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Do Exchange Rates Respond to Day-to-Day Changes in Monetary Policy Expectations?

Evidence from the Federal Funds Futures Market

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Abstract: This paper is the first to utilize the informational content embodied in Federal funds futures contracts for extracting day-to-day changes in expectations of future US monetary policy, in the context of a study of day-to-day exchange rate changes. We analyze more than 12 years of daily exchange rate data and show that continuous day-to-day changes in expectations of future US monetary policy has a significant and systematic impact on day-to-day changes in exchange rates. Our results imply that monetary policy matters for daily exchange rate determination in more ways than merely through infrequent, actual policy changes. Furthermore, when focusing on the actual monetary policy changes, the paper confirms that only the unexpected element of a policy change impacts exchange rates. The presented findings are generally consistent with market efficiency and the notion that exchange rates are forward-looking asset prices.

Key words: Expectations, Monetary Policy, Federal Funds Futures, Exchange Rates.

JEL Classifications: E52, F31, G14.

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1. Introduction

This paper adds to the literature on exchange rates and monetary policy in three ways. First, we analyze more than 12 years of daily exchange rate data and show that continuous day-to-day changes in expectations of future US monetary policy has a significant and systematic impact on day-to-day changes in exchange rates. This implies that monetary policy matters for daily exchange rate determination in more ways than merely through infrequent, actual policy changes. Second, focusing on the short-term, we find that day-to-day changes in policy expectations trigger same-day exchange rate responses as opposed to systematic delayed effects. This finding is consistent with exchange rate market efficiency. Third, we confirm that only the unexpected element of an actual monetary policy change impacts exchange rates. All three findings are consistent with the notion of exchange rates as being forward-looking asset prices.

Our analysis utilizes the informational content embodied in the Federal funds futures contracts for extracting day-to-day changes in expectations of future US monetary policy. Kuttner (2001) shows that Fed funds futures provide a "natural market based proxy for those expectations" (p. 527). By measuring changes in expectations directly, we avoid having to rely on survey data or specification of a model of the process driving monetary policy. No previous study has utilized continuous day-to-day changes in policy expectations extracted from the Fed funds futures prices in the context of a time-series analysis of exchange rates.[1]

Monetary models of exchange rate determination suggest that changes in monetary fundamentals will have an immediate impact on the spot exchange rate. For example, a tightening of US monetary policy through, say, an increase in US interest rates, produces a higher return on USD denominated assets, thereby inducing investors to sell foreign assets in

[1] Fatum and Hutchison (1999) performs a direct test of the signaling channel hypothesis of foreign exchange market intervention using daily data on Fed intervention in the DEM/USD rate and day-to-day changes in one- and two-months ahead Fed funds futures prices.

order to increase their holdings of USD assets. The associated switch in demand from foreign to domestic currency should then lead to an instant appreciation of the USD.

Several empirical studies, nevertheless, find that the initial exchange rate response to a monetary policy innovation is insignificant. Using three measures of monetary policy, Eichenbaum and Evans (1995) find that initial USD appreciation in response to a US monetary contraction is small in comparison with subsequent USD appreciation and for the GBP/USD and the JPY/USD exchange rates the initial response is insignificant. Similarly, Lewis (1995) shows that there is no significant immediate reaction to (again, three measures of) monetary policy for either the DEM/USD or the JPY/USD exchange rate. However, using the Fed funds target rate as a measure of monetary policy actions, Bonser-Neal, Roley and Sellon, Jr. (1998) find that exchange rates generally respond immediately to changes in US monetary policy.

In a recent study of real-time exchange rate responses to macro announcements, Andersen, Bollerslev, Diebold and Vega (2003) use survey data for extracting expectations of Fed fund target rates and find that unexpected news from FOMC deliberations have a large, immediate and significant impact on exchange rates.[2] A common feature of all these contributions is that they measure the impact of monetary policy based on actual and infrequent monetary policy changes. The time-series analysis presented in this paper is not confined to focusing on actual policy changes. Extracting continuous day-to-day changes in expectations of

[2] Andersen, Bollerslev, Diebold and Vega (2003) as well as our paper do not address the issue of exchange rate forecasting directly. However, both papers suggest that exchange rate markets process new information efficiently. Therefore, both papers have implications for forecasting in the sense that if exchange rate markets are efficient, it seems less surprising that the findings of Meese and Rogoff (1983) still stand (i.e. no structural exchange rate model, with or without monetary fundamentals, can consistently outperform the naïve no-change short-run forecast). Although some evidence has been presented in support of predictability at longer horizons and the importance of monetary fundamentals (Mark, 1995, and Chinn and Meese, 1995) some of that evidence has subsequently been disputed (Berkowitz and Giorgianni, 2001, and Killian, 1999). For a comprehensive survey of the empirical evidence on exchange rate forecasting under the monetary approach, see Neeley and Sarno (2002).

future US monetary policy from the Federal funds futures contracts allow us to analyze how day-to-day changes in policy expectations affect exchange rate markets.

Since the market for Fed funds futures opened in 1989, empirical studies have found the Fed funds futures contract an extremely useful proxy for market expectations of future monetary policy (see Carlson, McIntire and Thomson, 1995, and Krueger and Kuttner, 1996, for early contributions as well as Sack, 2002, and Sack, Swanson and Gurkaynak, 2002). Utilizing daily changes in the short-term Fed funds futures rates as a proxy for changes in expectations, we use a generalized autoregressive conditional heteroskedasticity (GARCH) time-series approach for testing whether day-to-day changes in expectations of the future monetary policy path have effects – same-day as well as delayed - on DEM/USD, JPY/USD and GBP/USD spot exchange rates. Second, we use an event study approach and the analysis of Fed funds futures data found in Kuttner (2001) for testing whether actual monetary policy changes – expected as well as unexpected - trigger same-day as well as delayed exchange rate responses.

We find that day-to-day changes in policy expectations have highly significant impacts on day-to-day changes for all three exchange rates in our sample. The coefficient estimates imply that a one percent change in expectations triggers at least a 0.04 percent change (for the JPY/USD sample) and at most a 0.07 percent change (for the DEM/USD sample) in exchange rates, suggesting that expectations of US monetary policy has very similar impacts across different exchange rates. We detect no systematic pattern of delayed exchange rate responses. In particular, we find very strong support for market efficiency when focusing on the DEM/USD and the GBP/USD exchange rates. Consistent with the time-series based analysis, our event study confirms that only the unexpected element of a policy change matters for exchange rate determination and, again, that delayed effects are absent.

The rest of the paper is organized as follows. Section 2 briefly discusses the data and the Fed funds futures market. Section 3 and 4 present the time-series based analysis and the event study approach, respectively. Section 5 concludes.

2. Data

Fed funds futures have been trading at the Chicago Board of Trade (CBOT) since 1989. Futures contracts with maturities of one- through five-months are traded, along with a current-month (spot-month) contract. By construction of the contracts, Fed funds futures rates implicitly embody predictions of the monthly average of the daily Fed funds rate for a future calendar month. For example, when the price of the one-month ahead contract changes on any given day in, say, January, this implies that market expectations of the average price of the Fed funds rate over the month of February has changed. Studies by Carlson, McIntire and Thomson (1995) and Krueger and Kuttner (1996) show that Fed funds futures rates provide efficient and unbiased predictors of future funds rate movements.

The futures data used in this paper consists of daily two- and three-month ahead Fed funds futures rates for the 27 March 1989 to February 6, 2002 period. Rates are quoted at close of business at the CBOT, which is 2 pm Chicago time (3 pm Eastern time).[3] The sample consists only of outstanding deferred contracts reflecting 30-day averages of the Fed funds term rates for periods of two and three months ahead, respectively. Expiration dates are not included in our sample and, therefore, maturity effects are not present.[4]

The underlying instrument, the Fed funds rate, is highly volatile, as the market for Fed funds is characterized by days of excess demand for reserves and days of excess supply of

[3] As usual, the CBOT futures prices are quoted as an index equal to 100 minus the rate of the contract.
[4] Kuttner (2001) details issues pertaining to the presence of maturity effects in the spot-month contract.

reserves. As a result, the FOMC objective for the Fed funds rate may not be met on any given day. However, the objective will be met on average and over time and "permanent changes in the Fed funds rate level are thus the consequences of deliberative policy decisions" (Carlson, McIntire and Thompson, 1995, p. 20). Therefore, if market participants expect a monetary policy change to occur during the next calendar month, this will be reflected in current Fed funds futures prices (with the exception of the spot-month contract). Furthermore, the Fed funds day-to-day volatility stemming from daily excess supply or demand for bank reserves will not impact the Fed funds futures prices. This suggest that while Fed funds futures data provide very accurate measures of expectations of future monetary policy, data on the Fed funds rate itself offer only an imprecise and "noisy" indication of the current monetary policy stance.

The daily timing of the futures data matches the daily timing of our foreign exchange market data. The latter data consists of spot prices for the DEM/USD, JPY/USD and GBP/USD exchange rates obtained from the Pacific Exchange Rate Service and recorded at noon Pacific time (3 pm Eastern time). We also incorporate into the event study analysis of section 4 exchange rates recorded at noon Eastern time. These rates are available from the Board of Governors of the Federal Reserve. Interest rate data and official foreign exchange intervention data are obtained from the central banks relevant for the study.

3. Exchange Rate Responses to Changes in Expectations of Monetary Policy

As a forward-looking asset price, an exchange rate should not only react to the unexpected element of an actual change in the current stance of monetary policy but also to a current change in the expectations of the future monetary policy stance. This section investigates the latter, whether spot exchange rates respond in a systematic way to changes in expectations of future monetary policy, while the following section investigates the former.

In order to measure current changes in expectations of future monetary policy, we use day-to-day changes in end-of-day (2 pm Central time) Fed funds futures rates for the two- and three-month ahead contracts.[5] We follow what has become the standard econometric technique for studies of daily exchange rate time series data and estimate GARCH models, as prescribed by Hsieh (1989) and Baillie and Bollerslev (1989) and others.

3.1 Empirical Methods

Studies of financial market time series in general and exchange rate time series in particular often find evidence of time-dependent variance in the residuals. Specifically, large and small errors tend to come in clusters and the size of the current error term seems dependent on the size of the previous error (see, for example, Engle 1982; Bollerslev 1986). In order to address this issue of autoregressive conditional heteroskedasticity (ARCH), we estimate a regression equation with residuals modeled as a GARCH process and, following Baillie and Bollerslev (1989), we include the contemporaneous explanatory variable (here the change in the Fed funds futures rate) both in the mean and the variance equations describing the dependent variable (the change in the spot exchange rate). The basic empirical relationship of the analysis is given by the GARCH(p,q) specification:

(1) $\Delta s_t = a + b_n \Delta FFF^i{}_{t-n} + \varepsilon_t,$ n = 0…15 and i = 2, 3.

(2) $\varepsilon_t \sim N(0, h_t)$

(3) $h_t = \alpha_0 + \sum_{j=1}^{q} \alpha_j e^2{}_{t-j} + \sum_{j=1}^{p} \beta_j h_{t-j} + \gamma \left| \Delta FFF^i{}_t \right|$

[5] Sack (2002) suggests that extracting changes in expectations under the implicit assumption of a constant or zero risk-premium does not pose problems as long as the extraction relies on short-term contracts.

where Δs_t is the first-difference in the log of the daily spot exchange rate and $\Delta FFF^{i=2}{}_{t-n}$ ($\Delta FFF^{i=3}{}_{t-n}$) is the first-difference in the log of the daily two-month ahead Fed funds futures rate (three-month ahead Fed funds futures rate).[6] Equation (2) states that the error term is normally distributed with zero mean and time-dependant (conditional) variance h_t. Equation (3) shows that the variance depends on the squared error of the past q periods (the ARCH terms), the conditional variance of the past p periods and the absolute value of the contemporaneous change in the log of the Fed funds futures rate.

Lags of the independent variable are incorporated into equation (1) in order to capture the short-run dynamic response of the exchange rate to the arrival of news regarding future monetary policy. More specifically, the estimations include 15 lags (three business weeks) of day-to-day changes in the Fed funds futures variable in order to assess how rapidly new information capable of altering the market's perception of expected future monetary policy translates into changes in the spot exchange rates. If exchange rate markets are highly efficient, changes in expectations of future monetary policy should be reflected almost instantaneously and not subsequently in the exchange rates. Given that the analysis utilizes daily data, a high degree of market efficiency would then be consistent with current changes in the Fed funds futures rates being systematically related to same-day changes in exchange rates (i.e. b_0 should be significant) while lagged changes in the futures rates should be unrelated to current exchange rates (i.e. b_i for $i = 1,...,15$ should all be insignificant).

We follow Eichenbaum and Evans (1995) and Kim and Roubini (2000) and others who argue that US monetary policy during the floating exchange rate regime under study is not

[6] Augmented Dickey-Fuller tests of the exchange rate and federal funds futures time series suggest the raw series are integrated of order one and that the series in first-differences are stationary.

systematically affected by short-term exchange rate movements. Therefore, short-term exchange rate volatility does not trigger changes in market expectations of future monetary policy and our equation (1) is not subject to simultaneous equation bias.

Since central bank foreign exchange intervention and actual interest rate changes conducted by either the Fed or foreign central banks (unless fully anticipated) may have an impact on day-to-day changes in the spot exchange rates, we add intervention and interest rate change dummy variables (labeled INTERVENDUM and INTRATEDUM, respectively) to equation (1) in order to control for the effects of such central bank actions.[7, 8]

Simultaneous estimations of equations (1) through (3) are carried out for each of the three exchanges rates (and the futures contracts with different maturities) separately over the sample period 27 March 1989 to 6 February 2002 (31 December 1998 for the DEM/USD sample). For each of the exchange rate regressions, we choose the most parsimonious GARCH specification possible that still allows us to accept the null hypothesis of no ARCH in the standardized residuals. We find that GARCH(2,1) models give the better fit when the DEM exchange rate time series is the dependent variable while GARCH(1,1) models give the better fit when focusing on the GBP and the JPY rates. Furthermore, we find that only in the case of the DEM is the current change in the Fed funds futures rate significant in the conditional variance equation.

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[7] The March 1989 to February 2002 sample encompasses 50 days of the US Federal Reserve changing the Target Rate, 20 days of the Bank of Japan changing the Japanese Discount Rate of Commercial Bills, 21 days of the Bundesbank changing the German Discount and Lombard Rates, and 51 days of the Bank of England changing the British Minimum Lending and Repo Rate. Official intervention in the DEM/USD was undertaken by either the Fed, the Bundesbank, or both on 125 days, while official interventions in the JPY/USD market was undertaken by either the Fed, the Bank of Japan, or both on 202 days. Due to unavailability of official Bank of England intervention data, it is not possible to control for intervention in the GBP/USD.

[8] We also expand equation (1) to incorporate various dummies in order to test for asymmetric exchange rate responses to monetary policy news. In particular, we separate expectations of future monetary tightening from expectations of future monetary loosening. We find, however, no evidence of asymmetries.

We report estimation results based on models including all fifteen lags of the Fed fund futures rate as well as models including only the contemporaneous change and no lags.[9]

3.2 *The DEM/USD Exchange Rate*

Tables 1 and 2 show the GARCH(2,1) estimation results from regressing changes in the 2-month ahead Fed funds futures rate and the 3-month ahead Fed funds futures rate, respectively, on the DEM/USD exchange rate changes. For both no-lags models (model 1 in tables 1 and 2) and both lag-models (model 2 in tables 1 and 2), the b_0 coefficient is positive and significant at the 99% level, suggesting that a change in current expectations of a future tightening (loosening) of US monetary policy has an immediate impact in terms of an appreciation (depreciation) of the USD vis-à-vis the DEM. The coefficient estimates show that a one percent change in expectations triggers a 0.06 (2-month ahead contracts) or a 0.07 (3-month ahead contracts) percent same-day change in the exchange rate. The estimated models are capturing the effects of *continuous* changes in expectations rather than capturing the effects of infrequent occurrences of actual monetary policy changes ("hard news" such as discrete changes in the Fed funds target rate). The highly significant elasticities show that while other factors clearly impact exchange rates as well, expectations of future monetary policy matter for exchange rate determination.

With respect to delayed effects and the issue of market efficiency, both tables show that none of the lag-models (model 2) display any significant lags. In particular, the fact that there is no sign of significant next-day effects (first lag is insignificant) offers very strong support for the

[9] We also test for the possibility that the conditional variance enters into the mean equation (1) but find no support for the GARCH-in-mean (GARCH-M) specification.

notion that exchange rate markets are highly efficient and characterized by same-day processing of changes in expectations.[10]

The conditional variance equation estimates confirm the presence of ARCH effects in the exchange rate time series. The ARCH-F and Q^2 tests indicate that both the models using the 2-month ahead futures rate (models 1 and 2 in table 1) and the no-lags model using the 3-month ahead futures rate (model 1 in table 2) are free of any ARCH effects left in the standardized residuals. For the lag-model using the 3-month ahead contracts (model 2 in table 2), presence of heteroskedasticity is rejected based on one of the specification tests while marginally significant based on the other. Furthermore, the absolute value of the current change in the Fed funds futures rate is highly significant (at 99%), of the expected (positive) sign and, therefore, appears to raise the conditional variance of the DEM/USD exchange rate. Put differently, changes in expectations of future monetary policy – whether expectations of a tightening or a loosening – is positively associated with increased volatility in the exchange rate market.

3.3 The GBP/USD Exchange Rate

The specification that best fits the GBP/USD exchange rate is the GARCH(1,1) model without the current change in the Fed funds futures rate entering the conditional variance equation. The results are very similar to those based on the DEM/USD exchange rate and, in particular, the key finding regarding current effects and same-day processing of information is repeated. The estimation results are shown in tables 3 and 4.

[10] For all three currencies, the exchange rate change was regressed on each lag of the change in the futures rate separately. Although the level of significance changes slightly in some cases, the described lag significance structures are completely robust to this alteration. Furthermore, all estimations were also carried out using OLS estimation techniques and Newey-West covariances (see Newey and West, 1987) and the described results are unchanged.

As before, the estimates of the current effect, b_0, are all positive and significant at the 99% level, indicating that a current expectation of a future tightening (loosening) of US monetary policy is associated with an same-day depreciation (appreciation) of the foreign currency. The magnitudes of the estimated coefficients (elasticities) suggest that a one percent change in expectations triggers a 0.05 (2-month ahead contracts) or a 0.065 (3-month ahead contracts) percent same-day change in the exchange rate.

Both lag-models (model 2) support the idea of highly efficient exchange rate markets as none of the 15 lags appear significant and of the same sign as the same-day exchange rate response. In particular, the finding of complete absence of next-day effects is repeated. There is one occurrence of a marginally significant delayed exchange rate response. It is of the opposite sign, occurs at the seventh lag (for both lag-models shown in tables 3 and 4), and it is of a much smaller magnitude than the initial response. This may indicate the presence of some degree of short-term mean-reversion present in the exchange rate series.

The conditional variance equation estimates confirm the presence of ARCH effects in the exchange rate time series. The specification tests show that none of the four models have ARCH effects left in the standardized residuals. In contrast to the DEM/USD exchange rate analysis, our estimations do not support that the independent variable should be included in the conditional variance equation when focusing on the GBP/USD rate. Therefore, we do not find evidence that uncertainty regarding future monetary policy is associated with increased volatility in the GBP/USD exchange rate market.

3.4 The JPY/USD Exchange Rate

The specification that best fits the JPY/USD exchange rate is the same GARCH(1,1) model that describes the GBP/USD rate. The results are very similar to those based on the other two exchange rates in our sample and the key findings repeated. However, the lag-structure is not as "clean". Tables 5 and 6 display these findings.

The estimates of the current effect are all positive and significant at the 99% level, and the magnitudes suggest that a one percent change in expectations of future US monetary policy triggers a 0.04 (2-month ahead contracts) or 0.045 (3-month ahead contracts) percent immediate change in the JPY/USD exchange rate.

The lag-model utilizing the 2-month ahead futures contracts (model 2 in table 5) provide some support for exchange rate market efficiency to the extent that the next-day as well as the day after the next-day responses are insignificant. However, the coefficient estimate of the third lag is positive and significant at the 95% level (while at a smaller magnitude). The latter finding indicates the presence of a delayed effect and, therefore, may not support the notion of market efficiency and instantaneous price adjustment. The other two cases of delayed significant exchange rate response are of the opposite sign (at the seventh and eighth lag) and seem consistent with short-term mean-reversion of the exchange rate series. The lag-model utilizing the 3-month ahead futures contracts (model 2 in table 6) do not provide support for exchange rate market efficiency as the next-day delayed effect is positive and significant at the 95% level. This finding suggests that it takes up to two business days for the JPY/USD market to fully adjust to the change in expectations regarding future US monetary policy. The one instance of a significant delayed effect beyond the next-day lag occurs at the seventh lag and its coefficient estimate is negative, consistent with short-term mean reversion.

As with the DEM/USD and the GBP/USD exchange rates, the reported specification tests show that none of the models have ARCH effects left in the standardized residuals. In contrast to the DEM/USD exchange rate analysis, but consistent with the GBP/USD findings, we do not find evidence that uncertainty regarding future monetary policy affects the conditional variance of the JPY/USD exchange rate market.

4. Exchange Rate Responses to Fed Funds Target Rate Changes

Whereas the previous section used Fed funds futures data for analyzing how continuous changes in *expectations* of future monetary policy affect current spot exchange rates, this section utilizes the Fed funds futures data for investigating how exchange rates respond to discrete, *actual* changes in monetary policy ("hard news"), the latter captured by changes in the Fed funds target rate. Using the Fed funds futures contracts allows us to distinguish between expected and unexpected target rate changes as only unexpected changes bring new information to the foreign exchange rate markets and, therefore, only unexpected changes should have an impact on exchange rates.

We formally test whether only the unexpected element of actual monetary policy changes is systematically related to exchange rate movements by incorporating the findings of Kuttner (2001). Kuttner (2001) analyzes the 42 target rate changes that occurred during the 1989 – 2000 period and uses daily spot-month Fed funds futures market data for disentangling expected from unexpected changes. He argues that unless there are expectations of further target rate changes occurring within the month, his method for extracting the unexpected element of a target rate change “delivers a nearly pure measure of the one-day surprise target change” (Kuttner, 2001, p. 529).[11, 12]

The analysis of this section uses an event study approach in the tradition of Cook and Hahn (1989) and Kuttner (2001). We regress the change in the (log of the) spot exchange rate on the expected and the unexpected part of the target rate change (displayed in Kuttner, 2001, p. 532):

$$(4) \qquad \Delta s_t = a + b_1 \tilde{r}_t^e + b_2 \tilde{r}_t^u + \varepsilon_t$$

where Δs_t is the first-difference in the log of the daily spot exchange rate and $\tilde{r}_t^e$ ($\tilde{r}_t^u$) is the expected (unexpected) target rate change in percent.

The exact timing of the data is an important issue. Until 1994, the Federal Reserve did not announce but signaled its decision to change the target rate through open market operations undertaken before noon (from 11.30 to 11.35 am) Eastern time. Starting in 1994, the Fed adopted

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[11] As pointed out by Kuttner (2001), there are two technical issues involved in using the Fed funds futures data for measuring expectations of future monetary policy. First, the Fed funds futures settlement price is calculated as an average of the relevant month’s Fed funds rate. Second, the Fed funds future is not based on the actual policy instrument, the targeted Fed funds rate, but on the effective market rate. Kuttner (2001) carefully addresses these issues and computes a policy surprise measure based on the one-day change in the spot-month future rate, utilizing that the day-t futures rate embodies the expected change on (or after) date t+1. If the target rate change occurs as expected, the spot rate will remain unchanged, while a deviation from the expected rate will cause the futures rate to change (in proportion to the remaining number of days affected by the unexpected change). Specifically, for all but the first day of the month, he computes the one-day surprise for date t as $\frac{m}{m-t}(f_{s,t} - f_{s,t-1})$, where m is the number of days in the month and $f_{s,t}$ is the spot-month futures rate on day t of month s. For the first day of the month, the one-month futures rate from the last day of the previous month replaces the term $f_{s,t-1}$.

[12] Within the context of VAR estimations utilizing high-frequency data, Faust, Rogers, Swanson and Wright (2002) also utilize Fed funds futures data for identifying the unexpected element of a change in the Fed funds target rate. Focusing on the long run and issues pertaining to overshooting and deviations from uncovered interest rate parity, they find, however, that the peak timing of the exchange rate response to a monetary policy shock is imprecisely estimated in the sense that the confidence interval for the peak timing includes immediate peaks as well as delays of several years.

a routine of announcing target rate changes and from 1995 and onwards it did so at 2.15 pm Eastern time.[13] Since the announcement routine has changed during the sample period at hand, no exchange rate quotes time-stamp is ideal for the entire 1989-2000 period.

In order to address the issue of timing, the event study analysis is carried out in three different ways, using different exchange rate quotes as well as a mix of quotes. First, we use exchange rates recorded at noon Eastern time (ideal for the 24 target rate changes that occurred prior to 1994). Second, we use exchange rates recorded at 3 pm Eastern time (ideal for the target rate changes that occurred during the last part of the sample). Third, we use a mix of exchange rate quotes (exchange rates recorded at noon Eastern time for the 24 target rate changes that occurred prior to 1994 and exchange rates recorded at 3 pm Eastern time for the target rate changes that occurred after 1994). We find the results to be qualitatively identical across all three approaches and, therefore, only report results based on the noon Eastern exchange rate quotes.[14]

Table 7 displays the results of the event study regressions for the three exchange rates in our sample. For all three currencies, unexpected target rate changes have a significant impact on exchange rates of the expected sign, that is a tightening of US monetary policy leads to an appreciation of the USD, consistent with the findings of the time-series analysis of the previous section. This finding is significant at the 95% significance level for all three currencies. Importantly, it is only the unexpected target rate change component that has a significant impact

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[13] See Kuttner (2001) and Andersen, Bollerslev, Diebold and Vega (2003).

[14] A fourth way of addressing the timing issue is to split up the sample into two sub-samples, use exchange rates with a noon Eastern time-stamp for the 1989-1994 sample and exchange rates with a 3 pm Eastern time-stamp for the 1995-2000 sample, and the conduct the event study analysis on these sub-samples separately. Since our full sample consists of relatively few events (42 for the JPY/USD and GBP/USD exchange rates and 38 for the DEM/USD exchange rate), splitting up the sample and thereby reducing the number of events at the outset seems unappealing for a baseline analysis. Carrying out the event study analysis as described - despite the concerns regarding the relatively small number of events - the signs of the estimated coefficients do not change, but these small-sample regressions do no longer provide evidence of significant linkages between target rate changes and subsequent exchange rate responses (with one exception, as the coefficient estimate of the unexpected target rate change is still positive and significant at the 95% level for the 1995-2000 DEM/USD rate sub-sample).

on the exchange rate, while the expected component has no effect on exchange rates. The magnitudes of the estimated exchange rate responses suggest that a one-percentage point change in the Fed funds target rate triggers at most a 0.02 percent change in the exchange rate.[15]

The table also shows that regressing the exchange rate on the actual target rate change (i.e. the sum of the expected and the unexpected component) instead of on the decomposed changes would suggest that monetary policy changes have no (for the case of the DEM/USD rate) or less of a significant impact on exchange rates. We take this finding as further evidence of the importance of addressing the issue of exchange rate responses to monetary policy changes in such a way that the true, unexpected monetary policy innovation is isolated from the expected monetary policy change.

By nature of an event study, the findings described in table 7 implicitly rely on the exchange rate change following a US monetary policy shock not being systematically related to other relevant economic news or developments such as monetary policy shifts in Germany, Japan or Great Britain or central bank foreign exchange intervention. In order to address this particular concern, we first turn the focus to the sub-sample of target rate changes that do not coincide with same-day or next-day interest changes conducted by the foreign central bank.[16] The findings using this sub-sample are reported in table 8. The table shows that only very few US target rate changes coincided with official foreign country interest rate changes – twice for the case of

[15] Melvin (2001) examines the first ten FOMC meetings following the February 1994 change in announcement policy. Using high-frequency data, he finds evidence of a switch to informed trading well before the end of the meeting such that policy news is disseminated into the financial markets prior to the public announcement made at the end of the FOMC meetings. In the context of our daily data analysis, we do not find evidence of significant "lead" effects.

[16] Observations where Fed funds target rate changes coincide with (same-day or next-day) changes in the German Discount and Lombard rates, the Japanese Discount Rate of Commercial Bills and the British Minimum Lending Rate and Repo Rate are excluded from the sample. We exclude both same-day and next-day foreign country interest rate changes since the former might affect the impact of the event itself (i.e. the US policy change) while the latter coincides with the associated post-event control period during which the exchange rate change is examined.

Germany (same-day), once for the case of Great Britain (next-day), and none for the case of Japan – and the results are almost identical to those based on the full sample.

Next, we focus on the sub-sample of target rate changes that do not coincide with same-day or next-day intervention operations conducted (unilaterally as well as multilaterally) by the Federal Reserve, the Bundesbank or the Bank of Japan.[17] Table 9 reports the estimation results. As before, only the unexpected target rate change appears significant (at the 95% level for the DEM/USD exchange rate and at the 90% level for the JPY/USD exchange rate), and its coefficient estimate is positive for all the four sub-samples.

So far, this section has investigated whether there appears to be immediate responses of exchange rates to monetary policy changes. We now turn the attention towards testing for delayed effects. More specifically, we estimate the model described by the following equation:

$$(5) \qquad \Delta s_{t+k} = a + b_1 \tilde{r}_t^e + b_2 \tilde{r}_t^u + \varepsilon_t \text{, k=1,…15.}$$

where Δs_{t+k} is the first-difference in the log of the spot exchange rate k-periods ahead. Estimating these 15 separate models for each of the three exchange rates in the sample and testing for significance of unexpected and expected monetary policy changes consistently reject the presence of delayed effects spanning over the three weeks following the immediate response to the target rate change.[18] In fact, for all the 45 models (15 lags estimated separately for each of the three exchange rates), no coefficient estimate appears significant at the 95% significance level or better and only one instance of significance at the 90% level occurs (a two-day delayed

[17] Due to unavailability of Bank of England intervention data, it is not possible to address the issue of intervention in the GBP/USD exchange rate. We exclude both same-day and next-day intervention observations for the same reasons as suggested in the context of foreign country interest rate changes.
[18] Estimation results based on equation (5) are not shown for brevity but available from the authors upon request.

effect for the case of the DEM/USD exchange rate). We interpret the absence of significant delayed effects as further evidence of exchange rate markets processing new information such as unexpected monetary policy innovations efficiently.

5. Conclusion

This paper utilizes the informational content embodied in the Fed funds futures contracts for testing whether day-to-day exchange rate changes appear systematically related to day-to-day changes in expectations of future monetary policy as well as actual changes in policy. Measuring changes in expectations directly, we avoid having to rely on survey data or specification of a model of the process driving monetary policy.

Our time-series based analysis strongly suggests that exchange rates respond immediately to changes in expectations of the future monetary policy stance. All our findings indicate that expectations of a future tightening of US monetary policy leads to a current appreciation of the USD. This holds true for all three exchange rates in our sample – DEM/USD, JPY/USD and GBP/USD. Focusing on the short-term, characterized by a period of three business weeks, our results are generally consistent with the perception of the exchange rate being a forward-looking asset price and the notion of exchange rate markets being efficient. We find very strong support for market efficiency when focusing on the DEM/USD and the GBP/USD exchange rates while the JPY/USD data produces less clear-cut results.

Using an event study methodology and building on work by Kuttner (2001), we use Fed funds futures data for investigating how exchange rates respond to actual monetary policy changes. The results from the event study analysis confirms the time-series based findings and show that exchange rates display same-day responses to the unexpected element of an actual policy change while the expected element has no impact. Absence of delayed effects across all three exchange rates provides further evidence of the exchange rate market's ability to rapidly and efficiently process new information.

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TABLE 1 **DEM/USD: Exchange Rate Responses to Changes in Expectations of Future Monetary Policy (The Latter Measured by Changes in the 2-Month Ahead Federal Funds Futures Rate)**

Daily Data: 27 March 1989 to 31 December 1998, GARCH Models. All Models run in first differences.
Lags in Parenthesis. All Variables (except dummies) measured in Natural Logs

	Model 1	Std Error	Model 2	Std Error
CONSTANT	-8.09E-05	0.000129	-6.00E-05	0.000133
DFFF2	0.056519***	0.016728	0.057022***	0.016354
DFFF2(-1)			0.012848	0.018091
DFFF2(-2)			0.017955	0.015625
DFFF2(-3)			0.014995	0.018676
DFFF2(-4)			-0.017467	0.014892
DFFF2(-5)			-0.024034	0.016325
DFFF2(-6)			0.021954	0.015546
DFFF2(-7)			-0.026987	0.018155
DFFF2(-8)			0.010443	0.016726
DFFF2(-9)			-0.002715	0.017742
DFFF2(-10)			0.012219	0.018523
DFFF2(-11)			-0.020972	0.018424
DFFF2(-12)			-0.011782	0.016144
DFFF2(-13)			0.008806	0.018204
DFFF2(-14)			-0.008555	0.018974
DFFF2(-15)			0.003293	0.017389
INTERVENDUM	0.000927**	0.000470	0.000674	0.000490
INTRATEDUM	-0.001580	0.000974	-0.001421	0.000974
Variance Equation				
CONSTANT	1.25E-06***	4.03E-07	1.15E-06***	3.74E-07
ARCH (1)	0.093772***	0.013818	0.085806***	0.014637
GARCH (1)	0.212359**	0.108237	0.388199*	0.212461
GARCH (2)	0.641174***	0.102158	0.482142**	0.199850
ABSDFFF2	0.000263***	6.48E-05	0.000195***	6.02E-05
No of Observations	2433		2418	
No of Iterations	16		15	
R-squared	0.01		0.02	
S.E. of regression	0.007		0.007	
Durbin-Watson stat	1.928		1.928	
ARCH-F (Q^2)	0.636	0.425 (P-val)	1.548	0.213 (P-val)
Q^2 (2)	0.742	0.690 (P-val)	1.925	0.382 (P-val)

* Denotes significance at 90%
** Denotes significance at 95%
*** Denotes significance at 99%

Data Sources: Federal Funds Futures: Chicago Board of Trade End of Day Prices (2 pm Chicago Time)
Exchange Rate Data: Pacific Exchange Rate Service (Noon Pacific Time, i.e. 2 pm Chicago Time).

TABLE 2 **DEM/USD: Exchange Rate Responses to Changes in Expectations of Future Monetary Policy (The Latter Measured by Changes in the 3-Month Ahead Federal Funds Futures Rate)**

Daily Data: 27 March 1989 to 31 December 1998, GARCH Models. All Models run in first differences.
Lags in Parenthesis. All Variables (except dummies) measured in Natural Logs

	Model 1	Std Error	Model 2	Std Error
CONSTANT	-7.08E-05	0.000130	-5.77E-05	0.000133
DFFF3	0.070814***	0.016284	0.069304***	0.016629
DFFF3(-1)			0.021642	0.017096
DFFF3(-2)			0.022327	0.015854
DFFF3(-3)			0.010753	0.018458
DFFF3(-4)			0.000641	0.014427
DFFF3(-5)			-0.021985	0.016338
DFFF3(-6)			0.024721	0.017195
DFFF3(-7)			-0.024377	0.016078
DFFF3(-8)			-0.003988	0.015908
DFFF3(-9)			0.002662	0.016105
DFFF3(-10)			0.007075	0.017312
DFFF3(-11)			-0.018229	0.016066
DFFF3(-12)			-0.004723	0.016289
DFFF3(-13)			0.006814	0.017014
DFFF3(-14)			-0.000589	0.017599
DFFF3(-15)			-0.003170	0.016394
INTERVENDUM	0.000895*	0.000462	0.000733	0.000483
INTRATEDUM	-0.001341	0.000971	-0.001329	0.000957
Variance Equation				
CONSTANT	9.22E-07***	3.49E-07	8.82E-07**	3.59E-07
ARCH (1)	0.088420***	0.012468	0.075213***	0.015422
GARCH (1)	0.218052**	0.101866	0.609483**	0.261152
GARCH (2)	0.653992***	0.097748	0.277286	0.244164
ABSDFFF3	0.000190***	5.60E-05	0.000174***	5.76E-05
No of Observations	2433		2418	
No of Iterations	25		18	
R-squared	0.01		0.02	
S.E. of regression	0.007		0.007	
Durbin-Watson stat	1.937		1.934	
ARCH-F (Q^2)	0.683	0.409 (P-val)	2.822	0.093 (P-val)
Q^2 (2)	0.684	0.710 (P-val)	3.651	0.161 (P-val)

* Denotes significance at 90%
** Denotes significance at 95%
*** Denotes significance at 99%

Data Sources: Federal Funds Futures: Chicago Board of Trade End of Day Prices (2 pm Chicago Time)
Exchange Rate Data: Pacific Exchange Rate Service (Noon Pacific Time, i.e. 2 pm Chicago Time).

TABLE 3 **GBP/USD: Exchange Rate Responses to Changes in Expectations of Future Monetary Policy (The Latter Measured by Changes in the 2-Month Ahead Federal Funds Futures Rate)**

Daily Data: 27 March 1989 to 2 February 2002, GARCH Models. All Models run in first differences.
Lags in Parenthesis. All Variables (except dummies) measured in Natural Logs

	Model 1	Std Error	Model 2	Std Error
CONSTANT	-2.29E-05	9.04E-05	-2.79E-05	9.28E-05
DFFF2	0.050552***	0.009721	0.050357***	0.010214
DFFF2(-1)			0.006360	0.009239
DFFF2(-2)			0.008504	0.009045
DFFF2(-3)			0.004679	0.009235
DFFF2(-4)			0.007893	0.009643
DFFF2(-5)			-0.013993	0.009624
DFFF2(-6)			-0.002897	0.009708
DFFF2(-7)			-0.020330*	0.010692
DFFF2(-8)			-0.000646	0.009532
DFFF2(-9)			-0.004990	0.010231
DFFF2(-10)			0.006683	0.012406
DFFF2(-11)			-0.011402	0.010567
DFFF2(-12)			-0.000875	0.010229
DFFF2(-13)			-0.015052	0.010692
DFFF2(-14)			-0.002887	0.010113
DFFF2(-15)			-0.010287	0.010456
INTRATEDUM	-0.000296	0.000466	-0.000221	0.000480
Variance Equation				
CONSTANT	6.42E-07***	1.12E-07	4.76E-07***	8.70E-08
ARCH (1)	0.061830***	0.006691	0.054961***	0.005301
GARCH (1)	0.918495***	0.008283	0.931588***	0.006537
No of Observations	3192		3177	
No of Iterations	14		16	
R-squared	0.01		0.01	
S.E. of regression	0.006		0.006	
Durbin-Watson stat	1.872		1.873	
ARCH-F (Q^2)	0.242	0.623 (P-val)	0.424	0.515 (P-val)
Q^2 (2)	1.997	0.368 (P-val)	1.284	0.526 (P-val)

* Denotes significance at 90%
** Denotes significance at 95%
*** Denotes significance at 99%

Data Sources: Federal Funds Futures: Chicago Board of Trade End of Day Prices (2 pm Chicago Time)
Exchange Rate Data: Pacific Exchange Rate Service (Noon Pacific Time, i.e. 2 pm Chicago Time).

TABLE 4 **GBP/USD: Exchange Rate Responses to Changes in Expectations of Future Monetary Policy (The Latter Measured by Changes in the 3-Month Ahead Federal Funds Futures Rate)**

Daily Data: 27 March 1989 to 2 February 2002, GARCH Models. All Models run in first differences.
Lags in Parenthesis. All Variables (except dummies) measured in Natural Logs

	Model 1	Std Error	Model 2	Std Error
CONSTANT	-5.51E-06	9.10E-05	-1.66E-05	9.28E-05
DFFF2	0.064692***	0.009871	0.063769***	0.010406
DFFF3(-1)			0.011046	0.010303
DFFF3(-2)			0.013983	0.009155
DFFF3(-3)			0.003014	0.010140
DFFF3(-4)			0.004536	0.009321
DFFF3(-5)			-0.006954	0.009510
DFFF3(-6)			-0.000158	0.010441
DFFF3(-7)			-0.019576*	0.010716
DFFF3(-8)			-0.004404	0.009894
DFFF3(-9)			-0.002994	0.009875
DFFF3(-10)			0.008930	0.012599
DFFF3(-11)			-0.007096	0.010658
DFFF3(-12)			0.002942	0.010829
DFFF3(-13)			-0.013763	0.010415
DFFF3(-14)			-0.003919	0.010063
DFFF3(-15)			-0.014267	0.010263
INTRATEDUM	-7.83E-05	0.000464	-9.82E-05	0.000481
Variance Equation				
CONSTANT	3.94E-07***	7.61E-08	4.72E-07***	8.53E-08
ARCH (1)	0.049079***	0.005001	0.054752***	0.005274
GARCH (1)	0.939401***	0.006045	0.931882***	0.006429
No of Observations	3192		3177	
No of Iterations	23		16	
R-squared	0.01		0.02	
S.E. of regression	0.006		0.006	
Durbin-Watson stat	1.878		1.878	
ARCH-F (Q^2)	0.857	0.355 (P-val)	0.364	0.546 (P-val)
Q^2 (2)	1.763	0.414 (P-val)	1.255	0.534 (P-val)

* Denotes significance at 90%
** Denotes significance at 95%
*** Denotes significance at 99%

Data Sources: Federal Funds Futures: Chicago Board of Trade End of Day Prices (2 pm Chicago Time)
Exchange Rate Data: Pacific Exchange Rate Service (Noon Pacific Time, i.e. 2 pm Chicago Time).

TABLE 5 **JPY/USD: Exchange Rate Responses to Changes in Expectations of Future Monetary Policy (The Latter Measured by Changes in the 2-Month Ahead Federal Funds Futures Rate)**

Daily Data: 27 March 1989 to 2 February 2002, GARCH Models. All Models run in first differences.
Lags in Parenthesis. All Variables (except dummies) measured in Natural Logs

	Model 1	Std Error	Model 2	Std Error
CONSTANT	0.000139	0.000126	0.000118	0.000130
DFFF2	0.038046***	0.012626	0.036055***	0.012891
DFFF2(-1)			0.015228	0.011538
DFFF2(-2)			0.014600	0.012101
DFFF2(-3)			0.027930**	0.013212
DFFF2(-4)			-0.018391	0.013034
DFFF2(-5)			0.003026	0.012938
DFFF2(-6)			-0.022915**	0.011118
DFFF2(-7)			-0.032501**	0.013017
DFFF2(-8)			-0.015259	0.014130
DFFF2(-9)			-0.000124	0.012763
DFFF2(-10)			0.010759	0.012421
DFFF2(-11)			-0.006497	0.012499
DFFF2(-12)			0.004181	0.013539
DFFF2(-13)			-0.018393	0.012397
DFFF2(-14)			-0.007801	0.012663
DFFF2(-15)			0.003573	0.012715
INTERVENDUM	0.000562	0.000985	0.000696	0.001004
INTRATEDUM	-0.001361***	0.000390	-0.001324	0.000404
Variance Equation				
CONSTANT	9.78E-07***	1.39E-07	8.89E-07***	1.37E-07
ARCH (1)	0.048955***	0.004548	0.047996***	0.004609
GARCH (1)	0.932578***	0.005995	0.935075***	0.006056
No of Observations	3192		3177	
No of Iterations	19		22	
R-squared	0.005		0.01	
S.E. of regression	0.007		0.007	
Durbin-Watson stat	1.946		1.951	
ARCH-F (Q^2)	0.412	0.521 (P-val)	0.392	0.531 (P-val)
Q^2 (2)	0.467	0.792 (P-val)	0.513	0.774 (P-val)

* Denotes significance at 90%
** Denotes significance at 95%
*** Denotes significance at 99%

Data Sources: Federal Funds Futures: Chicago Board of Trade End of Day Prices (2 pm Chicago Time)
Exchange Rate Data: Pacific Exchange Rate Service (Noon Pacific Time, i.e. 2 pm Chicago Time).

TABLE 6 **JPY/USD: Exchange Rate Responses to Changes in Expectations of Future Monetary Policy (The Latter Measured by Changes in the 3-Month Ahead Federal Funds Futures Rate)**

Daily Data: 27 March 1989 to 2 February 2002, GARCH Models. All Models run in first differences.
Lags in Parenthesis. All Variables (except dummies) measured in Natural Logs

	Model 1	Std Error	Model 2	Std Error
CONSTANT	0.000149	0.000126	0.000138	0.000130
DFFF3	0.045456***	0.013598	0.040289***	0.013999
DFFF3(-1)			0.030840**	0.013329
DFFF3(-2)			0.011482	0.013168
DFFF3(-3)			0.020013	0.014042
DFFF3(-4)			-0.015185	0.012496
DFFF3(-5)			0.006669	0.013159
DFFF3(-6)			-0.019410	0.012666
DFFF3(-7)			-0.030077**	0.014204
DFFF3(-8)			-0.019745	0.013306
DFFF3(-9)			0.002731	0.013897
DFFF3(-10)			0.005925	0.012784
DFFF3(-11)			-0.005296	0.011270
DFFF3(-12)			0.005244	0.014385
DFFF3(-13)			-0.015759	0.012264
DFFF3(-14)			0.000300	0.014223
DFFF3(-15)			0.004689	0.012551
INTERVENDUM	0.000675	0.000989	0.000756	0.001000
INTRATEDUM	-0.001398***	0.000393	-0.001350***	0.000405
Variance Equation				
CONSTANT	9.66E-07***	1.39E-07	8.83E-07***	1.37E-07
ARCH (1)	0.048860***	0.004606	0.048218***	0.004603
GARCH (1)	0.932954***	0.005989	0.935006***	0.006005
No of Observations	3192		3177	
No of Iterations	18		22	
R-squared	0.01		0.01	
S.E. of regression	0.007		0.007	
Durbin-Watson stat	1.951		1.954	
ARCH-F (Q^2)	0.485	0.486 (P-val)	0.460	0.498 (P-val)
Q^2 (2)	0.530	0.767 (P-val)	0.589	0.745 (P-val)

* Denotes significance at 90%
** Denotes significance at 95%
*** Denotes significance at 99%

Data Sources: Federal Funds Futures: Chicago Board of Trade End of Day Prices (2 pm Chicago Time)
Exchange Rate Data: Pacific Exchange Rate Service (Noon Pacific Time, i.e. 2 pm Chicago Time).

TABLE 7 **Exchange Rate Responses to Changes in the Federal Funds Target rate**

Daily Data: 6/1/1989 to 3/1/2000 (Except for the DEM/USD sample which ends 12/31/1998)

Responses to Expected and Unexpected Changes

	DEM/USD	Std Error	JPY/USD	Std Error	GBP/USD	Std Error
CONSTANT	-0.00062	0.00126	0.00032	0.00105	-0.00056	0.00104
EXPECTED	-0.00077	0.00521	0.00077	0.00432	0.00509	0.00427
UNEXPECTED	0.02031**	0.00857	0.01595**	0.00747	0.01509**	0.00738
R-squared	0.15		0.13		0.19	
S.E. of regression	0.007		0.006		0.006	
No of Observations	38		42		42	

Responses to Actual Changes

	DEM/USD	Std Error	JPY/USD	Std Error	GBP/USD	Std Error
CONSTANT	-0.00149	0.00121	-0.00038	0.00096	-0.00102	0.00093
ACTUAL	0.00611	0.00371	0.00554*	0.00301	0.00823***	0.00293
R-squared	0.07		0.08		0.16	
S.E. of regression	0.007		0.006		0.006	
No of Observations	38		42		42	

* Denotes significance at 90%
** Denotes significance at 95%
*** Denotes significance at 99%

Data Sources: Target Rate Changes (Actual, Unexpected and Expected): Kuttner (2001, p. 532)
Exchange Rate Data: Board of Governors of the Federal Reserve (Noon Eastern Time).

TABLE 8 **Exchange Rate Responses to Changes in the Federal Funds Target rate: Excluding Other Interest Rate Changes**

Daily Data: 6/1/1989 to 3/1/2000 (Except for the DEM/USD sample which ends 12/31/1998)

Responses to Expected and Unexpected Changes

	DEM/USD[a]	Std Error	JPY/USD[b]	Std Error	GBP/USD[c]	Std Error
CONSTANT	-0.00058	0.00125	n.a.	n.a.	-0.00049	0.00107
EXPECTED	-0.00132	0.00521	-	-	0.00553	0.00451
UNEXPECTED	0.01689*	0.00885	-	-	0.01516**	0.00747
R-squared	0.10		-		0.19	
S.E. of regression	0.006		-		0.006	
No of Observations	36		-		41	

* Denotes significance at 90%
** Denotes significance at 95%
*** Denotes significance at 99%

Data Sources: Target Rate Changes (Actual, Unexpected and Expected): Kuttner (2001, p. 532)
Exchange Rate Data: Board of Governors of the Federal Reserve (Noon Eastern Time).

a) The regression excludes same-day Bundesbank interest rate changes. No Bundesbank interest rate change took place on a business day immediately following a target rate change.
b) No Bank of Japan interest rate change coincided with or took place on a business day immediately following a target rate change.
c) The regression excludes next-day Bank of England interest rate changes. No Bank of England interest rate change took place on the same day as a target rate change.

TABLE 9 **Exchange Rate Responses to Changes in the Federal Funds Target rate: Excluding Observations Coinciding with Intervention**

Daily Data: 6/1/1989 to 3/1/2000 (Except for the DEM/USD sample which ends 12/31/1998)

Due to unavailability of official Bank of England intervention data it is not possible to exclude observations coinciding with intervention in the GBP/USD.

Responses to Expected and Unexpected Changes

	DEM/USD[a]	Std Error	DEM/USD[b]	Std Error	JPY/USD[c]	Std Error	JPY/USD[d]	Std Error
CONSTANT	-0.00098	0.00126	-0.00084	0.00122	0.00001	0.00106	0.00038	0.00112
EXPECTED	0.00071	0.00052	-0.00089	0.00504	0.00201	0.00435	0.00131	0.00448
UNEXPECTED	0.01833**	0.00853	0.02157**	0.00840	0.01432*	0.00746	0.01633*	0.00782
R-squared	0.14		0.18		0.13		0.14	
S.E. of regression	0.006		0.006		0.006		0.006	
No of Observations	37		36		41		40	

* Denotes significance at 90%
** Denotes significance at 95%
*** Denotes significance at 99%

Data Sources: Target Rate Changes (Actual, Unexpected and Expected): Kuttner (2001, p. 532)
Exchange Rate Data: Board of Governors of the Federal Reserve (Noon Eastern Time).

a) The regression excludes same-day Bundesbank and Fed intervention in the DEM/USD.
b) The regression excludes next-day Bundesbank and Fed intervention in the DEM/USD.
c) The regression excludes same-day Bank of Japan and Fed intervention in the JPY/USD.
d) The regression excludes next-day Bank of Japan and Fed intervention in the JPY/USD.