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OFFICIAL CENTRAL BANK INTERVENTIONS IN THE FOREIGN EXCHANGE MARKETS: A DCC APPROACH WITH EXOGENOUS VARIABLES

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Official Central Bank Interventions in the Foreign Exchange Markets: A DCC Approach with Exogenous Variables

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Abstract

This paper assesses the impact of official central bank interventions (CBIs) on exchange rate returns, their volatility and bilateral correlations. By exploiting the recent publication of intervention data by the Bank of England, this study is able to investigate official interventions by a total number of four central banks, while the previous studies have been limited to three (the Federal Reserve, Bundesbank and Bank of Japan). The results of the existing literature are reappraised and refined. In particular, unilateral CBI is found to be more successful than coordinated CBI. The likely implications of these findings are then discussed.

Keywords: Central bank interventions; Foreign exchange; Multivariate GARCH; Conditional correlations

JEL classification: C32; E58; F31; G15

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1 Introduction

It is now more than two decades since the Plaza Agreement signed on September 22, 1985 and the Louvre Accord on February 22, 1987.[1] These agreements were signed in order to induce US dollar depreciation and promote stability in currency markets, respectively. Economists, policy makers and central bank analysts still lack conclusive evidence on the impact of CBIs on exchange returns and especially on volatility. The majority of the empirical literature suggests that unilateral, and even coordinated intervention of two central banks, does not affect exchange returns and has in most of the cases the opposite outcome on volatility from that expected (among others see Beine, 2004; Beine et al., 2002; Fatum, 2002; Humpage, 1999; Baillie and Osterberg, 1997; Bonser-Neal and Tanner, 1996; Catte et al., 1992). That is, interventions associated with the Louvre Accord appear to have been counterproductive since they led to an increase in volatility as opposed to the intended decrease.

The purpose of this paper is to shed some light on the impact of official Central Bank Interventions (CBIs) on exchange rate returns, volatility and correlations of the DM (Euro after the 1999) and the JPY against the US dollar. This paper adds to the literature of CBIs in various respects. First, rather than relying only on G3 official CBIs, that is, the Bank of Japan, the Bundesbank (or the European Central Bank, ECB, after 1999) and the FED on the DM(EUR)/USD and the JPY/USD markets, as has already been investigated extensively in the literature, another major Central Bank is included, namely, the Bank of England (BoE). That is, the impact of the G4 official CBIs is examined. Such investigation will shed some more light to the argument that coordinated interventions are more powerful than unilateral ones (see Beine, 2004; Fatum, 2002; Humpage, 1999; Catte et al., 1992).

[1]The Plaza agreement was signed by the G5 countries, specifically France, West Germany, Japan, USA and UK, and the Louvre Accord by the G6 countries (Canada, France, West Germany, Japan, USA and UK). Italy was also an invited member in the Louvre Accord by declined to finalize the agreement.

Second, the literature has so far not investigated the number of central banks engaged in intervention. One of the main questions this paper tries to answer is whether the impact on exchange rate dynamics is more significant when two central banks intervene in coordination as opposed to three central banks. The approach adopted in this paper explicitly allows the investigation of the impact of officially announced coordinated interventions of two and three central banks, since the Bank of England (BoE) intervened several times in coordination with another two central banks, and which was part of the G6 Louvre Accord (1987). Accounting for the BoE official interventions might more accurately assess the real impact of officially announced CBIs in the post-Louvre Accord period. Ideally, we would investigate the impact of officially announced central bank interventions of all the countries that were involved in the Louvre Accord. That is, including the Bank of Canada (BoC) and the Bank of France (BoF), in addition to the Bank of England. However, since this paper examines the impact of officially announced CBIs, and since neither the BoC nor the BoF officially announce their interventions, at least for our sample period, they cannot be taken into account in this research.

The ineffective outcome of the G3 CBIs on exchange rate returns and volatility reported in the empirical studies might be attributed to several factors. One of which might be the omission of the Bank of England, which intervened several times in under our investigation sample, and which was part of the G6 Louvre Accord. Other factors include different sample periods and models used.

Moreover, as the empirical evidence suggests that intervention has been counterproductive, it raises several issues such as to why Central Banks keep conducting coordinated interventions when the result is the exact opposite from the expected one. That is, an increase as opposed to an anticipated decrease in exchange rate volatility. The inclusion of the BoE might provide more useful information on whether the impact of CBIs is counterproductive per se or is it due to the omission of other major central banks. Such information are of great importance for central banks' intervention policy decisions.

This paper focuses only the signalling channel through which CBIs might affect exchange rate dynamics and not the portfolio balance channel, since the empirical literature is not supportive of the latter.

The key findings are that unilateral CBIs are found to be more successful in influencing exchange returns than coordinated CBIs, when taking into account the interventions of the Bank of England. Coordinated CBIs could increase volatility as the number of central banks intervening in coordination increases. These results have implications for the effectiveness of central banks' intervention policy decisions.

The remainder of this paper is organized as follows. Section 2 describes the methodology and data. Section 3 presents the empirical results and section 4 concludes.

2 Methodology and Data

The data consists of daily observations of spot exchange rates of the Deutsche mark (Euro after 1999) and the Japanese yen, all against the US dollar, for the period of April 2, 1991 to October 19, 2001, obtained from the Bank of England online database.[2]

Following previous work on spot exchange rates data, where the spot rates are generally non-stationary, we focus on daily exchange rate returns defined as:

$$\Delta \ln y_t = \ln y_t - \ln y_{t-1} \tag{1}$$

where y_t is the spot exchange rate and ln is the natural logarithm.

The validity of this first logarithmic difference transformations in rendering the underlying series stationary is confirmed by the results of unit root tests for non-stationarity using the Augmented Dickey-Fuller (ADF) test statistic, which fails to reject the null hypothesis of a unit

[2] In order to make accurate comparisons, we use the same sample as in Beine (2004).

root in each of the logged spot exchange rates against stationary alternatives but reject that null when testing the stationarity of the logged first differences.[3]

The CBI data consists of official interventions of the Federal Reserve (FED), the Bank of Japan (BoJ), the Bundesbank (BB) (European Central Bank, ECB, after 1999) and the Bank of England (BoE).[4] Specifically, central bank purchases/sales of the Japanese yen and the Deutsche mark (Euro after 1999) measured in US dollars.

In order to assess the signalling channel, through which CBIs could influence exchange rates and their volatility, we use dummy variables that take the value of 1 when central banks intervene and 0 otherwise. In addition, we examine the impact of both unilateral and coordinated interventions of central banks. In the case of unilateral interventions, we use up to four dummies for the CBIs (capturing the impact of the G4 central banks included in our sample) on the JPY/USD and the DM(EUR)/USD. In the case of coordinated interventions, since each of the four banks intervened in both the DM(EUR)/USD and the JPY/USD (apart from the BB(ECB) which intervened only on the DM(EUR)/USD), it seems appropriate to use only two dummy variables reflecting the coordinated interventions of two central banks and one dummy for coordinated intervention of three central banks. Table 1 provides a definition of the dummy variables used.

[*Insert Table 1 around here*]

As previously mentioned the estimated parameter of coordinated interventions on exchange rate volatility is found to be significant, however, incorrectly signed (Beine, 2004; Fatum, 2002; Humpage, 1999; Catte et al., 1992). Nevertheless, the empirical literature has examined the impact of coordinated interventions of a maximum of two central banks. In this research, we

[3] These results can be provided by the author upon request.

[4] These intervention data were obtained from the Federal Reserve, the Japanese Ministry of Finance, the Bundesbank (ECB) and the HM treasury.

provide additional results for coordinated interventions conducted by three central banks.

2.1 The DCC approach

The model employed in this paper is the Dynamic Conditional Correlation developed by Engle (2002) which is defined as:

$$y_t = \mu_t(\theta) + \epsilon_t, \quad \text{where} \quad \epsilon_t|\Omega_{t-1} \sim N(0, H_t) \tag{2}$$

$$\epsilon_t = H_t^{1/2} u_t, \quad \text{where} \quad u_t \sim N(0, I) \tag{3}$$

$$H_t = D_t R_t D_t \tag{4}$$

where $y_t = (y_{it}, ..., y_{nt})'$ is a $nx1$ vector of exchange returns, specifically the DM(EUR), and JPY returns against the USD, thus $n = 2$, $\mu_t(\theta) = (\mu_{it}, \mu_{nt})'$ is the conditional $nx1$ mean vector of y_t, which can be specified as an ARMA process

$$\Psi_i(L)(y_{it} - \mu_{it}) = \Theta_i(L)\epsilon_t \tag{5}$$

$$\mu_{it} = \mu_i + \sum_{j=1}^{n_i} \delta_{ji}\chi_{j,t} \tag{6}$$

where L is the lag operator, $\Psi_i(L) = 1 - \sum_{j=1}^{n} \psi_{ij} L^j$ and $\Theta_i(L) = 1 - \sum_{j=1}^{n} \theta_{ij} L^j$. H_t is the conditional covariance matrix, $D_t = diag(h_{iit}^{1/2}, ..., h_{nnt}^{1/2})'$ is a diagonal matrix of square root conditional variances, where h_{iit} can be defined as any univariate GARCH-type model, and R_t is the $tx\left(\frac{n(n-1)}{2}\right)$ matrix containing the time-varying conditional correlations defined

$$R_t = diag(q_{11,t}^{-1/2}, ..., q_{nn,t}^{-1/2}) Q_t diag(q_{11,t}^{-1/2}, ..., q_{nn,t}^{-1/2}) \tag{7}$$

where $Q_t = (q_{ij,t})$ is a nxn symmetric positive definite matrix given by:

$$Q_t = (1 - \alpha - \beta)\bar{Q} + \alpha u_{t-1} u_{t-1}^{'} + \beta Q_{t-1} \tag{8}$$

where $u_t = (u_{1t} u_{2t} ... u_{nt})'$ is the $nx1$ vector of standardized residuals, $\bar{Q}$ is the nxn unconditional variance matrix of u_t, and α and β are nonnegative scalar parameters satisfying $\alpha + \beta < 1$.

The DCC model is estimated using the Quasi-Maximum Likelihood (QML) estimator under a multivariate Student distribution (see Harvey et al., 1992; Fiorentini et al., 2003). The multivariate Student distribution is applied as it is well known that the normality assumption of the innovations is rejected in most empirical applications dealing with daily exchange rate data. This adds an extra parameter to the estimation of each model, namely the degrees of freedom parameter, denoted by υ. When υ tends to infinity, the Student distribution tends to the normal density. When it tends to zero, the tails of the density become thicker and thicker. The parameter value indicates the order of existence of the moments, e.g. if $\upsilon = 2$, the second moments do not exist, but the first moments exist. For this reason it is convenient to assume that $\upsilon > 2$, so that the conditional variance-covariance matrix H_t is always interpretable as a conditional covariance matrix.

2.2 The effect of CBI

In order to assess the impact of CBIs on exchange returns, volatility and correlations the DCC model of Engle (2002) can be easily extended to incorporate exogenous variables as:

$$y_t = \mu_t(\theta) + d_t X_t + \epsilon_t, \quad \text{where} \quad \epsilon_t|\Omega_{t-1} \sim N(0, H_t) \tag{9}$$

$$\epsilon_t = H_t^{1/2} u_t, \quad \text{where} \quad u_t \sim N(0, I) \tag{10}$$

$$H_t = D_t R_t D_t \tag{11}$$

Where d_t is the $nx1$ vector of parameters entering the mean equation and X_t is a $nx1$ vector of exogenous variables that denote the set of central bank interventions at time t. The specification for the proposed model has a different evolution for Q_t that enters the R_t (the $t \times \left(\frac{n(n-1)}{2}\right)$ matrix containing the time-varying conditional correlations), and the later enters the conditional variance/covariance matrix H_t according to:

$$Q_t = (1 - \alpha - \beta)\bar{Q} + \alpha u_{t-1} u_{t-1}^{'} + \beta Q_{t-1} + \delta_{t-1} X_{t-1} \tag{12}$$

Where δ_t is the $nx1$ vector of parameters entering the conditional variance equation and X_{t-1} is a $nx1$ vector of exogenous variables that denote the set of central bank interventions at time $t-1$.[5] We focus on the impact of both unilateral and coordinated CBIs, on both the exchange returns, variances and correlations. The following section presents these results for the various definitions of the dummy variables.

3 Empirical results

In this section we begin by presenting the descriptive statistics of the data followed by the empirical results of the CBI impact under the DCC specification.

3.1 Descriptive statistics

Table 2 presents descriptive statistics of the mark(euro), and the yen returns series for the period of April 2, 1991 to October 19, 2001. The returns are calculated by taking the first logarithmic differences in exchange rates as denoted in equation (2.1). The means show the DM(EUR) and JPY with small positive and negative returns, respectively. The daily unconditional standard deviations of the JPY/USD return is greater than that for the DM exchange return, indicating that volatility is greater in the JPY as opposed to the DM returns. The excess kurtosis parameter estimate is significantly greater than zero for each returns series indicating non-normality of returns. In addition, it is more than double than that for the JPY exchange rate, indicating that extreme episodes (such as currency crises) are more than twice likely to occur in the JPY than in the DM(EUR) market. In addition, the Jarque-Bera statistic confirms that exchange returns are, as expected, not normally distributed since the null hypothesis of normally distributed

[5] More precisely, the dummy variables for CBIs equal to 1 when central bank(s) intervene in the purchase or sale of US dollars and to 0 when no intervention occurs. See Table 1 for a specific definition of the dummy variables used.

returns is persuasively rejected and the data are clearly skewed.

[*Insert Table 2 around here*]

The Ljung-Box Q statistic tests the null hypothesis of no serial correlation and is calculated using up to 10 lags for both daily returns and the squared returns series. A significant Q statistic rejects the null hypothesis of no serial correlation in returns, while a significant Q statistic for the squared returns series rejects the null hypothesis of homoskedastic squared returns. Table 2 reports the Q statistics to be significant at 10 lags across each returns series at the 5% level of significance. This indicates that all exchange rates cannot be characterized as random walk processes. The Q statistic in the squared returns is significant for each returns series indicating strong non-linear dependencies. This is also supported by Engle's ARCH-LM statistic. The last row of Table 2 clearly shows the presence of ARCH effects in returns up to 5 lags. The null hypothesis of no ARCH effects is rejected for each series at the 1% level of significance.

Figure 1, plots the exchange rates and returns series for the DM(EUR) and the JPY, all against the USD. One can clearly observe the introduction of the Euro at the beginning of 1999.[6] Focusing on the returns plots on the lower part of Figure 1, one can see the phenomenon of volatility clustering, that is, large (small) changes tend to be followed by large (small) changes of either sign.

[*Insert Figure 1 around here*]

The findings of higher order serial correlation, non-normality, non-linear dependency and volatility clustering support the decision to model exchange rate volatility using a GARCH-type process under the student-t distribution.

[6] The DM(EUR)/USD returns series on the bottom left panel in Figure 1 have been adjusted to account for the introduction of the Euro in 1999.

Columns 1 and 2 in Table 3 present the number of days that CBIs were carried out under the G4 assessment and under Beine's (2004) G3 assessment (which serve as the base for our comparisons), respectively. As previously mentioned, and as can be seen from Table 3, the number of interventions for the variables in common among this research and Beine's is different due to the intervention definitions in this research.[7]

[*Insert Table 3 around here*]

Among the G4 Central Banks, the Bank of Japan (BoJ) was by far the most active, as it intervened 176 times unilaterally in the JPY/USD market. The FED has conducted its interventions unilaterally only in the DM(EUR)/USD market. In addition, the FED relied solely on coordinated interventions with the BoJ in the JPY/USD market, whereas in the DM(EUR)/USD market it intervened with the BoJ, the BB/ECB and/or the BoE since 1995. The Bundesbank (BB) (or the European Central Bank, ECB, since 1999) has deployed its interventions solely in the DM(EUR)/USD market. A very interesting feature of Table 5.4 is the nature of the Bank of England's (BoE) interventions. The BoE has intervened several times

[7]By definition, in this research, the classification of CBIs differs. For instance, when the dummy variable that represents coordinated interventions conducted by 3 central banks in a currency and on a specific date is equal to 1, then instantaneously the dummy for coordinated interventions conducted by 2 central banks is equal to zero for that specific intervention and date. In addition, the dummy variables that represent the unilateral interventions for each of the 3 central banks are equal to zero on that date. For example, consider the sell of the DM/USD on August 19th, 1991 by the BoJ, the BB and BoE. Under Beine's (2004) framework and the rest of the papers that examined CBIs under the G3 assessment (that is without the BoE assessment) the construction of the intervention dummy variables for that date implies that these dummies are equal to zero for unilateral interventions by the BoJ and the BB, and equal to 1 for coordinated interventions of 2 central banks. In my classification, the dummy variables for unilateral intervention by the BoJ, the BB, the BoE and coordinated interventions of 2 central banks are equal to zero. However, the dummy variable for coordinated intervention of 3 central banks equals to 1. That is why in this classification there are fewer interventions regarding unilateral and coordinated interventions by 2 central banks.

in coordination with at least one another central bank in both markets, and unilaterally once in the JPY/USD market. Moreover, it has intervened six times in coordination with another two Central Banks in the DM(EUR)/USD as shown in the last row of column 1 in Table 2. The availability of official intervention data for the BoE motivates the examination of how the impact of CBIs on exchange returns, volatility and correlation changes when the BoE is also taken into account.

3.2 The DCC model performance

Table 4 presents the results of the DCC model performance described in Equation (2) - (4).

[*Insert Table 4 around here*]

The DCC model seems to perform very well in terms of capturing the DM(EUR) /USD and the JPY/USD exchange rate dynamics: (1) Both exchange returns exhibit heteroskedasticity, based on the significant estimated coefficients of the individual GARCH models. (2) The conditional correlations of the DM(EUR)/USD and the JPY/USD returns are highly persistent as shown by the significant parameter estimates of the DCC GARCH model. (3) The Li and McLeod (1981) test (which is a multivariate version of the Box-Pierce/Ljung-Box portmanteau test statistic for serial correlation) cannot reject the null hypothesis of no serial correlation on both standardized and squared standardized residuals, up to 20 lags. (4) The DCC model indicates that the correlations between these two returns are indeed time-varying. This can also be clearly seen in Figure 2, which plots the dynamic conditional correlation of the estimated DCC model in Table 5.5. The correlations during April 2, 1991 to October 19, 2001 vary between -0.05 to 0.8. Beginning from 1991, correlations between those two markets gradually declined till 1994, then there was an increasing trend till the mid-1995 followed by a declining trend till the end of 2000 when they became negative. Since the beginning of 2001, correlations varied around -0.05 to 0.2.

[*Insert Figure 2 around here*]

Having evaluated the good performance of the DCC model for the DM(EUR)/USD and JPY/USD exchange returns dynamics, the results of the DCC, extended with exogenous variables to incorporate the impact of both unilateral and coordinated officially announced interventions will be presented in the following sections.

3.3 The impact of Coordinated Interventions

The analysis begins with the impact of coordinated interventions on exchange rate returns, variances and correlations under the G4 assessment. These results are presented in Table 5. Columns (a) and (b), (c) and (d), and (e) present the results for coordinated interventions of 2 central banks in the DM(EUR)/USD and the JPY/USD markets, of 3 central banks in the DM(EUR)/USD market, and of 3 central banks in the DM(EUR)/USD market together with the coordinated interventions of 2 central banks in the JPY/USD market, respectively.

[*Insert Table 5 around here*]

When coordinated interventions are conducted by only 2 central banks in the DM(EUR)/USD and the JPY/USD markets, they have a significant impact only on the JPY volatility. However, no significant impact on exchange returns is evident. That is, coordinated interventions do not affect the exchange rate returns, which in line with the empirical literature (e.g. see Beine, 2004, and references therein). These results are presented in columns (a) and (b) in Table 5. Under specification (a), the dummy variables for coordinated CBIs that enter in both the mean and variance equations, attract significant coefficients only in the latter equation. Specifically, coordinated interventions in the DM(EUR)/USD market significantly decrease the

JPY volatility whereas, coordinated interventions in the JPY/USD market significantly increase the JPY volatility. In addition, coordinated CBIs in the DM(EUR)/USD and the JPY/USD markets do not have a significant impact on the DM(EURO) volatility. After dropping the dummy variables for the coordinated CBIs on returns, as they were found insignificant, the new specification under column (b) reports reduced impact of coordinated interventions on volatility. Now, coordinated CBIs in the DM(EUR)/USD markets do not significantly decrease the JPY volatility. The estimated parameter δCoDM is now significantly negative only at the 10% level. The signs and significance of the rest of the parameter estimates remain similar to those under specification (a). That is, when exactly two central banks intervene in coordination they can significantly affect the volatility of returns, and in some cases in the correct direction. Under (a) and (b) specifications, the Li and McLeod (1981) test reports no evidence of serial correlation on both standardized and squared standardized residuals, up to 20 lags. These results under the G4 assessment are partly in line with the empirical literature on the G3 assessment that shows that coordinated interventions can significantly affect only volatility, but in a positive way (see Beine, 2004; Beine et al., 2002; Bonser-Neal and Tanner, 1996, and references therein). We find instances that coordinated interventions of two central banks under the G4 assessment in the DM(EUR)/USD market to significantly decrease JPY volatility.

In addition, the existing literature suggests that coordinated interventions have a more significant impact on volatility as opposed to unilateral ones Beine (2004); Fatum (2002); Humpage (1999); Catte et al. (1992). The results recorded in the next section, which assesses the impact of unilateral interventions under the DCC model, are in line with this finding. However, there is no paper, to my knowledge, that examines the impact of a greater number of two central banks intervening in coordination. If the previous argument is correct, then coordinated interventions of three central banks should increase even more the impact on exchange rate volatility compared to interventions of one or two central banks.

According to Table 3, the Bank of England (BoE) intervened six times in our investigation sample in coordination with another two central banks in the DM(EUR)/USD market. Thus, it would be of interest to see how our results change when three central banks coordinate their interventions. Besides, apart from the FED, the BoJ and the BB/ECB, the BoE was among the G6 that signed the Louvre Accord in 1987 (and which officially announces its interventions). As previously mentioned, the aim of the Louvre Accord was to stabilize the turbulent international currency markets. Hence, the post-Louvre period performance of the impact of a greater number of central banks intervening in coordination on exchange rate dynamics is of great interest.

The results for coordinated interventions of three Central Banks in the DM/USD market are presented under columns (c) and (d) in Table 5. Since there were not any coordinated interventions conducted by three central banks in the JPY/USD market, we can only examine the impact of coordinated interventions of three central banks in the DM(EUR)/USD market. Under column (c) the dummies representing the coordinated interventions of three Central Banks in the DM(EUR)/USD market enter both in the conditional mean and variance equations, whereas under column (d) enter only in the conditional variance equation.

It is found, under column (c), that the impact of coordinated CBIs of three central banks is dramatically different to the impact of coordinated interventions of two central banks. Specifically, coordinated interventions of three Central Banks in the DM/USD market do not have a significant impact on exchange returns and volatilities. However, when the insignificant impact of three Central Banks in the DM/USD in the conditional mean equation is removed, the results under column (d) show that coordinated interventions of three central banks significantly increase the DM(EURO) volatility. The robustness of these results is strengthened even when coordination of three Central Banks in the DM(EUR)/USD market are modeled together with the coordination of two Central Banks in the JPY/USD market. These results are shown under column (e) in Table 5. That is, the greater number of Banks engaging in coordinated interventions does not necessarily increase the effectiveness on volatility. On the contrary, when more than two Central Banks intervene in coordination they can only increase exchange rate volatility. The DCC model under the various specifications in Table 5 do not suffer from serial correlation as the Li and McLeod (1981) test reports no evidence of serial correlation on both standardized and squared standardized residuals up to 20 lags. Figure 3, which plots the dynamic conditional correlations of the DCC model without exogenous variables (specification in Table 4), together with the ones from the DCC with exogenous variables in the estimations (b) and (d) of Table 5, shows that the magnitude of correlations is slightly intensified due to coordinated interventions.

[*Insert Figure 3 around here*]

These results could be of great importance for central banks' decisions on conducting coordinated interventions in a currency. According to these results if central banks wish to decrease exchange rate volatility, then it is preferable to intervene in coordination with only one another central bank and not in coordination with another two central banks; if it intervenes with another two central banks it will only increase volatility. If a central bank wishes to affect its exchange returns it should not intervene in coordination. Intervening in coordination with at least another central bank will have no impact on exchange returns, as the vast majority of the literature suggests (see Beine et al., 2009; Beine, 2004; Beine et al., 2002 and references therein). These results are specific to our G4 assessment of official CBIs and evidently further research is needed to determine whether and why the more coordination between central banks the less effective the outcome on exchange returns and volatility is.

3.4 The impact of Unilateral Interventions

The empirical results of the impact of unilateral CBIs on exchange rate returns, variances and correlations are presented in Table 6. Columns (a) and (b) present the results for the G3 and

G4 unilateral CBIs, respectively.[8]

[*Insert Table 6 around here*]

The results of the DCC model extended with exogenous variables under columns (a) in Table 6 provide evidence that unilateral G3 interventions have little impact on both mean returns and variances. Only CBIs conducted by the BoJ in the JPY/USD market significantly affect both the JPY and DM(EUR) returns. Specifically, unilateral interventions of the BoJ cause a depreciation of the US dollar. Unilateral interventions of the FED and the BB do not have a significant impact on the two returns. These results partially contradict the empirical literature that denotes unilateral interventions have no impact on returns (see Beine, 2004; Beine et al., 2002; Bonser-Neal and Tanner, 1996, among others) as the BoJ interventions in the JPY/USD market significantly affects the DM(EUR) and JPY returns.

Another interesting feature of column (a) in Table 6 is that unilateral interventions of the BoJ and the BB(ECB), even though increase their own exchange rate volatility, albeit insignificantly, have a significantly negative and positive externality impact on the JPY/USD and the DM(EUR)/USD markets, respectively. That is, unilateral interventions of the BoJ in the JPY/USD market significantly increase the DM(EUR) volatility and unilateral interventions of the BB(ECB) in the DM(EUR)/USD market significantly reduce the JPY volatility. The unilateral intervention impact of the FED on volatility of both returns is correctly negatively signed but insignificant. These results are in line with the empirical literature that indicates that unilateral interventions have a mixed effect on volatility (see Beine, 2004; Beine et al., 2002; Bonser-Neal and Tanner, 1996).

[8]The dummy variables used in the evaluation of the impact of the G3 and G4 CBIs are based on those in column 1 of Table 3. That is, these dummies are based on the definition of CBIs under the G4 assessment. In the following section which involves robustness analysis we present the results of the impact of unilateral interventions according to the dummies used in Beine's (2004) paper under the G3 assessment.

Including the BoE's unilateral interventions under our G4 assessment, the results seem to be more straighforward. Column (b) in Table 6, which presents these results, shows no evidence of significant increase in volatility due to unilateral official CBIs, which is in line with central banks' intentions. That is, the impact of the BoJ intervention in the JPY/USD market on the DM(EURO) volatility now becomes insignificantly positive and the BB(ECB) intervention in the DM(EUR)/USD market on the DM(EURO) volatility is now correctly negatively signed, although insignificant. The impact of interventions of the BoE in the JPY/USD market on both returns' volatility is also correctly signed, although insignificant.

In addition to the previous results, under column (a) in Table 6, of the impact of the G3 CBIs on exchange returns (with the use of dummies under the G4 assessment), unilateral interventions of the BoE significantly affect both DM/USD and JPY/USD returns, under column (b) in Table 6. That is, taking into account the BoE, unilateral interventions have a significant effect on returns and reduce volatility. These results contradict the empirical literature that finds that unilateral interventions have no impact on returns (see Beine, 2004; Beine et al., 2002; Bonser-Neal and Tanner, 1996). Moreover, the empirical literature, in most of cases, suggests that unilateral interventions significantly increase volatility, indicating that the intervention should be considered ineffective (see Beine 2004 and references therein). One major point of central banks' decisions to intervene is to decrease rather than increase exchange rate volatility. In this research we provide evidence that unilateral interventions are effective (or to be more precise, are productive), as their impact on mean returns is significant, and on volatility is correctly negatively signed and significant in the case of the BB(ECB) interventions in the DM(EUR)/USD market on the JPY volatility. No evidence that any of the unilateral interventions significantly increases volatility is reported, which is in line with Central Banks' intentions.

The conditional correlations of the DM(EUR) and JPY returns are highly persistent as shown by the significant estimated a and b parameters of these two DCC models in Table 6 indicating that correlation between these two returns are indeed time varying and driven by unilateral CBIs. Figure 4, which plots the dynamic conditional correlations of the DCC without exogenous variables (specification shown in Table 4), together with the ones from the DCC with exogenous variables from (a) and (b) in 6 shows that unilateral interventions increase the magnitude of correlations.

[*Insert Figure 4 around here*]

Last but not least, the DCC model is well specified as the Li and McLeod (1981) test reports no evidence of serial correlation on both standardized and squared standardized residuals, as it cannot reject the null hypothesis of no serial correlation on both standardized and squared standardized residuals, up to 20 lags.

3.5 Robustness Analysis

Having found evidence that unilateral interventions are more successful as opposed to coordinated interventions of 2 or 3 central banks under the G4 assessment, since the former affect returns and in minor cases reduce volatility, in this section several robustness checks are being performed.

In order to check the robustness of the results of the impact of the officially announced G4 unilateral and coordinated CBIs, dummy variables representing the impact of officially announced G3 CBIs were constructed. That is, we omitted the BoE's interventions, and replicated Beine's (2004) analysis by using the same dates and variables but under the DCC framework.[9] These results are presented in columns (a) and (b) on Table 7.

[*Insert Table 7 around here*]

[9]The dummy variables used for the G3 assessment were constructed based on the number of CBIs shown in the last column of Table 3

The results are almost identical to those of Beine (2004) obtained from the estimation of the VECH model for the equivalent parameters. That is, officially announced G3 unilateral and coordinated interventions affect exchange rate volatility and have no impact on returns. These results again justify the robustness of the results obtained under the G4 assessment through the DCC framework.

Another point of interest is to examine whether specific central banks, where that their unilateral interventions were found to be "effective", could still be effective when conducted in coordination with another specific central bank. As it was shown that the Bundesbank's (or ECB's after 1999) interventions in the DM(EUR)/USD market reduce volatility, it is of interest to check whether the Bundesbank (ECB) intervening together with at least another central bank decreased exchange rate volatility. The Bundesbank (ECB) intervened in coordination with at least another central bank in the DM(EUR)/USD market fifteen times. This specific choice of central banks intervening in coordination might shed light on the counterproductive evidence of coordinated interventions. Table 8 presents the empirical results for coordinated CBIs wherein the BB(ECB) is involved.

[*Insert Table 8 around here*]

As can be clearly seen, coordinated interventions involving the BB(ECB) neither significantly affect exchange returns nor volatility. Hence, even when a central bank, whose unilateral interventions are found to be successful, intervenes in coordination with another central bank, its impact on exchange returns and volatility diminishes.[10] This is in line with the empirical literature and which strengthens our previous results that coordinated CBIs are counterproductive. Clearly, further investigation needs to be done in order to find out why interventions are

[10]Other combinations of coordinated CBIs were investigated and the results were of the same qualitative nature. These results can be obtained from the author upon request.

so counterproductive when conducted in coordination.

Another interesting feature is to assess whether there exist any asymmetries, that is to investigate whether the purchase of US dollars has a different impact than the sale of US dollars in the foreign exchange markets. One would expect that the purchase (sale) of US dollars to be associated with a US dollar appreciation (depreciation). In addition, if successful, CBIs should significantly decrease volatility.

In order to assess whether any asymmetries exist whenever a CBI takes place, two sets of dummy variables were constructed. The one set of dummies involves dummies that are equal to one when a central bank purchases US dollars and zero otherwise, and the other set involves dummies that are equal to one when a central bank sells US dollars and zero otherwise. The number of purchases and sales of US dollars by each central bank are presented in Table 9. The BoJ again is once more the most active central bank with 149 purchases and 27 sales of US dollars during our data sample.

[*Insert Table 9 around here*]

The estimation results for the purchase and sale of USD are presented in Table 10 and 11, respectively. According to Table 10, coordinated purchases of US dollars do not significantly affect returns. Even though they are correctly positively signed (appreciation of the US dollar) when conducted on the DM(EUR)/USD market, they are found to be insignificant. In addition, coordinated purchases of USD in general increase volatility, the greater the number of central banks involved. In the case of unilateral CBIs, purchases of USD are associated with a significant appreciation of the US dollar and decreased volatility when interventions are conducted by the BoJ.[11] That is, unilateral purchases of US dollars are found to be more productive than

[11]Unilateral FED interventions are also found to cause an appreciation of the US dollar however, the estimated parameters are insignificant.

coordinated ones in terms of their effect on returns, as they are associated with the intended appreciation of the US dollar.

[*Insert Table 10 around here*]

In the case of sales of US dollars the results remain almost the same. These results are presented in Table 11. Coordinated sales of USD conducted by two central banks do not significantly affect returns and can only significantly decrease volatility in the JPY/USD (when conducted on the DM(EUR)/USD market). However, when coordinated sales of USD are conducted by three central banks, they still do not have a significant impact on returns but significantly increase volatility. In the case of unilateral interventions the estimated parameters accounting for sales of USD are correctly associated with a depreciation of the US dollar (negatively signed), and are significant when conducted by the BoJ and BoE. In the case of the impact on unilateral sales of US dollars on exchange rate volatility, one can see that, each of the unilateral interventions is associated with decreased volatility (as the estimated parameters are negatively signed), but are significant only when conducted by the BoJ.

[*Insert Table 11 around here*]

In conclusion, even when asymmetries are taken into account the results remain the same as those obtained from our main analysis, which strengthens our results. That is, the more coordination of central banks in the foreign exchange markets, the more counterproductive their impact on returns and volatility. Specifically, unilateral purchases and sales of US dollars affect returns in the intended direction and can significantly reduce exchange rate volatility only when conducted by the BoJ; however, coordinated interventions conducted by two central banks and, especially by three central banks, do not have the intended outcome on both returns and volatility.

4 Conclusion

In order to shed some light on the effectiveness of official CBIs, this paper examined the signalling channel through which official CBIs, conducted unilaterally or in coordination with two and three central banks, could affect exchange returns, their volatility and correlations. A novel contribution of this study is the assessment of the impact of the G4 CBIs on exchange returns, volatility and correlations. Specifically, in addition to the G3 CBIs impact of the Federal Reserve (FED), Bank of Japan (BoJ) and the Bundesbank [or European Central Bank (BB/ECB), after 1999] on the DM(EUR)/USD and the JPY/USD markets, that has been systematically examined in the literature, this paper provided contributory results on the G4 interventions by adding the Bank of England (BoE). This investigation was extended with the application of the DCC model of Engle (2002) that recently has used when modeling exchange returns dynamics because of its flexible structure and the specification of time-varying conditional correlations. This is another contribution of this paper, as the DCC has never been employed before to study the impact of CBIs on exchange rate dynamics. The DCC model performed very well in the various specifications and showed that CBIs intensify the DM(EUR)/USD and the JPY/USD dynamic conditional correlations.

Under the G4 assessment, it was found that official CBIs can significantly affect exchange returns only when these are conducted unilaterally. In the case of the impact of CBIs on volatility, it was found that unilateral interventions, in some cases, decrease volatility. However, coordinated interventions are more counterproductive the greater the number of central banks intervening in coordination.

The results of the impact of the G4 CBIs under the DCC assessment are strengthened by various robustness checks, such as re-examining the established G3 assessment, accounting for coordinated interventions by specific central banks that were found to be successful unilaterally, and accounting for asymmetries.

Based on our results, unilateral CBIs can influence returns in the intended direction, whereas coordinated CBIs do not have a significant impact on returns. In terms of the impact of CBIs on exchange rate volatility the results are as follows. Unilateral or even coordinated interventions of 2 central banks can, in minor cases, significantly decrease volatility. However, coordinated interventions of 3 central banks in the same currency can only increase volatility, which is the exact opposite of the central banks' intentions. These results have important implications for the effectiveness of Central Banks' intervention policy decisions. That is, if central banks wish to influence exchange rates and/or volatility, they should intervene unilaterally. The more central banks intervene in coordination the less, or the opposite from the, anticipated would be the generated outcome.

Moreover, CBIs in one market are found to positively affect correlations between foreign exchange markets. That is, CBIs conducted either unilaterally or in coordination in one market intensify volatility in other foreign exchange markets. This is true in a world of highly integrated financial markets and might be the reason why these CBIs, and especially coordinated ones, increase volatility in these markets in most of the cases.

A limitation of the results obtained in this paper is captured by the following question: had not central banks intervened, would the impact on returns and volatility have been different? This is a rather difficult question to address. Nonetheless, a recent growing literature has focused on the impact of official statements and speeches of central banks on foreign exchange markets prior to intervention (see, for instance Beine et al., 2009, and references therein)(see, for instance, Beine, Janssen and Lecourt, 2009, and references therein). Using this approach, our analysis could be extended to answer the above question.

In addition, the analysis in this paper was solely based on the investigation of the signalling channel through which CBIs could affect exchange returns, volatility and correlations using daily data under the DCC model. That is, the portfolio-balance channel was not examined. Hence, it would be of interest in further research to investigate how the impact of the G4 CBIs, in the context of the portfolio-balance model, changes.

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Table 1: Definition of exogenous-dummy variables

Variable	**Definition**
Exogenous variables in the conditional mean equation	
$dFED_{\mathrm{DM(EUR)}}$	Unilateral interventions of the FED on the DM(EUR)/USD market.
$dBOJ_{\mathrm{JPY}}$	Unilateral interventions of the BoJ on the JPY/USD market.
$dBB_{\mathrm{DM(EUR)}}$	Unilateral interventions of the BB(ECB) on the DM(EUR)/USD market.
$dBoE_{\mathrm{JPY}}$	Unilateral interventions of the BoE on the JPY/USD market.
$dCoDM(EUR)$	Coordinated interventions of 2 central Banks on the DM(EUR)/USD market.
$dCoDM(EUR)3$	Coordinated interventions of 3 central Banks on the DM(EUR)/USD market.
$dCoJPY$	Coordinated interventions of 2 central Banks on the JPY/USD market.
Exogenous variables in the conditional variance equation	
$\delta FED_{\mathrm{DM(EUR)}}$	Unilateral interventions of the FED on the DM(EUR)/USD market.
$\delta BOJ_{\mathrm{JPY}}$	Unilateral interventions of the BoJ on the JPY/USD market.
$\delta BB_{\mathrm{DM(EUR)}}$	Unilateral interventions of the BB(ECB) on the DM(EUR)/USD market.
$\delta BoE_{\mathrm{JPY}}$	Unilateral interventions of the BoE on the JPY/USD market.
$\delta CoDM(EUR)$	Coordinated interventions of 2 central Banks on the DM(EUR)/USD market.
$\delta CoDM(EUR)3$	Coordinated interventions of 3 central Banks on the DM(EUR)/USD market.
$\delta CoJPY$	Coordinated interventions of 2 central Banks on the JPY/USD market.

Table 2: Descriptive statistics of returns. 02.04.1991 - 19.10.2001

	DM(EUR)	**JPY**
Mean	0.0001	-0.0001
Standard Deviation	0.0068	0.0073
Skewness	-0.1294 [0.01]**	-0.7031 [0.00]**
Excess Kurtosis	2.1193 [0.00]**	5.7496 [0.00]**
Normality Test (JB)	507.11 [0.00]**	3897.6 [0.00]**
Q(10)	18.885 [0.04]*	20.746 [0.02]*
Q^2(10)	143.94 [0.00]**	288.63 [0.00]**
ARCH(5)	12.590 [0.00]**	27.489 [0.00]**

Notes: [] denote p-values. $Q(10)$ and $Q^2(10)$ is the Ljung-Box statistic for serial correlation in raw series and squared series, respectively. JB refers to the Jarque-Bera test. * 5% significant; ** 1% significant.

Table 3: Central Bank Interventions: 02.04.1991 - 19.10.2001

		Beine (2004)
	G4 assessment	**G3 assessment**
JPY/USD	**Number of interventions**	
Unilateral FED	0	1
Unilateral BoJ	176	180
Unilateral BoE	1	-
Coordinated interventions of 2 Central Banks	22	19
DM(EUR)/USD		
Unilateral FED	7	12
Unilateral BoJ	0	0
Unilateral BB/ECB	5	6
Unilateral BoE	0	-
Coordinated interventions of 2 Central Banks	10	12
Coordinated interventions of 3 Central Banks	6	-

Notes: The last column is taken from Table 2 of Beine (2004).

Table 4: DCC Model of DM(EUR) and JPY returns. 02.04.1991 - 19.10.2001

	Dependent Variables	Explanatory Variables	
Conditional Mean	**DM(EUR)**	Constant	0.0002 (1.99)*
	JPY	Constant	0.0243 (2.41)*
Conditional Variance	**DM(EUR)**	Constant	1.2e-07 (2.10)*
		α DM(EUR)	0.0351 (5.74)**
		β DM(EUR)	0.9596 (131.4)**
	JPY	Constant	0.0035 (2.70)**
		α JPY	0.0416 (6.73)**
		β JPY	0.9517 (135.5)**
		DCC α	0.0132 (261.1)**
		DCC β	0.9847 (967.3)**
		υ	5.7691 (13.19)**
		Log Lik.	7454.59
Standardized Residuals Based Tests			
		$Q(20)$	79.964 [0.45]
		$Q^2(20)$	87.440 [0.20]

Note: t-statistics in parenthesis. * and ** denote 5% and 1% significance, respectively.

Table 5: Coordinated CBIs: Signalling Channel analysis of DM(EUR) & JPY. 1991-2001

Dependent Var.	Explanatory Var.	(a)	(b)	(c)	(d)	(e)
Condit. Mean DM(EUR)	Constant	0.0002 (2.30)*	0.0002 (2.30)*	0.0002 (2.12)*	0.0002 (2.13)*	0.0002 (2.07)*
	$dCoDM(EUR)$	0.0015 (0.49)				
	$dCoDM(EUR)3$			0.0059 (1.62)		
	$dCoJPY$	3e-05 (0.02)				
JPY	Constant	0.0229 (2.33)*	0.0231 (2.24)*	0.0248 (2.51)*	0.0247 (2.36)*	0.0240
	$dCoDM(EUR)$	0.1858 (0.77)				
	$dCoDM(EUR)3$			0.1194 (0.64)		
	$dCoJPY$	-0.0019 (-0.01)				
Condit. Var. DM(EUR)	Constant	3.4e-07 (2.26)*	3.4e-07 (2.09)*	3.2e-07 (2.29)*	3.3e-07 (2.48)*	3.3e-07 (2.23)*
	$\delta CoDM(EUR)$	7.2e-06 (0.90)	7.4e-06 (0.88)			
	$\delta CoDM(EUR)3$			2.1e-05 (1.57)	2e-05 (2.14)*	2.4e-05 (1.76)
	$\delta CoJPY$	-3.3e-07 (-0.09)	-2.1e-07 (-0.06)			2.3e-06 (0.63)
	α DM(EUR)	0.0352 (5.78)**	0.0348 (5.72)**	0.0326 (5.78)**	0.0330 (5.17)**	0.0332 (5.19)**
	β DM(EUR)	0.9589 (135)**	0.9592 (130)**	0.9612 (140)**	0.9605 (133)**	0.9600 (126)**
JPY	Constant	0.0036 (2.34)*	0.0037 (2.49)*	0.0037 (2.34)*	0.0037 (2.49)*	0.0039 (2.25)*
	$\delta CoDM(EUR)$	-0.0690 (-3.05)**	-0.0736 (-1.73)			
	$\delta CoDM(EUR)3$			0.0123 (0.28)	0.0181 (0.51)	0.0231 (0.58)
	$\delta CoJPY$	0.1082 (2.31)*	0.1123 (2.37)*			0.0950 (1.98)*
	α JPY	0.0394 (5.66)**	0.0396 (6.30)**	0.0420 (6.30)**	0.0420 (6.08)**	0.0407 (6.19)**
	β JPY	0.9522 (112)**	0.9519 (126)**	0.9506 (121)**	0.9506 (123)**	0.9497 (115)**
	DCC α	0.0190 (4.99)**	0.0192 (4.93)**	0.0182 (4.91)**	0.0183 (4.91)**	0.0192 (5.01)**
	DCC β	0.9789 (229)**	0.9787 (227)**	0.9798 (233)**	0.9796 (232)**	0.9789 (225)**
	υ	5.8473 (14.06)**	5.8471 (13.29)**	5.8535 (12.85)**	5.8766 (13.29)**	5.9604 (13.36)**
	Log. Lik.	7461.2	7460.6	7460.1	7458.9	7461.6
Standardized Residuals Based Tests						
	$Q(20)$	78.62 [0.49]	78.73 [0.49]	77.76 [0.52]	76.26 [0.57]	75.75 [0.58]
	$Q^2(20)$	87.28 [0.20]	86.35 [0.22]	93.55 [0.10]	97.12 [0.06]	92.56 [0.11]

Note: Parenthesis and brackets are the t-statistics and p-values, respectively. * and ** denote 5% and 1% significance, respectively. See Table 1 for definitions of the exogenous (dummy) variables.

Table 6: Unilateral CBIs: Signalling Channel analysis of DM(EUR) & JPY. 1991-2001

Dependent Variables	Explanatory Variables	(a)	(b)
Conditional Mean	Constant	0.0003 (2.96)**	0.0003 (2.70)**
DM(EUR)	$dFED_{\mathrm{DM(EUR)}}$	-0.0013 (-0.56)	-0.0013 (-0.59)
	$dBoJ_{\mathrm{JPY}}$	-0.0011 (-2.88)**	-0.0011 (-2.48)*
	$dBB_{\mathrm{DM(EUR)}}$	0.0051 (1.79)	0.0051 (1.54)
	$dBoE_{\mathrm{JPY}}$		0.0319 (6.29)**
JPY	Constant	0.0310 (3.39)**	0.0310 (3.27)**
	$dFED_{\mathrm{DM(EUR)}}$	-0.2092 (-1.01)	-0.2081 (-1.28)
	$dBoJ_{\mathrm{JPY}}$	-0.1394 (-3.91)**	-0.1392 (-3.23)**
	$dBB_{\mathrm{DM(EUR)}}$	0.0064 (0.05)	0.0074 (0.05)
	$dBoE_{\mathrm{JPY}}$		0.7673 (3.11)**
Conditional Variance	Constant	1e-05 (40.6)**	3E-07 (2.15)*
DM(EUR)	$\delta FED_{\mathrm{DM(EUR)}}$	-4e-06 (-0.77)	-4e-06 (-0.67)
	$\delta BoJ_{\mathrm{JPY}}$	1e-06 (2.15)*	1e-06 (1.60)
	$\delta BB_{\mathrm{DM(EUR)}}$	1e-06 (0.14)	-1e-06 (-0.11)
	$\delta BoE_{\mathrm{JPY}}$		-2.2e-06 (-0.08)
	α DM(EUR)	0.0344 (8.16)**	0.0344 (5.70)**
	β DM(EUR)	0.9583 (252)**	0.9589 (129)**
JPY	Constant	0.0036 (2.69)*	0.0037 (2.24)*
	$\delta FED_{\mathrm{DM(EUR)}}$	-0.0020 (-0.04)	-0.0033 (-0.05)
	$\delta BoJ_{\mathrm{JPY}}$	0.0020 (0.37)	0.0020 (0.28)
	$\delta BB_{\mathrm{DM(EUR)}}$	-0.0850 (-4.76)**	-0.0854 (-3.58)**
	$\delta BoE_{\mathrm{JPY}}$		-0.0281 (-0.34)
	α JPY	0.0393 (6.71)**	0.0394 (5.93)**
	β JPY	0.9537 (136)**	0.9534 (117)**
	DCC α	0.0187 (7.21)**	0.0184 (4.58)**
	DCC β	0.9790 (327)**	0.9793 (213)**
	υ	5.7413 (14.11)**	5.7555 (22.87)**
	Log Lik.	7467.5	7474.8
Standardized Residuals Based Tests			
	$Q(20)$	78.4882 [0.50]	78.2778 [0.50]
	$Q^2(20)$	84.8886 [0.25]	86.3596 [0.22]

Note: Parenthesis and brackets are the t-statistics and p-values, respectively. * and ** denote 5% and 1% significance, respectively. See Table 1 for definitions of the exogenous (dummy) variables.

Table 7: Replication of Beine (2004) estimations under the G3 impact through the DCC model

Dependent Variables	Explanatory Variables	Coordinated Interventions (a)	(b)	Unilateral Interventions (c)	(d)
Conditional Mean	Constant		0.0002 (2.21)*		0.0002 (2.35)*
DM(EUR)	$dCoDM(EUR)$	0.0035 (1.44)			
	$dCoJPY$	-0.0001 (-0.07)			
	$dFED_{\text{DM(EUR)}}$			0.0003 (0.17)	
	$dBB_{\text{DM(EUR)}}$			0.0050 (1.76)	
JPY	Constant		0.0236 (2.48)*		0.0239 (2.49)*
	$dCoDM(EUR)$	0.1451 (0.90)			
	$dCoJPY$	0.0333 (0.17)			
	$dBoJ_{\text{JPY}}$			-0.0655 (-1.73)	
	$dBoJ_{\text{DM(EUR)}}$			0.0280 (0.00)	
Conditional Variance	Constant	4e-07 (2.01)*	4e-07 (2.39)*	4e-07 (2.48)*	4e-07 (41.84)**
DM(EUR)	$\delta CoDM(EUR)$	1e-05 (1.82)	2e-05 (2.06)*		
	$\delta CoJPY$	-1e-06 (-0.18)	-1e-06 (-0.15)		
	$\delta FED_{\text{DM(EUR)}}$			-4e-06 (-0.83)	-4e-06 (-0.82)
	δBoJ_{JPY}			1e-06 (1.69)	1e-06 (2.14)*
	$\delta BB_{\text{DM(EUR)}}$			1e-06 (0.15)	3e-06 (0.27)
	$\alpha DM(EUR)$	0.0334 (5.37)**	0.0330 (5.29)**	0.0344 (6.10)**	0.0341 (26.79)**
	$\beta DM(EUR)$	0.9588 (116)**	0.9592 (127)**	0.9579 (137)**	0.9585 (866)**
JPY	Constant	0.0042 (2.35)*	0.0042 (2.51)*	0.0036 (2.91)**	0.0037 (8.28)**
	$\delta CoDM(EUR)$	-0.0123 (-0.50)	-0.0090 (-0.32)		
	$\delta CoJPY$	0.1009 (1.98)*	0.1021 (1.99)*		
	$\delta FED_{\text{DM(EUR)}}$			-0.0019 (-0.0357)	-0.0032 (-0.0651)
	δBoJ_{JPY}			0.0022 (0.3555)	0.0022 (0.4500)
	$\delta BB_{\text{DM(EUR)}}$			-0.0825 (-3.8711)**	-0.0842 (-3.8631)**
	αJPY	0.0404 (5.9160)**	0.0406 (5.7592)**	0.0392 (7.1439)**	0.0400 (30.6338)**
	βJPY	0.9496 (112.1868)**	0.9495 (107.9598)**	0.9539 (148.3135)**	0.9528 (831.0234)**
	DCC α	0.0190 (4.4552)**	0.0196 (4.8976)**	0.0183 (4.8422)**	0.0184 (19.1672)**
	DCC β	0.9791 (209.2930)**	0.9784 (215.6425)**	0.9795 (227.6701)**	0.9793 (873.6994)**
	υ	6.0272 (12.8189)**	5.9500 (13.0542)**	5.8488 (14.5558)**	5.7838 (17.7490)**
	Log Lik.	7460.2167	7462.4958	7460.6221	7461.1064
Standardized Residuals Based Tests					
	$Q(20)$	77.8420 [0.5157]	76.0561 [0.5730]	78.6535 [0.4898]	79.4615 [0.4643]
	$Q^2(20)$	88.8644 [0.1675]	92.9871 [0.1036]	83.1936 [0.29470]	86.4296 [0.2165]

Note: Parenthesis and brackets are the t-statistics and p-values, respectively. * and ** denote 5% and 1% significance, respectively. See Table 1 for definitions of the exogenous (dummy) variables.

Table 8: Coordinated CBIs of BB(ECB) with at least another CB

Dependent Variables		**Explanatory Variables**	**Coordinated Interventions**
Conditional Mean	**DM(EUR)**	Constant	0.0002 (2.247)*
		$dCoDM(EUR)$	0.0034 (1.525)
	JPY	Constant	0.0241 (2.545)*
		$dCoDM(EUR)$	0.1340 (1.077)
Conditional Variance	**DM(EUR)**	Constant	3.62e-07 (2.637)*
		$\delta CoDM(EUR)$	1e-05 (1.801)
		$\alpha DM(EUR)$	0.0330 (5.566)**
		$\beta DM(EUR)$	0.9593 (139.1)**
	JPY	Constant	0.0038 (2.530)*
		$\delta CoDM(EUR)$	-0.0052 (-0.189)
		αJPY	0.0427 (6.566)**
		βJPY	0.9501 (119.6)**
		DCC α	0.0185 (5.221)**
		DCC β	0.9794 (241.96)**
		v	5.8490 (13.90)**
		Log Lik.	7459.8
Standardized Residuals Based Tests			
		$Q(20)$	78.32 [0.500]
		$Q^2(20)$	93.82 [0.093]

Note: Parenthesis and brackets are the t-statistics and p-values, respectively. * and ** denote 5% and 1% significance, respectively. See Table 1 for definitions of the exogenous (dummy) variables.

Table 9: Purchase and sale of USD. 1991-2001

	Purchase of USD	**Sale of USD**
JPY/USD	**Number of Interventions**	
Unilateral FED	0	0
Unilateral BoJ	149	27
Unilateral BoE	0	1
Coordinated Interventions		
of 2 Central Banks	18	4
DM(EUR)/USD		
Unilateral FED	6	2
Unilateral BoJ	0	0
Unilateral BB/ECB	0	0
Unilateral BoE	0	0
Coordinated Interventions		
of 2 Central Banks	6	4
Coordinated Interventions		
of 3 Central Banks	5	2

Table 10: The impact of purchase of USD. 1991-2001

Dependent Variables		Explanatory Variables	Coordinated Interventions (a)	(b)	Unilateral Interventions (c)
Conditional Mean		Constant	0.0002 (2.329)*	0.0002 (2.164)	0.0003 (2.783)
	DM(EUR)	$dCoDM(EUR)$	0.010 (2.412)*		
		$dCoDM(EUR)3$		0.0020 (0.500)	
		$dCoJPY$	-0.0014 (-0.642)		
		$dFED_{\mathrm{DM(EUR)}}$			-0.0028 (-1.535)
		$dBoJ_{\mathrm{JPY}}$			-0.0012 (-2.765)**
	(JPY)	Constant	0.0235 (2.514)*	0.0249 (2.471)*	0.0307 (3.188)**
		$dCoDM(EUR)$	1.0028 (2.236)*		
		$dCoDM(EUR)3$		0.0242 (0.115)	
		$dCoJPY$	-0.0915 (-0.364)		
		$dFED_{\mathrm{DM(EUR)}}$			-0.2953 (-1.909)
		$dBoJ_{\mathrm{JPY}}$			-0.1740 (-3.923)**
Conditional Variance		Constant	3e-07 (2.156)*	3e-07 (2.328)*	3e-07 (40.11)**
	DM(EUR)	$\delta CoDM(EUR)$	5e-06 (0.402)		
		$\delta CoDM(EUR)3$		2e-05 (1.818)	
		$\delta CoJPY$	1e-06 (0.195)		
		$\delta FED_{\mathrm{DM(EUR)}}$			-4e-06 (-0.653)
		$\delta BoJ_{\mathrm{JPY}}$			1e-06 (1.895)
		$\alpha DM(EUR)$	0.0374 (5.755)**	0.0322 (5.731)**	0.0362 (25.95)**
		$\beta DM(EUR)$	0.9572 (123.9)**	0.9620 (143.6)**	0.9573 (792.2)**
	(JPY)	Constant	0.0035 (2.369)*	0.0036 (2.427)*	0.0034 (7.056)**
		$\delta CoDM(EUR)$	0.0265 (0.159)		
		$\delta CoDM(EUR)3$		0.0261 (0.653)**	
		$\delta CoJPY$	0.0913 (1.221)		
		$\delta FED_{\mathrm{DM(EUR)}}$			-0.0163 (-0.336)
		$\delta BoJ_{\mathrm{JPY}}$			0.0101 (1.711)
		αJPY	0.0406 (5.656)**	0.0420 (6.597)**	0.0404 (27.77)**
		βJPY	0.9511 (114.9)**	0.9508 (127.1)**	0.9519 (741.6)**
		DCC α	0.0185 (5.125)**	0.0182 (4.552)**	0.0194 (16.99)**
		DCC β	0.9794 (242.7)**	0.9797 (221.9)**	0.9782 (729.3)**
		υ	5.8222 (13.79)**	5.8404 (14.36)**	5.7099 (17.51)**
		Log Lik.	7462.1	7458.9	7463.5
Standardized Residuals Based Tests					
		$Q(20)$	77.48 [0.527]	76.99 [0.543]	79.97 [0.448]
		$Q^2(20)$	86.48 [0.215]	93.95 [0.092]	83.05 [0.299]

Note: Parenthesis and brackets are the t-statistics and p-values, respectively. * and ** denote 5% and 1% significance, respectively. See Table 1 for definitions of the exogenous (dummy) variables.

Table 11: The impact of sale of USD. 1991-2001

Dependent Variables	Explanatory Variables	Coordinated Interventions (a)	(b)	Unilateral Interventions (c)	(d)
Conditional Mean	Constant	0.0002 (2.398)*	0.0002 (2.206)*	0.0002 (2.456)*	0.0002 (2.390)*
DM(EUR)	$dCoDM(EUR)$	-0.0110 (-2.469)*			
	$dCoDM(EUR)3$		0.0184 (1.509)		
	$dCoJPY$	-0.0015 (-0.394)			
	$dFED_{\text{DM(EUR)}}$			0.0012 (0.135)	0.0022 (0.161)
	$dBoJ_{\text{JPY}}$			-0.0010 (-0.813)	-0.0010 (-1.068)
	$dBoE_{\text{JPY}}$				0.0319 (6.268)**
(JPY)	Constant	0.0240 (2.641)**	0.0238 (2.288)*	0.0241 (2.564)*	0.0238 (2.440)*
	$dCoDM(EUR)$	-0.5942 (-2.534)*			
	$dCoDM(EUR)3$		0.4858 (1.267)		
	$dCoJPY$	-0.3346 (-1.173)			
	$dFED_{\text{DM(EUR)}}$			0.4054 (0.907)	0.4122 (0.960)
	$dBoJ_{\text{JPY}}$			-0.0296 (-0.343)	-0.0300 (-0.394)
	$dBoE_{\text{JPY}}$			0.7744 (3.434)	
Conditional Variance	Constant	4e-07 (2.489)*	3e-07 (2.171)*	3e-07 (2.354)*	3e-07 (2.229)*
DM(EUR)	$\delta CoDM(EUR)$	8e-05 (0.581)			
	$\delta CoDM(EUR)3$		1e-05 (0.563)		
	$\delta CoJPY$	-1e-05 (-1.160)			
	$\delta FED_{\text{DM(EUR)}}$			1e-05 (0.533)	1e-05 (0.454)
	δBoJ_{JPY}			-1e-07 (-0.083)	-1e-07 (-0.096)
	$dBoE_{\text{JPY}}$				-1e-05 (-0.338)
	$\alpha DM(EUR)$	0.0352 (5.863)**	0.0336 (5.495)**	0.0353 (6.143)**	0.0349 (5.822)**
	$\beta DM(EUR)$	0.9588 (132.1)**	0.9600 (121.8)**	0.9590 (140.2)**	0.9597 (132.7)**
(JPY)	Constant	0.0033 (3.229)**	0.0040 (2.436)*	0.0039 (2.971)**	0.0042 (2.830)**
	$\delta CoDM(EUR)$	-0.1096 (-3.1131)**			
	$\delta CoDM(EUR)3$		-0.0645 (-0.879)		
	$\delta CoJPY$	-0.0355 (-0.550)			
	$\delta FED_{\text{DM(EUR)}}$			-0.1011 (-1.197)	-0.1054 (-1.261)
	δBoJ_{JPY}			-0.0205 (-2.564)*	-0.0212 (-2.404)*
	$dBoE_{\text{JPY}}$			-0.0991 (-1.393)	
	αJPY	0.0391 (7.566)**	0.0412 (5.998)**	0.0395 (6.781)**	0.0392 (6.079)**
	βJPY	0.9549 (181.9)**	0.9509 (116.0)**	0.9536 (141.0)**	0.9533 (128.1)**
	DCC α	0.0177 (4.710)**	0.0110 (29615)**	0.0181 (5.540)**	0.0178 (4.452)**
	DCC β	0.9801 (231.7)**	0.9873 (1173)**	0.9797 (263.8)**	0.9801 (212.5)**
	υ	5.7890 (14.11)**	5.8096 (13.75)**	5.7727 (14.72)**	5.7865 (13.80)**
	Log Lik.	7461.7	7454.1	7459.4	7467.1
Standardized Residuals Based Tests					
	$Q(20)$	77.57 [0.524]	80.29 [0.438]	80.63 [0.428]	80.62 [0.428]
	$Q^2(20)$	89.10 [0.163]	78.76 [0.423]	89.04 [0.164]	88.94 [0.166]

Note: Parenthesis and brackets are the t-statistics and p-values, respectively. * and ** denote 5% and 1% significance, respectively. See Table 1 for definitions of the exogenous (dummy) variables.

Figure 1: Plots of Exchange Rates and Returns series. 02.04.1991 - 19.10.2001

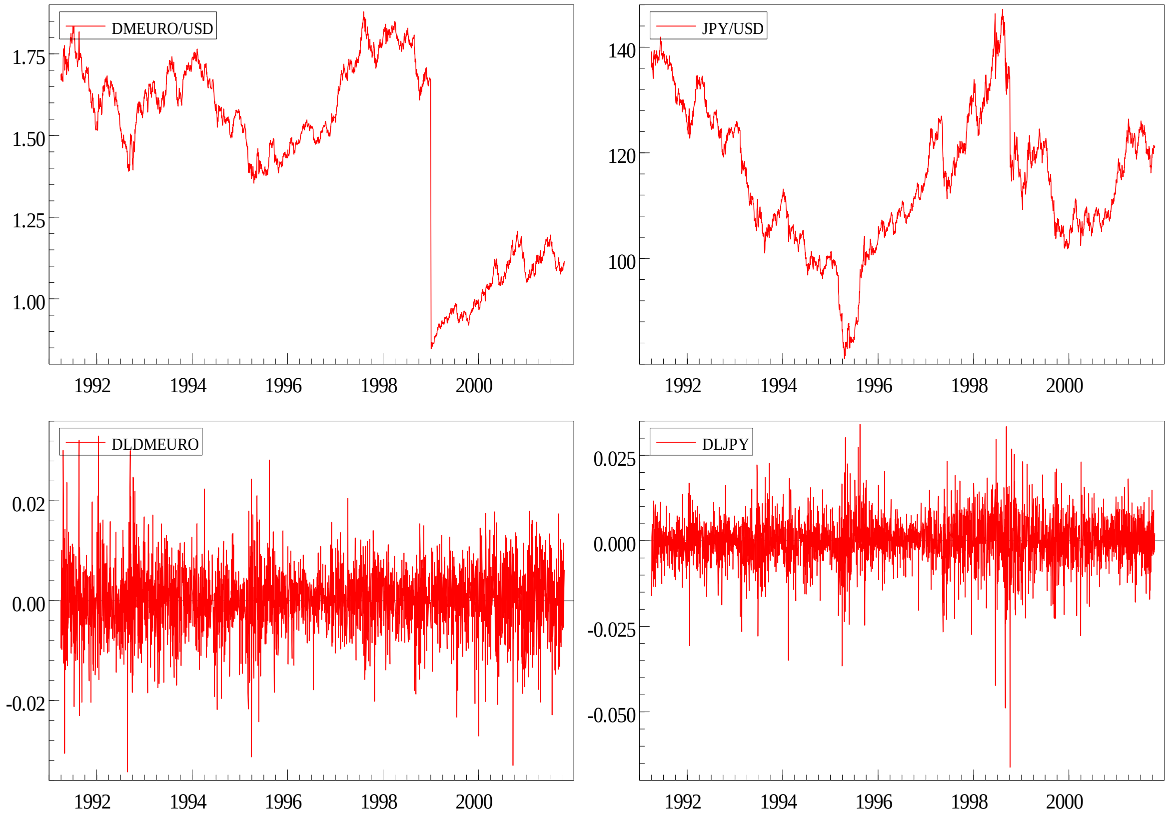

Figure 2: Conditional Correlations of the DM(EUR)/USD and the JPY/USD Returns

Figure 3: Dynamic Conditional Correlations of the DM(EUR)/USD and the JPY/USD Returns, including the ones from estimations (b) and (d) from Table 5

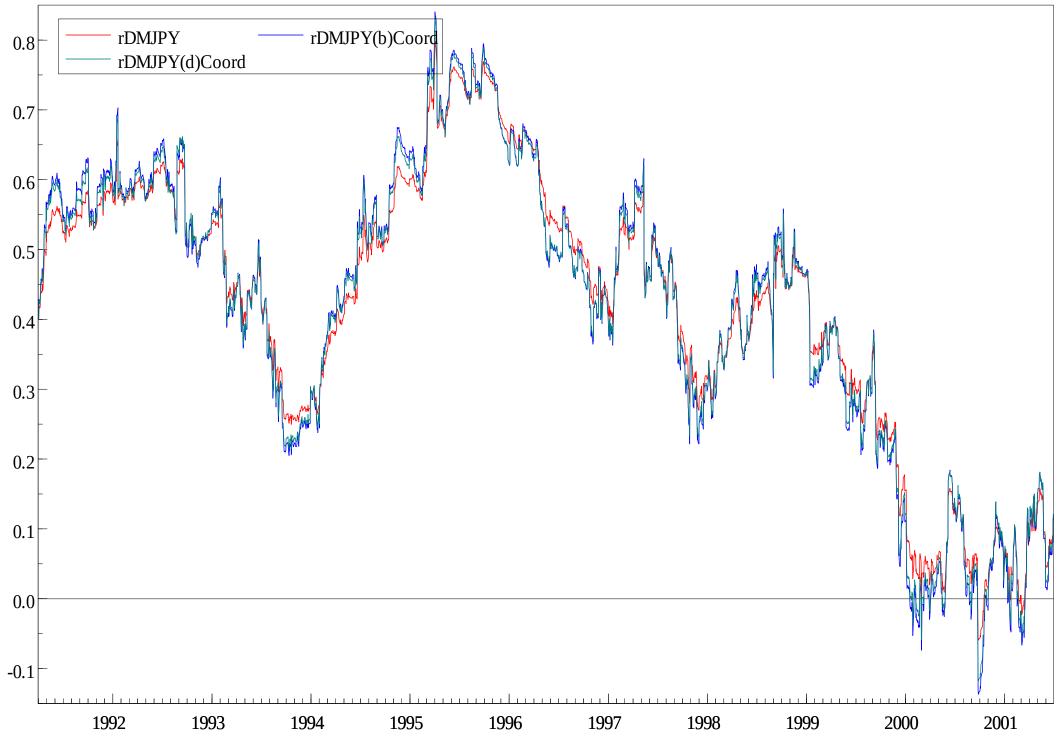

Figure 4: Dynamic Conditional Correlations of the DM(EUR)/USD and the JPY/USD Returns, including the ones from estimations (a) and (b) from Table 6