R O M E

Research On Money in the Economy

No. 13-07 – July 2013

Foreign Exchange Market Interventions and the $-¥ Exchange Rate in the Long Run

Joscha Beckmann, Ansgar Belke and Michael Kühl

ROME Discussion Paper Series

"Research on Money in the Economy" (ROME) is a private non-profit-oriented research network of and for economists, who generally are interested in monetary economics and especially are interested in the interdependences between the financial sector and the real economy. Further information is available on www.rome-net.org.

ISSN 1865-7052

Research On Money in the Economy

Discussion Paper Series
ISSN 1865-7052

No 2013-07, July 2013

Foreign Exchange Market Interventions and the $-¥ Exchange Rate in the Long Run*

Joscha Beckmann, Ansgar Belke and Michael Kühl

Dr. Joscha Beckmann
University of Duisburg-Essen
Department of Economics
Universitaetsstr. 12
D-45117 Essen
e-mail: joscha.beckmann@wiwinf.uni-due.de

Prof. Dr. Ansgar Belke
University of Duisburg-Essen
Department of Economics
Universitaetsstr. 12
D-45117 Essen
e-mail: ansgar.belke@uni-due.de
and
Institute for the Study of Labor (IZA) Bonn
Schaumburg-Lippe-Str. 5 – 9
D-53113 Bonn

Dr. Michael Kühl
Deutsche Bundesbank
Wilhelm-Epstein-Strasse 14
D-60431 Frankfurt/M.
e-mail: michael.kuehl@bundesbank.de

Abstract

This paper tries to clarify the question of whether foreign exchange market interventions conducted by the Bank of Japan are important for the dollar-yen exchange rate in the long run. Our strategy relies on a re-examination of the empirical performance of a monetary exchange rate model. This is basically not a new topic; however, we put our focus on two new questions. Firstly, does the consideration of periods of massive interventions in the foreign exchange market help to uncover a potential long-run relationship between the exchange rate and its fundamentals? Secondly, do Forex interventions support the adjustment towards a long-run equilibrium value? Our overall results suggest that taking periods of interventions into account within a monetary model does improve the goodness of fit of an identified long-run relationship to a significant degree. Furthermore, Forex interventions increase the speed of adjustment towards long-run equilibrium in some periods, particularly in periods of coordinated forex interventions. Our results indicate that only coordinated interventions seem to stabilize the dollar-yen exchange rate in a long-run perspective. This is a novel contribution to the literature.

JEL-Classification: E44, F31, G12

Keywords: Structural exchange rate models, cointegration, intervention analysis

*We are grateful for valuable comments from participants at the 10th Biennial WEA Pacific Rim Conference, the Göttinger Workshop "Internationale Wirtschaftsbeziehungen" and the 17th International Conference on Macroeconomic Analysis and International Finance. We also greatly appreciate helpful comments from Rasmus Fatum.

1. Introduction

The dollar-yen exchange rate has been the subject of controversy for more than thirty years. Since the breakdown of Bretton-Woods, the Japanese authorities have intervened more heavily in the foreign exchange rate market than those in any other industrialized country. Although it is recognized that the Bank of Japan has generally followed a strategy of "leaning against the wind" to minimize exchange rate movements, some authors have claimed that the early Japanese policy is biased towards limiting yen appreciation (Hutchinson, 1984). In July 2001, the Japanese Ministry of Finance published its daily intervention data going back to 1991.[1] Since then, many researchers have focused on three different issues: the effects of interventions on the exchange rate level, its impact on exchange rate volatility and the motivation for monetary authorities to intervene (Hoshikawa, 2008). As will be illustrated below, the present study analyzes the impact of interventions from a new perspective, departing from the first-mentioned strand of the literature and focusing on the long run. Hence, we will briefly describe the literature with regard to this topic before describing our specific contribution.[2]

The question of whether interventions are effective in influencing the level of the exchange rate has been discussed controversial. However, Sarno and Taylor (2001) claim that the literature delivers more evidence in favor of effectiveness in foreign exchange interventions in general. This is also true for Japan, although the evidence remains mixed. Some results suggest that interventions undertaken by the Japanese authorities have been effective (Dominguez, 2006; Taylor, 2005; Reitz and Taylor, 2012).[3] The findings of Fatum and Hutchinson (2005) provide evidence that even sterilized interventions by the Japanese authorities do influence the exchange rate. However, their effectiveness seems to depend on the horizon under observation in the sense that the impact of interventions disappears at longer horizons (Fratzscher, 2009b). Fratzscher (2009b) argues that the credibility of authori-

---

[1] The Foreign Exchange and Foreign Trade Law stipulates that the "Minister of Finance shall endeavor to stabilize the external value of the yen through foreign exchange trading and other measures" (Article 7.3). Moreover, "the Minister of Finance is legally authorized to conduct intervention as a means to achieve foreign exchange rate stability. The Bank of Japan, as the agent of the Minister of Finance, executes foreign exchange intervention. See Volz, and Fujimura (2011) for a detailed discussion.

[2] With regard to exchange market interventions and their impact on volatility, from a theoretical point of view credible Central Bank interventions, especially when they are coordinated, should reduce exchange rate volatility. The opposite should be true for non-credible arrangements (Frenkel et al., 2005; Dominguez, 1998). However, the results regarding this issue are not clear-cut. For studies related to this issue see Dominguez and Frankel (1993), Frenkel et al. (2005), Watanabe and Harada (2006) and Schnabl and Hillebrand (2008), among others.

[3] Taylor (2005) applies a Markov switching approach to the yen-dollar exchange rate over the period between April 1992 and December 2003. His results suggest that interventions are effective, as they increase the probability of real exchange rate stability. Reitz and Taylor (2012) utilize a smooth transition GARCH model for the period 1980 to 2004, which allows for non-linearities in the adjustment process.

ties plays a major role in the success of forex market interventions. Furthermore, as Taylor (2005) shows, effectiveness seems to be increase with the degree of misalignment.

In general, one aim of interventions is to achieve exchange rate stability at a level that is broadly consistent with fundamentals (Sarno and Taylor, 2001). This view is consistent with the fact that the Japanese authorities seem to intervene when the exchange rate has exceeded specific targets (Ito and Yabu, 2007). By estimating reaction functions, Ito (2003) identifies several possible aims of interventions and concludes that actions undertaken in the exchange market by the Japanese authorities were effective between June 1995 and March 2001, while this was not the case from April 1991 to May 1995. From this setting, the findings of Ito and Yabu (2007) suggest that Japanese interventions indeed followed a pattern of "leaning against the wind", as large changes seem to cause contrary interventions. This implies that the BoJ had a target value in mind.

This paper contributes to this debate by focusing on a question which has mostly been neglected in the empirical literature: the importance of interventions in a long-run perspective. If Japanese exchange rate policy has followed a strategy of leaning against the wind and aimed at restricting non-fundamental exchange rate fluctuations, which are also based on a long-run exchange rate target, the following question arises: Is there any influence on the long-run link between the exchange rate and fundamentals which stems from interventions in the foreign exchange market? To be more precise: do periods of massive interventions need to be accounted for when modeling the long-run relationships between the exchange rate and fundamentals? This is the central question we address in this study.

If interventions are important in the long-run, accounting for these periods should not only help disentangle the link between the exchange rate and fundamentals. The adjustment towards the equilibrium path should also be faster in these periods. Interventions usually occur when the exchange rate has roughly departed from its long-run level. Given that monetary authorities have private information about the fundamental level of the exchange rate, intervention periods can be used to proxy periods in which the exchange rate does not follow its fundamental path. By not taking this influence into account, the long-run relationship found empirically, as long as one can be identified, is severely biased. In addition, if interventions are successful and do limit the influence of noise traders by pushing exchange rates back to their fundamental values, this would tend to support a mean reverting behavior in the exchange rate which, in turn, would correspond to a break in the adjustment coefficients (see, e.g., Altavilla and De Grauwe, 2010, for the main argument). In this spirit, Juselius and MacDonald (2004) analyze parity relations between the United States and Japan. They argue that the cumulative impact of monetary intervention shocks is likely to describe an additional stochastic trend.

When focusing on the long-run relationship between the exchange rate and fundamentals, we obviously disregard features that are important in the context of exchange rate interventions such as the impact on volatility or instability issues regarding parameters.[4] However, these shortcomings are justified on the grounds that our research topic is novel and we are aiming to model a stable long-run relationship by taking interventions into account. From a policy point of view, the question of whether periods of massive interventions have had an impact on the cointegrating relationship between the exchange rate and fundamentals is also important, since the impact of interventions on long-run relationships may also be interpreted as a measure of effectiveness.

To put our topics of investigation under closer scrutiny, Section 2 proceeds with a theoretical consideration of interventions in structurally reduced exchange rate models and we identify regimes of heavy interventions undertaken by the Japanese authorities in the dollar-yen market.[5] In Section 3 we apply the cointegrated VAR approach of Johansen and Juselius to assess whether these periods should be accounted for in the cointegration vector and investigate whether the speed of adjustment that we find towards the long-run equilibrium is faster during periods of interventions. Section 4 concludes.

2. Economic methodology

2.1 Foreign exchange market interventions in theory

Four cases can be distinguished with regard to the characterization of interventions. Interventions may be carried out in a sterilized or unsterilized fashion and may or may not be made publicly available. Furthermore, it is possible that market participants actually perceive interventions when no actual interventions have occurred or if policymakers deliver an oral statement without actually intervening. With respect to the transmission of interventions, three channels can be identified. The portfolio balance effect arises when interventions change the relative supply of domestic to foreign assets which are assumed to be non-perfect substitutes. If interventions are successfully sterilized (with respect to money supply) such an effect continues to hold in contrast to the case of perfect substitutes. The signaling

[4] Beckmann et al. (2011) do, indeed, find significant parameter instability in cointegration regressions among the dollar-yen exchange rate and fundamentals.

[5] As described in section 3, including intervention periods of the Fed turned out to insignificant within our framework.

channel arises from the fact that policymakers provide market participants with new information, for example with respect to the future policy path, in cases of interventions. This mechanism might also be important in the case of sterilized interventions (Sarno and Taylor, 2001; Fatum, 2009). The coordination channel stems from a micro-based model. The idea here is that in a heterogeneous agent framework it is difficult for fundamental traders to make use of deviations in the exchange rate from a fundamental value because their trade horizon may not be sufficient to exploit arbitrage opportunities. This can be understood as a coordination failure. If the market sees the Central Bank as an agent with superior information, the announcement of interventions effectively acts as a coordinating signal to fundamental traders. In addition, the relative profits of agents are changed such that the arbitrageurs enter the market, which in turn supports the return of the exchange rate to a level consistent with fundamentals (Reitz and Taylor, 2008, 2012; Sarno and Taylor, 2001; Fratzscher, 2008). By definition, transmission through the signaling and coordination channels does not occur when participants are unaware of interventions and when no oral statements have been made.

In general, the decision in favor of interventions might be based on the belief in a specific fundamental value. Almekinder and Eijffinger (1996) and Ito and Yabu (2007) support this view with the help of reaction functions derived from a theoretical framework which consists of cost-minimizing behavior by the monetary authorities while taking a target exchange rate into account. Beine et al. (2009), for instance, use past exchange rate variations in a similar fashion as a measure of misalignment of the exchange rate from a fundamental value and as an empirical measure of interventions.

Non-fundamental impacts on the exchange rate typically lead to a deviation from an exchange rate target defined in terms of a long-run equilibrium between the exchange rate and its fundamentals. Arbitrageurs usually bring the exchange rate back to its fundamental value so that the equilibrium is preserved. However, arbitrage cannot be achieved if the trading horizon of the arbitrageurs is shorter than that of the noise traders. In addition, it may be rational to follow a trend to generate excess returns. In such a case, the adjustment process usually linked with arbitrage is abandoned and the exchange rate shows slow or no self-adjusting behavior. As a consequence, the Central Bank decides to intervene if the exchange rate has deviated to a specific extent (κ) from its target level that can be interpreted as a fundamental value (Equation (1)):

$$INT_t = \phi \left| S_{t-1} - S_{t-1}^T \right| \quad \text{for} \quad \left| S_{t-1} - S_{t-1}^T \right| > \kappa \tag{1}$$

The threshold term κ in Equation (1) may well reflect the policy costs mentioned by Ito and Yabu (2007).[6] Interventions (INT) are therefore related to periods of massive deviations in the exchange rate from its fundamental value. The coefficient ϕ captures the intensity with which the Central Bank reacts to deviations from the target level.[7]

Long periods of deviations from the fundamental value do not only affect the adjustment towards long-run equilibrium between the exchange rate and its fundamentals. The long-run relationship itself can also be distorted. The reason for this is that the "true" link between the exchange rate and its fundamentals is lost. The only way to obtain the long-run equilibrium in an empirical investigation is to take explicit account of the non-fundamental impact. A common solution to the problem of quantifying such periods is to include dummy variables in the long-run relationship. The following considerations motivate this proceeding. If non-fundamental factors are at work, the exchange rate consists of the fundamental part and the deviations from the fundamental path, with the latter summarized in Z_t:

$$S_t = S_t^{long} + Z_t = \beta' X_t + Z_t = \beta' X_t + Z_t^{nf} + Z_t^{f}. \tag{2}$$

Deviations from the equilibrium path can further be split into a non-fundamental part Z_t^{nf} and a fundamental part Z_t^{f} (Equation (2)). The latter can be understood as those deviations which will be removed by arbitrageurs (even when they are non-fundamentally initiated). From Equation (1) we can derive that interventions (INT_t) occur in cases of deviations from a target so that Z_t, and in particular Z_t^{nf}, as non-fundamental deviations, can be linked to the degree of interventions (neglecting, for simplicity, a threshold, as in Eq. (1)). Assuming that interventions in terms of purchases or sales of the domestic currency take place, and we are interested only in capturing the baseline effect, we can divide the periods of deviations from the fundamental value up into periods in which interventions occur (Z_t^{INT-k} with $INT-k$ denoting the k-th period of interventions) and periods without interventions, summarized in Z_t^{NO-INT}, such that $Z_t = \left(Z_t^{INT-1}, ..., Z_t^{INT-k}, Z_t^{NO-INT}\right)$. The term Z_t^{NO-INT} takes the value 0 when interventions occur. In doing so, we are able to relate specific periods of interventions to deviations in the exchange rate from the fundamental value.

6 It is assumed that the target exchange rate coincides with the fundamental exchange rates.

7 In contrast to Ito and Yabu (2007), we draw on the absolute deviations from the target value because we are not interested in the direction of interventions at this point.

$$Z_t^{INT-k} = \begin{cases} INT_t \cdot 1(T_{k-start} \le t \le T_{k-end}) & if \quad INT_t \neq 0 \\ 0 & otherwise \end{cases} \qquad with \ k = 1,...,K \ , \tag{3}$$

where $1(T_{k-start} \le t \le T_{k-end})$ is an indicator function that takes the value one for the defined period and zero otherwise. Without knowing the exact degree of interventions we can build a variable I_t^k that is able to capture the k-th period of interventions, such that

$$I_t^k = \begin{cases} 1 & \text{for} \quad Z_t^{INT\text{-}k} \neq 0 \\ 0 & \text{for} \quad Z_t^{INT-k} = 0 \end{cases} \qquad for\, k = 1,...,K. \tag{4}$$

All periods of interventions covered by the intervention dummies can be summarized in the vector I_t . With its help, Eq. (2) can be rewritten, so that

$$S_t = \beta' X_t + \delta' I_t + u_t \tag{5}$$

arises, where δ is a vector of weighting coefficients and u_t comprises all deviations from the fundamental value while no interventions occur. Equation (5) can be directly compared with Equation (2). The term u_t reflects the process Z_t^f and the intervention part $\delta' I_t$ the non-fundamental impact which is assumed to be known by the policy maker. Now, there are two possible outcomes which may indicate successful interventions. The first is that the k-th parameter δ in Eq. (5) is zero. Knowing that interventions have occurred, this could imply that the interventions are entirely successful because the long-run equilibrium is preserved. The second possibility is that the k-th coefficient δ in Eq. (5) shows the direction of the deviation from the target value while the deviation itself, i.e. the equilibrium error, shrinks. Such an outcome indicates that the Central Bank has correctly identified non-fundamental deviations from a fundamental value. Owing to the fact that insignificance may also be due to non-successful interventions, we focus on significant intervention periods when evaluating our empirical results.

2.2 Modeling the long run

In order to identify a possible fundamental value of the exchange rate, it is necessary to consider an economic theory. In the literature concerned with interaction models between fundamentals-based traders and noise traders, purchasing power parity is often seen as the baseline model (Frenkel et al., 2005; De Grauwe and Grimaldi, 2006; Reitz and Taylor, 2008, 2012). Sometimes, the fundamental value is based on a model which contains only money supply and real income with unit elasticities (following for instance Mark, 1995). We base our theoretical considerations on a reduced form of the exchange rate determination model that stems from the class of monetary models. We feel legitimized to argue that the Central Bank evaluates the fundamental value of the exchange with the help of a broader set of fundamentals. The basic form of the monetary model in log form can be written as (Frenkel, 1976; Frankel, 1979; MacDonald and Taylor, 1994):

$$S_t = \mu + \beta_1 m_t - \beta_1^f m_t^f - \beta_2 y_t + \beta_2^f y_t^f + \beta_3 i_t - \beta_3^f i_t^f , \qquad (6)$$

where μ is a constant, *m* represents the money supply, *y* real income and *i* the interest rates; *f* stands for foreign variables. A rise in the exchange rate *S* corresponds to a depreciation in the domestic currency. By using the monetary model as presented in Equation (6) it is assumed that the real exchange rate is constant in the long run. However, in reality this is generally not true. Moreover, the PPP is usually constructed using the consumer price index, which starts from the assumption that it holds for a mixture of traded and non-traded goods. Strictly speaking, the PPP is a concept for traded goods, so the prices of traded goods must be taken into account (Dornbusch, 1976). Assuming that PPP holds for tradable goods and the domestic price level is an average of non-traded and traded goods, we can rewrite Equation (6) to add to our model the ratios of (domestic and foreign) tradable prices to non-tradable prices:

$$S_t = \mu + \beta_1 m_t - \beta_1^f m_t^f - \beta_2 y_t + \beta_2^f y_t^f + \beta_3 i_t - \beta_3^f i_t^f + \beta_4 \pi_t - \beta_4^f \pi_t^f + \beta_5 \left(\frac{p_t^t}{p_t^{nt}} \right) - \beta_5^f \left(\frac{(p_t^t)^f}{(p_t^{nt})^f} \right) \qquad (7)$$

with π as the inflation rate, which serves as a measure of inflation expectations. The last two terms, namely the two ratios of traded to non-traded goods (domestic and foreign), reflect the real exchange rate. The domestic currency appreciates when the price of tradables increases relative to that of non-tradables. Consequently, our model is able to respond to productivity differentials between countries, i.e. the well-known Harrod-Balassa-Samuelson effect (Harrod, 1939; Balassa 1964; Samuelson 1964).[8]

A reduced form of the model, as given in Equations (5) and (7), is usually estimated imposing a priori restrictions on the coefficients. Quite frequently, it is assumed that the domestic and foreign coefficients are identical for domestic and foreign variables. However, in order to start our analysis as unrestrictive as possible, we remove these restrictions. This method is generally supported by the fact that coefficients that are restricted to being equal for each variable typically tend to result in biased coefficients (Haynes and Stone, 1981). With regard to the topic of our investigation, removing these restrictions is also important, since the tradi-

[8] Wu and Hu (2009) emphasize the importance of the Harrod-Balassa-Samuelson effect when modeling deviations from purchasing power parity using an ESTAR model.

tional monetary model assumes that domestic and foreign assets are perfect substitutes for each other. Consequently, the portfolio effect of interventions does not occur in such settings. By means of relaxing the symmetry restriction regarding interest rates, we therefore also relax the assumption that domestic and foreign bonds are perfectly interchangeable.[9] Hence, the model we employ contains elements of the portfolio balance approach of Branson (1977), which is preferable in work if risk premia are important.

2.3 Definition of periods of massive foreign exchange market interventions in Japan

Interventions in the dollar-yen market have occurred frequently in the free-floating era. An interesting question is whether time periods with exceptional magnitudes of interventions can be identified. In the following, we will describe six prominent cases. As official data are only available from 1991, most analyses up to this point are based on changes in the official foreign reserves as a proxy for interventions, and on the evaluation of press articles. Basically, both indicators can be applied to our topic because we are interested in periods of heavy interventions. Since we do not necessarily need to specify the exact amounts in the cointegration analysis, we make use of these reported intervention periods. We will account for the identified periods in our cointegration analysis by using intervention dummies, which we can specify without this knowledge. Moreover, such a procedure is adequate because we are working with monthly data rather than daily data. For the period 1993 to 2000, Galati et al. (2005) compare Reuters reports on interventions with the actual amounts of interventions. Since their results suggest that the probability that interventions had actually been undertaken if they were reported by Reuters was 0.84, they conclude that these reports quite precisely match interventions actually undertaken (Galati et al., 2005). As we will describe later, we will in addition rely on changes in the foreign exchange reserves.

Figure 1 shows the nominal yen-dollar exchange rate in conjunction with the identified periods of interventions which we will describe in this section. It can be seen that the yen-dollar exchange rate has fluctuated remarkably, especially during the 1980s.

-Figure 1 about here-

After the breakdown of Bretton Woods in 1973, the yen started to depreciate after a short spell of appreciation as a result of speculative capital flowing out of the country. Consequently, the monetary authorities in Japan began to sell dollars. The yen stabilized at around 300

[9] Goldberg (2000) argues that a rejection of the symmetry restriction relating to the interest rate differential is either linked to imperfect capital mobility or provides evidence in favor of the approach of imperfect knowledge over rational expectation.

yen per dollar in 1974. Our investigation begins in 1976, when Japanese policy switched in the direction of moderating the appreciation of the yen, while in general limiting the amount of interventions (Takagi, 1991). This pattern changed on different occasions when the yen appreciated heavily. This was especially true in the period from October 1977 until the end of 1978. In November 1977, the amount of interventions came to around 32 percent of the trade volume in the foreign exchange market. In March 1978 it had gone up to 44 percent (Komiya and Suda, 1983; Takagi, 1991). From November 1978, the Bank of Japan joined the Fed, the Deutsche Bundesbank and the Swiss National Bank in a coordinated attempt at selling yen to dampen its appreciation. Japan's exchange rate policy changed again at the beginning of 1979, when the yen started a spell of depreciation. It follows that the purpose of these interventions was to support the currency. These efforts were particularly intensified in the spring and autumn of 1979 (Takagi, 1991). However, accounting for the fact that the amount of interventions slowed down after the spring, we have decided to end our first intervention period (I1) in April 1979, with the beginning specified as October 1977.

From 1981 onwards, the frequency of interventions by the Japanese authorities shrank. This is an indication that Japanese exchange rate policy was biased towards preventing yen appreciation, as the authorities did little to prevent the massive yen depreciation against the dollar. However, the Plaza Agreement held in New York on 22 September 1985 initiated a series of coordinated interventions after the participants stated that "exchange rates should better reflect fundamental economic conditions." The Group of Five reached an agreement to conduct simultaneous sales up to 18 billion dollars (Obstfeld, 1990) in order to weaken the dollar. As a result, the Fed supported the BoJ in stabilizing the dollar-yen exchange rate. When the yen appreciated to 200 yen/dollar, the aim of Japan's exchange rate policy became to stabilize the yen instead of allowing it to appreciate. Consequently, from March 1986, the Japanese began purchasing dollars (Takagi, 1991). During May of the same year, the members of the Tokyo summit again committed themselves to market interventions. The participants of the Louvre Accord also expressed the will to maintain nominal exchange rates near existing levels (Obstfeld, 1990). Large interventions also occurred from immediately after the stock market crash of October 1987 through to December. In particular, the period after the Plaza Agreement is often regarded as an example of successful interventions in the foreign exchange market. The credibility of the statements, the degree of international coordination and the fact that market participants indeed assessed the dollar as undervalued are identified as possible reasons for this. Accordingly, our second period (I2) runs from September 1985 to until January 1988.[10] [11]

Between April 1989 and April 1990 the Fed intervened in the dollar-yen market without a support of the BoJ. This is the reason why we label this period Fed intervention period (Ifed).[12]

Although the yen experienced a period of appreciation from 1991, it seems that the Japanese did not intervene significantly to stop this development. For the rest of the decade the yen remained remarkably strong, considering that the Japanese economy suffered from deflation and weak real economic growth (Schnabl and Hillebrand, 2003). According to Fratzscher (2008), oral interventions favored a weaker yen after it appreciated to above 120 yen/dollar in 1993. While a stronger yen was briefly supported in 1998, public statements afterwards again expressed the view that it should depreciate. As already mentioned, data on actual Japanese foreign interventions have been published since April 1991. For the period up to 2004, Hoshikawa (2008) distinguishes between a period of low frequency interventions, from June 1995 to December 2002, and high frequency interventions, from April 1991 to May 1995 and from January 2003 up to 2004 respectively. Ito and Yabu (2007) argue that the change in 1995, which corresponds to a structural break in their reaction function, is attributable to the appointment of Dr. Sakakibara as director of the International Finance Bureau of the Ministry of Finance in June of that year. Concerning the yen/dollar interventions, three periods of huge amounts of interventions can be observed during the nineties and will be accounted for in the following. The third period (I3) goes from May 1991 to August 1992 and is characterized by frequent interventions of small magnitude; while the fourth period (I4), from April 1993 until January 1996, is also characterized by frequent interventions of small magnitude.[13] During this period, the Fed also intervened in the dollar-yen market to some extent. The fifth period from January 1999 until January 2000 (I5) is characterized by huge but low-frequency interventions. Again, most interventions during the 1990s were aimed at lowering

[10] The Fed also intervened in the dollar-yen market in late 1988. Nearly all of these interventions occurred in November 1988. This is the reason why we do not extend the second period to include the Fed interventions.

[11] During this period, interventions were qualitatively different. While the Plaza Agreement was aimed at preventing the appreciation of the US dollar, i.e. US dollar sales occurred, the Louvre Accord should stop the initiated countermovement by US dollar purchases. Since we are not interested in the direction of the intervention, we treat both periods as one period.

[12] As will be seen in Section 3.2, this period has no statistical significance.

[13] Since the BoJ also intervened at the beginning of 1996, we decide to end this intervention period in January 1996.

the appreciation of the yen, which suggests that Japan was seeking to weaken its currency (Morel and Teiletche, 2004).

Confronted with deflation, conventional monetary policy lost its effectiveness after the Central Bank cut the overnight interest rate to almost zero percent and the real interest rate remained positive. The exchange rate policy therefore became even more important in stopping the downward spiral of deflation by stimulating demand over a lowering of the value of the yen. As a result, massive dollar-supporting interventions took place between 2001 and 2004. The Bank of Japan sold 35 trillion yen in exchange for dollars between January 2003 and March 2004 (Fatum and Hutchinson, 2005). Accordingly, our sixth period runs from September 2001 until March 2004 (I6).

Since that time the Japanese authorities have rarely intervened (Fratzscher, 2008). Even when the yen started to fall heavily against the dollar in 2005, they did little to stop the trend by intervening in the currency market. This is another hint that the Japanese intervention policy is indeed biased toward preventing the yen appreciating. The Bank of Japan did, however, intervene in September 2010 and again in March 2011. Nevertheless, these activities cannot be seen as periods of massive interventions, for which reason we omit them.

3. Data and empirical results of the cointegrated VAR approach

3.1 Data

We work with monthly data taken between January 1976 and December 2007, although the BoJ did also intervene in later periods. We have not accounted for the time period thereafter because our main aim is to focus on periods of interventions lasting several months, i.e. looking at the role of interventions in a long-run perspective. The BoJ (officially) intervened after our chosen end only on two days: 15 September 2010 and 18 March 2011.[14] Consequently, these interventions do not match our definition. Furthermore, we decide to include only the period until the financial crisis emerged, although the last intervention period ended on 16 March 2004. The reason for this is that in the course of the financial crisis remarkable swings

[14] Both dates are related to specific events. The first date must be seen in conjunction with the sovereign debt crisis in several EU member states against the background of dampening flight-to-safety impacts on the exchange rate. In March 2011, the BoJ intervened after a devastating natural disaster.

in exchange rates could be observed (Fratzscher, 2009a). Since these developments can potentially affect the estimation of the long-run relationship, we stop at the end of 2007.[15]

For money supply we opt for the monetary aggregate M1. Real income is proxied by the industrial production index. In our model we include two different price measures. On the one hand we include the rate of inflation that is calculated based on the consumer price index (CPI). On the other, as suggested by Wolff (1987), we make use of a relative price measure which is the price ratio of tradable to non-tradable goods.[16] Regarding the short-term interest rates, we decide on using money market rates with a maturity of three months. As usual, exchange rates, money supply and real income are expressed in logarithms. All series are seasonally adjusted and are taken from international financial statistics from the International Monetary Fund.

We start our empirical investigation with the application of a battery of well-known unit root tests to our data. The results suggest that all series should be treated as non-stationary and integrated of order one (I(1)).[17] Consequently, we should apply cointegration methods to analyze the link between exchange rates and fundamentals.

3.2 The cointegrated VAR approach: econometric methodology

In general, the concept of cointegration refers to linear combinations of non-stationary variables which result in stationary equilibrium errors. As a result, the linear combination(s) can be interpreted as a long-run relationship(s). There are different ways of testing for cointegration among a couple of variables. In the following, we apply the multivariate test by Johansen (1988), which draws upon the following vector autoregression representation (VAR):

$$\Delta X_t = \alpha\beta' X_{t-1} + \Gamma_1 \Delta X_{t-1} + ... + \Gamma_k \Delta X_{t-k-1} + \Phi D_t + \varepsilon_{t,} \qquad t = 1,...,T \quad \text{and} \quad k = 1,...,q \qquad (8)$$

The non-stationary behavior is accounted for by a reduced rank restriction of the long-run matrix Π, which can be fragmented into two matrices α and β such that $\Pi = \alpha\beta'$. The term β gives the coefficients of the variables for the r long-run relation(s) while α contains the adjustment coefficients describing the reaction of each variable to disequilibria from the

[15] Of course, we estimated models with longer periods and there are several hints of structural breaks after 2007. However, our fourth cointegration vector (see below) seems to be stable. The complete estimation results are available upon request.

[16] The price of tradable goods is proxied by the producer price index, while the consumer price index serves as a proxy for the basket of non-tradables.

[17] We conducted the ADF, the Phillips Peron and the KPPs test. The results are available upon request.

r long-run relations given by the $r \times 1$ vector $\beta' X_{t-1}$. The term $\Gamma_k \Delta X_{t-k}$ describes the short-run dynamics of the model using p dependent variables (Juselius, 2006). The deterministic components are given by the $(p \times 1)$ vector ΦD_t, while ε_t describes an independent and identically distributed error term. In the present case, the expression μ includes the constant term and ΦD_t dummies to account for outliers in the residuals.

In the case of persistent deviations from the long-run equilibrium relationship with specific variables as the driving forces behind this development, the omission of these forces would lead to biased cointegration coefficients. The reason behind this bias is straightforward as we show in the following.

The true regression model should be

$$S_t = \beta' X_t + Z_t^{nf} + \varepsilon_t = \beta' X_t + \delta' I_t + \varepsilon_t, \tag{9}$$

where ε_t is a white noise error term. The regression model from which the investigation starts is

$$S_t = \beta'^{*} X_t + \varepsilon_t^{*}. \tag{10}$$

The relationship between the omitted variable and the X_t variables can be described with the help of the familiar "auxiliary" regression as

$$Z_t^{nf} = \delta' I_t = \lambda' X_t + \eta_t, \tag{11}$$

where η_t is a white noise error term. Inserting Eq. (11) in Eq. (9) and rewriting this expression yields

$$S_t = (\beta' + \lambda') X_t + \eta_t + \varepsilon_t. \tag{12}$$

Equation (12) is the underlying model when Eq. (10) is estimated. An estimation based on Equation (10), although Eq. (9) is true, generates the familiar omitted variable bias. Consequently, it holds that

$$\beta'^{*} = \beta' + \lambda' \gamma \tag{13}$$

and

$$\varepsilon_t^{*} = \eta_t + \varepsilon_t. \tag{14}$$

By neglecting the non-fundamental variable the estimated cointegration vector is biased and does not reflect the "true" parameters. What is more, the biased estimated cointegration coefficients also produce biased adjustment coefficients, because $\Pi = \alpha^{*}\beta^{'*}$ holds. In addition, the finding of cointegration itself is affected by Equation (14).[18] Cointegration requires the error series η_t to be stationary. This is the case when the potentially omitted variable is either stationary or linked to the non-stationary fundamentals in the long run, as can be seen from Equation (11). Taken this as given, the omission of relevant deviations from the target value of the exchange rate produces a biased cointegration vector.

Bearing these arguments in mind, we can take deviations from the long-run relationship into account by rewriting the cointegration space based on Eq. (8). The long-run ΠX_t matrix can be split up as $\Pi = \tilde{\alpha}\tilde{\beta}'\tilde{X}_t$, where $\tilde{X}_t$ also contains the dummies for the intervention periods that are considered significant according to exclusion tests later on. We restrict these components to lying in the cointegration space. In the following, we will not focus on the short-run view in our model, as our aim is to investigate the long-run importance of interventions.

3.2.1 Prior analysis: determination of the rank and exclusion tests

We now proceed with the determination of the rank, that is, determining the number of stationary long-run relationships. The intervention periods identified in Subsection 2.3 enter as dummy variables when we specify them as shifts in the cointegration vector. They are marked as I1, I2, I3, I4, I5 and I6, respectively. To identify the number of cointegrating relations r we rely on the trace test developed by Johansen (1988). Owing to the large numbers of variables under observation and to the fact that the inclusion of exogenous shift dummies may alter the results of the trace test, we have simulated the asymptotic distribution by applying Monte Carlo simulations. The simulations were carried out for random walks with a length of 400 months and 2500 iterations. The results are presented in Table 1.

Table 1 about here

The hypothesis of a rank of four can clearly be rejected at the 1% level, according to the test statistic, while a rank of five is marginally not rejected at the 5% level. A rank of six cannot be rejected. Since the choice of rank is important and the results are not clear-cut, we have also considered recursive estimates of the rank tests, which are available upon request. Altogeth-

[18] This is a very simplified explanation of the problem in cointegration regressions because we merely draw on a single equation framework although we are using a multivariate one. Our aim here is to highlight the general problem of omitted variables in a cointegration framework.

er, the results suggest that a rank of 5 seems to be an adequate choice, although the results are inconclusive to some extent. For this reason, as a robustness check, we have estimated our model additionally for a rank of 6. The results, which are available upon request, did not change the findings to a significant degree. We therefore proceed in the following by describing the results for a rank of 5. Turning to some diagnostics, Table 2 shows that the hypothesis of no autocorrelation cannot be rejected for the first four lags at all conventional levels.

Table 2 about here

In the next step, we run exclusion likelihood ratio tests to analyze whether the intervention dummies should be included in our model (Juselius and MacDonald, 2004).[19] A joint LR-exclusion test for all intervention periods rejects the hypothesis that all periods should be excluded from our model, with a test statistic of 399.732 at the 1% level. From this finding we proceed by testing for the significance of each intervention period to achieve an adequate model structure based on a general-to-specific approach. We present the results in Table 3.[20]

Table 3 about here

The findings suggest that none of the intervention periods should be excluded from our model at least at the 10% level. However, for the last two periods during the nineties (I4 and I5) the hypothesis of exclusion is only rejected at the 10% level. This result is not surprising, since the literature is sharply divided with regard to the efficiency of interventions during the nineties (Sarno and Taylor, 2001). When identifying the cointegrating vectors as described in the next section, further tests suggested that I4 gained significance after I5 was omitted from the cointegrating space. We therefore exclude I5 only for the final estimations. A re-estimation of rank and autocorrelation tests for our reduced model without I5 still suggests that a rank of five is the adequate choice with the hypothesis of five long-run relationships not being rejected at the 5% level and autocorrelation still firmly rejected. The results are presented in the three columns on the right-hand side in Table 1 and Table 2.

[19] As mentioned in Section 2.3, we also considered intervention periods of the Fed. According to the results of exclusion tests, the additional period that we labeled Fed intervention period (from April 1989 until March 1990) should not be included in the cointegrating space. For this reason, we omit this period.

[20] The lag-length of the model is based on tests for autocorrelation and the ARCH effect. The corresponding results for the ARCH effect are available upon request. According to Rahbek et al. (2002), the results we gain in the following are still robust under the remaining ARCH-effects. Because of the high skewness and kurtosis of some variables, dummies have been included in some cases. While excess kurtosis does not introduce a significant bias to the cointegration estimation results, the results are sensitive to excess skewness (Juselius, 2006; Juselius and MacDonald, 2004). After introducing dummy variables into the system, the rejection of the assumption of normality is due to excess kurtosis, so that our results are still reliable. Jarque-Bera statistics for each variable and dates of the dummies introduced are also available upon request.

3.2.2 Hypothesis testing and identification of the long-run structure

After we have determined the rank, the Johansen approach provides the maximum likelihood estimates of the unrestricted cointegrating relations. In order to achieve interpretable economic relationships for the long-run structure, in cases of a rank greater than one it is necessary to implement restrictions on β that at least just identify it because the cointegration vectors are otherwise not unique. By having an economic model at hand, further restrictions can also be implemented so that the model becomes over-identified. The hypothesis tests are based on a likelihood ratio procedure described in Johansen and Juselius (1992, 1994).

Although we are primarily interested in the link between the exchange rate and its fundamentals, we have to specify all five cointegration vectors. In so doing, it is required that we have further reasonable economic relations at hand. In restricting the exchange rate and the variables of the other economies to zero we aim at specifying two vectors to represent the domestic economies of Japan (relation 1) and the United States (relation 2) respectively. The Japanese money supply turned out to be insignificant so we removed it from relation 1. The third vector links the exchange rate to prices. Consequently, we originally included the rates of inflation and the ratio of tradable to non-tradable goods. However, only U.S. inflation and the Japanese price ratio turned out to be significant. To model the relationship between the exchange rate and the remaining fundamentals, we follow the monetary model as described and include interest rates, money supply, income of both countries and the exchange rate into the fourth vector. Restrictions of the fifth vector were guided by the significance of the coefficients. The resulting relations are presented in Table 4.

Table 4 about here

The implied restrictions are accepted with a very high p-value of 0.414. As the focus of our analysis is on the exchange rate, we do not extensively discuss the results of the first and second relations corresponding to the domestic economies of Japan and the United States and the fifth relation. The empirical findings for the exchange rate do appear raher promising. Money supply and interest rates enter with the correct sign in the fourth relation for both economies. This is also true for US inflation and the Japanese price ratio in the third relation. However, both US and Japanese income series turn out to be significant but enter with the wrong sign in relation four. This might mean that, owing to business cycle linkages, the effect of income on the exchange rate does not work via the money demand channel. This argument seems to be plausible because direct price effects do not enter the long-run relationship. Interestingly, the symmetry restriction with respect to money is also valid in the fourth vector. In addition, the corresponding coefficients can be restricted to having the same magnitude as the coefficient for the nominal exchange, namely a value of one. This is a strong result which relates to the original version of the monetary model (Frankel, 1979). Applying zero restrictions to the intervention periods in the third and/or fourth long-run relationships results in a breakdown of the long-run relationships, since the resulting restrictions are rejected. Hence, evidence of the monetary approach in the form described above is only provided if the intervention periods are included.

Next, referring to the adjustment coefficients for the restricted model, we tackle the question of whether the exchange rate adjusts to deviations from the established long-run relations. These coefficients are more closely examined in Table 5.

Table 5 about here

The results show that the exchange rate adjusts to the fourth relationship, which includes money, interest rates and income, as well as to the third long-run relationship, which includes prices and inflation.

The results show that the intervention periods are important in the relations referring to the exchange rate. For the third relation, all intervention periods except I1 gain significance for the exchange rate/price relation, while the first two periods are important for the relationship between the exchange rate and the remaining fundamentals. This is consistent with the view that the exchange rates deviated remarkably from their fundamental values during the 1980s. To some extent, we could argue that interventions during that time seem to have been justified because their inclusion in a time series model supports the finding of a theory-consistent relationship between the exchange rate and its fundamentals. In contrast, all other intervention periods are not relevant to the fourth relation, which means that the long-run link between exchange rate and its fundamentals can be found without taking additional effects into account.

Our results, are broadly robust with respect to different specifications. As already described, we estimated the model with different cointegration ranks and also with different ends of the sample. It turns out that vectors three and four are relatively robust regarding the coefficient, the signs and the included dummies. However, the constitution of the other cointegration vectors partly changes.

Overall, the results of this section suggest that fundamentals play an important role in exchange rate movements when intervention periods are included.

3.2.3 Additional adjustment effects in periods of interventions

Since we assume that the Central Bank has knowledge of a misalignment in the exchange when it intervenes, we must conclude that it has a fundamental link between exchange rate and fundamentals in mind. Insignificant dummy variables in our estimated long-run relationship could be an indication that Central Bank interventions have been successful. The reason for this is that the Central Bank intervenes when there is a misalignment, and when we cannot find ex post any misalignments in long-run data the interventions might be seen as being successful. However, if the dummies are significant, there is indeed an indication of a misalignment that could not be completely removed. A clearer hint at successful interventions should be that the adjustment towards the long-run equilibrium is enhanced during periods of interventions. Consequently, the adjustment coefficient in Eq. (14) might be greater.

In order to check whether the adjustment towards the long-run relationship is greater during periods of interventions, we re-estimate the VECM in a slightly extended form. We keep all error correction terms as obtained (except dummies) but modify the exchange rate equation of the VECM in the sense that we allow for changes in the adjustment parameter during each period of interventions. These changes depend on the magnitude of the interventions in each intervention period, i.e. we interrelate each error correction term with the volume of interventions. From this point of view, we are able to evaluate the additional adjustment effects during each period that stem from the strength of the intervention behavior. Hence, the exchange rate equation in the VECM becomes

$$\Delta X_t^S = \mu^S + \sum_{i=1}^{5} \alpha_i{}^S ECT_{i,t-1} + \sum_{i=1}^{5} \sum_{m=1,2,3,4,5,6} \alpha_i{}^S ECT_{i,t-1} Int_{m,t-1} + \sum_{i=1}^{3} \Lambda^S X_{t-i} + \sum_{i=0}^{3} \Xi^S Z_{t-i} + D_t + \varepsilon_t \tag{15}$$

while all other equations remain unchanged. The term α_i in Eq. (15) denotes the adjustment coefficient in the *i*-th error correction term. The variables $Int_{m,t-1}$ capture the intervention volume during each *m*-th intervention period.[21] The terms Λ^S and Ξ^S are matrices of coefficients regarding the lagged endogenous variables X_{t-i} and exogenous variables Z_{t-i}. Dummy variables are captured by D_t and μ^S is an intercept. In contrast to the estimation of the long-run relationship, we include the fifth intervention period again. Concerning the modi-

[21] Since we do not have intervention volumes before 1991 we proxy them with the help of changes in foreign exchange reserves. We expect that changes due to true interventions should be greater than valuation effects.

fied exchange rate equation, the results from the re-estimated VECM are presented in Table 6, where we focus solely on the cointegration vectors three and four.

Table 6 about here

In accordance with the maximum likelihood estimates, the dollar-yen exchange rate adjusts significantly to equilibrium errors of the third and fourth error correction term. The fourth error correction term reflects the long-run relationship of the exchange rate with its fundamentals (stemming from the monetary model). Based upon conventional significance levels, it turns out that the adjustment is faster in the second and fourth intervention period as compared to the overall effect for both the third and the fourth term. From these results, it seems that Central Bank interventions have partly improved the adjustment towards its equilibrium path. Since we relate intervention volumes to changes in the adjustment coefficient, we are able to deliver evidence that interventions provide the reasons for our results. Interestingly, this is true for both error correction terms. Hence, interventions increase the adjustment speed towards both long-run empirical relationships between exchange rates and fundamentals at the same time. However, the effects in both periods differ with respect to their economic importance. Although the effects are statistically significant in both periods, the adjustment speed is only increased remarkably in the second intervention period. From this point of view, this can only be seen as an indication of successful interventions in a long-run perspective. Furthermore, during the first, third, fifth, and sixth intervention periods no additional effect can be identified empirically. It is worth mentioning that the two periods with additional effects are associated with longer lasting interventions (see, again, Table 1). In addition, the second period is characterized by coordinated interventions, as described in Section 2.3. This is consistent with the literature, which states that coordinated interventions made known to the public are more likely to succeed (Beine et al., 2009; Fratzscher, 2009b).

Our results indicate that interventions have not been efficient in terms of reinforcing the self-adjusting behavior of the exchange rate in every period. This is in line with further approaches, we applied. We also experimented with smooth transition models in which interventions enter the transition variable.[22] However, the results give no clear evidence of the smooth transition types of non-linearity with monthly data. The reason for this might be that those periods are very heterogeneous, and smooth transition adjustments taking interventions into account can only be measured using daily data.[23]

[22] We estimated a STR-VECM in which the transition function was very similar to Reitz and Taylor (2008).

[23] See, for example, Reitz and Taylor (2012) for the dollar-yen exchange rate.

4. Conclusion

In this paper we have conducted an empirical examination of the relevance of periods of interventions in the dollar-yen exchange rate for the long-run relationship. From this we can draw some major conclusions. Our findings clearly suggest that one needs to account for periods of massive interventions when modeling the long-run relationship between exchange rates and fundamentals. The intervention periods identified are important when modeling the long-run link between exchange rates and fundamentals. Long-run coefficients as well as adjustment coefficients are in line with theory. In addition, we can show that the volume of the interventions sometimes interacts with the adjustment to the long-run value. It can be stated that interventions support the adjustment in some periods. Economically relevant effects seem only to exist in periods of coordinated interventions. These results suggest that coordinated interventions had an influence on the link between the dollar-yen exchange rate and its monetary fundamentals.

Insofar as the judgment of efficiency with regard to interventions is concerned, our results do not yield clear-cut answers concerning the question of whether such interventions are successful in achieving a specific level in the exchange rate. What we can say, however, is that in the Japanese case interventions helped stabilize a long-term relationship between fundamentals and the dollar-yen exchange rate in periods of widely accepted misalignments. The fact that significant intervention periods can be related to coordinated interventions (second period) support the literature that coordinated interventions that are made known to the public are more likely to succeed (e.g. Beine et al., 2009; Fratzscher, 2009b).

With regard to the different intervention channels, it seems therefore reasonable to assume that the signaling and the coordination channels are important in the long run. The reason for this is that oral statements or interventions made publicly available and which are in line with the stance of monetary policy give market participants a guideline when it comes to building expectations. If, for example, the authorities state that they are willing to bring the exchange rate back to its fundamental value, as was done in the Plaza Agreement, market participants may also pay more attention to these factors. However, our results do not provide a general general justification of interventions. From a general point of view, it seems that central banks will struggle when trying to influence a floating exchange rate in a single-handedly approach. An interesting question which is currently under investigation by the authors is whether an empirically established fundamental value is useful in explaining the intervention behavior of the BOJ in a policy function framework based on daily exchange rates.

References

Almekinders, G. and S. Eijffinger (1996): A Friction Model of Daily Bundesbank and Federal Reserve Intervention, in: *Journal of Banking and Finance*, Vol. 20(8), pp. 1365-1380.

Altavilla, C. and P. De Grauwe (2010): Non-linearities in the Relation between the Exchange rate and its Fundamentals, in: *International Journal of Finance and Economics*, Vol. 15(1), pp. 1-21.

Balassa, B. (1964): The Purchasing-Power Parity Doctrine: A Reappraisal, in: *Journal of Political Economy*, Vol. 72 (6), pp. 584-596.

Beckmann, J., A. Belke and M. Kühl (2011): Cointegration, Structural Breaks and Monetary Fundamentals of the Dollar/Yen Exchange, in: *International Advances in Economic Research*, 17(4), pp. 397-412.

Beine, M., O. Bernal, J.Y. Gnabo and C. Lecourt (2009): Intervention Policy of the BoJ: A Unified Approach, in: *Journal of Banking and Finance*, Vol. 33(5), pp. 904-913.

Branson, W.H. (1977): Asset Markets and Relative Prices in Exchange Rate Determination, in: *Sozialwissenschaftliche Annalen*, Vol. 1, pp. 69-89.

De Grauwe, P. and M. Grimaldi (2006): Exchange Rate Puzzles: A Tale of Switching Attractors, in: *European Economic Review*, Vol. 50(1), pp.1-33.

Dominguez, K. M. and J. A. Frankel (1993): Does Foreign-Exchange Intervention Matter? The Portfolio Effect, in: *American Economic Review*, Vol. 83(5), pp. 1356-1369.

Dominguez, K.M. (2006): When do Central Bank Interventions Influence Intra-Daily and Longer-Term Exchange Rate Movements?, in: Journal of International Money and Finance, Vol. 25(7), pp. 1051–1071.

Dominguez, K.M. (1998): The *Dollar Exposure of Japanese Companies*, in: *Journal of the Japanese and International Economies*, Vol. 12(4), pp. 388-405.

Dornbusch, R. (1976): The Theory of Flexible Exchange Rate Regimes and Macroeconomic Policy, in: *Scandinavian Journal of Economics*, Vol. 78(2), pp. 255-275.

Fatum, R. and M.M. Hutchison (2005): Foreign Exchange Intervention and Monetary Policy in Japan, 2003-04, in: *International Economics and Economic Policy*, Vol. *2*(2-3), pp. 241-260.

Fatum, R (2009): Official Japanese Intervention in the JPY/USD Exchange Rate, Market: Is It Effective and Through Which Channel Does It, in: *Institute for monetary and economic Studies*, IMES Discussion Paper No. 2009-E-12.

Frankel, J. (1979): On the Mark: A Theory of Floating Exchange Rates Based on Real Interest Differentials, in: *American Economic Review*, Vol. 69(4), pp. 610-622.

Frenkel, J.A. (1976): A Monetary Approach to the Exchange Rate: Doctrinal Aspects and Empirical Evidence, in: *The Scandinavian Journal of Economics*, Vol. 78(2), pp. 200-224.

Fratzscher, M. (2008): Communication and Exchange Rate Policy, in: *Journal of Macroeconomics*, Vol. 30(4), pp. 1651-1672.

Fratzscher, M. (2009a): What Explains Global Exchange Rate Movements during the Fnancial Crisis?, in: *Journal of International Money and Finance*, Vol. 28(8), pp. 1390-1407.

Fratzscher, M. (2009b): How Successful is the G7 in Managing Exchange Rates?, in: *Journal of International Economics*, Vol. 79(1), pp. 78-88.

Frenkel, M., C. Pierdzioch and G. Stadtmann (2005): The Effects of Japanese Foreign Exchange Market Interventions on the Yen/ U.S. Dollar Exchange Rate Volatility, in: *International Review of Economics and Finance*, Vol. 14(1), pp. 27-39.

Galati, G., W. Melick and M. Micu (2005): Foreign Exchange Market Intervention and Expectations: The Yen/Dollar Exchange Rate, in: *Journal of International Money and Finance*, Vol. 24(6), pp. 982-1011.

Goldberg, M.D. (2000): On Empirical Exchange Rate Models: What Does a Rejection of the Symmetry Restriction on Short-Run Interest Rates Mean?, in: *Journal of International Money and Finance*, Vol. 19(5), pp. 673-688.

Harrod, R. (1939): *International Economics*, Cambridge University Press, Cambridge.

Haynes, S. and J. Stone (1981): On the Mark: Comment [On the Mark: A Theory of Floating Exchange Rates Based on Real Interest Differential], in: *American Economic Review*, Vol. 71(5), pp. 1060-1067.

Hillebrand, E. and G. Schnabl (2008): A Structural Break in the Effects of Japanese Foreign Exchange Intervention on Yen/Dollar Exchange Rate Volatility, in: *International Economics and Economic Policy*, Vol. 5(4), pp. 389-401.

Hillebrand, E. and G. Schnabl (2003): *The Effects of Japanese Foreign Exchange Intervention: GARCH Estimation and Change Point Detection*, Departmental Working Papers No. 2003-09.

Hoshikawa, T. (2008): The Effect of Intervention Frequency on the Foreign Exchange Market: The Japanese Experience, in: *Journal of International Money and Finance*, Vol. 27(4), pp. 547-559.

Hutchison, M. (1984): Official Japanese Intervention in Foreign Exchange Markets- Leaning Against the Wind, in: *Economic Letters,* Vol. 15(1-2), pp. 115-120.

Ito T (2003): Is Foreign Exchange Intervention Effective? The Japanese Experiences in the 1990s, in: Mizen P. (ed) Monetary History Exchange Rates and Financial Markets, Essays in Honor of Charles Goodhart, Vol. 2., Edward Elgar, Cheltenham UK, pp. 126-153.

Ito, T. and T. Yabu (2007): What Prompts Japan to Intervene in the Forex Market? A New Approach to a Reaction Function, in: *Journal of International Money and Finance*, Vol. 26(2), pp.193-212.

Johansen, S. and K. Juselius (1994): Identification of the Long-Run and the Short-Run Structure: An Application to the ISLM Model, in: *Journal of Econometrics*, Vol. 63(1), pp. 7-36.

Johansen, S. and K. Juselius (1992): Testing Structural Hypotheses in a Multivariate Cointegration Analysis of the PPP and the UIP for the UK, in: *Journal of Econometrics*, 53(1-3) 1992, pp. 211-244.

Johansen, S. (1988): Statistical Analysis of Cointegration Vectors, in: *Journal of Economic Dynamics and Control*, Vol. 12(2-3), pp. 231-254.

Juselius, K. (2006): The Cointegrated VAR Approach: Methodology and Applications, Oxford University Press, Oxford.

Juselius, K. and R. MacDonald (2004): International Parity Relationships between the USA and Japan, in: *Japan and the World Economy*, Vol. 16(1), pp. 17-34.

Komiya, R. and M. Suda (1983): *Japan's Foreign Exchange Policy 1971-82*, ALLEN & UNWIN, Crows Nest.

MacDonald, R. and M. Taylor (1994): The Monetary Model of the Exchange Rate: Long-run Relationships, Short-run Dynamics and how to Beat a Random Walk, in: *Journal of International Money and Finance*, Vol. 13(3), pp. 276-290.

Mark, N. (1995): Exchange Rates and Fundamentals: Evidence on Long-Horizon Predictability, in: *American Economic Review*, Vol. 85(1), pp. 201-218.

Morel, C. and J. Teiletche (2004): Do Interventions in Foreign Exchange Markets Modify Investors' Expectations? The Experience of Japan Between 1992 and 2003*,* University of Paris-Dauphine Working Paper.

Obsteld, M. (1990): A Model of Currency Depreciation and the Debt-Inflation Spiral, in: *Journal of Economic Dynamics and Control*, Vol. 15(1), pp. 151–177.

Rahbek, A., E. Hansen and J. G. Dennis (2002): ARCH Innovations and their Impact on Cointegration Rank Testing, Department of Theoretical Statistics, in: *Centre for Analytical Finance,* Working Paper no.22, University of Copenhagen.

Reitz, S. and M.P. Taylor (2008): The Coordination Channel of Foreign Exchange Intervention: a Nonlinear Microstructural Analysis, in: *European Economic Review*, Vol. 52(1), pp.55-76.

Reitz, S. and M.P. Taylor (2012): FX Intervention in the Yen-US Dollar Market: a Coordination Channel Perspective, in: *International Economics and Economic Policy*, Vol.9 (2), pp.111-128.

Samuelson, P. (1964): Theoretical Notes on Trade Problem, in: *Reviews of Economics and Statistics*, Vol. 46 (2), pp. 145-154.

Sarno, L. and M. P. Taylor (2001): Official Intervention in the Foreign Exchange Market: is it Effective and, if so, how Does It Work?, in: *Journal of Economic Literature,* Vol. 39(3), pp. 839-868.

Takagi, S. (1991): Foreign Exchange Market Intervention and Domestic: Monetary Control in Japan, 1973-1989, in: *Japan and the World Economy,* Vol. 3(2), pp. 147-180.

Taylor, M.P. (2005): Official Foreign Exchange Intervention as a Coordination Signal in the Dollar-Yen Market, in: *Pacific Economic Review*, Vol. 10(1), pp. 73-82.

Volz, U. and M. Fujimura (2011): The Political Economy of Japanese Monetary and Exchange Rate Policy, in: *Economic Review*, Vol. 1(1), pp. 3-46.

Watanabe, T and K. Harada (2006): Effects of the Bank Japan´s Intervention on Yen/ Dollar Exchange Rate Volatility, in: *Journal of the Japanese and International Economics*, Vol. 20(1), pp. 99-111.

Wolff, C.C.P. (1987): Time-Varying Parameters and the Out-of-Sample Forecasting Performance of Structural Exchange Rate Models, in: *Journal of Business and Economic Statistics*, Vol. 5(1), pp. 87-97.

Wu, J. and Y. Hu (2009): New Evidence on Nominal Exchange Rate Predictability, in: *Journal of International Money and Finance*, Vol. 28(6), pp. 1045-1063.

Tables

Table 1: Rank test of the model including interventions

		Including I1, I2, I3, I4, I5, I6			Including I1, I2, I3, I4, I6		
p-r	r	Eig.Value	Trace	P-Value	Eig.Value	Trace	P-Value
11	0	0.304***	700.977	0.000	0.300***	675.217	0.000
10	1	0.274***	563.104	0.000	0.267***	539.427	0.000
9	2	0.244***	441.370	0.000	0.243***	421.529	0.000
8	3	0.200***	335.276	0.000	0.197***	315.919	0.000
7	4	0.152***	250.657	0.003	0.144***	232.427	0.006
6	5	0.141**	187.922	0.042	0.134**	173.383	0.052
5	6	0.095	129.979	0.290	0.097	118.655	0.326
4	7	0.091	91.854	0.433	0.085	80.028	0.597
3	8	0.068	55.730	0.725	0.060	46.225	0.854
2	9	0.048	28.840	0.859	0.033	22.830	0.938
1	10	0.026	10.103	0.913	0.026	10.088	0.829

Note: The table shows Johansen's (1988, 1991) cointegration test. The term r denotes the cointegration rank and p the number of variables. Eig.Value are the Eigenvalues and Trace refer to the trace statistic. The p-values denoted correspond to a simulation with T = 400 and 2500 replications. The terms I1, I2, I3, I4, I5 and I6 refer to the intervention periods specified in the text. * denotes statistical significance at the 10% level, ** at the 5% level and *** at the 1% level.

Table 2: Tests for autocorrelation

		Including I1, I2, I3, I4, I5, I6		Including I1, I2, I3, I4, I6	
LM(1):	$\chi^2(121)$	117.466	[0.574]	115.356	[0.628]
LM(2):	$\chi^2(121)$	137.362	[0.147]	136.363	[0.161]
LM(3):	$\chi^2(121)$	135.714	[0.170]	141.146	[0.102]
LM(4):	$\chi^2(121)$	119.947	[0.510]	122.696	[0.440]

Note: The table shows Lagrange multiplier tests on autocorrelation up to lag *p* (*LM(p))*. LM tests are distributed as χ^2 with degrees of freedom in parentheses. The terms I1, I2, I3, I4, I5 and I6 refer to the intervention periods specified in the text. P-values are in brackets.

Table 3: Exclusion tests for the model including the intervention I1, I2, I3, I4, I5, and I6

r	DGF	5% C.V.	I1	I2	I3	I4	I5	I6
4	4	9.488	11.934**	20.865***	16.439***	7.095	7.011	14.711***
			[0.018]	[0.000]	[0.002]	[0.131]	[0.135]	[0.005]
5	5	11.070	15.874***	21.856***	16.502***	9.848*	10.019*	14.726**
			[0.007]	[0.001]	[0.006]	[0.080]	[0.075]	[0.012]
6	6	12.592	23.847***	29.982***	19.747***	16.128**	13.014**	18.678***
			[0.001]	[0.000]	[0.003]	[0.013]	[0.043]	[0.005]

Note: The table reports likelihood ratio tests on variable exclusion, i.e. whether the variable enters the cointegration vector for the model including interventions. The terms I1, I2, I3, I4, I5 and I6 refer to the intervention periods specified in the text. P-values are in brackets. * denotes statistical significance at the 10% level, ** at the 5% level and *** at the 1% level. DGF denotes degrees of freedom and C.V. are the critical values.

Table 4: Restricted cointegration vectors

	S	m^J	m^{US}	y^J	y^{US}	i^J	i^{US}	π^J	π^{US}	$(p^t/p^{nt})^J$	$(p^t/p^{nt})^{US}$	I1	I2	I3	I4	I6	TREND
CI1				-0.009***		-0.009***		1		-0.450***						-0.070***	-0.000***
				(-13.300)		(-13.300)				(-9.357)						(-5.596)	(-4.155)
CI2			0.169***		0.708***		-0.017		1							-0.098***	-0.002***
			(6.670)		(12.046)		(-15.718)									(-5.159)	(-9.282)
CI3	1								7.732***	-3.780***			0.242***	0.338***	0.230***	-0.216***	
									(9.046)	(-20.837)			(5.329)	(4.704)	(6.411)	(-3.511)	
CI4	1	-1	1	-0.223	1.897***	0.059***	-0.059***					0.433***	0.281***				
				(-1.545)	(16.329)	(7.830)	(-7.830)					(6.291)	(6.306)				
CI5						-0.342***	-0.012***	37.976***	1	-15.502***	-1.221***	0.065***		-0.049***		-2.714***	-0.011***
						(-13.421)	(-10.414)	(326.761)		(-8.423)	(-13.225)	(6.281)		(-5.385)		(-5.632)	(-4.141)

Test of restricted model: $\chi^2(31)$ = 32.057 [0.414].

Note: The table provides the estimates of each cointegration vector (*CI*) with t-statistics in parentheses. * denotes statistical significance at the 10% level, ** at the 5% level and *** at the 1% level. The last row shows the likelihood ratio test for over-identifying restrictions with p-values in bracket. The LR test is distributed as $\chi 2$ with *p* degrees of freedom $\chi^2(p)$. The variable *S* denotes the exchange rate, *m* money supply, *y* real income, *i* short-term interest rates, *π* rates of inflation and *p* the prices of tradables (*t*) and non-tradables (*nt*). The term *US* refer to the USA and *j* to Japan.

Table 5: Adjustment coefficients for the restricted model

	α_1	α_2	α_3	α_4	α_5
Δs	8.435**	0.054	-0.055***	-0.033***	-0.218*
	(-1.980)	(0.695)	(-3.721)	(-2.724)	(-1.945)
Δm^J	1.587	0.004	-0.003	0.007*	-0.041
	(-1.282)	(0.166)	(-0.591)	(-1.849)	(-1.265)
Δm^{US}	-0.169	0.022	0.002	0.004*	0.003
	(-0.232)	(1.674)	(0.991)	(1.874)	(0.131)
Δy^J	2.394	0.063*	-0.018***	0.005	-0.067
	(1.290	(1.846)	(-2.755)	(0.926)	(-1.364)
Δy^{US}	-0.462	-0.013	-0.009***	0.004	0.013
	(-0.481)	(-0.741)	(-2.742)	(-1.540)	(0.525)
Δi^{US}	52.945	6.946***	-0.462***	-0.377***	-1.586
	(1.281)	(9.208)	(-3.250)	(-3.186)	(-1.456)
Δi^J	-118.242***	-1.484**	0.063	-0.304***	3.156***
	(-3.208)	(-2.205)	(0.500)	(-2.874)	(-3.248)
$\Delta \pi^{US}$	1.613***	0.034***	-0.006***	0.001	-0.043***
	(3.078)	(-3.506)	(-3.316)	(0.836)	(-3.090)
$\Delta \pi^J$	-2.676***	-0.011	0.007***	-0.007***	0.070***
	(-4.062)	(-0.904)	(3.124)	(-3.537)	(4.013)
$\Delta(p^t/p^{nt})^J$	2.393***	0.035**	0.004*	-0.003	-0.064***
	(3.099)	(-2.512)	(-1.672)	(-1.335)	(-3.126)
$\Delta(p^t/p^{nt})^{US}$	-4.657***	0.010	0.010***	-0.018***	0.121***
	(-4.969)	(0.603)	(3.058)	(-6.856)	(-4.897)

Note: The table reports the adjustment coefficients towards the long-run equilibrium for the restricted model. The columns α_k contain the adjustment coefficients with respect to the *k*-th error correction term specified in Table 4 and the corresponding t-values, which are in parentheses. The variable *S* denotes the exchange rate, *m* money supply, *y* real income, *i* short-term interest rates, *π* rates of inflation and *p* the prices of tradables (*t*) and non-tradables (*nt*). The term *US* refer to the USA and *j* to Japan. The term *Δ* refers to first differences. * denotes statistical significance at the 10% level, ** at the 5% level and *** at the 1% level.

Table 6: Adjustment effects on the JPY/USD exchange rate during periods of intervention

	α_i	$\alpha_i \times I1$	$\alpha_i \times I2$	$\alpha_i \times I3$	$\alpha_i \times I4$	$\alpha_i \times I5$	$\alpha_i \times I6$
ECT_3	-0.021*	0.190	-0.906***	2.44×10^{-06}	-3.26×10^{-07}**	-6.34×10^{-07}*	-3.68×10^{-08}
	(-1.816)	(0.649)	(-5.677)	(0.914)	(-1.963)	(-1.647)	(-0.818)
ECT_4	-0.038***	-0.013	-0.366**	-5.32×10^{-06}	-5.75×10^{-07}**	1.97×10^{-07}	-1.03×10^{-07}
	(-3.471)	(-0.082)	(-2.178)	(-1.185)	(-2.369)	(0.631)	(-1.109)

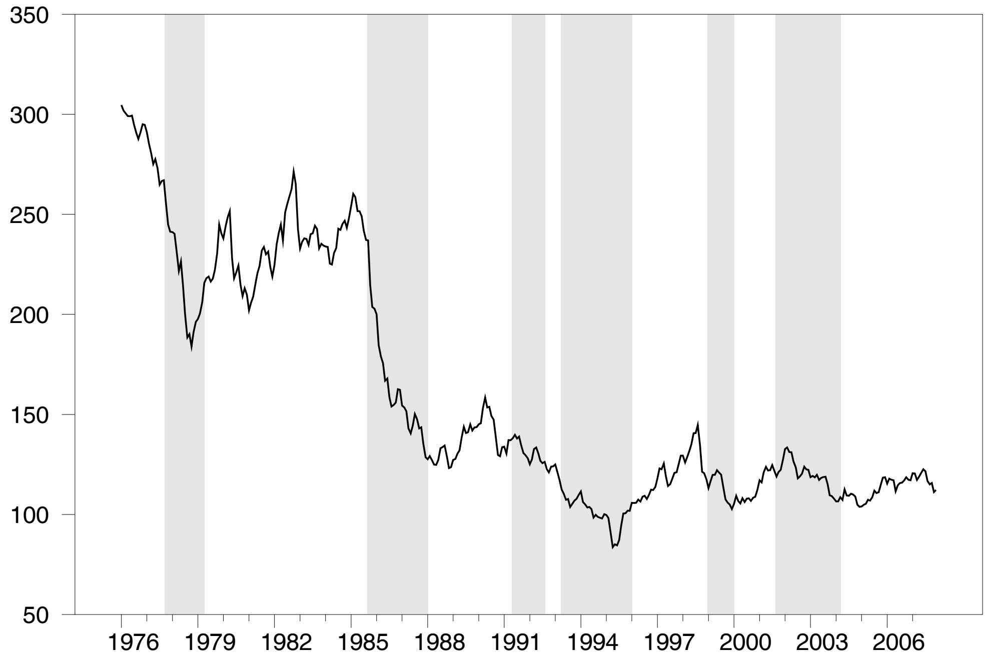
Note: The table reports estimation results from a near VECM carried out by a seemingly unrelated regression approach with HAC standard errors. The VECM is extended with respect to the JPY/USD exchange rate equation at which the superscript *S* hints:

$$\Delta X_t^S = \mu^S + \sum_{i=1}^{5} \alpha_i^S ECT_{i,t-1} + \sum_{i=1}^{5} \sum_{m=1,2,3,4,6} \alpha_i^S ECT_{i,t-1} I_{m,t-1} + \sum_{i=1}^{3} \Lambda^S X_{t-i} + \sum_{i=0}^{3} \Xi^S Z_{t-i} + D_t + \varepsilon_t$$

. The term α_i denotes the adjustment coefficient on the *i*-th error correction term (ECT). An indicator function for the *m*-th intervention period is given by $I_{m,t-1}$. The terms Λ^S and Ξ^S are matrices of coefficients regarding the lagged endogenous variables X_{t-i} and exogenous variables Z_{t-i}. Dummy variables are captured by D_t and μ^S is an intercept. t-values are in parentheses. *, ** and *** denote significance at the 10%, 5% and 1% levels. The terms I1, I2, I3, I4, I5 and I6 refer to the intervention periods specified in the text.

Figures

Figure 1: Path of the Yen-Dollar exchange rate between 1975 and 2007 and periods of massive foreign exchange intervention by the Bank of Japan



Note: The graph shows the development of the Yen/USD exchange rate between January 1976 and December 2007 in conjunction with periods of massive intervention (shaded areas) as defined in the main text.

The following ROME Discussion Papers have been published since 2007:

1	2007	Quo vadis, Geldmenge? Zur Rolle der Geldmenge für eine moderne Geldpolitik	Egon Görgens Karlheinz Ruckriegel Franz Seitz
2	2007	Money and Inflation. Lessons from the US for ECB Monetary Policy	Ansgar Belke Thorsten Polleit
3	2007	Two-Pillar Monetary Policy and Bootstrap Expectations	Peter Spahn
4	2007	Money and Housing – Evidence for the Euro Area and the US	Claus Greiber Ralph Setzer
5	2007	Interest on Reserves and the Flexibility of Monetary Policy in the Euro Area	Ulrike Neyer
1	2008	Money: A Market Microstructure Approach	Malte Krueger
2	2008	Global Liquidity and House Prices: A VAR Analysis for OECD Countries	Ansgar Belke Walter Orth Ralph Setzer
3	2008	Measuring the Quality of Eligible Collateral	Philipp Lehmbecker Martin Missong
4	2008	The Quality of Eligible Collateral and Monetary Stability: An Empirical Analysis	Philipp Lehmbecker
5	2008	Interest Rate Pass-Through in Germany and the Euro Area	Julia von Borstel
1	2009	Interest Rate Rules and Monetary Targeting: What are the Links?	Christina Gerberding Franz Seitz Andreas Worms
2	2009	Current Account Imbalances and Structural Adjustment in the Euro Area: How to Rebalance Competitiveness	Ansgar Belke Gunther Schnabl Holger Zemanek
3	2009	A Simple Model of an Oil Based Global Savings Glut – The “China Factor” and the OPEC Cartel	Ansgar Belke Daniel Gros
4	2009	Die Auswirkungen der Geldmenge und des Kreditvolumens auf die Immobilienpreise – Ein ARDL-Ansatz für Deutschland	Ansgar Belke

5	2009	Does the ECB rely on a Taylor Rule? Comparing Ex-Post with Real Time Data	Ansgar Belke Jens Klose
6	2009	How Stable Are Monetary Models of the Dollar-Euro Exchange Rate? A Time-varying Coefficient Approach	Joscha Beckmann Ansgar Belke Michael Kühl
7	2009	The Importance of Global Shocks for National Policymakers – Rising Challenges for Central Banks	Ansgar Belke Andreas Rees
8	2009	Pricing of Payments	Malte Krüger
1	2010	(How) Do the ECB and the Fed React to Financial Market Uncertainty? The Taylor Rule in Times of Crisis	Ansgar Belke Jens Klose
2	2010	Monetary Policy, Global Liquidity and Commodity Price Dynamics	Ansgar Belke Ingo G. Bordon Torben W. Hendricks
3	2010	Is Euro Area Money Demand (Still) Stable? Cointegrated VAR versus Single Equation Techniques	Ansgar Belke Robert Czudaj
4	2010	European Monetary Policy and the ECB Rotation Model Voting Power of the Core versus the Periphery	Ansgar Belke Barbara von Schnurbein
5	2010	Short-term Oil Models before and during the Financial Market Crisis	Jörg Clostermann Nikolaus Keis Franz Seitz
6	2010	Financial Crisis, Global Liquidity and Monetary Exit Strategies	Ansgar Belke
7	2010	How much Fiscal Backing must the ECB have? The Euro Area is not the Philippines	Ansgar Belke
8	2010	Staatliche Schuldenkrisen – Das Beispiel Griechenland	Heinz-Dieter Smeets
9	2010	Heterogeneity in Money Holdings across Euro Area Countries: The Role of Housing	Ralph Setzer Paul van den Noord Guntram B. Wolff
10	2010	Driven by the Markets? ECB Sovereign Bond Purchases and the Securities Markets Programme	Ansgar Belke

11	2010	Asset Prices, Inflation and Monetary Control – Re-inventing Money as a Policy Tool	Peter Spahn
12	2010	The Euro Area Crisis Management Framework: Consequences and Institutional Follow-ups	Ansgar Belke
13	2010	Liquiditätspräferenz, endogenes Geld und Finanzmärkte	Peter Spahn
14	2010	Reinforcing EU Governance in Times of Crisis: The Commission Proposals and beyond	Ansgar Belke
01	2011	Current Account Imbalances in the Euro Area: Catching up or Competitiveness?	Ansgar Belke Christian Dreger
02	2011	Volatility Patterns of CDS, Bond and Stock Markets before and during the Financial Crisis: Evidence from Major Financial Institutions	Ansgar Belke Christian Gokus
03	2011	Cross-section Dependence and the Monetary Exchange Rate Model – A Panel Analysis	Joscha Beckmann Ansgar Belke Frauke Dobnik
04	2011	Ramifications of Debt Restructuring on the Euro Area – The Example of Large European Economies' Exposure to Greece	Ansgar Belke Christian Dreger
05	2011	Currency Movements Within and Outside a Currency Union: The Case of Germany and the Euro Area	Nikolaus Bartzsch Gerhard Rösl Franz Seitz
01	2012	Effects of Global Liquidity on Commodity and Food Prices	Ansgar Belke Ingo Bordon Ulrich Volz
02	2012	Exchange Rate Bands of Inaction and Play-Hysteresis in German Exports – Sectoral Evidence for Some OECD Destinations	Ansgar Belke Matthias Göcke Martin Günther
03	2012	Do Wealthier Households Save More? The Impact of the Demographic Factor	Ansgar Belke Christian Dreger Richard Ochmann
04	2012	Modifying Taylor Reaction Functions in Presence of the Zero-Lower-Bound – Evidence for the ECB and the Fed	Ansgar Belke Jens Klose

05	2012	Interest Rate Pass-Through in the EMU – New Evidence from Nonlinear Cointegration Techniques for Fully Harmonized Data	Joscha Beckmann Ansgar Belke Florian Verheyen
06	2012	Monetary Commitment and Structural Reforms: A Dynamic Panel Analysis for Transition Economies	Ansgar Belke Lukas Vogel
07	2012	The Credibility of Monetary Policy Announcements: Empirical Evidence for OECD Countries since the 1960s	Ansgar Belke Andreas Freytag Jonas Keil Friedrich Schneider
01	2013	The Role of Money in Modern Macro Models	Franz Seitz Markus A. Schmidt
02	2013	Sezession: Ein gefährliches Spiel	Malte Krüger
03	2013	A More Effective Euro Area Monetary Policy than OMTs – Gold Back Sovereign Debt	Ansgar Belke
04	2013	Towards a Genuine Economic and Monetary Union – Comments on a Roadmap	Ansgar Belke
05	2013	Impact of a Low Interest Rate Environment – Global Liquidity Spillovers and the Search-for-yield	Ansgar Belke
06	2013	Exchange Rate Pass-Through into German Import Prices – A Disaggregated Perspective	Joscha Beckmann Ansgar Belke Florian Verheyen
07	2013	Foreign Exchange Market Interventions and the $-¥ Exchange Rate in the Long Run	Joscha Beckmann Ansgar Belke Michael Kühl