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Explaining the Dollar-Euro Rate: Do Stock Market Returns Matter?

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Abstract: This paper investigates how US and European equity markets affected the US dollar-euro rate from the introduction of the euro through April 2001. More detailed the following questions are raised: First, do movements in the stock market help to explain movements in the exchange rate? Second, how large is the impact of stock market returns on the exchange rate? And third, does the exchange rate respond differently to different equity markets? The investigation was carried out using daily data within a vector-autoregression model (VAR). Surprisingly, positive returns on US equities as well as on European stock markets had a negative impact on the US dollar-euro rate. Quantitatively, the US dollar-euro rate seems to be more influenced by European stock markets compared to US stock markets. Further, there is evidence for a somewhat weaker impact of technology stock indices on the US dollar-euro rate compared with broader market indices. Finally, the long-term interest rate differential seems to contain more information about exchange rate movements than the short-term interest rate differential.

Keywords: Exchange Rates, Information Share
JEL classification: C32, F31

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1 Introduction

On January 1, 1999 the euro was introduced as a new currency on the international financial markets representing eleven member states which irrevocably fixed their domestic currencies against the newly created euro.[1] Over the next two years the euro almost steadily depreciated against the major currencies (see figure 1 for the dollar-euro rate). This gave reason to an extensive discussion about the source(s) of that widely unexpected performance of the euro on foreign exchange markets. This paper investigates how the main equity markets influenced the external value of the euro from its start through April 2001.

More detailed the following questions are raised:

1. Do movements in the stock market help to explain movements in the exchange rate?
2. How large is the impact of stock market returns on the exchange rate?
3. Does the exchange rate respond differently to different equity markets?

The investigation was carried out using a vector-autoregression model (VAR).

The remainder of the paper is organized as follows: After presenting the results of earlier studies on this subject in section two, section three introduces the framework for our analysis. Section four gives details on the data, descriptive statistics, and specification tests. In section five the estimation results are presented. Section six concludes.

2 Previous Studies

In its May 2001 World Economic Outlook (WEO) the International Monetary Fund (IMF) discusses possible sources of the weakness of the euro and the strength of the US dollar with a closer look at the contribution of exchange rate models to explain observed facts. Conventional theory predicts an appreciation of the domestic currency when the current account is in surplus (current transactions imply a higher demand for home currency) or domestic interest rates exceed foreign interest rates (excess returns increase the demand for domestic currency). But, in practice, the euro depreciated despite the record current account deficit of the US, the interest rate hikes of the European Central Bank, and the interest rate cuts of the Federal Reserve. Another explanation emphasizes the bilateral portfolio equity flows

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[1] Greece joined the European Monetary Union at the beginning of 2001 as its twelfth member.

out of the euro area.[2] Net capital inflows into the US increased from $25 billion in the early 1990's to almost $500 billion in 2000, with increasing weight on government agency bonds, corporate bonds, and in particular equities.[3] Further, there is a considerable increase of net inflows from the euro area, which is not the case for inflows from Japan. The empirical investigation carried out in the May 2001 WEO yields the following results:[4]

- Equity flows matter for the dollar-euro rate, but not for the yen-dollar rate.

- There is little evidence for the importance of merger and acquisition flows for the (dollar-euro and yen-dollar) exchange rate.

- No significant impact of net bond flows on the exchange rate, either dollar-euro or yen-dollar.

- The long-term interest rate differentials matter for the dollar-euro as well as the yen-dollar rate, while short-term interest rate differentials do not.

The increasing weight of equity flows emphasizes the importance of future growth prospects for the determination of the exchange rate.

Along those lines, Corsetti and Pesenti (1999) argue in their early assessment of EMU that the growth differential accounts for the observed depreciation up to that time. The depreciation of the euro went in line with the revisions of growth forecasts for both currency areas. But even now, when growth forecasts for the US are sharply revised downwards, the euro does not seem to gain in value.

Cohen and Loisel (2000) investigated the euros performance from January 1999 through March 2000. Within their framework, which is closely related to ours, they used daily Morgan Stanley Capital International (MSCI) stock market indices and the short-term interest rate differential between the US and Euroland to explain daily movements of the dollar-euro rate. Impulse response analysis surprisingly indicated that the euro depreciated after a positive supply shock within the euro area (measured by a positive innovation to the MSCI index for Euroland), a result which is confirmed in this study. They provided a Mundell-Fleming type of explanation to their results. According to Cohen and Loisel (2000), coordination failure among EMU member coun-

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[2] See IMF (2001), p. 70 and the references given there.

[3] See IMF (2001), pp. 70-71.

[4] See IMF (2001), pp. 72-73. Bivariate regressions using quarterly data covering the period from 1988 through 2000 were estimated. Explanatory variables in the bivariate regressions were (a) current account and capital flow variables such as bilateral current account balance, bilateral net bond flows, bilateral net equity flows, and net foreign investment; (b) traditional underlying factors such as long-term and short-term interest rate differentials, and relative current growth; as well as (c) alternative underlying factors such as relative stock returns and relative expected growth.

tries let their fiscal policies be too tight, causing the depreciation of the euro. In an environment of low demand in the euro area, a positive supply shock needed to be absorbed outside the euro area through a depreciated currency. Compared to that, demand in the US was strong; a supply shock in the US was absorbed internally. However, this explanation does not hold for the yen-dollar rate. While fiscal policy in Japan can be considered as loose, overall demand is rather low.[5] Within the Mundell-Fleming set-up, it is excess demand which finally causes the appreciation of the home currency. A positive supply shock in Japan should therefore have the same consequences for the yen (i.e. depreciate the currency) as a positive supply shock in the euro area for the euro.

A different approach to explain exchange rate movements does not rely so heavily on fundamentals. Obstfeld and Rogoff (2000) called the disconnection of exchange rates from fundamentals an "outstanding puzzle in international finance".[6] Meese and Rogoff (1983) found that macroeconomic models can not predict exchange rates better than a random walk, at least at short horizons. Baxter and Stokman (1989) emphasized the mismatch of exchange rate volatility with variations of fundamental macroeconomic variables under a floating exchange rate regime. DeGrauwe (2000) provides an intuitive explanation for the disconnection-puzzle. He argues that there is "great uncertainty about the true equilibrium value of the exchange rate".[7] The uncertainty emerges for two reasons: First, the difficulty to predict future values of fundamentals, and second, the uncertainty of the transmission process from the fundamentals to the exchange rate. Hence, speculative dynamics arise in foreign exchange markets in which chartists interact with fundamentalists. "Exchange rate movements themselves 'frame' ('anchor') the markets perception of fundamental strength or weakness of the economy".[8] An appreciating currency must be a sign of a strong economy. Within that frame new information will be evaluated. Agents tend to select news which corroborate their perception and disregard news which are contrary to their beliefs. This process can only continue as long as the discrepancy between beliefs and facts becomes not too large.

Sinn and Westermann (2001) claimed that currency substitution accounts for the weak euro. DM banknotes circulating in Eastern Europe and in the black economy in Europe as a whole are converted into other (hard)

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[5] According to the May 2001 World Economic Outlook Japan's output gap for 2000 was -3.3 percent of GDP.

[6] Obstfeld and Rogoff (2000), p. 31. Obstfeld and Rogoff (2000) presented a model with transaction costs to explain the disconnection of exchange rates and prices.

[7] De Grauwe (2000), p. 16.

[8] De Grauwe (2000), p. 27.

currencies, mainly the US-dollar, due to uncertainty about the changeover or to avoid bank transactions. They argue that the residual of their estimated demand function for the German monetary base reflects that substitution process. However, it remains unclear, whether the unexplained decline of the German monetary base is due to the substitution of DM-cash holdings with US-dollar holdings in Eastern Europe and/or the black economy or due to substitutional effects between the monetary base and other components of broader monetary aggregates.

Following the evidence presented in IMF (2001), our study concentrates on the role of equity returns for exchange rate movements and extends the scope of the analysis of Cohen and Loisel (2000) in three directions. First, we investigate the response of the dollar-euro rate to shocks to different stock markets: technology stocks vs. broader market indices. Second, we try to quantify the size of the impact of the different markets using variance decompositions; and third, we include the long-term interest rate differential into the analysis.

3 Framework of Analysis

3.1 Theoretical Background

A natural starting point for the analysis of exchange rate movements is the well known interest parity (IP). The IP reflects the idea that in equilibrium returns on domestic assets should equal those on foreign assets adjusted for expected exchange rate movements. Hence, the exchange rate adjusts such that expected returns on domestic and foreign assets (in domestic currency) equalize.[9]

In this paper we take a wider interpretation of the uncovered interest parity (UIP), to include stock market returns. Nevertheless, returns on US dollar assets should equal returns on euro denominated assets, adjusted for expected exchange rate movements. Some authors call that relation uncovered asset return parity (UAP).[10]

$$E_{t-1}(e_t) - e_{t-1} = \alpha E_{t-1}(r_t) - \beta E_{t-1}(r_t^*) + \gamma(i_t - i_t^*) \tag{1}$$

Expected movements in the exchange rate ($E_{t-1}(e_t) - e_{t-1}$), (e denotes the log of the exchange rate quoted in units of domestic currency for one unit

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[9] IP in its uncovered form, i.e. with unsettled exchange rate risk performs poor empirically; while the covered IP (exchange rate risk is eliminated through forward transactions) holds almost perfectly.

[10] See for example Fratzscher (2001).

of foreign currency) are a function of expected returns on domestic stocks ($E_{t-1}(r_t)$), expected returns on foreign stocks ($E_{t-1}(r_t^*)$), and the interest rate differential ($i_t - i_t^*$). We assume that the response of the exchange rate to domestic and foreign interest rate innovations is symmetric, while we allow for an asymmetric response to returns on domestic and foreign equities. Positive expected returns on domestic equities, negative expected returns on foreign equities, and a positive interest rate differential should lead to an appreciation of the domestic currency.

Some difficulty arises if one wants to measure the expected movement in the exchange rate. Forward rates are not an appropriate measure, because they are tied to the difference in interest rates over that specific time horizon (covered interest parity, CIP); otherwise there would be an arbitrage opportunity. The same problem applies to expected stock returns. To solve this problem, we used ex post materialized changes in the exchange rate and the relevant stock markets as a proxy for expected changes in these variables. The difference between expected and actual returns is ε_t, a serially uncorrelated zero-mean shock. That deviates, strictly speaking, from the UIP, but nevertheless there may be some merit for an "ex post UIP" or "ex post UAP" (eq. 2).

$$\Delta e_t = \alpha r_t - \beta r_t^* + \gamma(i_t - i_t^*) + \varepsilon_t \tag{2}$$

3.2 Empirical Modeling

3.2.1 Motivation

The investigation was carried out using a vector-autoregression model (VAR), since we are interested in (a) the interdependence of the variables, i.e. the response of one variable to a shock to another variable, and (b) the size of that impact. The variables included in the system are those of the UAP.

$$By_t = \Gamma_0 + \sum_{s=1}^{L} \Gamma_s y_{t-s} + \varepsilon_t \tag{3}$$

Equation (3) gives the structural form of the VAR. y_t is a vector including all variables at time t, Γ_0 is a vector of constants, Γ_s include the coefficients on the lags of y_t, and ε_t is a vector containing the structural shocks. The B matrix describes the contemporaneous interdependence among the variables in the system. Premultiplication by B^{-1} yields the VAR in standard form (eq. (4)) which can be estimated by OLS.

$$y_t = A_0 + \sum_{s=1}^{L} A_s y_{t-s} + e_t \quad , \text{with} \quad A_x = B^{-1}\Gamma_x \quad \text{and} \quad e_t = B^{-1}\varepsilon_t \tag{4}$$

3.2.2 Identifying Restrictions

The common problem in VARs with estimating impulse response functions or variance decompositions is that one has to impose additional identifying restrictions to recover the structural shocks. Having done that, the calculation of the impact of a structural shock on all other variables is straightforward.

To recover the structural shocks we relied on the Choleski decomposition, which factors the variance-covariance matrix (VCV) of the residuals into a single lower triangular matrix P, for which $VCV = PP'$ holds.[11]

$$VCV = 1/T\sum_{t=1}^{T} e_t e_t' = 1/T\sum_{t=1}^{T} B^{-1}\varepsilon_t\varepsilon_t' B^{-1\prime} = B^{-1}DB^{-1\prime} = PP' \quad , \text{with}$$

$$D = 1/T\sum_{t=1}^{T}\varepsilon_t\varepsilon_t'$$

D is the variance-covariance matrix of the structural shocks. D has the variances of the structural shocks on its diagonal, the other elements are zero (the covariances between the structural shocks are zero).

The Choleski decomposition is equivalent to the assumption that a shock to the variable ordered first contemporaneously affects all other variables, a shock to the variable ordered second affects all variables except the first contemporaneously, and so on (a shock to the last variable has a contemporaneous impact only on itself). Because of the lags of each variable included in the VAR all variables affect all other variables in the system with no more than a lag of one period, in our case after one day.

One can justify the use of that particular decomposition by building on the difference in trading hours: the European markets can react to the close of US markets only with a lag of one day. Further we use the daily foreign exchange reference rates from the European Central Bank (ECB), which are determined around 2:15 p.m. ECB time each day, a time when European markets are still open and US markets have not opened yet. These arguments suggest an ordering of these three variables as follows: exchange rate, European market, US market.

However, to adopt a framework as general as possible, we do not stick with a particular ordering (and the implied restrictions). Instead, the system

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[11] Hamilton (1994), pp. 91-92.

was estimated across all possible combinations of the four variables, to let every variable contemporaneously affect the others and in turn being affected contemporaneously by the other variables in the system. There are two reasons for that approach: First, we are interested in the upper and the lower bound of the information share that one variable contributes to the other, and, second, we want to test the sensitivity of our results to the ordering of the variables. The variable ordered first maximizes its impact on all the others, while the variable ordered last finds its impact on the others minimized.

3.2.3 Innovation Accounting

If the variables in the VAR are covariance stationary, then there exists a vector-moving-average representation (VMA), eq. (5).

$$y_t = \mu + \sum_{i=0}^{\infty} \Psi_i e_{t-i} = \mu + \sum_{i=0}^{\infty} \Phi_i \varepsilon_{t-i} \quad \text{, where} \quad \Psi_i = A_1^i \quad \text{and} \quad \Phi_i = \Psi_i B^{-1} = A_1^i B^{-1} \tag{5}$$

The Φ_i matrices contain the coefficients, which describe the impact of the structural shocks on all variables.

$$\Phi_i = \begin{bmatrix} \phi_{11}^{(i)} & \phi_{12}^{(i)} & \phi_{13}^{(i)} & \phi_{14}^{(i)} \\ \phi_{21}^{(i)} & \phi_{22}^{(i)} & \phi_{23}^{(i)} & \phi_{24}^{(i)} \\ \phi_{31}^{(i)} & \phi_{32}^{(i)} & \phi_{33}^{(i)} & \phi_{34}^{(i)} \\ \phi_{41}^{(i)} & \phi_{42}^{(i)} & \phi_{43}^{(i)} & \phi_{44}^{(i)} \end{bmatrix} \tag{6}$$

$\phi_{11}^{(1)}$ is the impact of a structural shock to the first variable on the first variable after one period, $\phi_{42}^{(10)}$ is the impact of a structural shock to the second variable on the fourth variable after ten periods. A plot of row j, column k element of Φ_i as a function of i is called the impulse response function.[12] Summing up the individual $\phi_{jk}^{(i)}$ from $i = 0, ..., I$ gives the accumulated response of variable j to a structural shock to variable k. The accumulated impulse responses of the first difference correspond to the impulse response of the level.

Another tool to describe the interactions among the variables is the forecast error variance decomposition. Starting over from the VMA representation of the VAR, the forecast error n periods ahead is

$$y_{t+n} - E(y_{t+n}) = \sum_{i=0}^{n-1} \Phi_i \varepsilon_{t+n-i} \tag{7}$$

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[12] See Hamilton (1994), p. 319.

The forecast error can be decomposed into the contributions of the individual structural shocks. Since the weights and the variances of the structural shocks are known, it is possible to assign a certain proportion of the total forecast error variance to the variance of each structural shock. We refer to that proportion as the information share.[13]

4 Data, Descriptive Statistics, and Specification Tests

Data. All data is at daily frequency and covers the period from January 4, 1999 through April 30, 2001 for a total of 597 observations. Exchange rates are daily reference rates of the European Central Bank (ECB), obtained from the ECB's website. As stock market returns we considered Dow Jones Euro Stoxx 50 (DJES 50), Nemax 50, Standard & Poor's 500 (S&P 500), Nasdaq 100, and Nikkei 225 (all obtained from datastream). As short-term interest rates we used the Euro Overnight Index Average (Eonia), the overnight rate on Japanese government bonds (both from datastream), and the Federal Funds rate (from the website of the Board of Governors of the Federal Reserve System). Long-term interest rates are 10 year bond yields for Germany, the US, and Japan, obtained from datastream. Daily returns are calculated as the first difference of the log of the specific series. Table 1 displays some descriptive statistics.

Correlations. Changes in the dollar-euro rate are negatively correlated with contemporaneous and one day lagged returns on Euroland stocks as well as on US stocks (see table 2). Stock market returns in Euroland have a larger negative contemporaneous correlation with the dollar-euro rate, while US stock market returns have a larger negative correlation at a lag of one day. Changes in the yen-dollar rate are positively correlated with US stock market returns with a lag of one day, and negatively correlated with Japanese stock market returns.

Stock market returns for the euro area are positively correlated with current and one day lagged returns on US-indices, while the returns on the Japanese Nikkei 225 are only positively correlated with returns on the S&P 500 with a lag of one day. The significant lag of one day may be due to the influence of the US stock markets as the world's largest stock market on other markets and/or to non-overlapping trading hours. Interest rate differentials do not show any significant correlation with any of the other variables.

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[13] For a related application of the forecast error variance decomposition to equity trading see Grammig et al. (2001).

Unit Roots. The dollar-euro rate, the stock market indices in Europe and in the US, and the short-term interest rate differential are found to be I(1).[14] However, the long-term interest rate differential was found to be stationary at the 5% level of significance. The same applies to the time series concerning Japan: the yen-dollar rate, the stock market index, and the short-term interest rate differential are I(1), only the long-term interest rate differential is stationary at the 5% level of significance.

Following the UAP, the variables we want to include in our estimation are the *change* in the exchange rate, the *change* of the stock market indices, and the *level* of the interest rate differential. There seems to be no problem when using the long-term interest rate differential, because then all variables in the system are stationary. However, the short-term interest rate differential raises some difficulties: theory suggests to use the level, the VAR requires stationarity. We decided to estimate both systems. As will be discussed in the next section, it did not really matter, because the short-term interest rate differential (in level as well as in first difference) did not contribute to the explanation of the other variables.

Lag Length. To specify the lag order of the VAR we relied on likelihood ratio tests (LR) and the Akaike Info Criterion (AIC).[15] Using these test statistics we found overwhelming evidence for the inclusion of three lags in VAR-models including the short-term interest rate differential. For VAR-models including the long-term interest rate differential, LR-tests and the AIC improved only marginally when two instead of three lags were used. Since we want to compare the results across different systems, we decided to include three lags in all estimated VARs.

Cointegration. To discriminate between a VAR-specification in first differences and a Vector-errorcorrection (VEC) specification, we followed Johansen to test for cointegration. We found no evidence for a cointegrating relation between the dollar-euro rate, the stock market indices for Europe and the US, and the long-term interest rate differential or any subset of these variables. The same result emerges when the related time series for Japan are tested. Therefore, we stick with the VAR specification in first differences. A cointegrating relation was found when the long-term interest rate differential was replaced by its short-term counterpart. That result also holds for Euroland-US system and the Japan-US system (see table 4). Again, we stress the reader's patience and refer to the next section for a proof that the use of the short-term interest rate differential is inappropriate.

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[14] Tested using DF or ADF tests. The test results are reported in table 3.

[15] For a recent discussion of lag-order selection criteria see Kilian and Ivanov (2001).

5 Estimation Results

5.1 Interest Rate Differentials

Because of the overwhelming theoretical foundation and despite the poor empirical evidence, we considered the short-term interest differential into our set of variables. Since we are investigating the sources of daily exchange rate movements, the overnight interest rates seem to be the appropriate measure. However, as indicated in IMF (2001) and confirmed in this study, long-term interest rates seem to have a considerably higher impact on the exchange rate than short-term interest rates.

5.1.1 The Short-Term Interest Rate Differential

Block exogeneity and block causality tests indicated that a model specification without the short-term interest rate differential is sufficient. Granger-causality tests on the equations of all other variables of the VAR-system also indicated that the null hypothesis that all coefficients on the short-term interest rate differential are zero could not be rejected. Impulse response analysis revealed that unanticipated shocks to the short-term interest rate differential had no significant impact on the exchange rate or stock markets. Estimating a VEC-model, using the cointegrating relation suggested by the Johansen test, did not change that result at all.

5.1.2 The Long-Term Interest Rate Differential

Block exogeneity and block causality tests indicated that a model specification without the long-term interest rate differential is sufficient.[16] However, there is strong evidence in favor of the current value of the long-term interest rate differential. Granger-causality tests indicated that the null hypothesis that all coefficients on the long-term interest rate differential are zero could not be rejected for the exchange rate equation and the DJES 50 equation, but is rejected at the 8% level for the S&P 500 equation (and at the 1% level for long-term interest rate differential equation). Further, impulse response analysis shows a significant impact of the long-term rates on the other variables. Therefore all systems are estimated using the respective long-term interest rate differential.

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[16] The block exogeneity test and the block causality test indicated that the correlation of the residuals is not reduced significantly when the long-term interest rate differential is included. The restrictions were significant at the 14% level and the 77% level, respectively. The large difference is due to the current value of the long-term interest rate differential, which is significant at standard levels.

5.2 Impulse Response Analysis

5.2.1 System with DJ Euro Stoxx 50 and S&P 500

Impulse Response Functions (IRFs) describe the response of a variable to a shock to a certain variable included in the system over a given time horizon. They are estimated by imposing the identifying restrictions of the Choleski decomposition (limited contemporaneous interdependence) across various orderings. Two representative sets of the IRFs and their corresponding two standard deviation confidence intervals are shown in figures 8 and 9. Error bands are computed using the Monte Carlo method.[17] Some fairly robust results emerge:

- The dollar-euro rate, the DJES 50, and the S&P 500 are highly persistent, a positive innovation to itself has a permanent impact. That confirms the result of the unit root tests.

- A positive innovation to the DJES 50 significantly depreciates the euro against the dollar. This result is robust with respect to the ordering of the variables in the VAR.

- A positive shock to the S&P 500 let the dollar significantly appreciate against the euro in the very short run. However, the evidence becomes mixed after a few periods. Depending on the ordering of the variables in the VAR-system, the impact of a positive innovation to the S&P 500 on the US dollar ranges from a significant appreciation over an insignificant appreciation to a significant depreciation.

- The depreciation of the euro after a positive innovation to the DJES 50 is larger than the depreciation of the euro after a positive innovation to the S&P 500, suggesting that the link between the external value of the domestic currency and the domestic stock market is closer for the euro area compared to the US.

- The effect of a positive innovation to the exchange rate (depreciating the dollar and appreciating the euro) on equity prices in the US and Euroland remains unclear.

- A positive innovation to the S&P 500 has a permanent, significantly positive impact on the DJES 50. The effect is about equally splitted into an immediate and a one day lagged impact (if the specification allows for a contemporaneous impact). On the contrary, the impact of a positive innovation to the DJES 50 on the S&P 500 depends on the ordering of the variables,

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[17] Standard deviations of the IRFs are based on 100 simulations of the VAR, where the coefficients of the reduced form VAR model are drawn from a normal distribution conditioned on the variance-covariance matrix of the residuals drawn from an inverse Wishart distribution.

and thus, remains unclear. That is a clear indication that European markets follow US markets.

- Innovations to the long-term interest rate differential, defined as the yield on German government bonds with a remaining maturity of 10 years minus the yield on US government 10year-bonds, have only small and very short-lived effects on the other variables. A positive innovation to the long-term interest rate differential, which could mirror a shock that increases the German bond yield or a shock that lowers the US bond yield, slightly appreciates the euro and let the S&P 500 as well as the DJES 50 increase. These effects become insignificant after a few days.

Most of the results are in line with theory. Positive innovations in a country's stock market or interest rates let its currency appreciate, and stock markets around the world are positively correlated. A more extensive discussion is needed with respect to the impact of innovations in the DJES 50 on the dollar-euro rate.

In the introduction, we highlighted the failure of conventional models to explain the dollar-euro rate; further there seems to be some evidence that equity flows gained in importance for exchange rate movements over the last years, especially for the dollar-euro rate. But what is driving these flows? According to our results, it is not returns. The euro depreciated despite the good performance of equity markets in the euro area. It seems that neither conventional (current transactions and interest rates) nor more recent approaches (equity returns) help to explain the current low of the euro.

That leads to another possible argument, for which only anecdotal evidence exists: There is a deep scepticism against the euro among market participants. Those who were bullish for the euro since its start simply lost a lot of money if they pursued their investment strategy. That argument is in line with the idea of "framing" presented by de Grauwe (2000) and hints at the possible importance of chartist trading in foreign exchange markets. Exchange rate movements itself provide a "frame" in which news are interpreted. Now, when interest rates in the euro area and the US are as narrow as they have not been for a long time, when growth in the US is lower than in Euroland, and even Nasdaq came down, the euro remained weak. All these pieces together were not enough to let the confidence return. On the contrary, it may have deepened the scepticism.

5.2.2 System with Nasdaq 100 and Nemax 50

Turning to the investigation using indices of tech stocks, that is re-estimate all systems using the Nemax 50, the Nasdaq 100 together with the dollar-euro rate and the long-term interest rate differential. IRFs are shown in figures

10 and 11. The main results are qualitatively identical to those reported for the system including the DJES 50 and the S&P 500. In addition some ambiguities disappear. Deviations from the results reported above emerge with respect to the size of the impulse responses. In detail:

- The surprising result of a depreciation of the euro after a positive innovation to the home stock market (here Nemax 50) still holds.

- The IRFs of the exchange rate after a positive innovation to the Nasdaq 100 have now all a negative sign, although some remain insignificant.

- Again, the size of the impact on the exchange rate is larger after a positive innovation to the European index than the US index, suggesting a closer link between equity and foreign exchange markets in Europe compared with the US.

- Another interesting result is that the response of the exchange rate to positive shocks to tech stocks is *smaller* compared with the response to positive shocks to broader market indices. Put it different, Nemax and Nasdaq had a smaller influence on the dollar-euro rate than the S&P or the DJ Euro Stoxx.

- The response of the Nemax 50 to a shock to the Nasdaq 100 is almost identical to the response of the DJES 50 to a shock to the S&P 500. However, the Nasdaq shows a non-ambiguous positive and significant relation to innovations to the Nemax 50.

5.2.3 System with Nikkei 225 and S&P 500

To further enlighten the relation of exchange rate movements and stock market returns, we apply our methodology to the yen-dollar rate, the Nikkei 225, the S&P 500, and the long-term interest rate differential between Japan and the US. IRFs (displayed in figure 12) are remarkably robust with respect to the ordering of the variables. Here, the world is still in line with theory: Positive returns on the Japanese stock market appreciate the yen, while positive returns on the US stock market depreciate the Japanese yen, at least initially (after four periods the impact is reversed to an appreciation of the yen). Thus, there seem to be euro-specific factors which account for the weakness of the euro. Again, there is strong evidence for a closer link between the Japanese stock market and the external value of the yen compared to the link between the US stock market and the external value of the US dollar.

5.3 Information Shares

What is the contribution of innovations in each stock market to the exchange rate? We refer to the proportion of innovation variance in variable i explained by innovations in variable j as its information share. The Choleski factorization of VCV yields an upper bound of the impact for the variable ordered first and a lower bound on the impact for the variable ordered last. Decomposing the forecast error variance across systems with various orderings gives a lower and an upper bound for the information share.

First of all, all variables explain most of their variation over all time horizons itself (see table 6). In general, the information shares change very little when the time horizon is changed. We report figures for a forecast horizon of 20 business days. Innovations to the DJES 50 explain between 2 and 5.6 percent of the volatility of the dollar-euro rate. Innovations to the S&P 500 explain from 1.5 to 2.5 percent of the volatility of the exchange rate. Again, as the impulse response the share of the forecast error variance is lower for tech indices. Innovations to the Nemax 50 explain between 0.4 and 2.3 percent of the volatility of the dollar-euro rate, while innovations to the Nasdaq 100 explain between 0.6 and 2.0 percent of that volatility. Innovations to the long-term interest rate differential explain from 2.4 to 3.9 percent of the volatility of the dollar-euro rate regardless which stock market indices are included. For the explanation of the volatility of the yen-dollar rate the contribution of innovations to the Nikkei 225 range from 2.4 to 2.6 percent, while the contribution of innovations to the S&P 500 is between 2.1 and 2.2 percent, and the contribution of innovations to the long-term interest rate differential is only 0.2 to 0.3 percent. Thus, according to the impulse response functions and the variance decompositions two results emerge: First, European stock markets have a higher impact on the dollar-euro rate than US stock markets, and, second, technology indices have a lower impact on the dollar-euro rate than broader market indices.

As a by-product we obtain some evidence on the integration of stock markets: innovations to the S&P 500 explain between 13.6 and 30.3 percent of the volatility of the DJES 50, and between 14.4 and 14.6 percent of the volatility of the Nikkei 225. On the other side, the S&P 500 is basically unaffected by the Nikkei 225 (0.1-0.4 percent of its volatility is due to innovations to the Nikkei 225) and little affected by the DJES 50 (0.6-22.7 percent of its volatility is due to innovations to the DJES 50). That underlines the sizeable impact of US equity markets on European and Japanese equity markets.

According to the results of our variance decomposition, markets for technology stocks seem to be somewhat less integrated compared with their broader counterparts. Innovations to the Nasdaq 100 explain between 9.4

and 26.6 percent of the volatility of the Nemax 50; innovations to the Nemax 50 explain between 0.1 and 19.2 percent of the volatility of the Nasdaq 100.

6 Conclusion

The depreciation of the euro is at odds with conventional theory. The euro depreciated despite the growing current account deficit of the US, despite the interest rate hikes of the ECB and cuts of the Federal Reserve which narrowed (most recently inverted) the short-term interest rate differential, and despite the narrowing of the long term interest rate differential. But also more recent attempts to explain the weakness of the euro, such as net capital flows, have some shortcomings. Our study provides evidence against the theory that equity returns are the driving force of the weakness of the euro. Even when European stock market performed well the euro depreciated. However, we found some other interesting results. Stock market returns and the long-term interest rate differential seem to be about equally important in explaining movements in the dollar-euro rate, and clearly more important than the short-term interest rate differential. Stock market returns are more important than the long- and the short-term interest rate differential in explaining movements in the yen-dollar rate. Exchange rates and stock markets seem to be linked more closely in the euro area and Japan when compared with the US. The dollar-euro rate seems to be somewhat less affected by technology stock market indices compared to broader market indices.

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A Tables

Series	Obs	Mean	Std Error	Minimum	Maximum
Level of …					
Dollar/Euro	597	0.9842	0.0834	0.8252	1.1790
Yen/Dollar	597	111.9832	6.4399	101.6200	126.3500
DJ Euro Stoxx 50	597	4428.44	655.43	3325.56	5464.43
Nemax 50	597	4615.61	1672.58	1305.25	9603.46
S&P 500	597	1359.87	87.03	1103.25	1527.45
Nasdaq 100	597	2849.65	794.43	1370.75	4704.73
Nikkei 225	597	16484.06	2065.44	11819.70	20833.21
Fed Funds	597	5.59	0.69	4.23	7.03
Eonia	597	3.63	0.94	1.74	5.75
Jap. Gov. Bills Overnight	597	0.17	0.23	0.03	3.00
Germany 10y Bonds	597	4.87	0.53	3.63	5.65
US 10y Bonds	597	5.74	0.52	4.62	6.78
Japan 10y Bonds	597	1.72	0.22	1.04	2.53
Eonia - Fed Funds	597	-1.9659	0.7289	-3.5700	1.1200
Japan Overnight - Fed Funds	597	-5.4268	0.6787	-6.9675	-2.9200
10y Germany - 10y US	597	-0.8700	0.3667	-1.6710	-0.0770
10y Japan - 10y US	597	-4.0133	0.5147	-5.0860	-2.3060
1st difference of the log of …					
Dollar/Euro	596	-0.0005	0.0075	-0.0225	0.0420
Yen/Dollar	596	0.0001	0.0071	-0.0288	0.0300
DJ Euro Stoxx 50	596	0.0004	0.0135	-0.0485	0.0375
Nemax 50	596	-0.0011	0.0311	-0.1279	0.1341
S&P 500	596	0.0000	0.0132	-0.0600	0.0489
Nasdaq 100	596	0.0000	0.0317	-0.1031	0.1720
Nikkei 225	596	0.0001	0.0142	-0.0723	0.0722
1st difference of …					
Fed Funds	596	-0.0009	0.1573	-1.1200	1.2600
Eonia	596	0.0029	0.1550	-0.6900	1.1600
Jap. Gov. Bills Overnight	596	-0.0004	0.1823	-2.1250	1.9375
Germany 10yr Bonds	596	0.0011	0.0578	-0.2240	0.2070
US 10y Bonds	596	0.0021	0.0450	-0.1390	0.1930
Japan 10y Bonds	596	-0.0015	0.0484	-0.3110	0.2810

Table 1: Descriptive Statistics for Exchange Rates and Stock Market Indices

i	DE,DXX (-i)	DE,DXX (+i)	DE,DSP (-i)	DE,DSP (+i)	DXX,DSP (-i)	DXX,DSP (+i)
0	**-0.1820**		-0.0526		**0.4464**	
1	**-0.1015**	0.0903	**-0.1319**	0.0648	**0.3309**	-0.0173
2	-0.0352	0.0046	0.0810	-0.0097	0.0135	-0.1091
3	0.0397	0.0390	0.0140	0.0002	-0.0336	0.0099
4	0.0225	0.0069	-0.0149	0.0896	-0.0370	-0.0247
5	-0.0427	0.0256	-0.0273	0.0394	-0.0331	0.0031
6	0.0245	-0.0094	0.0474	-0.0454	-0.0371	-0.0968
7	0.0502	-0.0601	-0.0047	-0.0136	-0.0025	0.0074
8	-0.0034	0.0142	-0.0101	0.0082	-0.0116	0.0236
9	0.0664	-0.0557	0.0515	-0.0361	-0.1114	0.0217
10	-0.0364	-0.0287	0.0527	-0.0678	0.0007	0.0455

i	DE,DIFF (-i)	DE,DIFF (+i)	DE,DIFFL (-i)	DE,DIFFL (+i)
0	-0.0235		0.0210	
1	-0.0144	-0.0058	0.0491	0.0252
2	0.0095	0.0073	0.0172	0.0320
3	0.0081	-0.0098	0.0188	0.0381
4	0.0154	-0.0101	0.0161	0.0313
5	-0.0140	0.0099	0.0188	0.0332
6	-0.0227	-0.0107	0.0181	0.0382
7	-0.0243	-0.0149	0.0211	0.0234
8	-0.0081	-0.0068	0.0237	0.0361
9	-0.0100	-0.0080	0.0154	0.0419
10	-0.0111	-0.0048	0.0178	0.0519

I	DE,DNEU (-i)	DE,DNEU (+i)	DE,DNAS (-i)	DE,DNAS (+i)	DNEU,DNAS (-i)	DNEU,DNAS (+i)
0	**-0.1244**		**-0.0802**		**0.4005**	
1	**-0.0865**	0.0396	**-0.0934**	0.0688	**0.3068**	-0.0445
2	-0.0024	0.0359	0.0653	0.0069	-0.0262	-0.0269
3	-0.0491	-0.0469	-0.0384	-0.0234	0.0186	0.0225
4	-0.0175	0.0121	-0.0062	0.0637	0.0813	-0.0708
5	-0.0305	0.0774	-0.0270	0.0390	0.0458	0.0574
6	-0.0069	-0.0606	0.0276	-0.0523	-0.0648	-0.0886
7	0.0209	-0.0659	-0.0105	-0.0182	0.0428	0.0729
8	-0.0460	-0.0073	-0.0021	0.0358	0.0216	0.0573
9	0.0540	0.0016	0.0534	-0.0081	-0.0283	0.0203
10	-0.0050	-0.0652	0.0511	0.0035	0.0857	-0.0447

i	DJU,DNIK (-i)	DJU,DNIK (+i)	DJU,DSP (-i)	DJU,DSP (+i)	DNIK,DSP (-i)	DNIK,DSP (+i)
0	0.0571		0.0187		0.0451	
1	**-0.0723**	0.0345	**0.0811**	0.0176	**0.3753**	0.0012
2	**-0.1076**	0.0445	-0.0175	-0.0131	0.0504	-0.0162
3	**-0.1331**	0.0811	-0.1052	-0.0106	-0.0458	-0.0075
4	0.0103	0.0326	-0.0845	0.0119	0.0155	0.0104
5	0.0064	-0.0331	-0.0067	-0.0241	0.0475	-0.0296
6	0.0300	-0.0116	-0.0665	-0.0324	-0.0188	0.0022
7	-0.0059	0.0015	0.0363	-0.0259	-0.0285	-0.0166
8	-0.0814	-0.0113	-0.0405	-0.0069	0.0203	0.0010
9	0.0231	-0.0170	-0.0123	-0.0057	-0.0407	0.0253
10	0.0167	-0.0614	-0.0738	0.0769	-0.1474	-0.0126

i	DJU,DIFFJU (-i)	DJU,DIFFJU (+i)	DJU,DIFFLJ (-i)	DJU,DIFFLJ (+i)
0	-0.0033		0.0331	
1	0.0011	0.0005	0.0524	0.0313
2	-0.0133	-0.0010	0.0465	0.0242
3	-0.0105	-0.0023	0.0559	0.0281
4	0.0245	-0.0058	0.0620	0.0275
5	0.0305	0.0042	0.0887	0.0228
6	0.0067	-0.0152	0.0562	0.0206
7	0.0051	-0.0195	0.0696	0.0142
8	-0.0091	-0.0184	0.0613	0.0176
9	-0.0202	-0.0078	0.0644	0.0128
10	-0.0080	0.0067	0.0585	0.0132

Key: i index of leads (+i) and lags (-i);
1st difference of the log of: US dollar-euro rate (DE), DJES 50 (DXX), S&P 500 (DSP),
Nemax 50 (DNEU), Nasdaq 100 (DNAS), yen-US dollar rate (DJU), Nikkei 225 (DNIK),
Short-term interest rate differential euro-dollar (DIFF) and yen-dollar (DIFFJU),
Long-term interest rate differential euro-dollar (DIFFL) and yen-dollar (DIFFLJ)

Table 2: Correlations of First Differences of Exchange Rates, Stock Market Indices, and Interest Rate Differentials over Various Leads and Lags

	without trend			**including trend**				
Critical Values:	1%	5%	10%	1%	5%	10%		
	-3.43	-2.86	-2.57	-3.96	-3.41	-3.12		
	***	**	*	***	**	*		
Series	Lags included in ADF-test	t-stat on (rho-1)	Level of significance	Lags included in ADF-test	t-stat on (rho-1)	Level of significance	t-stat on trend	Level of significance
Log of ...								
Dollar/Euro	0	-1.859		**0**	**-2.769**		**-2.198**	***
Yen/Dollar	**0**	**-1.037**		0	-0.891		1.009	
DJ Euro Stoxx 50	**0**	**-1.535**		0	-1.233		0.226	
Nemax 50	0	0.140		**0**	**-0.593**		**-2.419**	***
S&P 500	**0**	**-2.562**		0	-2.466		-0.706	
Nasdaq 100	**0**	**-1.380**		0	-0.976		-1.457	
Nikkei 225	0	-1.504		**0**	**-2.344**		**-2.543**	***
Level of ...								
Sh-t int rate diff EU-US	2	-1.288		**2**	**-2.576**		**2.767**	***
L-t int rate diff EU-US	1	-1.329		**1**	**-3.639**	**	**3.441**	***
Sh-t int rate diff JA-US	**2**	**-2.325**		2	-1.904		-0.044	
L-t int rate diff JA-US	**0**	**-2.992**	**	0	-2.774		0.848	
1st difference of the log of ...								
Dollar/Euro	0	-24.488	***					
Yen/Dollar	0	-25.179	***					
DJ Euro Stoxx 50	0	-23.718	***					
Nemax 50	0	-22.942	***					
S&P 500	0	-24.365	***					
Nasdaq 100	1	-19.607	***					
Nikkei 225	0	-24.390	***					
1st difference of ...								
Sh-t int rate diff EU-US	3	-17.112	***					
L-t int rate diff GE-US	0	-33.471	***					
Sh-t int rate diff JA-US	1	-30.735	***					
L-t int rate diff JA-US	0	-25.665	***					

Table 3: Unit Root Tests

Series	$r = 0$	$r \leq 1$
$/E Rate, DJES 50, S&P 500 (all in logs), and Short-Term Int. Rate Diff.	48.25*	14.32
$/E Rate, Nemax 50, Nasdaq 100 (all in logs), and Short-Term Int. Rate Diff.	41.82	17.45
Y/$ Rate, Nikkei 225, S&P 500 (all in logs), and Short-Term Int. Rate Diff.	57.43*	28.34
$/E Rate, DJES 50, S&P 500 (all in logs), and Long-Term Int. Rate Diff.	30.89	15.10
$/E Rate, Nemax 50, Nasdaq 100 (all in logs), and Long-Term Int. Rate Diff.	31.92	15.78
Y/$ Rate, Nikkei 225, S&P 500 (all in logs), and Long-Term Int. Rate Diff.	37.47	22.81
5% (1%) Osterwald and Lenum (1992) Critical Values	47.21 (54.46)	29.68 (35.65)
*,** indicate significance level		

Table 4: Cointegration Tests

DJ Euro Stoxx 50 / S&P 500	Exchange Rate Innovation	DJ Euro Stoxx 50 Innovation	S&P 500 Innovation	Interest Rate Differential Innovation
Exchange Rate $/E	0.934	0.025	0.016	0.025
DJ Stoxx 50	0.040	0.821	0.136	0.002
S&P 500	0.009	0.223	0.757	0.011
Int Rate Diff	0.008	0.038	0.003	0.951
Nemax 50 / Nasdaq 100	Exchange Rate Innovation	Nemax 50 Innovation	Nasdaq 100 Innovation	Interest Rate Differential Innovation
Exchange Rate $/E	0.958	0.012	0.006	0.024
Nemax 50	0.015	0.888	0.095	0.002
Nasdaq100	0.012	0.186	0.796	0.006
Int. Rate Diff	0.006	0.081	0.001	0.912
Nikkei 225 / S&P 500	Exchange Rate Innovation	Nikkei 225 Innovation	S&P 500 Innovation	Interest Rate Differential Innovation
Exchange Rate Y/$	0.952	0.025	0.021	0.002
Nikkei 225	0.010	0.844	0.144	0.001
S&P 500	0.002	0.004	0.989	0.006
Int. Rate Diff	0.002	0.011	0.014	0.973

Table 5: Information Shares of the Home-Market Index, the US-Market Index, the Long-Term Interest Rate Differential, and the Exchange Rate vs the US-Dollar. To obtain the information shares the system was ordered as follows: exchange rate, European (Japanese) stock market, US stock market, and long-term interest rate differential. The time horizon of the forecast error variance decomposition is 20 periods.

DJ Euro Stoxx 50 / S&P 500	Exchange Rate Innovation		DJ Euro Stoxx 50 Innovation		S&P 500 Innovation		Interest Rate Differential Innovation	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
Exchange Rate $/E	0.890	0.934	0.020	0.056	0.015	0.025	0.025	0.039
DJ Stoxx 50	0.010	0.040	0.657	0.851	0.136	0.303	0.002	0.007
S&P 500	0.005	0.009	0.006	0.227	0.756	0.978	0.010	0.017
Int Rate Diff	0.000	0.008	0.011	0.038	0.000	0.018	0.951	0.984
Nemax 50 / Nasdaq 100	Exchange Rate Innovation		Nemax 50 Innovation		Nasdaq 100 Innovation		Interest Rate Differential Innovation	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
Exchange Rate $/E	0.929	0.958	0.004	0.023	0.006	0.020	0.024	0.039
Nemax 50	0.007	0.015	0.704	0.897	0.094	0.266	0.002	0.034
Nasdaq100	0.005	0.012	0.001	0.192	0.793	0.990	0.005	0.023
Int. Rate Diff	0.001	0.006	0.010	0.081	0.001	0.021	0.912	0.987
Nikkei 225 / S&P 500	Exchange Rate Innovation		Nikkei 225 Innovation		S&P 500 Innovation		Interest Rate Differential Innovation	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
Exchange Rate Y/$	0.950	0.952	0.024	0.026	0.021	0.022	0.002	0.003
Nikkei 225	0.010	0.010	0.843	0.845	0.144	0.146	0.001	0.001
S&P 500	0.001	0.002	0.001	0.004	0.988	0.992	0.005	0.006
Int. Rate Diff	0.000	0.002	0.008	0.011	0.013	0.019	0.971	0.975

Table 6: Bounds for Information Shares Using the Long-Term Interest Rate Differential. To obtain the lower and the upper bound on information shares the system was estimated across all possible orderings. The time horizon of the forecast error variance decomposition is 20 periods.

DJ Euro Stoxx 50 / S&P 500	Exchange Rate Innovation		DJ Euro Stoxx 50 Innovation		S&P 500 Innovation		Interest Rate Differential Innovation	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
Exchange Rate $/E	0.924	0.953	0.021	0.053	0.017	0.024	0.005	0.008
DJ Stoxx 50	0.008	0.037	0.658	0.849	0.137	0.303	0.004	0.008
S&P 500	0.005	0.008	0.006	0.229	0.763	0.987	0.002	0.003
Int Rate Diff	0.001	0.001	0.001	0.021	0.005	0.020	0.971	0.987

Nemax 50 / Nasdaq 100	Exchange Rate Innovation		Nemax 50 Innovation		Nasdaq 100 Innovation		Interest Rate Differential Innovation	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
Exchange Rate $/E	0.960	0.975	0.007	0.023	0.007	0.020	0.006	0.010
Nemax 50	0.007	0.015	0.716	0.893	0.094	0.267	0.005	0.006
Nasdaq100	0.004	0.011	0.001	0.192	0.795	0.989	0.005	0.009
Int. Rate Diff	0.001	0.002	0.001	0.006	0.010	0.029	0.969	0.984

Nikkei 225 / S&P 500	Exchange Rate Innovation		Nikkei 225 Innovation		S&P 500 Innovation		Interest Rate Differential Innovation	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
Exchange Rate Y/$	0.953	0.954	0.023	0.025	0.019	0.021	0.001	0.003
Nikkei 225	0.011	0.011	0.835	0.837	0.144	0.147	0.007	0.009
S&P 500	0.001	0.002	0.001	0.004	0.977	0.988	0.009	0.017
Int. Rate Diff	0.002	0.003	0.003	0.006	0.006	0.028	0.966	0.986

Table 7: Bounds for Information Shares Using the Short-Term Interest Rate Differential. To obtain the lower and the upper bound on information shares the system was estimated across all possible orderings. The time horizon of the forecast error variance decomposition is 20 periods.

B Time Series Plots

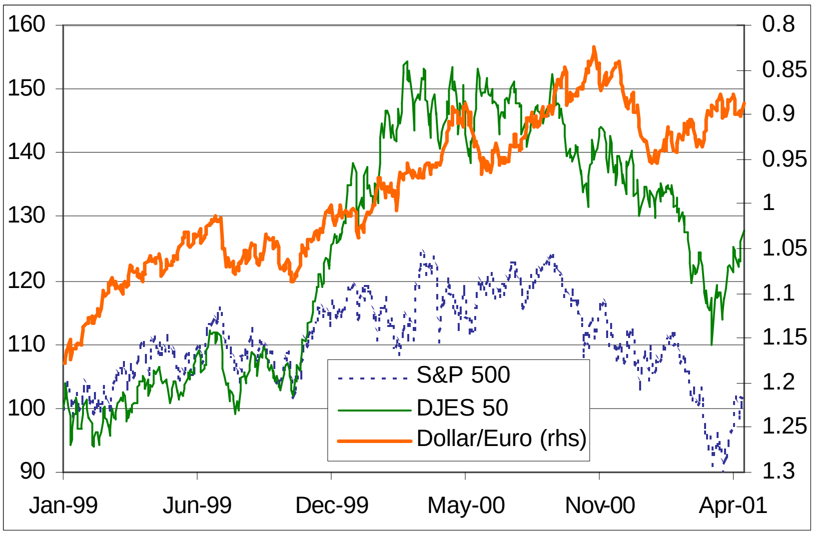

Figure 1: US Dollar/Euro Exchange Rate, Dow Jones Euro Stoxx 50, and S&P 500

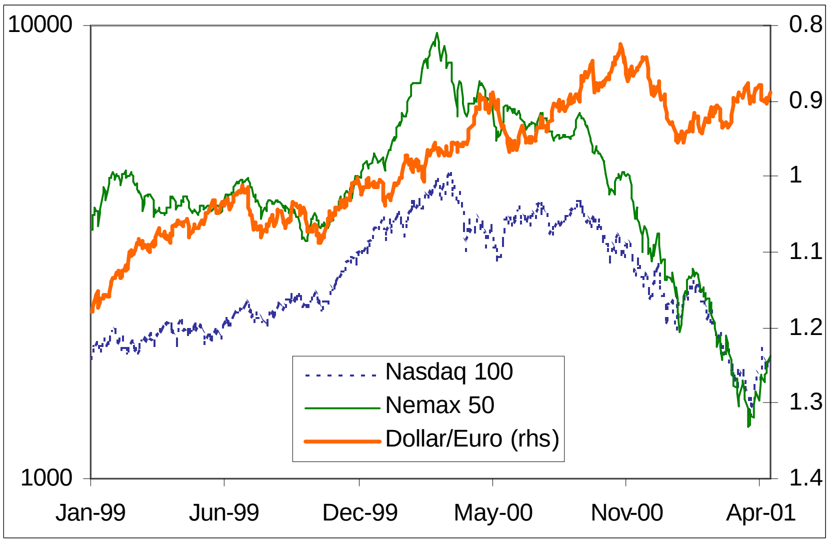

Figure 2: US Dollar/Euro Exchange Rate, Nemax 50, and Nasdaq 100

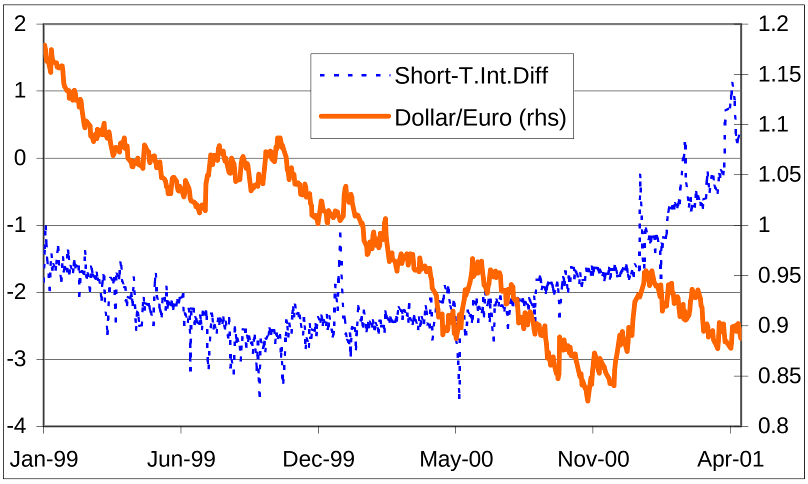

Figure 3: US Dollar/Euro Exchange Rate and Short-Term Interest Rate Differential (Euro-Dollar)

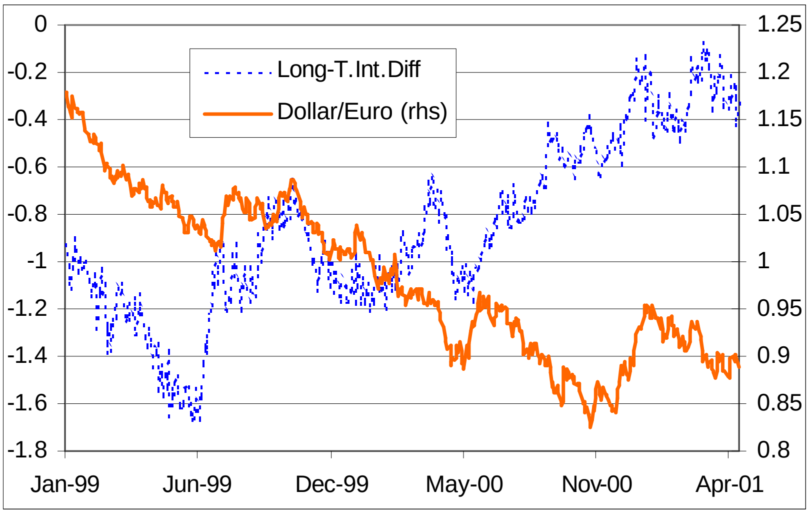

Figure 4: US Dollar/Euro Exchange Rate and Long-Term Interest Rate Differential (Euro-Dollar)

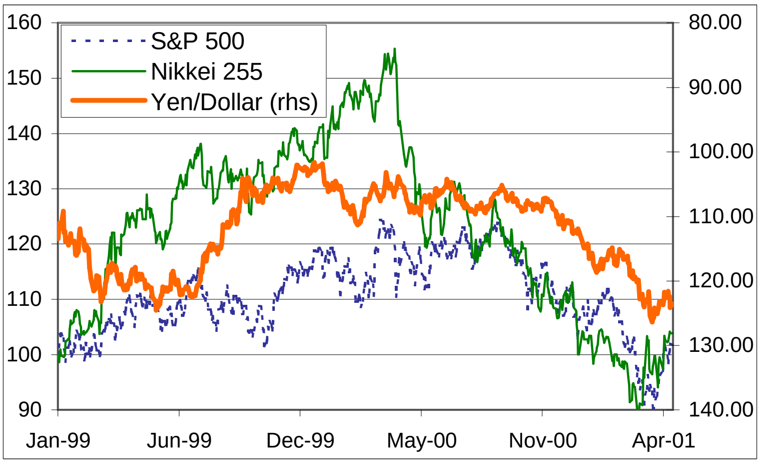

Figure 5: Yen/US Dollar Exchange Rate, Nikkei 225, and S&P 500

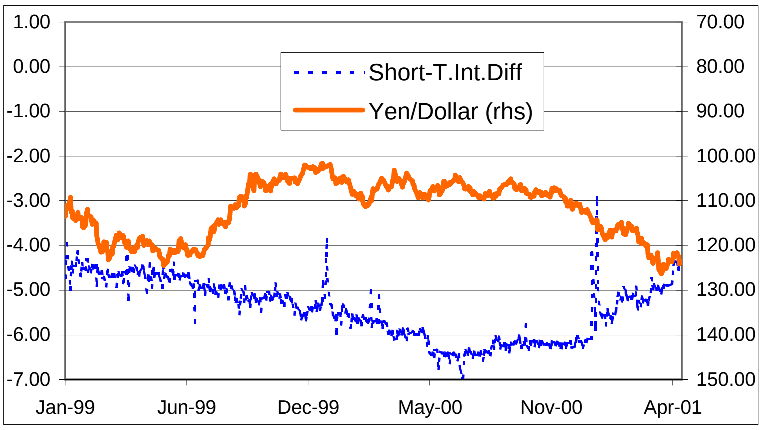

Figure 6: Yen/US Dollar Exchange Rate and Short-Term Interest Rate Differential (Yen-Dollar)

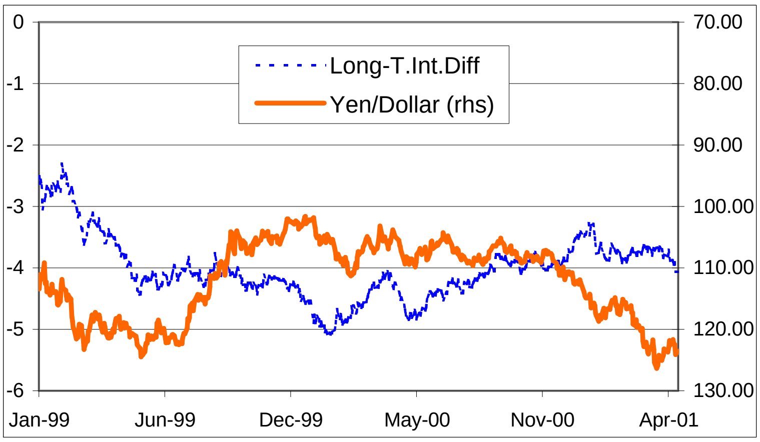

Figure 7: Yen/US Dollar Exchange Rate and Long-Term Interest Rate Differential (Yen-Dollar)

C Impulse Response Functions and Confidence Intervals of +/- Two Standard Deviations

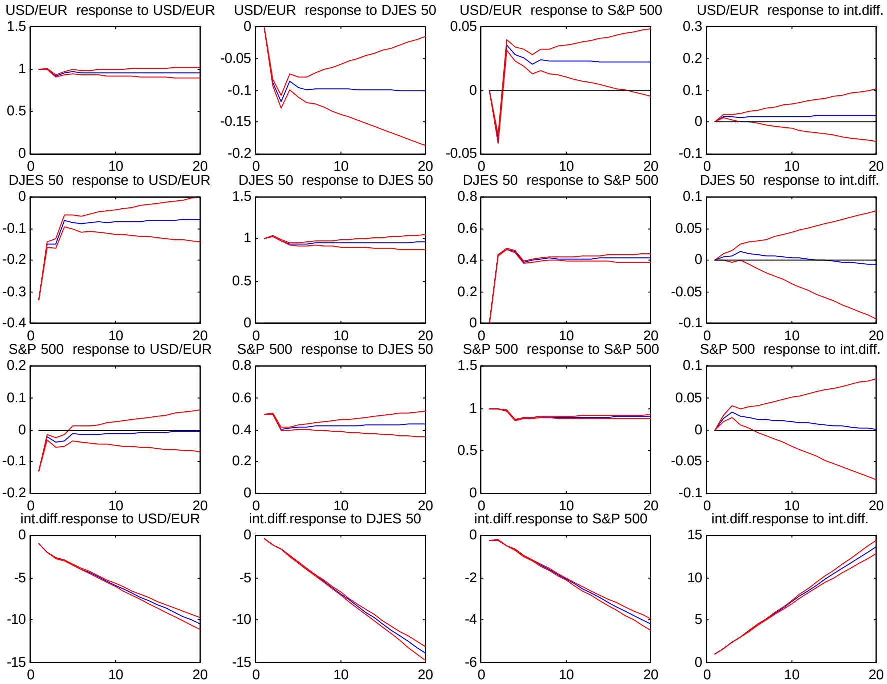

Figure 8: System with Dow Jones Euro Stoxx 50 and S&P 500, ordered: US Dollar-Euro Rate, DJES 50, S&P 500, and Long-Term Interest Rate Differential

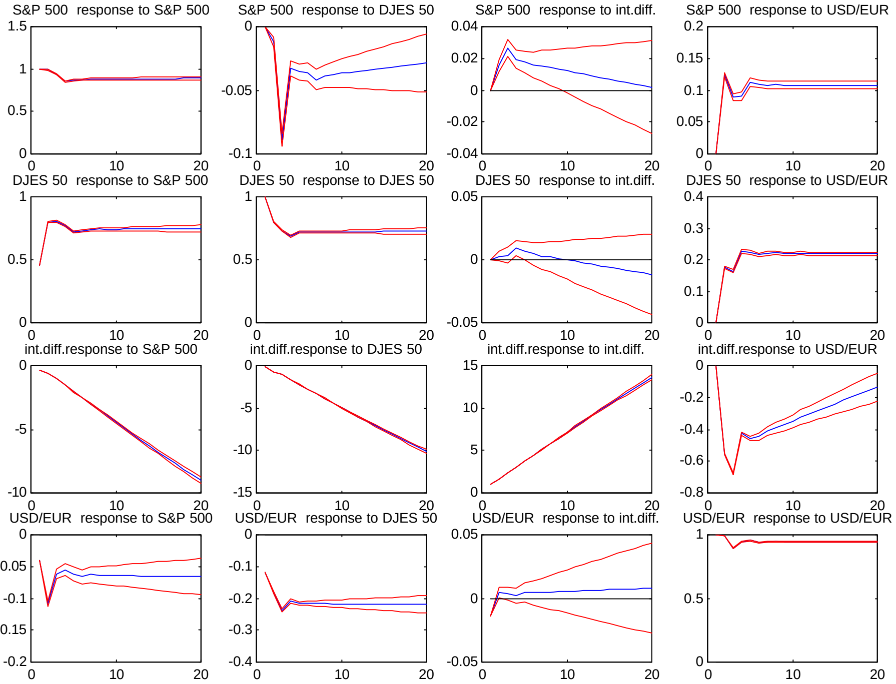

Figure 9: System with Dow Jones Euro Stoxx 50 and S&P 500, ordered: S&P 500, DJES 50, Long-Term Interest Rate Differential, and US Dollar-Euro Rate

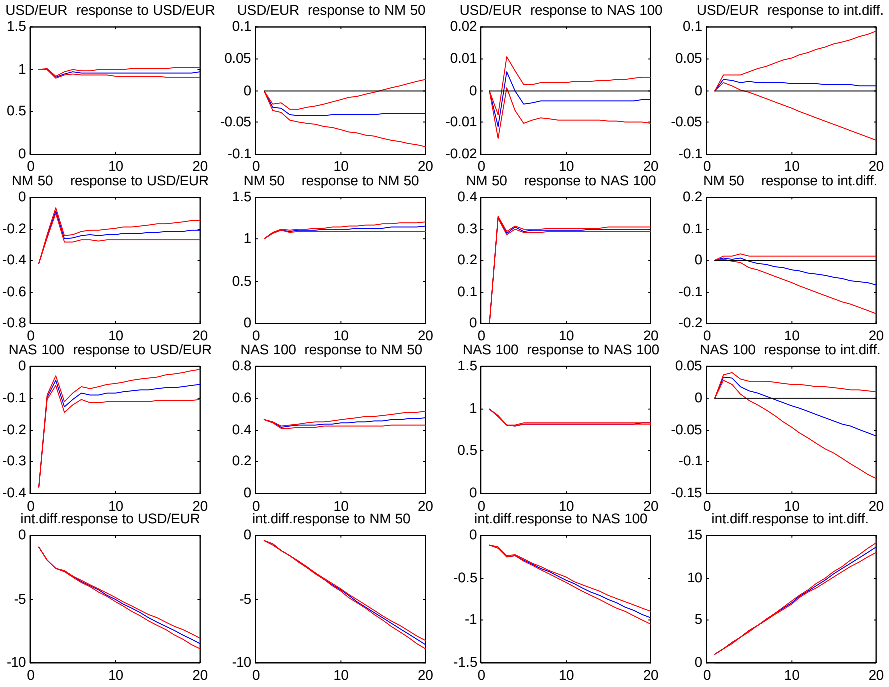

Figure 10: System with Nemax 50 and Nasdaq 100, ordered: US Dollar-Euro Rate, Nemax 50, Nasdaq 100, and Long-Term Interest Rate Differential

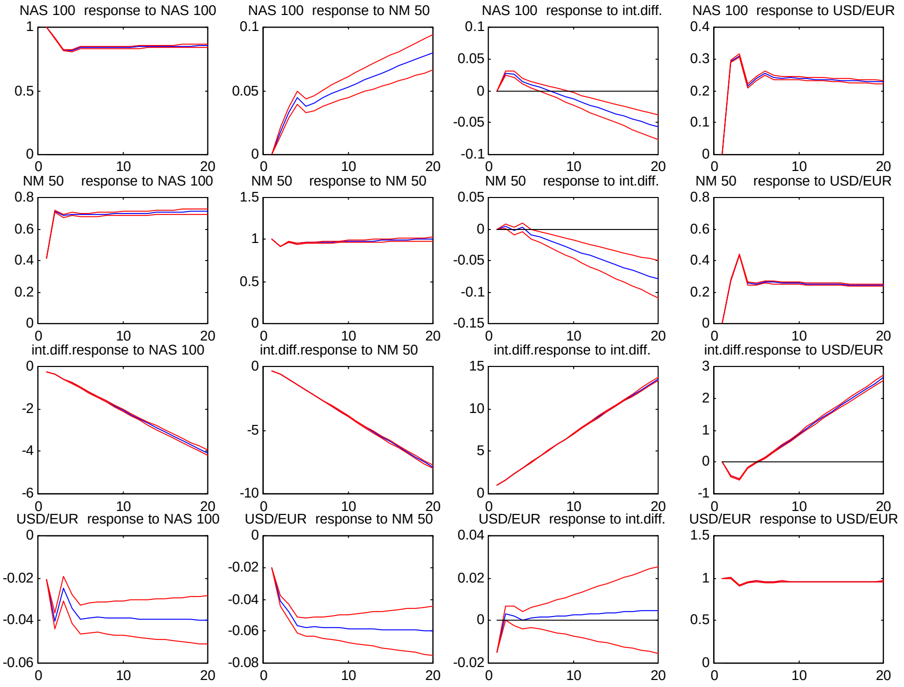

Figure 11: System with Nemax 50 and Nasdaq 100, ordered: Nasdaq 100, Nemax 50, Long-Term Interest Rate Differential, and US Dollar-Euro Rate

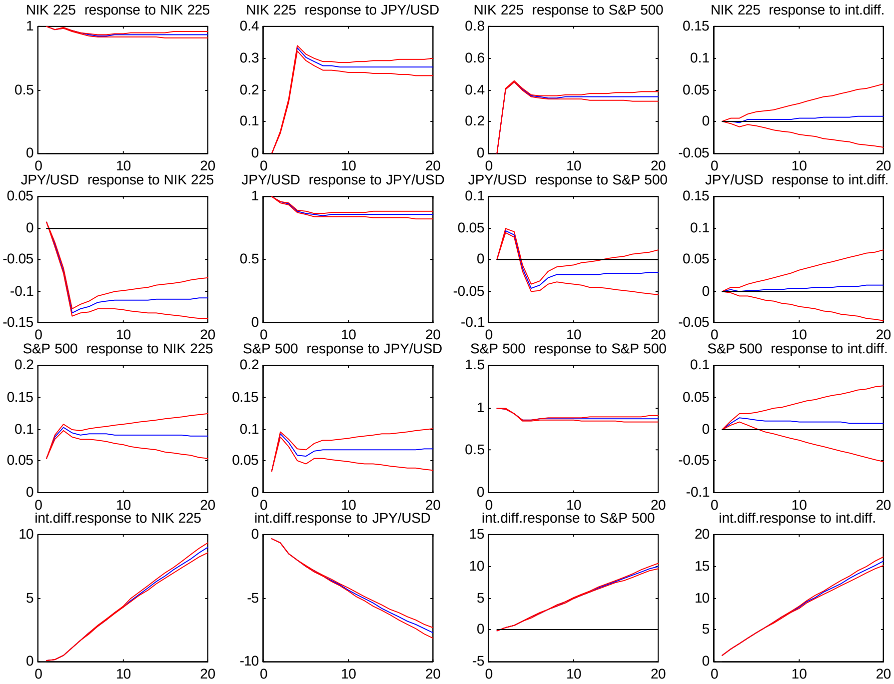

Figure 12: System with Nikkei 225 and S&P 500

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