October 2003 for interventions on the JPY/USD<sup>10</sup>. Details on interventions over this period are presented in Table 1. It appears that the BoJ intervened 273 times, which is equivalent to a 9% probability of intervention each day. 19 of these interventions were coordinated with the Fed, which never intervened alone on the JPY/USD in this period. Table 1 also shows two noteworthy characteristics. First, interventions tend to be very concentrated over time since, throughout the period, the likelihood of a new intervention conditionally to an intervention on the

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<sup>9</sup> The data are available on the Japanese Ministry of Finance's website (<http://www.mof.go.jp/english/e1c021.htm>).

<sup>10</sup> The interventions on the JPY/USD account for more than 95% of the BoJ's interventions in this period. A few exceptions can nonetheless be noted. In November 1997, the BoJ intervened to support the Indonesian rupiah. On a few occasions, the BoJ intervened against the euro (in 1993, it intervened against the Deutschemark). With the exception of the coordinated intervention of 22 September 2000 aimed at bolstering the euro, these interventions have systematically been carried out jointly with interventions against the dollar, the size of euro interventions being much smaller than the dollar ones.

previous day is close to 60%. This cluster of interventions is noticeable in Figure 1 that represents the BoJ's interventions (panel A), the Fed's ones (panel B) and their total (panel C). Second, interventions have mainly been aimed at attempting to depreciate the JPY against the USD, with 249 days of interventions consisting of purchases of dollars (91.2%) and 24 days of sales of dollars (8.8%).

Japan<sup>11</sup> therefore has primarily sought to weaken its currency. Not only is an appreciation in the yen detrimental for exports, the Japanese economy's main driving force of growth, but it also weighs on the value of profits repatriated from abroad, and this factor is not neutral given that Japan has for many years been a large net creditor in international capital markets. In addition to these usual motivations, in the case of Japan, there is the one of an economy in deflation since at least 1998 (panel D of Figure 1). As monetary policy is restricted by already zero nominal intervention rates, an aggressive exchange rate policy has become one of the major policy tool to reflate the economy. Japanese authorities have never explicitly and formally adopted an exchange-rate target. However, on many occasions, Japanese officials have announced that the level, or the dynamics, of the exchange rate did not suit them. Some of the literature has attempted to determine the motivations behind the BoJ's interventions via the estimation of reaction functions. The literature has often reached the conclusion that the BoJ intervened when the exchange rate drew away from target parity levels<sup>12</sup> and, on certain occasions but not systematically, when volatility was increasing (Dominguez and Frankel [1993], Baillie and Osterberg [1997], Ito [2002], Galati et al. [2004], Frenkel et al. [2005]). Galati et al. (1999, 2004) show furthermore that higher order moments (skewness and kurtosis) do not seem to play a role in decision taking.

### **3 – Methodology**

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<sup>11</sup> In this study, we will talk indifferently about Japan or the BoJ to refer to the initiator of the intervention policy. In Japan, as in the United States and in contrast with the Euro zone, exchange rate policy is left to the sole discretion of the Ministry of Finance (MoF), and the central bank implements this policy (Foreign Exchange and Foreign Trade Law; Article 7 -paragraph 3).

<sup>12</sup> The implicit targets put forward by Funabashi (1988) have been frequently used for that purpose. Ito (2002) defends the simpler idea that the level of JPY/USD 125 has been the dividing-point between interventions aimed at boosting and weakening the yen.

In this section, we describe the methodology we have used. Our approach mainly consists in combining two recent advances made in the empirical literature about FX interventions: (i) drawing on options data to characterize more precisely the distribution of market expectations; (ii) the redefinition of interventions in terms of events.

### 3.1 – Option data and risk-neutral densities

Most empirical studies of interventions in foreign exchange markets have been limited to the sole analysis of the mean and volatility of returns. At the same time, the empirical financial literature has recently looked into the development of methods to recover the risk-neutral density (RND) of expectations about underlying assets drawn from option data. Among the applications to exchange rates, one can cite Jondeau and Rockinger (2000) for their study of the DEM/FRF parity during the 1997 French snap election, Leahy and Thomas (1999) for their study of the USD/CAD parity around the time the referendum about sovereignty for Quebec was held and Campa and Chang (1996), Malz (1997) or Söderlind (2000) for their analysis of the European Monetary System crisis. Galati and Melick (1999) and Galati et al. (2004) analyze the impact of interventions in foreign exchange markets on the first four moments of the RND.

Theoretically, the deduction of the RND from observed option prices is easy since it is obtained as the second derivative of the price of the option versus the strike price (Breen and Litzenberger [1978]). In practice, however, this is made extremely difficult by the fact that a limited number of quoted prices are available and because, furthermore, they are not necessarily equi-spaced and as a result one has to impose a specification in order to construct the RND. Jackwerth (1999) classifies methods into three categories: the option price approach, the RND approximating function approach and the volatility smile approach. We briefly present these methods below. Before that, one should note that the interpretation of the RND is not immediate because the latter apprehends both the likelihood granted by the market for each level of the exchange rate and the attitude of agents



towards risk. It is very difficult to draw a distinction between the two<sup>13</sup>. Here, we use the usual hypothesis of assuming that risk aversion remains unchanged. This seems reasonable over short periods and allows us to interpret moves in RND as a change in agents' expectations.

The option price approach consists in modelling the relation between option prices and strike prices and, subsequently, to use the result of Breeden and Litzenberger (Bates [1991], Aït-Sahalia and Lo [1998]). Nevertheless, these techniques are not often used in practice because they are both unstable and very demanding in terms of computations or data<sup>14</sup>. Furthermore, approaches aimed at directly linking option prices and strike prices must satisfy many constraints: (i) option prices are bounded by arbitrage conditions; (ii) for a zero strike price, the price of the call option is equal to the price of the underlying asset minus the present value of dividend flows; (iii) for high strike prices, the price of the call tends towards zero.

In the RND approximating function approach<sup>15</sup>, one seeks to minimise the difference between theoretical option prices and actual prices. Theoretical prices are drawn from a specific RND with a distinction between the methods that specify the underlying stochastic process (stochastic volatility process, jump-diffusion process) and the methods that suppose a functional form for the RND (Burr III, generalised beta distribution, Edgeworth expansions, Gram-Charlier expansions, Hermite polynomials, mixture of log-normal distributions, etc...).

The volatility smile approach consists in modelling the function linking implied volatilities and strike prices, from observations at different strike prices. Once this relationship is estimated, it is transformed into a function linking option prices and strike prices through the Black-Scholes model, and the RND is ultimately deducted as the numerical second derivative of this function. This method presents many advantages in comparison with the one that directly links option prices and strike

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<sup>13</sup> For a discussion in the case of exchange rates, see Galati et al. (2004).

<sup>14</sup> The kernel approach used by Aït-Sahalia and Lo (1998) requires time series data. Furthermore, it supposes that the stochastic process that governs the price of the underlying asset is stable over time whereas the other methods do not make such a hypothesis since they are estimated on day-by-day basis.

<sup>15</sup> See Jondeau and Rockinger (2000) for a comparison of these methods with regard to currency options.

prices. Firstly, the strike price/smile volatility function is far smoother, and this reduces numerical problems in practice. Secondly, it is consistent with the fact that on OTC markets, options are quoted in terms of volatility levels rather than prices. The most widespread approach to interpolate between actual volatilities observed is to use a cubic spline, following Campa, Chang and Reider (1998). A major problem encountered with the spline approach is that it requires specifying a value for the smoothing parameter. The method proposed by Shimko (1993) does not depend on such a parameter, since it supposes that implied volatility is a quadratic function (which has to be estimated) of the strike price.

In this study we use data covering the quotations of currency options for one of the main market makers based in London. For FX options, OTC markets represent the overwhelming majority of transactions and the traded options, furthermore, present the advantage of being quoted at a fixed maturity and being of European type. Data are quoted at 12.00 GMT and break down into three segments (in each case for a maturity of 30 days and for the JPY/USD): at-the-money (ATM) implied volatility, risk reversal (RR) and the strangle (STR). In OTC FX markets, the at-the-money option is defined in reference to a forward price, not a spot price. The risk reversal is the difference in the level of implied volatility of a call and a put with a same delta (and the same maturity). By construction (see Malz [1997]), it is a measure of the skewness of the smile. The strangle is obtained as the difference between the average of implied volatilities of a call and a put with the same delta and the implied ATM volatility. By construction, it provides a measure of the degree of the smile's curvature and therefore of that of the kurtosis. Drawing on these three quotations, it is possible to infer the associated option prices or volatilities for various deltas. In the literature, several authors (see, for instance, McCauley and Melick [1996]) have suggested deducting six option prices, three calls and three puts, from this kind of data. This offers the advantage that it then becomes possible to use techniques based on the RND approximating function that, often, requires estimating a high number of parameters (e.g. a mixture of two lognormals requires 5 parameters to be estimated). One

then faces the problem that since the put-call parity is necessarily verified for European options as are options in the OTC FX market, information is redundant between calls and puts<sup>16</sup>. Consequently, with data such as ours, which are the most frequent in the case of FX options, we can draw only on three true option prices and not six and, therefore, the choice of techniques proves to be limited. Malz (1997) has proposed a technique that is especially adapted to this type of data. It consists of a quadratic approximation of the relation between implied volatility and the option's delta. There are several advantages to be found in interpolating in the delta space: (i) unlike the strike price space, the delta space is bounded, so that all possible prices are covered; (ii) the method in the delta space gives greater weight to near-the-money observations and a lesser one to observations significantly out-of- or in-the-money, which corresponds to less liquid options. The delta is obtained as the first (partial) derivative of option prices versus the spot price. By convention, it is calculated within the Black and Scholes framework, the delta of a put being transformed to become positive:

$$\begin{aligned}\delta_C &\equiv \partial C_t / \partial S_t = e^{-r^*(T-t)} \Phi(d_1), \\ \delta_P &\equiv -\partial P_t / \partial S_t = e^{-r^*(T-t)} \Phi(-d_1) = e^{-r^*(T-t)} (1 - \Phi(d_1)), \quad (1) \\ d_1 &= \frac{\ln(S_t / K) + ((r - r^*) + 0.5\sigma^2)(T-t)}{\sigma\sqrt{(T-t)}}.\end{aligned}$$

$\delta_C$  and  $\delta_P$  denotes for the delta of the call and the put, respectively,  $C_t$  and  $P_t$  the price of the call and that of the put,  $S_t$  the exchange rate level,  $K$  the strike price,  $\sigma$  the volatility,  $r$  the domestic interest rate,  $r^*$  the currency's interest rate and  $T$  the maturity. We deduct from relation (1) that the deltas are bounded for both the calls and the puts,  $0 \leq \delta_C, \delta_P \leq e^{-r^*(T-t)} \leq 10$ , and that they are linked by the relationship:  $\delta_P = e^{-r^*(T-t)} - \delta_C$ . Given these definitions and if it is supposed that the implied volatility function is a quadratic function of the deltas, we obtain the following relationship<sup>17</sup>:

<sup>16</sup> These consequences of the call-put parity are also castigated by Bliss and Panigirtzoglou (2000) and Söderlind (2000).

<sup>17</sup> Note that expression (2) is different from that suggested by Malz (1997) as it corrects two small approximations the author made. First, the delta of an at-the-money option is equal to  $0.5e^{-r^*(T-t)}$ , not 0.5. Second, the delta of a put is not equal to  $1 - \delta_C$ , but to  $e^{-r^*(T-t)} - \delta_C$ .

$$\sigma(\delta) = ATM + RR \times \left( \frac{\delta - 0.5e^{-r^*(T-t)}}{0.5 - e^{-r^*(T-t)}} \right) + 4 \times STR \times \left( \frac{\delta - 0.5e^{-r^*(T-t)}}{0.5 - e^{-r^*(T-t)}} \right)^2. \quad (2)$$

The delta is defined in reference to the call options. Function (2) is then transformed into a (continuous) function linking implied volatility to the strike price by the inversion of the bijective (i.e. non-ambiguous) relationship between the delta and strike price given by (1). The RND is then obtained as the second derivative of this function relative to the strike price.

Once the RND is obtained, we calculate the moments of the distribution. Let  $\hat{m}^{(n)}$  denote the centered moment of order  $n$ . The first moment corresponds to the average (risk-neutral) market expectation of the JPY/USD exchange rate. By construction, the average of the RND corresponds to the forward price. In practice, given the low level of interest rates and the fact that we use option with short maturities ( $T - t$  is small), the forward is very close to the spot exchange rate. Over the period we are considering (April 1992-November 2003), the correlation between the spot and the forward is higher than 0.99 for both the levels and the first-order changes. The second moment, i.e. variance  $\hat{m}^{(2)}$ , provides an estimate of the uncertainty surrounding future trends in exchange rates. It is important to observe that the variance differs from the implied volatility. To convert the variance of the RND into an implied volatility measure, we follow Weinberg (2001) and use the results of Jarrow and Rudd (1982) where implied volatility is deduced as  $\sigma_{imp} = \sqrt{\ln(\hat{m}^{(2)} / (\hat{m}^{(1)})^2) / (T - t)}$ . The third moment, i.e. skewness, constitutes a measure of asymmetry, in other words the relative likelihood granted by the market for a far higher or far lower exchange rate in the future (relatively to the forward rate). In our case, a positive (respectively, negative) skewness reflects the fact that the market grants a greater likelihood to a stronger (respectively, weaker) than a lower (respectively, stronger) dollar in the future. Alongside the usual definition of skewness,  $\hat{m}^{(3)} / (\hat{m}^{(2)})^{3/2}$  denoted Sk1, we have chosen other definitions (see Bliss and Panigirtzoglou [2000]): (i) the intensity defined by Campa et al (1996) denoted Sk2; (ii) the Pearson measure based on the mode,  $(\hat{m}^{(1)} - Mode) / \hat{m}^{(2)}$ ,

denoted Sk3; (iii) the Pearson measure based on the median  $(\hat{m}^{(1)} - \hat{q}_{50}) / \hat{m}^{(2)}$ , denoted Sk4; (iv) a measure that is robust in the presence of outliers, denoted Sk5, and which we calculate as the ratio  $(\hat{q}_{75} - \hat{q}_{50}) / (\hat{q}_{50} - \hat{q}_{25})$  where  $\hat{q}_{\alpha}$  denotes the  $\alpha$ -percentile of the distribution. The fourth moment is the kurtosis, calculated as  $\hat{m}^{(4)} / (\hat{m}^{(2)})^2$ . It is a measure of uncertainty but this time concentrated on extremes in the sense that it measures the importance granted by the market to large moves in the exchange rate, regardless of their direction.

### 3.2 – Methodology of event study

To analyze the impact of interventions on distribution moments, we use an event study. The pertinence of this type of methodology in the case of currency interventions, given their sporadic nature, has been demonstrated empirically by Fatum (2000) and Fatum and Hutchison (2003a, 2003b) with regard to the impact on the returns on the spot exchange rate. The starting point of an event study is to define “the event” and identify an observation period of it, which is called the event window. The behaviour of the variable we are interested in — in our case, the different moments of the distribution — during the event window is compared with that on two different periods, a pre-event period and a post-event period.

The overwhelming majority of event studies in finance (modification of capital, earnings reporting, entries and exits from stock market indexes, etc.) bear on one-off events. Interventions in foreign exchange markets conversely are often carried out at very short time intervals, even over several days in a row (see section 2). Thus, repeated interventions on several consecutive days can be seen as a single event as they may correspond to the same political decision based on a particular economic and financial environment. The choice of the event window is therefore not evident: if it is too small, one can mistakenly distinguish two events while in fact we are dealing with a single phase of intervention; if it is too large, various intervention phases can be considered — just as erroneously — as stemming from the same economic policy decision and especially result in situations where

periods overlap. Generally speaking, one therefore has to determine arbitrarily a maximum number of days without any intervention that are accepted (so-called “tranquility” days) while considering one is still dealing with the same event. Fatum and Hutchison (2003b) set a maximum number of five tranquility days. With a view to ensuring comparability, we have also chosen this number as our basic criterion. Like these authors, we also provide a sensitivity analysis for 15 “tranquility” days. Its results are discussed in section 4.

The first step is thus to determine event periods during the period April 1992-October 2003, over which we observe our option data<sup>18</sup>. The events thus defined are detailed in Table 2 where we specify their starting and end dates, the length of the interval in terms of days of interventions and non-intervention, the amount and the direction of interventions and lastly we specify whether the intervention was coordinated or not with the Fed. All in all, we work on 50 events with an average duration of 8 business days<sup>19</sup>. These 50 events break down into 43 phases of yen sales — for an average amount of JPY 1,058 bn — and 7 phases of yen purchases — for an average amount of JPY 681 bn. On twelve occasions, the Fed intervened jointly with the BoJ. It did so only once to bolster the yen (on 17 June 1998), and this corresponds to the last episode of coordinated interventions on the JPY/USD. This disequilibrium between phases of purchases and phases of sales implies that the extensions we present in section 5 are established only in the first case.

The structure of events in the general case is specified in diagram 1.  $t_i$  stands for the first day of the  $i$ -th period of intervention,  $\tau_i$  stands for the duration (in days) of the  $i$ -th period of intervention and  $k$  is the size of the window of pre-event and post-event periods. The pre-event period is defined as ranging between  $t_i - k$  and  $t_i - 1$ . The event period is defined as ranging between  $t_i$  and  $t_i + \tau_i - 1$  included. The post-event period is defined as ranging between  $t_i + \tau_i$  and  $t_i + \tau_i + k - 1$ . Note that

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<sup>18</sup> Note in particular that we have not been able to analyze the period April 1991-March 1992 studied by Fatum and Hutchison (2003b) and by Galati et al. (2004).

<sup>19</sup> Note that events of a “1-day of intervention” type, equivalent to the usual manner in which interventions are analysed according to a time series approach, occur in only 14 cases out of 50.

we have included the last day of intervention in the post-event sample. This is consistent with the usual practice but poses the problem of the simultaneity bias. Note however that it is concentrated here on a single day of intervention among a succession of interventions. Furthermore, in the case of the BoJ, it is known that this bias is supposed to be less significant in the sense that its interventions have generally occurred in trading mornings in Tokyo (i.e. approximately 01.00 or 02.00 GMT) whereas option data are collected here during the trading day in London (12.00 GMT). Lastly, the results are hardly sensitive to this hypothesis (see section 4 in which we discuss the results when we exclude the last intervention day from the post-event sample).

Let  $M_t$  denote the level of a moment in period  $t$ . We denote  $\Delta M_i^{\text{pre}}$  and  $\Delta M_i^{\text{post}}$  the changes in moments in the pre-event and post-event intervals, respectively, with  $\Delta M_i^{\text{pre}} = M_{t_i-1} - M_{t_i-k}$  and  $\Delta M_i^{\text{post}} = M_{t_i+\tau_i+k-1} - M_{t_i+\tau_i}$ . To analyze the significance of changes in the moment, we define two null hypotheses<sup>20 21</sup>:

$$H_0^{(1)} : E(\Delta M_i^{\text{post}}) = 0, \quad (3)$$

$$H_0^{(2)} : E(\Delta M_i^{\text{post}} - \Delta M_i^{\text{pre}}) = 0. \quad (4)$$

Just like Fatum and Hutchison (2003a, 2003b), we exclude the event period from our analysis by considering exclusively variations outside the event period. By doing so, if the effect of the intervention is immediate (for example if purchases of dollars are reflected by an instantaneous and durable appreciation in the dollar against the yen), this type of hypothesis will not be capable of totally identifying this effect. The tests can then be deemed conservative.  $H_0^{(1)}$  represents the strongest form of the test by seeking to ascertain whether the intervention is reflected by a significant

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<sup>20</sup> These hypotheses are implicitly tested by Fatum and Hutchison (2003a,b) on exchange rate returns. The first null hypothesis corresponds to their “Direction” test, the second null hypothesis to their “Reversal” or “Smoothing” tests depending on the sign of the return in the pre-event period.

<sup>21</sup> In the case of the average and the variance, we have considered the logarithm of the moment rather than the moment itself. In this way, we look at relative, not absolute, variations. In particular, changes in the average are very close to spot returns on the JPY/USD. Note nonetheless that conclusions are insensitive to this logarithmic transformation.

change in the moment in the following period.  $H_0^{(2)}$  compares post-event changes with pre-event changes. It is weaker because it does not necessarily require the moment to change following the intervention. Let us take the example of an intervention aimed at driving the yen downwards following a significant rise in the Japanese currency: if the intervention is to be deemed efficient, it might be sufficient that with  $H_0^{(2)}$  the exchange rate levels off or even that the yen appreciates anew but to a smaller extent. Testing this weak form of intervention success has a meaning for the first moment (Fatum and Hutchison [2003a,b]), but is probably more questionable for higher order moments. For instance, in the case of the second moment, it is disputable to conclude that an intervention is not a failure just because the variance increase has decelerated. Thus, we must be cautious in interpreting the results of  $H_0^{(2)}$ . As will become apparent in Section 4, our conclusions are nevertheless valid for both hypothesis and not dependent on that point.

Finally, let us precise the definition of alternative hypotheses. For rejection of the null hypotheses to be consistent with a notion of success achieved by the intervention, we set the following alternative hypotheses. Regarding the average and the various measures of skewness, we set the alternative test as a positive variation in the moment for yen sales and a negative variation in the moment for yen purchases. With regard to variance and kurtosis, we set the alternative test as a negative variation in the moment in all cases. The levels of significance correspond to tests on one tail of the distribution.

In event studies, null hypotheses such as  $H_0^1$  and  $H_0^{(2)}$  are usually tested via a t-test. It is well known, however, that a t-test can prove to be fragile in a framework such as ours (small sample size, underlying distribution of variations in moments which is unknown, sensitivity to extreme observations). Therefore, we have completed the t-test by a bootstrap. The bootstrap is a very general technique that consists in creating an empirical distribution for a statistic, by drawing with replacement from the original sample while constraining the null hypothesis to be respected. All bootstrap results presented in this article are based on 10,000 replications. Moreover, we also tested



the significance of changes in moments by a non-parametric Sign test. In such a case, the null hypothesis is modified since the nullity of the median is tested. The Sign test is an exact test that is valid for any continuous distribution whatever. The statistic of the Sign test is distributed according to a binomial distribution with parameters 0.5 and  $n$ , where  $n$  stands for the number of observations. We count the number of successes in a manner consistent with the alternative hypotheses detailed above. Thus, we count a success for every fall (rise) in the average or in the skewness for purchases (sales) of yen or for a decline in volatility or in kurtosis regardless of the direction of the intervention.

#### **4 – Do interventions change market expectations?**

In this section, we report the results of significance of changes in moments during the 50 intervention events. The moments calculated on a day-by-day basis are shown in Figure 2. Several points are worth noting. First, regarding skewness, we present the evolution of the usual measure but evolutions for other definitions are virtually identical regardless of the definition. Second, the vertical axis is truncated for variance. In particular, the variance of the RND has attained a level of 160 (or, in equivalent implied volatility terms, an annualized level of 37%) in the early days of October 1998. However, this period is not included in our analysis since no intervention took place in the second half of 1998 (see Table 2) <sup>22</sup>.

The results of the event study are shown in Tables 3A (event window equal to 2 days), 3B (event window equal to 5 days) and 3C (event window equal to 10 days). In each case, we draw a distinction between tests, for the various moments, according to the direction of the intervention and according to the type of null hypothesis. We systematically show the results according to the t-test with bootstrap and the Sign test, but a noteworthy point is that every time they are very similar, confirming their robustness notably with respect to the rejection of standard distributional hypotheses.

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<sup>22</sup> However, one should note that the joint intervention which took place on June 17, 1998 might have played a significant role. See Cai, Cheung, Lee and Melvin (2001) for a detailed analysis of the determinants of the dramatic yen/dollar volatility of 1998.

Regarding the mean of the RND, the interventions seem effective regardless of the horizon, the direction of the intervention and the type of null hypothesis. On average, an intervention in favour of the dollar is followed by an appreciation in the dollar ranging from 0.7% two days after the intervention to 0.95% ten days after the intervention, with 0.91% recorded after five days. For its part, an intervention in favour of the yen is reflected by a depreciation in the dollar of about 1.3% after ten days. Note that, as expected, the intervention seems more effective when the dynamics rather than the level is considered, and this is logical since  $H_0^{(2)}$  is less demanding than  $H_0^{(1)}$  is. Note also that yen sales seem more effective than yen purchases. However, one should pay attention to the disequilibrium of the sample: we have 43 events in the first case, against 7 in the second, and the difference in terms of degrees of freedom implies a loss of power of the test in the second case. With a different sampling period and drawing on another methodology, our results on the mean therefore tend to confirm those reported by Fatum and Hutchison (2003b). Given the correlation previously noted between spot and forward, this consistency in results is not surprising. Conversely, our results contradict those reported by Galati et al. (1999, 2004) as they did not find any significant impact of exchange rate interventions on the RND mean. In our opinion, the difference clearly stems from the fact we have used an event study type methodology whereas Galati et al. used a time-series approach. Note in particular that the difference in results with regard to the mean cannot be accounted for by the method used to construct the RND since we are dealing with the forward rate. Its value therefore does not depend on the estimation method — it depends exclusively on the spot and the interest rate differential on the horizon — and the various methods generally impose it as a constraint<sup>23</sup>. In other words, it does not give rise to divergences between the various methods used to extract the RND.

The results with respect to variance are more ambiguous. If dependence on the horizon is relatively insignificant, results diverge noticeably with regard to the direction of the intervention. While yen sales seem to lead to a significant decline in volatility (results are especially significant in the case of

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<sup>23</sup> Note that in the Malz (1997) method, this condition is not imposed; it is complied with by construction.

the Sign test and  $H_0^{(2)}$ ), yen purchases are followed by a rise in volatility (which would sometimes be significant if we were to reverse the alternative hypothesis<sup>24</sup>). The consensus in the literature (see, *inter alia*, Bonser-Neal and Tanner [1996], Baillie and Osterberg [1997], Dominguez [1998], Beine, Bénassy-Quéré and Lecourt [2002], Frenkel et al. [2005], Hillebrand and Schnabl [2003]) is that interventions lead to an increase in volatility, whether the latter is drawn from a GARCH model or implied from options. In our case, the most frequent interventions in the period (in other words aimed at weakening the yen) seem to result in the opposite impact, i.e. a decrease in volatility. Here again, the difference can largely be accounted for by methodology. While the usual regression techniques consider the immediate impact of the intervention on volatility, we analyze the impact during a larger period following the intervention, for intervals ranging from 2 trading days to 10 trading days. Note that it is possible to reconcile the two results. In a microstructural framework (see Lyons [2001]), it is highly probable that the intervention should result, in the short term, in an increase in volatility via trading because, first, interventions can create an imbalance in the inventories of market-makers and, second, traders have to interpret this new information. In the longer term, however, the effect is more neutral and the intervention can even lead to a decrease in volatility if it allows the objectives of authorities in terms of economic policy to be clarified. Actually, Dominguez (2003) emphasises that the increase in volatility recorded in the short term is not persistent. Another explanation is the result found by Beine (2003) and Beine, Laurent and Lecourt (2003) that volatility changes following an intervention depend on the initial level of volatility. In particular, interventions during high volatility regimes tend to be followed by decreases in exchange rate volatility.

The results concerning skewness are conclusive. Yen sales systematically lead to a significant rise (at a 95% confidence threshold in most cases) in skewness, i.e. expectations move towards a greater likelihood, in the future, of a stronger than a weaker dollar. By contrast, yen purchases are

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<sup>24</sup> In the latter case, and in contrast with the results on the mean, we are accordingly not dealing with just a problem of test power since the direction of change is not the right one.

systematically followed by a decline in skewness, i.e. a distortion in the density of expectations in favour of a yen rise. As with the mean, note that the results are less significant in the case of yen purchases, and this might be related to the lack of power because of the lower number of observations. Moreover, note that the results are very similar, regardless of the measure of skewness used, and this is logical since they are highly correlated (the correlations fluctuate between 0.84 and 0.99) and this is a striking argument in favour of the robustness of results, notably with regard to their sensitivity to the distribution tails of the RND. These positive results are contrary to those reported by Galati et al. (1999, 2004) with regard to the moments drawn from the RND. Once more, we account for the difference by the opposition between an event study and a time series approach. Note however, that Beine et al. (2004) also identify significant impact on realized skewness, but limited to the case of coordinated USD purchases and for the DEM/USD parity. It is also consistent to find similarity in results between the first and the third moments<sup>25</sup>, although both do not give identical information. In particular, it is logical to observe that a credible and effective intervention, beyond its impact on the level of the exchange rate, may change expectations in favour of a greater likelihood granted to a continuation of the move in the same direction.

Lastly, the results regarding kurtosis are also very clear. In no case did interventions allow kurtosis to be reduced significantly. For yen sales, kurtosis actually frequently moves in the opposite direction to the expected one by increasing. Therefore, interventions apparently fail to reduce significantly uncertainty among agents about extreme swings in the JPY/USD. As far as we know, the only authors to have analysed the impact on the fourth moment are Galati et al. (1999, 2004) who also concluded that there was no significant impact. Note, however, that drawing a conclusion about the fourth moment is tricky. In contrast with lower order moments, a satisfactory estimate of the fourth-order moment supposes one can draw on options which are deep out-of-the-money. In our

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<sup>25</sup> Empirically, the first and third moments are correlated positively, as the correlations fluctuate, according to the measure of skewness, between 0.23 and 0.29 for levels and between 0.13 and 0.46 for the first-order differences. See Galati et al (2004) for a similar point of view. One could link this result to that reported by Campa, Chang and Reider (1998) who have shown that risk-reversals (i.e. a direct form of measuring the skewness of the RND) are correlated positively to observed variations in the exchange rate.

case, the delta of options are equal to 0.25, 0.5 and 0.75. One can find options traded in the market for a delta far more remote from 0.5<sup>26</sup> but it is extremely difficult — and even impossible — to obtain a track record covering such quotations over ten years as is our case and caution is called for since these options are rather illiquid.

The previous results are established for 5 tranquility days and a post-event period that includes the last day of intervention, and this corresponds to the basic framework set up by Fatum and Hutchison (2003b). We have gradually eased these hypotheses. We do not present these results in detail, but we rapidly discuss modifications in relation to the basic study<sup>27</sup>.

The case where we include 15 tranquility days leads to a subsequent decrease in the number of events. This is because, by increasing the number of tranquility days, we allow what was seen as different phases with 5 tranquility days, to be regrouped into a single event. Concretely, we have 23 events corresponding to yen sales (against 43 with 5 tranquility days) and 6 phases of of yen purchases (against 7 previously). The results for the mean and skewness are virtually unchanged. The only problem is a loss of significance for the increase in skewness in the case of yen sales and the t-test, something that in all likelihood can be accounted for by the loss of power stemming from the reduction of the sample (as is confirmed by the lack of any significant impact in the case of yen purchases where the reduction of the sample is less noticeable). Modifications are more sensitive with regard to variance and kurtosis in the sense of a greater effectiveness. The decline in variance becomes more significant with regard to yen sales for the 5- and 10-day event windows and in the case of two forms of hypothesis. For its part, the decrease in kurtosis in the case of yen purchases becomes significant, but the rejection of the null hypothesis is restricted to  $H_0^{(1)}$ .

The case in which the last event day is excluded is interesting in several respects. First, it allows us to keep the same sample size, and therefore *a priori* the same power for the test. Second, it illustrates

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<sup>26</sup> See for example Jondeau and Rockinger (2000) who use options with deltas ranging from 0.10 to 0.90 for a sample limited to various dates during the period May 1996 to June 1997.

<sup>27</sup> Detailed tables of results are available upon request from the authors.

the indecision prevailing in the literature with respect to the endogeneity bias. Indeed, in time series approach that studies the impact of the interventions by regressions, some authors have sometimes considered the day following the intervention as the reference period to avoid to simultaneously measure the impact of the event and its motivation but this way of operating is probably too radical as it probably tends to underestimate the impact of the intervention if it does not last very long (see Sarno and Taylor [2001] for a discussion). In this study, we look at longer periods than are usually covered in the literature, insofar as they last several days after the intervention. In accordance with what intuition suggests, excluding the last day leads to slightly less positive results with respect to the effectiveness of interventions. Regarding yen sales, nonetheless, the impact on the mean and skewness of interventions remains very significant. The decrease in variance is more significant only for  $H_0^{(1)}$ , and regardless of the horizon drawn upon. Regarding yen purchases, in the basic results, the decrease in the mean is significant (at a 95% confidence threshold) for  $H_0^{(1)}$  only in the case of a window equal to two days (see Table 3A). When we exclude the last day of intervention from the post-event window, this significance disappears. By contrast, the significance remains ensured for  $H_0^{(2)}$  regardless of the horizon or the test statistic.

## **5 – Extensions**

In this section, we discuss some developments achieved with respect to previous results. In particular, we analyze the sensitivity of results to: (i) the coordination of interventions; (ii) the simultaneous dissemination of news. Given the low number of interventions consisting in yen purchases, these sensitivity analyses are carried out only in the case of the 43 episodes of yen sales. In each case, we present the results equivalent to those from t-tests in Tables 3A to 3C for the various sub-samples as well as a significance test of difference between sub-samples. Significance is once again established via a bootstrap, with 10,000 replications, under the null hypothesis of a lack of difference between

the sub-samples. To save space, we concentrate on hypothesis  $H_0^{(1)}$ . The main results are also valid for hypothesis  $H_0^{(2)}$ <sup>28</sup>.

### 5.1. Coordinated vs. non-coordinated interventions

Table 4 shows the results obtained when the sample is broken down into interventions coordinated between the BoJ and the Fed (i.e. 11 cases) and when this is not the case (32 cases)<sup>29</sup>. The results clearly show that a coordinated intervention increases effectiveness, and this is in line with the consensus found in the literature (see Sarno and Taylor [2001]). Coordination thus allows the dollar to appreciate more markedly against the yen, in a range of nearly 1% for a 2-day horizon to nearly 2% for a 10-day horizon. The difference between coordinated and non-coordinated interventions is significant at the 98% confidence threshold regardless of the horizon. Conversely, coordinated interventions do not lead to a more substantial decrease in volatility; in fact the opposite tends to be the case and significantly at a 99% confidence threshold (if we reverse the alternative hypothesis). While coordination also implies a greater efficiency in terms of skewness, the difference, however, is significant at a 90% confidence threshold only in the case of Sk1, Sk4 and Sk5 measures and for a 5-day horizon. Lastly, trends in kurtosis are insensitive whether the intervention is coordinated or not.

### 5.2. The impact of news

A frequently raised criticism concerning intervention studies is that the impact of other news is not controlled. In particular, exchange rate changes can result from the release of macroeconomic news at the same time, and not from the intervention. Within a time series framework, several authors have accordingly introduced variables to take into account this effect, either by considering stock market returns and volatility (Bonser-Neal and Tanner [1996]), or more directly by introducing the publications of economic statistics (Galati et al. [1999, 2004]). Within an event study framework,

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<sup>28</sup> A detailed breakdown of all the results is available on request.

<sup>29</sup> Note that we ignore here the case of interventions carried out on 22 September 2000 at the initiative of the ECB and aimed at sustaining the euro. These interventions did not directly concern the JPY/USD and cannot be assimilated with the BoJ's exchange rate policy.

taking into account news is less evident. Fatum and Hutchison (2003b) show the robustness of their results when changes in the intervention rates of the Fed and the BoJ are taken into account. Given that the BoJ overall has not budged from its zero interest rate policy since 1999, we did not believe replicating such a study was called for. Conversely, we have sought to assess the effect of other economic and political news by segmenting events according to the level of stock market volatility observed at the same time. Stock market volatility is here calculated in an equal-weighted manner between the implied volatilities of the Nikkei and of the S&P 500, as available from Bloomberg (two month maturity and at-the-money options). The underlying idea is that if the event period is marked by important economic and political news, this will be reflected by a rise in stock market volatility while in the other way round, one does not expect the stock market volatility to be influenced by the currency interventions.

Table 5 shows the results obtained by comparing events associated with stock market volatility in excess of its median with events associated with volatility lower than the median. A few conclusions stand out markedly. First, as expected, the decrease in variance of expectations is less subsequent following phases marked by an upturn in stock market volatility (the difference, however, is significant only at the 90% threshold and only for a 10-day horizon). Secondly, with the exception of a 10-day horizon, there is no noticeable impact on the mean, and consequently the effectiveness of interventions does not seem to be lowered by the presence of other news<sup>30</sup>. Thirdly, the impact on skewness depends largely on the chosen horizon and is never significant. Fourthly, kurtosis seems, paradoxically, lower after phases marked by an upturn in stock market volatility but the difference is not significant regardless of the horizon (it nearly is at 5 days). In conclusion, apparently the results are not very sensitive to taking into account other macroeconomic news, with the exception of variance. In this last case, this tends to confirm once again the instability of results.

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<sup>30</sup> Note that Galati et al. (2004) also conclude that their conclusions are not affected by the introduction of news in their regressions.



## 6 - Conclusion

In this article, we have analysed the impact of the BoJ's official interventions on the first four moments of the distribution of market (risk-neutral) expectations on the JPY/USD exchange rate. Following Fatum and Hutchison (2003b), we have favoured an approach based on event studies, far more adapted to the nature of intervention data (as they occur as clusters) than the conventional time series approach. Our results clearly show that the BoJ's interventions can be deemed effective.

We show that purchases (sales) of dollars are reflected by an increase (decrease) in the first moment — the JPY/USD forward rate, which is consistent with previous evidence by Fatum and Hutchinson (2003b). We also show that interventions have clear and significant effects on skewness, in line with the direction of interventions. This result, which is in sharp contrast with Galati et al. (1999, 2004) ones, is important as it shows that interventions have not only direct effects on the level of the exchange rate but also orientate expectations towards future changes in the same direction. In line with previous literature (Beine [2003], Beine, Laurent and Lecourt [2003], Dominguez [2003]), we also find that results are ambiguous regarding volatility and depend on the horizon, the direction of intervention and the simultaneous release or not of other news (as measured via stock market volatility). Conversely, kurtosis appears to be insensitive to interventions.

Several extensions of this work could be considered. First, it would be interesting to use other methods to estimate moments. In particular, parametric measures could be proposed, such as for example for skewness via the estimate of asymmetrical Student distribution (Hansen [1994]). Second, we have restricted this study to the first four moments. It could be interesting to test the modification of the RND as a whole. Third, one could also try to investigate the sensitivity of the results to recent aspects of Japanese interventions and notably the questions of sterilization (Fatum and Hutchison [2004]) and secrecy of interventions (Beine and Lecourt [2004], Gnabo and Lecourt [2004]).

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**TABLE 1: BO J INTERVENTIONS (APRIL 1992 – OCTOBER 2003)**

	<b>April 1992-October 2003</b>
<b>Total interventions</b>	<b>273</b>
Coordinated with Fed	19
Probability of intervention	9.0%
Conditional probability of repeated intervention	58.6%
<b>Dollar purchases</b>	<b>249</b>
Coordinated with Fed	18
Average spot exchange rate	106.3
Average amount (bns \$)	1.626
Median amount (bns \$)	0.649
Minimum amount (bns \$)	0.003
Maximum amount (bns \$)	13.223
<b>Dollar sales</b>	<b>24</b>
Coordinated with Fed	1
Average spot exchange rate	129.45
Average amount (bns \$)	1.502
Median amount (bns \$)	0.263
Minimum amount (bns \$)	0.025
Maximum amount (bns \$)	20.143

Note. This table details the interventions of the BoJ and the Fed on the JPY/USD exchange rate during the April, 1992 – October, 2003 period. Sources: Fed, BoJ.

**TABLE 2: DEFINITIONS OF EVENTS OVER THE WHOLE PERIOD (5-DAY “TRANQUILITY”)**

Date of event		Number of days			Amount of intervention		Coordinated with Fed - Y/N
From	To	Total	Interventions	No intervention	Bns JPY	Bns USD	
Apr 27, 92	Apr 30, 92	4	3	1	-167	-1.25	N
May 22, 92	Jun 25, 92	25	10	15	-315	-2.45	N
Jul 24, 92	Jul 27, 92	2	2	0	-48	-0.37	N
Aug 7, 92	Aug 11, 92	3	2	1	-16	-0.13	N
Apr 2, 93	May 7, 93	26	17	9	811	7.28	Y
May 26, 93	Jun 15, 93	15	13	2	1026	9.59	Y
Jun 28, 93	Jun 28, 93	1	1	0	11	0.10	N
Jul 30, 93	Aug 27, 93	21	17	4	837	8.12	Y
Sep 7, 93	Sep 7, 93	1	1	0	22	0.21	N
Feb 15, 94	Mar 4, 94	14	9	5	398	3.82	N
Mar 29, 94	May 4, 94	27	16	11	580	5.64	Y
Jun 20, 94	Jul 12, 94	17	11	6	635	6.34	Y
Aug 18, 94	Aug 25, 94	6	6	0	149	1.52	N
Sep 6, 94	Sep 20, 94	11	4	7	79	0.80	N
Oct 3, 94	Oct 3, 94	1	1	0	16	0.16	N
Oct 14, 94	Nov 3, 94	15	8	7	466	4.80	Y
Feb 17, 95	Apr 18, 95	43	34	9	2444	27.53	Y
May 31, 95	May 31, 95	1	1	0	106	1.25	Y
Jun 28, 95	Jun 28, 95	1	1	0	43	0.51	N
Jul 7, 95	Jul 7, 95	1	1	0	87	1.00	Y
Aug 2, 95	Aug 2, 95	1	1	0	721	7.95	Y
Aug 11, 95	Aug 15, 95	3	2	1	171	1.80	Y
Sep 6, 95	Sep 8, 95	3	2	1	1084	10.89	N
Sep 22, 95	Sep 22, 95	1	1	0	599	6.06	N
Feb 20, 96	Feb 27, 96	6	5	1	1604	15.27	N
Dec 17, 97	Dec 19, 97	3	3	0	-1059	-8.24	N
Apr 9, 98	Apr 10, 98	2	2	0	-2816	-21.65	N
Jun 17, 98	Jun 17, 98	1	1	0	-346	-2.51	Y
Jan 12, 99	Jan 12, 99	1	1	0	656	5.87	N
Jun 10, 99	Jun 21, 99	8	4	4	2938	24.29	N
Jul 5, 99	Jul 5, 99	1	1	0	784	6.41	N
Jul 20, 99	Jul 21, 99	2	2	0	584	4.93	N
Sep 10, 99	Sep 14, 99	3	2	1	1020	9.49	N
Nov 29, 99	Nov 30, 99	2	2	0	1135	11.12	N
Dec 24, 99	Dec 24, 99	1	1	0	370	3.64	N
Jan 4, 00	Jan 4, 00	1	1	0	575	5.59	N
Mar 8, 00	Mar 15, 00	6	2	4	997	9.44	N
Apr 3, 00	Apr 3, 00	1	1	0	1385	13.22	N
Sep 17, 01	Sep 28, 01	10	7	3	3146	26.74	N
May 22, 02	May 23, 02	2	2	0	1086	8.72	N
May 31, 02	Jun 4, 02	3	2	1	1404	11.32	N
Jun 24, 02	Jun 28, 02	5	3	2	1502	12.52	N
Jan 15, 03	Jan 29, 03	11	8	3	678	5.74	N
Feb 24, 03	Mar 10, 03	11	9	2	1613	13.72	N
May 8, 03	May 27, 03	14	11	3	3900	33.43	N
Jun 5, 03	Jun 25, 03	15	7	8	629	5.34	N
Jul 3, 03	Jul 16, 03	10	9	1	2027	17.21	N
Aug 29, 03	Sep 16, 03	13	11	2	4457	38.12	N
Sep 30, 03	Oct 14, 03	11	8	3	2554	23.08	N
Oct 28, 03	Oct 30, 03	3	3	0	182	1.68	N

Note. This table details the events defined with five maximum days of tranquility.

**TABLE 3A: DOES INTERVENTION CHANGE IMPLIED MOMENTS? 2-DAYS PERIOD RESULTS**

		<b>Mean</b>	<b>Variance</b>	<b>Sk1</b>	<b>Sk2</b>	<b>Sk3</b>	<b>Sk4</b>	<b>Sk5</b>	<b>Kurtosis</b>
<b><i>Change in levels <math>H_0^{(1)}</math></i></b>									
Yen sales / Dollar purchases ( $n = 43$ )									
t-test	Mean	0.00699	-0.04833	0.04190	0.01056	0.02175	0.01143	0.00964	-0.00890
	t-stat	4.096	-1.786	2.298	2.430	1.882	2.537	2.731	-0.490
	p-value	0.0005	0.0506	0.0095	0.0096	0.0230	0.0045	0.0021	0.3125
Sign test	# successes	33	29	29	28	29	29	29	20
	p-value	0.0001	0.0069	0.0069	0.0158	0.0069	0.0069	0.0069	0.6196
Yen purchases / Dollar sales ( $n = 7$ )									
t-test	Mean	-0.01289	0.03856	-0.0389	-0.0134	-0.0075	-0.0107	-0.0093	-0.00938
	t-stat	-1.616	1.467	-1.296	-1.268	-0.743	-1.337	-1.378	-0.351
	p-value	0.0368	0.9437	0.0955	0.0737	0.1565	0.0749	0.0757	0.3844
Sign test	# successes	6	2	4	4	4	4	3	4
	p-value	0.0078	0.7734	0.2266	0.2266	0.2266	0.2266	0.5000	0.2266
<b><i>Change in dynamics <math>H_0^{(2)}</math></i></b>									
Yen sales / Dollar purchases ( $n = 43$ )									
t-test	Mean	0.01565	-0.08960	0.07159	0.01828	0.02897	0.01944	0.01658	0.00300
	t-stat	6.810	-2.491	3.397	3.722	1.695	3.786	4.166	0.146
	p-value	0.0000	0.0117	0.0007	0.0002	0.0446	0.0001	0.0000	0.5534
Sign test	# successes	36	30	33	35	30	32	32	22
	p-value	0.0000	0.0027	0.0001	0.0000	0.0027	0.0003	0.0003	0.3804
Yen purchases / Dollar sales ( $n = 7$ )									
t-test	Mean	-0.0162	0.0803	-0.0619	-0.0215	-0.0040	-0.0160	-0.0137	0.04011
	t-stat	-2.228	1.095	-1.882	-1.466	-0.223	-1.791	-1.782	0.606
	p-value	0.0051	0.8820	0.0190	0.0297	0.3930	0.0179	0.0202	0.7711
Sign test	# successes	6	3	6	6	4	6	6	4
	p-value	0.0078	0.5000	0.0078	0.0078	0.2266	0.0078	0.0078	0.2266

Note. This table reports the estimation results for the event study of the impact of BoJ and Fed interventions on JPY/USD risk-neutral moments. The results are computed for the basis case of a maximum of five days of tranquillity and the last day of intervention included in the post-even window. p-values are calculated using the bootstrapped distribution for the t-test. See body part of the text for definitions of null and alternative hypothesis.

**TABLE 3B: DOES INTERVENTION CHANGE IMPLIED MOMENTS? 5-DAYS PERIOD RESULTS**

		Mean	Variance	Sk1	Sk2	Sk3	Sk4	Sk5	Kurtosis
<b><i>Change in levels <math>H_0^{(1)}</math></i></b>									
Yen sales / Dollar purchases ( $n = 43$ )									
t-test	Mean	0.0091	-0.0613	0.0461	0.0114	0.0329	0.0131	0.0115	0.0097
	t-stat	3.816	-1.509	1.885	1.796	2.232	2.147	2.363	0.392
	p-value	0.0008	0.1031	0.0308	0.0534	0.0075	0.0159	0.0112	0.6413
Sign test	# successes	34	30	26	29	30	27	29	20
	p-value	0.0000	0.0027	0.0631	0.0069	0.0027	0.0330	0.0069	0.6196
Yen purchases / Dollar sales ( $n = 7$ )									
t-test	Mean	-0.0089	0.0709	-0.0526	-0.0161	-0.0094	-0.0138	-0.0121	-0.0228
	t-stat	-3.034	1.275	-2.271	-1.892	-1.028	-2.297	-2.390	-1.525
	p-value	0.0933	0.8932	0.0125	0.0115	0.0680	0.0120	0.0110	0.0839
Sign test	# successes	6	2	6	6	6	7	7	4
	p-value	0.0078	0.7734	0.0078	0.0078	0.0078	0.0000	0.0000	0.2266
<b><i>Change in dynamics <math>H_0^{(2)}</math></i></b>									
Yen sales / Dollar purchases ( $n = 43$ )									
t-test	Mean	0.0205	-0.1544	0.1046	0.0251	0.0489	0.0285	0.0244	0.0342
	t-stat	6.235	-2.811	3.656	3.890	2.507	4.221	4.735	0.959
	p-value	0.0000	0.0083	0.0000	0.0000	0.0049	0.0000	0.0000	0.8200
Sign test	# successes	37	32	34	33	32	33	35	17
	p-value	0.0000	0.0003	0.0000	0.0001	0.0003	0.0001	0.0000	0.8890
Yen purchases / Dollar sales ( $n = 7$ )									
t-test	Mean	-0.0177	0.0387	-0.0928	-0.0297	-0.0221	-0.0245	-0.0214	-0.0268
	t-stat	-3.409	0.294	-2.306	-1.607	-0.986	-2.370	-2.449	-1.120
	p-value	0.0007	0.5874	0.0147	0.0225	0.1439	0.0093	0.0095	0.1185
Sign test	# successes	7	3	6	6	4	6	6	4
	p-value	0.0000	0.5000	0.0078	0.0078	0.2266	0.0078	0.0078	0.2266

Note. See table 3A.



**TABLE 3C: DOES INTERVENTION CHANGE IMPLIED MOMENTS? 10-DAYS PERIOD RESULTS**

		Mean	Variance	Sk1	Sk2	Sk3	Sk4	Sk5	Kurtosis
<b><i>Change in levels <math>H_0^{(1)}</math></i></b>									
Yen sales / Dollar purchases ( $n = 43$ )									
t-test	Mean	0.00950	-0.05215	0.04383	0.01205	0.03263	0.01227	0.01072	0.01059
	t-stat	2.822	-1.317	1.654	1.697	2.564	1.870	2.061	0.417
	p-value	0.0038	0.1230	0.0486	0.0612	0.0053	0.0333	0.0237	0.6388
Sign test	# successes	32	28	25	28	32	29	30	18
	p-value	0.0003	0.0158	0.1110	0.0158	0.0003	0.0069	0.0027	0.8198
Yen purchases / Dollar sales ( $n = 7$ )									
t-test	Mean	-0.0128	0.0998	-0.0513	-0.0154	-0.0085	-0.0140	-0.0125	-0.0331
	t-stat	-1.816	1.250	-1.790	-1.824	-0.858	-1.852	-1.864	-1.127
	p-value	0.1343	0.8380	0.0908	0.0624	0.1405	0.0718	0.0752	0.1575
Sign test	# successes	5	2	5	5	5	5	5	4
	p-value	0.0625	0.7734	0.0625	0.0625	0.0625	0.0625	0.0625	0.2266
<b><i>Change in dynamics <math>H_0^{(2)}</math></i></b>									
Yen sales / Dollar purchases ( $n = 43$ )									
t-test	Mean	0.0195	-0.1229	0.0829	0.0224	0.0425	0.0228	0.0199	0.0612
	t-stat	4.631	-2.076	2.358	2.541	2.151	2.678	2.993	1.500
	p-value	0.0000	0.0334	0.0079	0.0067	0.0119	0.0023	0.0014	0.9116
Sign test	# successes	33	29	29	32	30	30	31	13
	p-value	0.0001	0.0069	0.0069	0.0003	0.0027	0.0027	0.0010	0.9931
Yen purchases / Dollar sales ( $n = 7$ )									
t-test	Mean	-0.0281	0.0714	-0.0931	-0.0317	-0.0172	-0.0252	-0.0225	-0.0264
	t-stat	-2.854	0.541	-1.683	-1.521	-0.809	-1.738	-1.796	-0.587
	p-value	0.0194	0.7093	0.0497	0.0317	0.1474	0.0434	0.0413	0.2452
Sign test	# successes	5	3	4	4	5	4	4	3
	p-value	0.0625	0.5000	0.2266	0.2266	0.0625	0.2266	0.2266	0.5000

Note. See table 3A.

**TABLE 4: COORDINATED VS NON-COORDINATED INTERVENTIONS**

		Mean	Variance	Sk1	Sk2	Sk3	Sk4	Sk5	Kurtosis
<b>Window length = 2 days</b>									
<b>Individual tests</b>									
Coordinated	Mean	0.0138	0.0013	0.0534	0.0133	0.0264	0.0140	0.0121	-0.0100
(n = 11)	p-value	0.000	0.523	0.069	0.039	0.256	0.035	0.015	0.408
Non-coordinated	Mean	0.0047	-0.0654	0.0379	0.0096	0.0201	0.0106	0.0088	-0.0085
(n = 32)	p-value	0.016	0.031	0.042	0.037	0.039	0.027	0.022	0.344
<b>Tests of differences</b>									
Coordinated vs non-	Mean	0.0092	0.0666	0.0154	0.0036	0.0063	0.0034	0.0033	-0.0015
coordinated	p-value	0.009	0.992	0.344	0.352	0.386	0.371	0.341	0.478
<b>Window length = 5 days</b>									
<b>Individual tests</b>									
Coordinated	Mean	0.0179	-0.0321	0.1029	0.0226	0.0338	0.0271	0.0235	0.0283
(n = 11)	p-value	0.000	0.335	0.012	0.010	0.154	0.003	0.003	0.727
Non-coordinated	Mean	0.0061	-0.0714	0.0265	0.0076	0.0325	0.0083	0.0073	0.0033
(n = 32)	p-value	0.039	0.128	0.177	0.185	0.022	0.130	0.113	0.541
<b>Tests of differences</b>									
Coordinated vs non-	Mean	0.0119	0.0393	0.0764	0.0150	0.0013	0.0188	0.0161	0.0250
coordinated	p-value	0.0107	0.9893	0.0895	0.1491	0.4683	0.0878	0.0726	0.6767
<b>Window length = 10 days</b>									
<b>Individual tests</b>									
Coordinated	Mean	0.0239	-0.0053	0.0637	0.0215	0.0257	0.0178	0.0166	0.0595
(n = 11)	p-value	0.000	0.487	0.046	0.014	0.140	0.018	0.009	0.909
Non-coordinated	Mean	0.0045	-0.0683	0.0370	0.0088	0.0350	0.0104	0.0087	-0.0062
(n = 32)	p-value	0.125	0.072	0.129	0.168	0.010	0.109	0.104	0.394
<b>Tests of differences</b>									
Coordinated vs non-	Mean	0.0194	0.0629	0.0267	0.0127	-0.0093	0.0074	0.0079	0.0658
coordinated	p-value	0.0072	0.9928	0.3313	0.2134	0.6246	0.3111	0.2496	0.8878

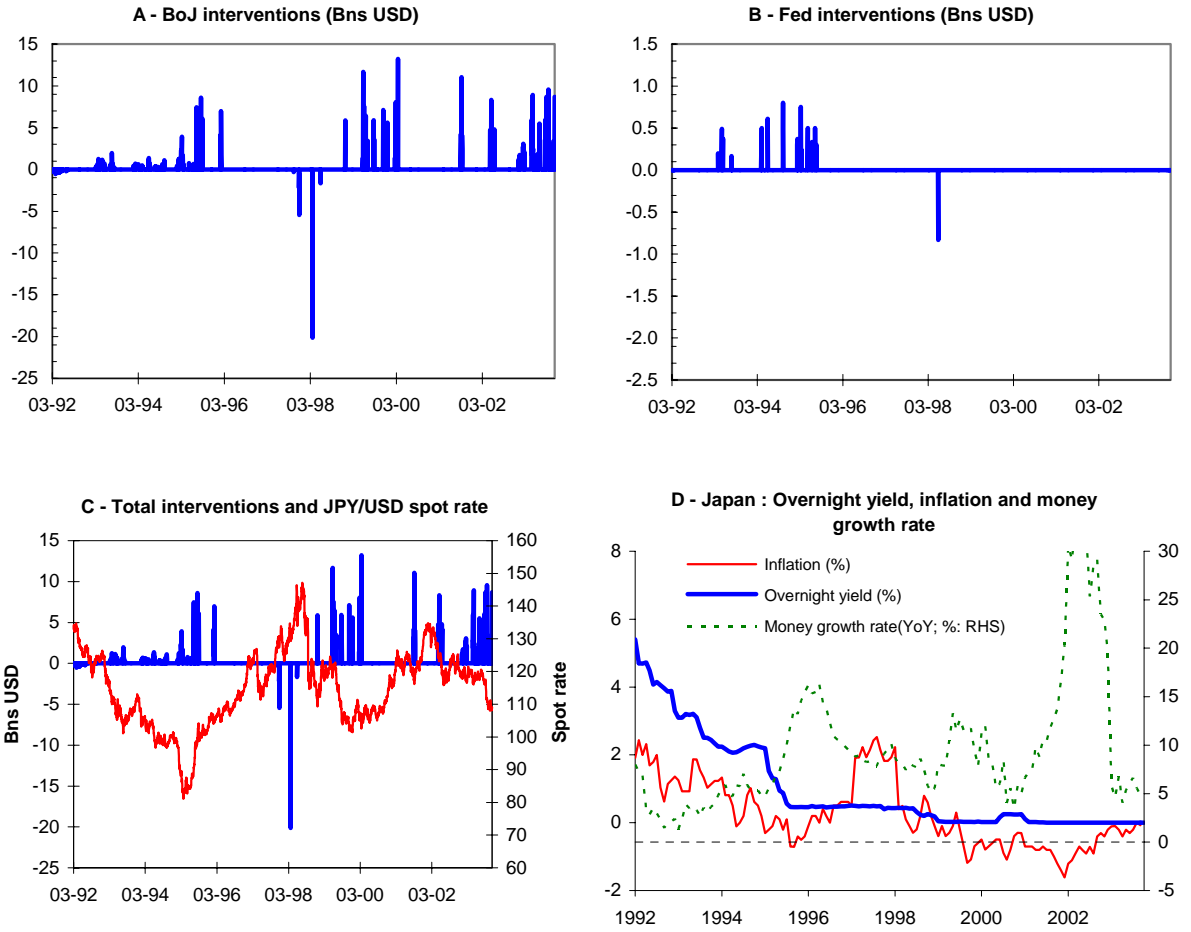
Note. This table reports results of the event-study when conditioning the sample on interventions being or not coordinated with the Fed. In every case, the significance of the mean statistics is based on the bootstrap method with 10000 replications. Results based on the Sign test are available upon request.

**TABLE 5: THE IMPACT OF NEWS. CONDITIONING THE SUCCESS OF INTERVENTIONS ON STOCK MARKET VOLATILITY**

		Mean	Variance	Sk1	Sk2	Sk3	Sk4	Sk5	Kurtosis
<b>Window length = 2 days</b>									
<b>Individual tests</b>									
Large stock market volatility ( $n = 21$ )	Mean	0.0071	-0.0260	0.0618	0.0154	0.0314	0.0162	0.0132	-0.0294
	p-value	0.025	0.301	0.016	0.028	0.017	0.016	0.015	0.085
Small stock market volatility ( $n = 22$ )	Mean	0.0069	-0.0697	0.0229	0.0059	0.0125	0.0069	0.0063	0.0107
	p-value	0.000	0.021	0.170	0.125	0.237	0.090	0.054	0.632
<b>Tests of differences</b>									
Large vs small	Mean	0.0001	0.0437	0.0389	0.0095	0.0189	0.0093	0.0069	-0.0401
	p-value	0.4906	0.5094	0.1415	0.1329	0.2085	0.1512	0.1692	0.1296
<b>Window length = 5 days</b>									
<b>Individual tests</b>									
Large stock market volatility ( $n = 21$ )	Mean	0.0073	0.0230	0.0618	0.0126	0.0348	0.0153	0.0122	-0.0216
	p-value	0.085	0.662	0.057	0.169	0.051	0.080	0.098	0.219
Small stock market volatility ( $n = 22$ )	Mean	0.0109	-0.1418	0.0310	0.0103	0.0310	0.0110	0.0108	0.0397
	p-value	0.000	0.003	0.167	0.053	0.043	0.049	0.010	0.813
<b>Tests of differences</b>									
Large vs small	Mean	-0.0036	0.1648	0.0308	0.0023	0.0038	0.0043	0.0014	-0.0613
	p-value	0.7805	0.2195	0.2708	0.4305	0.4378	0.3639	0.4401	0.1002
<b>Window length = 10 days</b>									
<b>Individual tests</b>									
Large stock market volatility ( $n = 21$ )	Mean	0.0023	-0.0324	-0.0088	-0.0026	0.0280	-0.0006	0.0007	0.0075
	p-value	0.327	0.329	0.621	0.606	0.081	0.540	0.471	0.526
Small stock market volatility ( $n = 22$ )	Mean	0.0163	-0.0710	0.0941	0.0260	0.0370	0.0246	0.0203	0.0135
	p-value	0.000	0.150	0.007	0.006	0.014	0.006	0.005	0.683
<b>Tests of differences</b>									
Large vs small	Mean	-0.0140	0.0387	-0.1028	-0.0286	-0.0090	-0.0252	-0.0196	-0.0060
	p-value	0.9823	0.0177	0.9757	0.9806	0.6457	0.9754	0.9751	0.4532

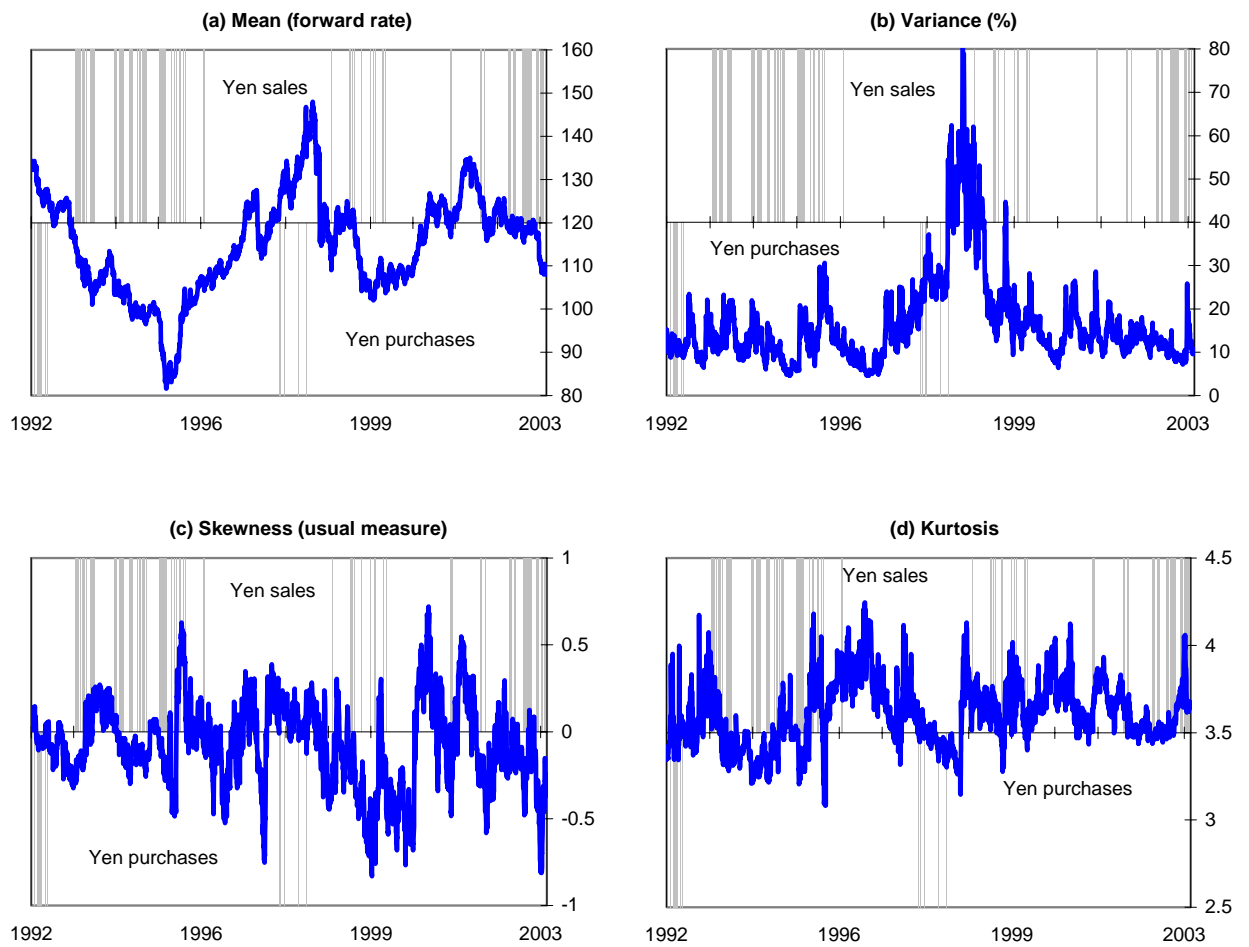
Note. This table reports results of the event-study when conditioning the sample on interventions being associated with a stock market volatility (aggregated upon the Nikkei and the S&P 500 indexes) above or below its median value. In every case, the significance of the mean statistics is based on the bootstrap method with 10000 replications. Results based on the Sign test are available upon request

**FIGURE 1. INTERVENTIONS ON JPY/USD, 1992-2003**



Sources: Fed, BoJ, Datastream.

**FIGURE 2. INTERVENTIONS AND THE MOMENTS OF THE RISK-NEUTRAL DENSITY**



**DIAGRAM 1: STRUCTURE OF EVENTS**

