

# **Micro Effects of Macro Announcements: Real-Time Price Discovery in Foreign Exchange\***

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## **Abstract**

Using a new dataset consisting of six years of real-time exchange rate quotations, macroeconomic expectations, and macroeconomic realizations (announcements), we characterize the conditional means of U.S. dollar spot exchange rates for Germany, England, Japan, Switzerland and the Euro. In particular, we show that announcement surprises (that is, divergences between expectations and realizations, or “news”) produce conditional mean jumps; hence high-frequency exchange rate dynamics are linked to fundamentals. The details of the linkage are intriguing and include announcement timing, size and sign effects. The sign effect refers to the fact that the market reacts to news in an asymmetric fashion: bad news has greater impact than good news, which we relate to recent theoretical work on information processing and price discovery.

**Key Words:** Exchange Rates; News Announcements; Jumps; Market Microstructure; High-Frequency Data; Expectations Data; Anticipations Data; Order Flow; Asset Return Volatility; Forecasting.

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## 1. Introduction

How is news about fundamentals incorporated into asset prices? The topic confronted by this question – characterization of the price discovery process – is one of the most important in all of financial economics. Unfortunately, however, it is also one of the least well understood. Indeed, some influential empirical studies have gone so far as to suggest that, for some assets (notably foreign exchange), prices and fundamentals are largely disconnected.<sup>1</sup>

In this paper we provide an empirical examination of price discovery in the challenging context of foreign exchange. Using a newly-constructed dataset consisting of six years of real-time exchange rate quotations, macroeconomic expectations, and macroeconomic realizations (announcements), we characterize the conditional means of U.S. dollar spot exchange rates for Germany, England, Japan, Switzerland and the Euro. In particular, we show that announcement surprises (that is, the difference between expectations and realizations, or “news”) produce conditional mean jumps. Hence exchange rates *are* linked to fundamentals, and we provide a detailed analysis of the speed and pattern of adjustment.

We show that conditional-mean adjustments of exchange rates to news takes place very quickly, effectively amounting to “jumps,” in contrast to conditional variance adjustments, which are much more gradual, and that an announcement’s impact depends on its timing relative to other related announcements, and on whether the announcement time is known in advance. We show, moreover, that the adjustment response pattern is characterized by size and sign effects: large news surprises have disproportionately greater effects than small surprises, and bad news has greater impact than good news. Finally, we relate our results to recent theoretical and empirical work on asset return volatility in its relation to information processing and price discovery.

Our results relate to the earlier literature in interesting ways, and we believe that at least three features differentiate our product. These include our focus on foreign exchange markets, our focus on conditional mean as opposed to conditional variance dynamics, and the length and breadth of our sample of exchange rate and announcement data. Let us discuss them briefly in turn.

First, we focus on foreign exchange markets as opposed to stock or bond markets, and we address the central open issue in exchange rate economics – the link between exchange rates and fundamentals. It is comforting, however, that a number of good recent papers focusing largely on bond

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<sup>1</sup> The classic statement is of course Meese and Rogoff (1983). Mark (1995) and Mark and Sul (1998) find that fundamentals matter in the long run but not in the short run. Evans and Lyons (2001) find that order flow matters in the short run but fail to link order flow to fundamentals. Hence there still exists no evidence of short-run dependence of exchange rates on fundamentals.

markets reach conclusions similar to ours. Balduzzi, Elton and Green (1999), for example, examine the effects of economic news on prices in the U.S. inter-dealer government bond market, finding strong news effects and quick incorporation of news into bond prices, and Fleming and Remolona (1997, 1999) show that the largest bond price movements stem from the arrival of news announcements.

Second, we focus primarily on exchange rate conditional means as opposed to conditional variances. That is, we focus primarily on the determination of exchange rates themselves, as opposed to their volatility. We maintain this focus both because the conditional mean is of intrinsic interest, and because volatility can't be extracted accurately unless the conditional mean is first modeled adequately. Hence our work is very different from that of Andersen and Bollerslev (1998) and Payne (1996), for example, who examine calendar and news effects in high-frequency asset return volatility but fail to consider the effects of news on returns themselves.

Third, we use a new dataset with a comparatively long time span, and we use broad sets of exchange rates and macroeconomic indicators.

Notwithstanding the improvements relative to earlier literature, however, our work bears strong resemblance to its ancestors. Indeed, several studies have linked macroeconomic news announcements to jumps in exchange rates, and our work may be viewed as a confirmation and elaboration. Goodhart, Hall, Henry, and Pesaran (1993), for example, examine one year of high-frequency \$/pound exchange rates and two specific news events – a U.S. trade figure announcement and a U.K. interest rate change – and conclude in each case that the news caused an exchange rate jump. Almeida, Goodhart and Payne (1998) study three years of high-frequency DM/\$ exchange rates and a larger set of news announcements, finding systematic and short-lived news effects. Finally, Dominguez (1999) finds that most large exchange rate changes occur within 10 seconds of a macroeconomic news announcement, and that close timing of central bank interventions to news announcements increases their effectiveness.

We proceed as follows. In section 2 we describe our high-frequency exchange rate and macroeconomic expectations and announcements data. In section 3 we characterize the speed and pattern of exchange rate adjustment to macroeconomic news, documenting announcement timing effects, announcement size effects, and announcement sign effects. In section 4 we relate the sign effects (i.e., greater exchange rate response to bad news than to good news) to recent theories of information processing and price discovery. We conclude in section 5.

## **2. Real-Time Exchange Rates, Expected Fundamentals, and Announced Fundamentals**

Throughout the paper we use data on exchange rate returns in conjunction with data on expectations and announcements of macroeconomic fundamentals. The data are novel in several

respects, such as the simultaneous high frequency and long calendar span of the exchange rate returns, and the real-time nature of the expectations and announcements of fundamentals. Here we describe them in some detail.

### Exchange Rate Data

The raw 5-minute CHF/\$, DM/\$, Euro/\$, pound/\$ and yen/\$ return series were obtained from Olsen and Associates. The full sample consists of continuously-recorded 5-minute returns from January 3, 1992 through December 30, 1998, or 2,189 days, for a total of  $2,189 \cdot 288 = 630,432$  high-frequency foreign exchange (FX) return observations. As in Müller et al. (1990) and Dacorogna et al. (1993), we use all of the interbank quotes that appeared on the Reuters screen during the sample period to construct our 5-minute returns. Each quote consists of a bid and an ask price together with a “time stamp” to the nearest second. After filtering the data for outliers and other anomalies, we obtain the price at each 5-minute mark by linearly interpolating the average of the log bid and the log ask at the two closest ticks. We then construct continuously-compounded returns as the change in these 5-minute average log bid and ask prices. Goodhart, Ito and Payne (1996) and Danielsson and Payne (1999) find that the basic characteristics of 5-minute FX returns constructed from quotes closely match those calculated from transactions prices (which are not generally available). Implicit evidence on the similar characteristics of bid-ask averages and transactions prices is also provided by a comparison of Andersen, Bollerslev, Diebold and Labys (2001a), which uses bid/ask averages, to Andersen, Bollerslev, Diebold and Ebens (2001), which uses transactions prices, producing qualitatively identical results for return distributions and dynamics.

It is well known that the activity in the foreign exchange market slows decidedly over the weekend and certain holiday non-trading periods; see Müller et al. (1990). So as not to confound the distributional characteristics of the various volatility measures by these largely deterministic calendar effects, we explicitly excluded a number of days from the raw 5-minute return series. Whenever we did so, we always cut from 21:05 GMT the night before to 21:00 GMT that evening. This particular definition of a “day” was motivated by the ebb and flow in the daily FX activity patterns documented in Bollerslev and Domowitz (1993) and keeps the daily periodicity intact. In addition to the thin weekend trading period from Friday 21:05 GMT until Sunday 21:00 GMT, we removed several fixed holidays, including Christmas (December 24 - 26), New Year’s (December 31 - January 2), and July Fourth. We also cut the moving holidays of Good Friday, Easter Monday, Memorial Day, July Fourth (when it falls officially on July 3), and Labor Day, as well as Thanksgiving and the day after. Although our cuts do not account for all of the holiday market slowdowns, they capture the most important daily calendar effects.

Finally, we deleted some of the returns contaminated by brief lapses in the Reuters data feed. This problem, which occurred almost exclusively during the early part of the sample, manifested itself in the form of sequences of zero or constant 5-minute returns in places where the missing quotes had been interpolated. To remedy this, we simply removed the days containing the fifteen longest DM/\$ zero runs, the fifteen longest DM/\$ constant runs, the fifteen longest Yen/\$ zero runs, and the fifteen longest Yen/\$ constant runs. Because of the overlap among the four different sets of days defined by these criteria, we actually removed only 25 days. In the end we were left with 1,724 days of data, containing  $T = 1,724 \cdot 288 = 496,512$  5-minute return observations.

To gain a preliminary feel for the nature of unconditional 5-minute exchange rate return distributions, we calculated some standard descriptive statistics (not reported to save space). The mean 5-minute returns are of course negligible and dwarfed by the standard deviations, and the distributions of the 5-minute returns are approximately symmetric but distinctly non-Gaussian, due to excess kurtosis. Ljung-Box statistics indicate serial correlation in both returns and absolute returns.

Digging deeper via the return autocorrelations in the first column of Figure 1, we see that the returns display very small but nevertheless statistically significant serial correlation at the very shortest lags, presumably due to microstructure effects. All told, the serial correlation in returns appears minor, particularly in contrast to the serial correlation in absolute returns, which appears huge, as shown in the second column of Figure 1. The sample autocorrelations of absolute returns display very slow decay and pronounced diurnal variation, in line with the results of Ederington and Lee (1993) and Andersen and Bollerslev (1998). Interestingly, not only the shapes but also the amplitudes of the diurnal patterns in absolute returns differ noticeably across currencies.

#### Expected Fundamentals, Announced Fundamentals, and News

We use the International Money Market Services (MMS) real-time data on expected and realized (“announced”) macroeconomic fundamentals, and we define news as the difference between expectations and realizations. Every week since 1977, MMS has conducted a Friday telephone survey of about forty money managers, collected forecasts of all indicators to be released during the next week, and reported the median forecasts from the survey. Numerous influential studies, from early work such as Urich and Wachtel (1984) through recent work such as Balduzzi, Elton and Green (1999), have verified that the MMS expectations contain valuable information about the variable being forecasted and in most cases are unbiased and less variable than those produced from extrapolative benchmarks such as ARMA models.

In Table 1 we offer a brief description of salient aspects of U.S. and German economic news announcements. We show the total number of observations in our news sample, the agency reporting each announcement, and the time of the announcement release. It is interesting to note that U.S. announcements arrive at fixed days and times known in advance, whereas although German announcements arrive on fixed days known in advance, their timing within the day is variable and not known in advance.

In Table 2 we show the pattern of U.S. release dates throughout the month.<sup>2</sup> This is of potential importance, because there is some redundancy across indicators. For example, consumer and producer price indexes, although of course not the same, are nevertheless related, and Table 2 reveals that the producer price index is released earlier in the month. Hence one might conjecture that producer price news would have a greater effect on asset prices than consumer price news, as the consumer price news may not be so newsworthy if one already knows the producer price news!

We follow Balduzzi, Elton and Green (1999) in using standardized news. That is, because units of measurement differ across economic variables, we divide the surprise by its sample standard deviation to facilitate interpretation. The standardized news associated with indicator  $k$  at time  $t$  is

$$S_{kt} = \frac{A_{kt} - E_{kt}}{\hat{\sigma}_k},$$

where  $A_{kt}$  is the announced value of indicator  $k$ , and  $E_{kt}$  is the market expected value of indicator  $k$  as distilled in the MMS median forecast. We have forty macroeconomic indicators (as described in Table 1), so  $k=1, \dots, 40$ , and we have 496,512 5-minute intervals in our sample, so  $t = 1, \dots, 496,512$ . By using standardized news, we can provide meaningful comparisons of the responses of different exchange rates to different pieces of news. Operationally, we estimate those responses by regressing asset returns on news; because  $\hat{\sigma}_k$  is constant for any indicator  $k$ , the standardization affects neither the fit of the regressions nor the statistical significance of response estimates.

### 3. Exchange Rates and Fundamentals

We will specify and estimate a model of high-frequency exchange rate dynamics that allows for the possibility of news affecting both the conditional mean and the conditional variance. Our goal is to determine whether high-frequency exchange rate movements are linked to fundamentals, and if so how, and our motivations are both “highbrow” and “middlebrow.” The highbrow motivation is obviously the possibility of refining our understanding of the fundamental determinants of exchange rates, the central

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<sup>2</sup> The design of the table follows Chart 2 of Fleming and Remolona (1997).

and still largely-unresolved question of exchange rate economics. The middlebrow motivation is the possibility of improved high-frequency volatility estimation via allowance for jumps due to news, as misspecification of the conditional mean (for example by failing to allow for jumps, if jumps are in fact present) will produce distorted volatility estimates.<sup>3</sup>

### Modeling the Response of Exchange Rates to News

We model the the 5-minute spot exchange rate,  $R_t$ , as a linear function of  $I$  lagged values of itself, and  $J$  lags of news on each of  $K$  fundamentals:

$$R_t = \beta_0 + \sum_{i=1}^I \beta_i R_{t-i} + \sum_{k=1}^K \sum_{j=0}^J \beta_{kj} S_{k,t-j} + \varepsilon_t, \quad t = 1, \dots, T. \quad (1)$$

As discussed earlier,  $K=40$  and  $T=496,512$ . We chose  $I=5$  and  $J=2$  based on the Schwarz and Akaike information criteria.<sup>4</sup>

We allow the disturbance term in the 5-minute return model (1) to be heteroskedastic. Following Andersen and Bollerslev (1998), we estimate the model using a two-step weighted least squares (WLS) procedure. We first estimate the conditional mean model (1) by ordinary least squares regression, and then we estimate the time-varying volatility of  $\varepsilon_t$  from the regression residuals, which we then use to perform a weighted least squares estimation of (1). We approximate the disturbance volatility using the model:

$$|\hat{\varepsilon}_t| = c + \psi \frac{\hat{\sigma}_{dt}}{\sqrt{288}} + \sum_{k=1}^K \sum_{j'=0}^{J'} \beta_{kj'} |S_{k,t-j'}| + \left( \sum_{q=1}^Q \left( \delta_q \cos\left(\frac{q2\pi t}{288}\right) + \phi_q \sin\left(\frac{q2\pi t}{288}\right) \right) + \sum_{r=1}^R \sum_{j''=0}^{J''} \gamma_{rj''} D_{r,t-j''} \right) + u_t. \quad (2)$$

The left-hand-side variable,  $|\hat{\varepsilon}_t|$ , is the absolute value of the residual of equation (1), which proxies the volatility in the 5-minute interval  $t$ . As revealed by the right-hand side of equation (2), we model 5-minute volatility as driven partly by the volatility over the day containing the 5-minute interval in question,  $\hat{\sigma}_d$ , partly by news  $S$ , and partly by a calendar effect pattern consisting largely of intraday effects that capture the high-frequency rhythm of deviations of intraday volatility from the daily average. Specifically, we split the calendar effects into two parts. The first is a Fourier flexible form with

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<sup>3</sup> We will not pursue volatility estimation in this paper but plan to do so in future work. For a discussion of the effects of conditional mean and variance jumps on the properties of the “realized volatility” estimator, see Andersen, Bollerslev, Diebold and Labys (2001b).

<sup>4</sup> We also tried allowing for negative  $J$ , to account for announcement leakage before the official time, but doing so proved unnecessary.

trigonometric terms that obey a strict periodicity of one day.<sup>5</sup> The second is a set of dummy variables  $D$  capturing the Japanese lunch, the Japanese open, and the U.S. late afternoon during U.S. daylight saving time.

Let us explain in greater detail. Consider first the daily volatility,  $\hat{\sigma}_d$ , which is the one-day-ahead volatility forecast for day  $d$  (the day that contains time  $t$ ) from a simple daily conditionally-Gaussian GARCH(1,1) model using spot exchange rate returns from January 2, 1986 through December 31, 1998. Because  $\hat{\sigma}_d$  is intended to capture the “average” level of volatility on day  $d$ , it makes sense to construct it using a GARCH(1,1) model, which is routinely found to provide accurate approximations to daily asset return volatility dynamics.<sup>6</sup>

Now consider the Fourier part of the calendar effects, which is very flexible and may be given a semi-nonparametric interpretation, as argued by Gallant (1981). The Schwarz and Akaike information criteria chose a rather low  $Q=4$  for all currencies, which achieves parametric economy and promotes smoothness in the intraday seasonal pattern.

Finally, consider the news effects  $S$  and non-Fourier calendar effects  $D$ . To promote tractability while simultaneously maintaining flexibility, we impose polynomial structure on the response patterns associated with the  $\beta_{kj}$  and  $\gamma_{rj}$  parameters.<sup>7</sup> For example, if a particular news surprise affects volatility from time  $t_0$  to time  $t_0 + J'$ , we can represent the impact over the event window  $\tau = 0, 1, \dots, J'$  by a polynomial specification,  $p(\tau) = c_0 + c_1\tau + \dots + c_P\tau^P$ . For  $P = J'$  this would imply the estimation of  $J'+1$  polynomial coefficients and would not constrain the response pattern in any way. Use of a lower-ordered polynomial, however, constrains the response in helpful ways: it promotes parsimony and hence tractability, retains flexibility of approximation, and facilitates the imposition of sensible constraints on the response pattern. For example, we can enforce the requirement that the impact effect slowly fades to zero by imposing  $p(J') = 0$ .

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<sup>5</sup> We also translate the Fourier terms leftward as appropriate during U.S. daylight savings time. (Only North America and Europe have daylight savings time.)

<sup>6</sup> For surveys of GARCH modeling in financial environments, see Bollerslev, Chou and Kroner (1992) and Diebold and Lopez (1995). Other possibilities, also explored with little change in qualitative results, include use of daily realized volatilities as in Andersen, Bollerslev, Diebold and Labys (2001a, b) and Andersen, Bollerslev, Diebold and Ebens (2001).

<sup>7</sup> This is particularly important in the case of conditional variance as opposed to conditional mean dynamics, because conditional variances turn out to adjust to shocks more slowly than do conditional means, thereby involving longer distributed lags. Hence, although tractability did not require the imposition of polynomial shape on the conditional mean distributed lags, it does require it on the conditional variance distributed lags.



Polynomial specifications ensure that the response patterns are completely determined by the response horizon  $J'$ , the polynomial order  $P$ , and the endpoint constraint imposed on  $p(J')$ . For news effects  $S$ , we take  $J'=12$ ,  $P=2$ ,  $p(J')=0$ , and we furthermore impose a common structure on all forty announcements,  $p_k(\tau)=\gamma_k p_0(\tau)$ , where  $p_k(\tau)$  refers to the polynomial for macroeconomic indicator  $k$ , and  $p_0(\tau)$  denotes a fixed baseline pattern. We calibrate the baseline pattern by fitting to a subset of the most important announcements, resulting in  $(c_0, c_1, c_2) = (2.0545, -0.5015, 0.04309)$ . As for the non-Fourier calendar effect response patterns  $D$ , for the Japanese market opening we use  $J''=6$ ,  $P=1$ ,  $p(J'')=0$ , for the Japanese lunch hour we use  $J''=0$  (i.e., it is just a standard dummy variable with no polynomial response), and for the U.S. late afternoon during U.S. daylight saving time we use  $J''=60$ ,  $P=2$ , and  $p(0)=p(J'')=0$ .<sup>8</sup>

In closing this subsection, we note that we could have handled the volatility dynamics differently. In particular, instead of estimating explicit parametric models of volatility dynamics, we could have simply estimate equation (1) using heteroskedasticity and serial correlation consistent (HAC) standard errors. We find that approach less attractive than the one we adopted, for at least three reasons. First, we are interested not only in performing heteroskedasticity-robust inference about the coefficients (done both by our WLS and by HAC estimation) in equation (1), but also in obtaining the most efficient estimates of those coefficients (done by WLS but not HAC). Second, although HAC estimation is asymptotically robust to residual heteroskedasticity of unknown form, its general robustness may come at the price of inferior finite-sample performance relative to estimation of a well-specified parametric volatility model.<sup>9</sup> Third, both the intra- and inter-day volatility patterns are of intrinsic financial economic interest and hence one may want estimates of them (despite the fact that they are not central to the analysis of this paper). Nevertheless, as a check on the robustness of our results to estimation method, we also performed all of the empirical work in this paper using HAC estimation, with no change in any of the qualitative results.

#### News Effects I: News Announcements Matter

The model (1)-(2) provides an accurate approximation to both conditional mean and conditional variance dynamics. In figure 2 we show the actual and fitted average intraday volatility patterns, which agree closely. However, the model contains so many variables, and lags of those variables, that it would

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<sup>8</sup> The Japanese opening is at 8 pm Eastern daylight savings time, the Japanese lunch hour is 11 pm through 12:30 am Eastern daylight savings time, the U.S. late afternoon during daylight savings time is defined to start at 3 pm Eastern daylight savings time.

<sup>9</sup> See Chesher and Jewitt (1987) and Rao (1970).

prove counterproductive to report all of the parameter estimates. Instead, in Figure 3 we present graphically the results for the most important indicators, and we discuss those results (and some others) in what follows.

Let us first consider the effects of U.S. macroeconomic news, as summarized in Figure 3. Throughout, news exerts generally statistically significant influence on exchange rates, whereas expected announcements generally do not. That is, only *unanticipated* shocks to fundamentals affect exchange rates, in accordance with the predictions of rational expectations theory. Many U.S. indicators have statistically significant news effects across all currencies, including payroll employment, durable goods orders, trade balance, initial unemployment claims, NAPM index, retail sales, consumer confidence, and GDP (advance).

The general pattern is one of very quick exchange rate conditional mean adjustment, characterized by a jump immediately following the announcement, and little movement thereafter. Favorable U.S. “growth news” tends to produce dollar appreciation, and conversely, which is consistent with a variety of models of exchange rate determination, from simple monetary models (e.g., Mark, 1995) to more sophisticated frameworks involving a U.S. central bank reaction function that embodies a preference for low inflation (e.g., Taylor, 1993).<sup>10</sup> One can see from the center panel of the first row of Figure 3, for example, that a one standard deviation U.S. payroll employment surprise tends to appreciate (if positive) or depreciate (if negative) the dollar against the DM by 0.15 %.<sup>11</sup> This is a sizeable move, from both statistical and economic perspectives. On the statistical side, we note that only 0.7% of our 5-minute returns show an appreciation or depreciation bigger than 0.10%. On the economic side, we note that 0.15% is also large relative to the average DM/\$ spread, which tends to be around 0.06% during the period we study, as documented by Hasbrouck (1999, Table 1).

Now let us focus on the DM/\$ rate in some detail, which is of particular interest both because of its central role in the international financial system during the period under study, and because we have news data on both U.S. and German macroeconomic indicators.<sup>12</sup> First consider the effects of U.S. macroeconomic news on the DM/\$ rate. News announcements on a variety of U.S. indicators

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<sup>10</sup> For most of our macroeconomic indicators, including those on which we primarily focus, the sign of a “good shock” is clear: movements associated with increased real economic activity or decreased inflation are good. Sometimes, however, it is not obvious which direction should be viewed as good, as perhaps with consumer credit.

<sup>11</sup> We interpret a one standard deviation surprise as “typical.”

<sup>12</sup> German news is the only non-U.S. news that is readily available from MMS.

significantly affect the DM/\$ rate, including payroll employment, durable goods orders, trade balance, initial claims, NAPM index, retail sales, consumer confidence, CPI, industrial production, leading indicators, housing starts, construction spending, factory orders, new home sales, and GDP (advance, preliminary and final).

Now consider the effect of *German* macroeconomic news on the DM/\$ rate.<sup>13</sup> In sharp contrast to the large number U.S. macroeconomic indicators whose news affects the DM/\$ rate, only a very few German macroeconomic indicators significantly affect it (M3 and industrial production). We conjecture that the disparity may be due to the fact, detailed in Table 1, that the release times of U.S. macroeconomic indicators are known exactly (day and time) but only inexactly for Germany (day but not time). Uncertain release times may result in less market liquidity around announcement times and hence less trading associated with announcements, ultimately resulting in less response to announcements.<sup>14</sup> Alternatively, reaction to German news might occur more slowly than for U.S. news, perhaps for a few hours after the announcement, or it could occur gradually during the days and hours *before* the announcement due to leakage, which is evidently more common in Germany than in the U.S. Our present econometric framework would fail to detect such effects.

Most of the explanatory power of the exchange rate conditional mean model (1) comes from the lagged values of the dependent variable and the contemporaneous news announcement. Hence, although fifty-eight percent of the days in our sample contain a news announcement, to a good approximation the news predicts only the direction and magnitude of the exchange rate movement during the 5-minute post-release intervals, which correspond to only two tenths of one percent of the sample observations. To focus on the the importance of news during announcement periods, we now estimate the model

$$R_t = \beta_k S_{kt} + \varepsilon_t, \quad (3)$$

where  $R_t$  is the 5-minute return from time  $t$  to time  $t+1$  and  $S_{kt}$  is the standardized news corresponding to announcement  $k$  ( $k=1,\dots,40$ ) at time  $t$ , and we estimate the model using only those observations  $(R_t, S_{kt})$  such that an announcement was made at time  $t$ .

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<sup>13</sup> To a first approximation, German news is relevant only for DM/\$ determination, in contrast to U.S. news, which is relevant for the determination of all U.S. dollar exchange rates.

<sup>14</sup> Alternative explanations include (1) reaction to German news announced with variable release time may occur more slowly than for U.S. news – perhaps for a few hours after the announcement -- which our present econometric framework would fail to capture, and (2) greater pre-announcement leakage in Germany may results in adjustments taking place gradually in the days and hours leading up to the announcement.

We show the estimation results in Table 3, which contains a number of noteworthy features. First, news on many of the fundamentals exerts a significant influence on exchange rates. This is of course expected, given our earlier estimation results for equation (1) as summarized in Figure 3.

Second, unlike the  $R^2$  values for equation (1), which are typically very small, the  $R^2$  values for equation (3) are often quite high. News announcements occur comparatively rarely and have a non-negligible but short-lived impact on exchange rates; hence the  $R^2$  in an equation such as (3) must be low when computed across all 5-minute observations. In contrast, one naturally expects higher  $R^2$  values when computed using only announcement observations, although the precise size is of course an empirical matter. Table 3 reveals  $R^2$  values that are quite high, often around 0.3 and sometimes approaching 0.6.

#### News Effects II: Announcement Timing Matters

One might wonder whether, within the same general category of macroeconomic indicators, news on those released earlier tends to have greater impact than those released later. To evaluate this conjecture, we grouped the U.S. indicators into seven types: real activity, consumption, investment, government purchases, net exports, prices, and forward-looking. Within each group, we arranged the announcements in the chronological order described in Table 2. The conjecture is generally verified. In the estimates of equation (3) within each indicator group, the announcements released earliest tend to have the highest  $R^2$  and statistically significant coefficients.<sup>15</sup> In Figure 4 we plot the  $R^2$  of equation (3) within each indicator group, as a function of the release ordering. The clearly prevalent downward slopes reveal that the early announcements have greater impact.

#### News Effects III: Responses Vary Systematically with the Size and Sign of the News

We have seen that news about macroeconomic fundamentals significantly affects high-frequency exchange rates. Thus far we have allowed only for constant news effects, but it is natural to go farther and ask whether the news effects vary with the size and/or sign of the surprise. To address this issue we generalize equation (3) by allowing the impact response coefficient  $\beta_k$  to be proportional to the news surprise  $S_{kt}$ , allowing for a different constant of proportionality on each side of the origin,<sup>16</sup>

$$\beta_k = \begin{cases} \beta_{0k} S_{kt} & \text{if } S_t \leq 0 \\ \beta_{1k} S_{kt} & \text{if } S_t > 0. \end{cases} \quad (4)$$

<sup>15</sup> One exception is the nominal group; the consumer price index seems more important than the producer price index, despite its earlier release date.

<sup>16</sup> Making  $\beta_k$  a proportional rather than a linear function of  $S_{kt}$ , as we have done, desirably enforces the constraint that zero surprises have zero impact.

Inserting (4) into (3) yields the impact response specification,

$$R_t = \begin{cases} \beta_{0k} S_{kt}^2 + \varepsilon_t & \text{if } S_t \leq 0 \\ \beta_{1k} S_{kt}^2 + \varepsilon_t & \text{if } S_t > 0. \end{cases} \quad (5)$$

Following Engle and Ng (1993), we call the union of  $\beta_{0k} S_{kt}^2$  to the left of the origin and  $\beta_{1k} S_{kt}^2$  to the right of the origin the “news impact curve.” In the top row of Figure 5 we show the news impact curves averaged across all macroeconomic fundamentals,  $k = 1, \dots, 40$ . It is clear that, on average, the effect of macroeconomic news does vary with both its size and sign: large absolute surprises have disproportionately large impact, and negative surprises have greater impact than positive surprises.<sup>17</sup> To our knowledge, we are the first to document such size and sign effects in the response of exchange rates to news.<sup>18</sup>

It is interesting to see whether the size and sign effects prevail when we look separately at the most important news announcements. In the remaining rows of Figure 5 we show the news impact curves for payroll employment, trade balance, durable goods orders and initial claims. The size effect holds for all of the exchange rates and for all of the individual indicators shown. The sign (asymmetry) effect is also generally maintained, although there is some variation across indicators and currencies. Asymmetry in exchange rate response to payroll employment news, for example, is more pronounced than average, whereas it is largely absent in response to trade balance news.

#### News Effects IV: Volatility Adjusts to News Gradually

As discussed previously and documented in Figure 3, exchange rates adjust to news immediately. It is interesting to note, however, that exchange rate *volatilities* adjust only gradually, with approximately complete adjustment occurring only after  $J'=12$  5-minute periods.

We provide details in Table 4. As already noted, and as shown again in the top panel of the table, the contemporaneous return response coefficients are sizeable and statistically significant, and the full response occurs immediately. In contrast, the contemporaneous volatility response coefficients, although statistically significant, are smaller, as shown in the middle panel of the table. Importantly,

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<sup>17</sup> Our work is very different from that of Engle and Ng (1993) and many subsequent related studies, despite the superficial resemblance in terms of documenting asymmetric response to news. In particular, the Engle-Ng news impact curve tracks the *variance* of *equity* returns conditional upon the sign and size of *past returns* (with no allowance for a time-varying conditional mean return), whereas our news impact curve tracks the *mean* of *forex* returns conditional upon the sign and size of *macroeconomic news*.

<sup>18</sup> Evidence of asymmetric conditional-mean news effects exists in other contexts, however. For example, Conrad, Cornell and Landsman (2001) find asymmetric effects of earnings news on stock returns.

however, the complete response of volatility to news occurs only after an hour or so, and the complete response is noticeably larger than either the contemporaneous volatility response or the contemporaneous return response, as shown in the bottom panel of the table.

#### News Effects V: Pure Announcement Effects in Volatility

It is possible, and it has been found in bond market studies such as Fleming and Remolona (1997, 1999), that the mere presence of an announcement might boost volatility, quite apart from the size of the associated surprise. To explore this possibility we add to the returns equation (1)  $J$  lags of announcement period dummies on each of  $K$  fundamentals, and we also add to the volatility equation (2)  $J'$  lags of announcement period dummies on each of  $K$  fundamentals. We report the results in Table 5. The announcement dummies are generally insignificant in the returns equation (1) but generally significant in the volatility equation (2).

#### News Effects VI: FOMC News

The Federal Open Market Committee's (FOMC) announcement of the federal funds rate target, although likely producing important news, is nonstandard and hence is not typically examined. It is nonstandard because prior to February 1994 it was not announced; instead, the FOMC *signaled* the target rate, but did not state it explicitly, through open market operations performed from 11:30 to 11:35 am Eastern time on the day of the FOMC meeting. In February 1994, the FOMC began to announce changes in the target rate on meeting days, albeit at irregular times, and from 1995 onward it announced the target rate on meeting days regularly at 2:15 pm Eastern time.<sup>19</sup>

To assess the effects of FOMC news, we need to know announcement days and times, as well as the market's expected fed funds rate target and the announced (or signaled) value. Determination of announcement days and times is relatively straightforward. We collected the irregular 1994 announcement times from Reuters.<sup>20</sup> Before 1994 we use an 11:30 am Eastern announcement time, and after 1995 we use a 2:15 pm announcement time.<sup>21</sup> Determination of market expectations are similarly straightforward: we use MMS survey data on expected federal fund rate targets from January 1992 to December 1998. The announcements themselves are trickier to construct, due to the pre-1994 FOMC

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<sup>19</sup> See Kuttner (2001).

<sup>20</sup> The announcement times were 11:00 am Eastern time on 02/04/94, 2:20 pm on 03/22/94, 07/06/94 and 11/15/94, 2:26 pm on 05/17/94, and 2:15 pm on 12/20/94.

<sup>21</sup> The FOMC can also surprise the market by changing the fed funds target between FOMC meetings. Because this doesn't happen often in our sample (five times in 62) and we don't have the exact timing of such policy changes, we do not account for them.

secrecy; we use the announcement data constructed by Brandt, Edelen and Kavajecz (2001), kindly provided by Kenneth Kavajecz.

To assess the importance of the target fed funds rate surprise we use it in the contemporaneous exchange rate news response regression (3), and we report the results in Table 6. The large and statistically significant coefficients, and high  $R^2$ s, are striking. News from FOMC deliberations clearly influences exchange rates.

#### **4. Asymmetric Response, Information Processing and Price Discovery**

Two strands of literature imply asymmetry in the response of exchange rates to news. In particular, they imply that bad news in good times should have an unusually large impact, a view commonly heard as well in the practitioner community, as emphasized by Conrad, Cornell, and Landsman (2001). In this section, we use a novel aspect of our Money Market Services data – the cross-sectional dispersion of forecasts across analysts – to test the mechanism through which such implications arise in the exchange rate context.<sup>22</sup>

The first literature is “behavioral” and focuses primarily on equities, at the firm level. Barberis, Shleifer and Vishy (1998), for example, model investors as believing that firm earnings follow a two-state regime-switching process – erroneously, as earnings actually follow a random walk – with mean-reverting earnings in state 0 and upward trending earnings in state 1. Hence a series of positive earnings leads investors to infer that state 1 holds, with the concomitant expectation of additional positive earnings. In such a situation, bad news generates a large negative response because it is a surprise, whereas good news generates little response because it is anticipated.

The second literature uses a rational expectations equilibrium approach and focuses more on the market level as opposed to the firm level, as in Veronesi (1999), David and Veronesi (2001), and Johnson (2000, 2001). Veronesi (1999), in particular, models investors as (correctly) believing that the economy follows a two-state regime-switching process, with “low” and “high” states corresponding to recessions and expansions. Agents solve a signal extraction problem to determine the probability  $\pi(t)$  of being in the high state, and equilibrium asset prices can be shown to be increasing *and convex* functions of  $\pi(t)$ . The intuition for this key result is simple. Suppose that  $\pi(t-1) \approx 1$ , i.e., investors believe that the high state almost surely prevails. Then if bad news arrives at time  $t$ , two things happen: first, expected future asset values decrease, and second,  $\pi(t)$  decreases (i.e., state risk increases). Risk-averse investors

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<sup>22</sup> Note that our entire sample takes place in good times – the 1990s. Hence during our sample period, the theoretical prediction that “bad news in good times should have unusually large effects,” degenerates to “bad news should have unusually large effects,” which is what we found.

require additional returns for bearing this additional risk; hence they require an additional discount on the asset price, which drops by more than it would in a present-value model. Conversely, suppose investors are confident that the low state prevails, i.e.,  $\pi(t-1) \approx 0$ . Then if good news arrives at time  $t$ , expected future asset values increase, but  $\pi(t)$  also increases (i.e., state risk again increases). As before, investors require additional returns for bearing this additional risk; hence they require a discount on the asset price, which increases by less than it would in a present-value model.

It is not our intention here to test the practitioner claim that prices respond most strongly to bad news in good times, or to test Veronesi's model or combine it with the Barberis-Shleifer-Vishny model. First, our dataset is not well-suited to that purpose; it contains, for example, only expansionary times (the 1990s). Second, Conrad, Cornell and Landsman (2001) have already made admirable progress in that regard, finding general support for the assertion that (stock) prices respond most strongly to bad news in good times. Third, the Barberis-Schleifer-Vishny model is not particularly well-suited to the forex context relevant here, as it focuses on the earnings stream for an individual firm.

Instead, we take the practitioner claim as true, and we focus on Veronesi's model, whose underlying macroeconomic regime switching is more relevant for foreign exchange dynamics. We use an interesting feature of our MMS expectations data to assess the key alleged mechanism through which bad news in good times translates into large price moves: increased uncertainty about the state of the economy. In particular, we have data not only on the *median* expectations of macroeconomic fundamentals, but also on the associated *standard deviations* across the individual forecasters. Hence we can check directly whether uncertainty about the state of the economy, as proxied by the standard deviation of expectations across the individual forecasters, increases following the arrival of bad news in good times.<sup>23</sup>

According to the standard U.S. business cycle chronology produced by the National Bureau of Economic Research, the U.S. has been in an expansion since March of 1991; hence our entire sample is in the high state, so that all bad news can be viewed as bad news in good times. Before proceeding to examine the effect of bad news arrivals on subsequent forecast dispersion, however, two issues arise in taking the Veronesi model to the data.

First, it is not clear what timing in the data matches the generic timing in the model. Clearly, bad news at time  $t-1$  means that expectations for time  $t$  are formed in a bad news environment, but what if the

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<sup>23</sup> Forecast dispersion across forecasters and forecast uncertainty are in general different objects. They are commonly found, however, to be positively correlated, as in Zarnowitz and Lambros (1987).



news at  $t-2$  was bad and the news at  $t-1$  was not? Perhaps agents have a memory that lasts longer than one announcement period, so that even the latter case should be viewed as a bad news environment. In general, we might say that we are in a bad news environment if the news was bad at any of times  $t-1$ ,  $t-2$ , ...,  $t-d$ , and the question then is how to choose  $d$ . Second, to enhance our chances of detecting the “Veronesi effect,” if it exists, we may not want to track the arrival of all bad news, but rather only bad news that exceeds some minimal threshold, say the  $p$ -th percentile of the distribution of bad news, where  $p$ , like  $d$ , must be chosen.

To reduce the effects of data mining, we simply set  $d=1$  and  $p=50\%$  (i.e., the median). In Figure 6 we plot the standard deviation of the MMS payroll employment, durable goods orders and trade balance forecasts. The shaded areas indicate significantly bad news times using the  $d=1$  and  $p=50\%$ . The plots show that the forecast uncertainty is indeed higher following bad news than in other times; the uncertainty of payroll employment is thirty percent higher, the uncertainty of durable goods orders is six percent higher, and the uncertainty of the trade balance is twelve percent higher. These effects are robust to reasonable variation in  $p$  and  $d$ .

## **5. Concluding Remarks and Directions for Future Research**

The goal of the research on which this paper reports is to deepen our understanding of the links between exchange rate movements and news about fundamentals. To that end, in this paper we have documented important news effects, with asymmetric response patterns. Let us conclude by relating our results to work on order flow and drawing implications for future research.

In recent innovative work, Evans and Lyons (2001) show that signed order flow is a good predictor of subsequent exchange rate movements. The work is satisfying in that it deepens our understanding of the determinants of high-frequency exchange rate movements, but less satisfying in that we remain ignorant of the determinants of high-frequency order flow. We, in contrast, have shown that news affects exchange rates. Combining our perspectives focuses attention on the causal links among news, order flow and forex movements, which in our view is a prime candidate for future research. It will be of interest, for example, to determine whether news affects exchange rates via order flow or instantaneously.<sup>24</sup> Put differently, it will be of interest to see whether the predictive power of order flow comes from better information about fundamentals or from price pressure. In the different context of

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<sup>24</sup> Note that, following French and Roll (1986) and Fleming and Remolona (1999), publicly available news may be incorporated in prices instantaneously, even without trading.

equities, Froot and Ramadorai (2001) conclude that the predictive power comes largely, although not exclusively, from better information about fundamentals.

A second key direction for future research is pushing farther with the implications of Veronesi (1999) for the analysis of high-frequency news effects. Presently we have verified that the key mechanism that amplifies the effects of bad news in good times in Veronesi's model – increased state uncertainty – is operative in the data. But one could of course go farther and exploit the broader implications of Veronesi's work for our approach, namely that news effects are in general a function of state uncertainty, by including interactions of news with state uncertainty in both our conditional mean and conditional variance specifications. This would be particularly interesting if data were available on exchange rates and fundamentals spanning bad as well as good times, but as of this writing, such data remain elusive.

Finally, of great interest would be exploration not only of the effects of regularly-scheduled quantitative news on macroeconomic fundamentals (done in this paper), but also the effects of irregularly-scheduled, qualitative "headline news," because price movements and perhaps order flow may respond to both. It is not obvious, however, how to do so in a compelling way; both the conceptual and the practical complications seem daunting.

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**Table 1**  
U.S. News Announcements

Announcement	Obs. <sup>1</sup>	Source <sup>2</sup>	Dates <sup>3</sup>	Announcement Time <sup>4</sup>
<b>Quarterly Announcements</b>				
1- GDP Advance	47	BEA	05/22/87-10/30/98	8:30 am
2- GDP Preliminary	46	BEA	06/17/87-12/23/98	8:30 am
3- GDP Final	47	BEA	01/22/87-11/24/98	8:30 am
<b>Monthly Announcements</b>				
<u>Real Activity</u>				
4- Nonfarm Payroll Employment	144	BLS	12/05/86-12/04/98 <sup>5</sup>	8:30 am
5- Retail Sales	145	BC	12/11/86-12/11/98	8:30 am
6- Industrial Production	145	FRB	12/15/86-12/16/98	9:15 am
7- Capacity Utilization	145	FRB	12/15/86-12/16/98	9:15 am
8- Personal Income	142	BEA	12/18/86-12/24/98 <sup>6</sup>	10:00/8:30 am <sup>7</sup>
9- Consumer Credit	129	FRB	04/04/88-12/07/98	3:00 pm <sup>8</sup>
<u>Consumption</u>				
10- Personal Consumption Expenditures	143	BEA	12/18/86-12/24/98 <sup>9</sup>	10:00/8:30 am <sup>10</sup>
11- New Home Sales	117	BC	03/02/89-12/02/98	10:00 am
<u>Investment</u>				
12- Durable Goods Orders	143	BC	12/23/86-12/23/98 <sup>11</sup>	8:30/9:00/10:00 am <sup>12</sup>
13- Construction Spending	128	BC	04/01/88-12/01/98 <sup>13</sup>	10:00 am
14- Factory Orders	127	BC	03/30/88-12/04/98 <sup>14</sup>	10:00 am
15- Business Inventories	129	BC	04/14/88-12/15/98	10:00/8:30 am <sup>15</sup>
<u>Government Purchases</u>				
16- Government Budget Deficit	124	FMS	04/21/88-12/21/98 <sup>16</sup>	2:00 pm
<u>Net Exports</u>				
17- Trade Balance	128	BEA	04/14/88-12/17/98	8:30 am
<u>Prices</u>				
18- Producer Price Index	145	BLS	12/12/86-12/11/98	8:30 am
19- Consumer Price Index	145	BLS	12/19/86-12/15/98	8:30 am
<u>Forward-Looking</u>				
20- Consumer Confidence Index	90	CB	07/30/91-12/29/98	10:00 am
21- NAPM Index	107	NAPM	02/01/90-10/01/98	10:00 am
22- Housing Starts	145	BC	12/30/86-12/30/98	8:30 am
23- Index of Leading Indicators	145	CB	12/30/86-12/30/98	8:30 am
<b>Weekly Announcements</b>				
24- Initial Unemployment Claims	384	ETA	07/18/91-12/31/98	8:30 am
25- Money Supply, M1	628	FRB	12/04/86-12/31/98	4:30 pm
26- Money Supply, M2	563	FRB	03/03/88-12/31/98	4:30 pm
27- Money Supply, M3	563	FRB	03/03/88-12/31/98	4:30 pm

**Table 1 (continued)**  
German News Announcements<sup>17</sup>

Announcement	Obs. <sup>1</sup>	Source <sup>2</sup>	Dates <sup>3</sup>	Announcement Time <sup>4</sup>
<b>Quarterly Announcements</b>				
28- GDP	24	GFSO	03/09/93-12/03/98	Varies
<b>Monthly Announcements</b>				
<u>Real Activity</u>				
29- Employment	59	FLO	04/06/93-12/08/98	Varies
30- Retail Sales	59	GFSO	04/14/93-12/10/98	Varies
31- Industrial Production	63	GFSO	05/04/93-12/07/98	Varies
<u>Investment</u>				
32- Manufacturing Orders	62	GFSO	04/06/93-12/07/98	Varies
33- Manufacturing Output	64	GFSO	03/02/93-12/07/98	Varies
<u>Net Exports</u>				
34- Trade Balance	61	GFSO	07/13/93-12/11/98	Varies
35- Current Account	61	BD	07/13/93-12/11/98	Varies
<u>Prices</u>				
36- Consumer Price Index	68	GFSO	03/01/93-12/23/98	Varies
37- Producer Prices	65	GFSO	03/18/93-12/22/98	Varies
38- Wholesale Price Index	68	GFSO	03/16/93-12/16/98	Varies
39- Import Prices	68	GFSO	03/26/93-12/21/98	Varies
<u>Monetary</u>				
40- Money Stock M3	66	BD	03/18/93-12/18/98	Varies

Notes: We group the U.S. monthly news announcements into seven groups: Real activity, the four components of GDP (consumption, investment, government purchases and net exports), prices, and forward-looking. Within each group, we list U.S. news announcements in chronological order.

Footnotes:

1. Total number of observations in the announcements sample.
2. Bureau of Labor Statistics (BLS), Bureau of the Census (BC), Bureau of Economic Analysis (BEA), Federal Reserve Board (FRB), National Association of Purchasing Managers (NAPM), Conference Board (CB), Financial Management Office (FMO), Employment and Training Administration (ETA), German Federal Statistical Office (GFSO, Statistisches Bundesamt Deutschland), Federal Labor Office (FLO, Bundesanstalt für Arbeit), Bundesbank (BD).
3. Starting and ending dates of the announcements sample.
4. Eastern standard time. Daylight savings time starts on the first Sunday of April and ends on the last Sunday of October.
5. 10/98 is a missing observation.
6. 11/95, 2/96 and 03/97 are missing observations.
7. In 01/94, the personal income announcement time moved from 10:00 am to 8:30 am.
8. Beginning in 01/96, consumer credit was released regularly at 3:00 pm. Prior to this date the release times varied.
9. 11/95 and 2/96 are missing observations.
10. In 12/93, the personal consumption expenditures announcement time moved from 10:00 am to 8:30 am.
11. 03/96 is a missing observation.
12. Whenever GDP is released on the same day as durable goods orders, the durable goods orders announcement is moved to 10:00 am. On 07/96 the durable goods orders announcement was released at 9:00 am.
13. 01/96 is a missing observation.
14. 10/98 is a missing observation.
15. In 01/97, the business inventory announcement was moved from 10:00 am to 8:30 am.
16. 05/88, 06/88, 11/98, 12/89 and 01/96 are missing observations.
17. Prior to 1994 the data refer only to West Germany. Beginning in 1994, the data refer to unified Germany. The timing of the German announcements is not regular, but they usually occur between 2:00 am and 8:00 am eastern standard time.

**Table 2**  
U.S. Macroeconomic Announcement Release Dates  
Data for Month X

Consumer Confidence																					
				NAPM Index																	
				Nonfarm Payroll Employment																	
				Retail Sales																	
				Producer Price																	
				Industrial Production and Capacity Utilization																	
								Consumer Price Index													
				Housing Starts																	
				Government Budget Deficit																	
				Durable Goods Orders																	
												GDP (quarterly)									
								New Home Sales													
				Personal Income and Personal Consumption Expenditures																	
												Leading Indicators									
								Factory Orders													
												Construction Spending									
								Consumer Credit													
												Business Inventories									
												Trade Balance									
22	25	28	31	3	6	9	12	15	18	21	24	27	30	2	5	8	11	14	17	20	23
Month X				Month X+1										Month X+2							

Notes: We show the sequence of announcement dates corresponding to data for month X, for most of the economic indicators used in the paper. For example, March (month X) consumer credit data are announced between May (month X+2) 5 and May 10. GDP data are special, because they are released only quarterly. Hence, the GDP data released in a given month are either advance, preliminary or final depending on whether the month is the first, second or third of the quarter. For example, first quarter Q1 GDP advance data are announced between April (month X+1) 27 and May 4, first quarter GDP preliminary data are announced between May (month X+2) 27 and June 4, and first quarter GDP final data are announced between June (month X+3) 27 and July 4. The table is based on 2001 Schedule of Release Dates for Principal Federal Economic Indicators, produced by the U.S. Office of Management and Budget and available at <http://clinton4.nara.gov/textonly/OMB/pubpress/pei2001.html>.



**Table 3**  
U.S. Contemporaneous News Response Coefficients and  $R^2$  Values

Announcement	Pound/\$		Yen/\$		DM/\$		CHF/\$		Euro/\$	
	$\beta_k$	$R^2$	$\beta_k$	$R^2$	$\beta_k$	$R^2$	$\beta_k$	$R^2$	$\beta_k$	$R^2$
<b>Quarterly Announcements</b>										
1- GDP Advance	0.029	0.098	0.036	0.102	0.08*	0.301	0.079*	0.307	0.061*	0.420
2- GDP Preliminary	0.038	0.134	0.022	0.081	0.055*	0.185	0.057*	0.207	0.017	0.048
3- GDP Final	-0.004	0.004	0.019	0.048	0.017	0.029	0.010	0.007	0.006	0.010
<b>Monthly Announcements</b>										
<u>Real Activity</u>										
4- Nonfarm Payroll Employment	0.098*	0.189	0.084*	0.214	0.161*	0.237	0.144*	0.269	0.08*	0.232
5- Retail Sales	0.048*	0.225	0.019	0.066	0.067*	0.241	0.059*	0.170	0.041*	0.193
6- Industrial Production	0.020*	0.105	0.019*	0.078	0.029*	0.131	0.034*	0.147	0.018*	0.086
7- Capacity Utilization	0.017	0.061	0.016	0.055	0.021	0.046	0.023	0.058	0.018	0.041
8- Personal Income	0.007	0.015	0.001	0.000	0.006	0.007	0.003	0.001	-0.005	0.005
9- Consumer Credit	0.002	0.002	0.009	0.019	0.004	0.012	0.002	0.002	-0.002	0.004
<u>Consumption</u>										
10- Personal Consumption Expend.	-0.003	0.003	0.005	0.006	-0.007	0.010	-0.011	0.012	0.007	0.008
11- New Home Sales	0.002	0.002	0.011	0.030	0.01	0.015	-0.002	0.001	0.005	0.003
<u>Investment</u>										
12- Durable Goods Orders	0.055*	0.266	0.027*	0.081	0.088*	0.363	0.085*	0.355	0.043*	0.237
13- Construction Spending	0.019*	0.087	0.01*	0.026	0.031*	0.091	0.017*	0.034	0.015	0.030
14- Factory Orders	0.011	0.024	0.006	0.006	0.018	0.038	0.019	0.041	0.031*	0.102
15- Business Inventories	-0.004	0.008	0.01	0.029	0.009	0.012	0.002	0.001	0.007	0.015
<u>Government Purchases</u>										
16- Government Budget Deficit	0.007*	0.057	0.008	0.038	0.002	0.003	0.010	0.050	0.003	0.006
<u>Net Exports</u>										
17- Trade Balance	0.092*	0.529	0.112*	0.370	0.138*	0.585	0.124*	0.480	0.084*	0.414
<u>Prices</u>										
18- Producer Price Index	0.005	0.003	0.000	0.000	0.019	0.020	0.017	0.017	0.018*	0.046
19- Consumer Price Index	0.016	0.048	0.012	0.033	0.031*	0.101	0.035*	0.104	0.015	0.027
<u>Forward-Looking</u>										
20- Consumer Confidence Index	0.037*	0.174	0.022*	0.103	0.058*	0.222	0.054*	0.214	0.035*	0.189
21- NAPM Index	0.028*	0.199	0.012*	0.036	0.039*	0.141	0.036*	0.146	0.025*	0.074
22- Housing Starts	0.006	0.008	0.005	0.007	0.017	0.028	0.02*	0.033	0.008	0.009
23- Index of Leading Indicators	0.012	0.031	0.009	0.006	0.012	0.009	0.011	0.005	-0.005	0.005
<b>Weekly Announcements</b>										
24- Initial Unemployment Claims	-0.014*	0.025	-0.012*	0.019	-0.022*	0.036	-0.026*	0.046	-0.019*	0.058
25- Money Supply, M1	0.000	0.000	0.000	0.000	0.004*	0.020	0.004*	0.019	0.002*	0.009
26- Money Supply, M2	0.000	0.000	-0.001	0.001	0.004*	0.019	0.005*	0.030	0.002*	0.013
27- Money Supply, M3	0.000	0.000	0.001	0.002	0.002	0.004	0.004*	0.023	0.002*	0.011

**Table 3 (continued)**  
 German Contemporaneous News Response Coefficients and  $R^2$  Values

	Pound/\$		Yen/\$		DM/\$		CHF/\$		Euro/\$	
	$\hat{\beta}_k$	$R^2$	$\hat{\beta}_k$	$R^2$	$\hat{\beta}_k$	$R^2$	$\hat{\beta}_k$	$R^2$	$\hat{\beta}_k$	$R^2$
	<b>Quarterly Announcements</b>									
28- GDP	-0.004	0.042	-0.002	0.001	-0.007	0.022	-0.011	0.068	-0.004	0.015
	<b>Monthly Announcements</b>									
<u>Real Activity</u>										
29- Employment	0.000	0.000	0.002	0.001	0.000	0.000	0.01*	0.045	0.003	0.003
30- Retail Sales	0.001	0.001	0.004	0.008	-0.003	0.004	-0.002	0.003	-0.01*	0.091
31- Industrial Production	-0.011*	0.059	-0.009	0.036	-0.017*	0.172	-0.015*	0.105	-0.005	0.015
<u>Investment</u>										
32- Manufacturing Orders	-0.007	0.025	-0.008	0.029	-0.011	0.061	-0.01	0.042	-0.002	0.002
33- Manufacturing Output	-0.001	0.001	-0.017*	0.091	-0.007	0.041	-0.009	0.048	-0.007	0.034
<u>Net Exports</u>										
34- Trade Balance	-0.004	0.018	0.001	0.000	0.000	0.000	0.001	0.001	-0.005	0.019
35- Current Account	-0.003	0.009	0.006	0.019	-0.006	0.035	-0.006	0.033	-0.006	0.031
<u>Prices</u>										
36- Consumer Price Index	-0.020*	0.159	-0.004	0.016	0.000	0.000	0.007	0.016	-0.001	0.001
37- Producer Prices	-0.002	0.003	0.003	0.012	-0.003	0.003	-0.004	0.011	-0.008	0.015
38- Wholesale Price Index	0.000	0.000	0.003	0.003	-0.011	0.039	-0.003	0.005	0.004	0.012
39- Import Prices	0.007	0.079	-0.009	0.049	0.003	0.005	0.006	0.019	-0.003	0.003
<u>Monetary</u>										
40- Money Stock M3	-0.02*	0.215	0.000	0.000	-0.033*	0.181	-0.02*	0.113	-0.023*	0.161

Notes: We estimate the contemporaneous exchange rate news response model,  $R_t = \beta_k S_{kt} + \epsilon_t$ , where  $R_t$  is the 5-minute return from time  $t$  to time  $t+1$  and  $S_{kt}$  is the standardized news corresponding to announcement  $k$  ( $k=1, \dots, 40$ ) made at time  $t$ . We estimate the regression using only those observations ( $R_t, S_{kt}$ ) such that an announcement was made at time  $t$ . We report the  $\hat{\beta}_k$  and  $R^2$  values, and we mark with an asterisk those coefficients that are statistically significant at the five percent level, using heteroskedasticity and autocorrelation consistent standard errors.

**Table 4**  
Return and Volatility News Response Coefficients

Announcement	Pound/\$	Yen/\$	DM/\$	CHF/\$	Euro/\$
<b>Contemporaneous Return Response, <math>\beta_{k0}</math></b>					
Nonfarm Payroll Employment	0.098*	0.085*	0.161*	0.144*	0.080*
Durable Goods Orders	0.055*	0.026*	0.087*	0.084*	0.043*
Trade Balance	0.093*	0.113*	0.140*	0.127*	0.086*
Initial Unemployment Claims	-0.013*	-0.013*	-0.021*	-0.025*	-0.018*
<b>Contemporaneous Volatility Response, <math>\beta_{k0}</math></b>					
Nonfarm Payroll Employment	0.058*	0.053*	0.084*	0.077*	0.058*
Durable Goods Orders	0.017*	0.010*	0.027*	0.018*	0.018*
Trade Balance	0.023*	0.040*	0.034*	0.031*	0.026*
Initial Unemployment Claims	0.003*	0.004*	0.010*	0.010*	0.005*
<b>Cumulative Volatility Response, <math>\sum_{j'=0}^{J'} \beta_{kj'}</math></b>					
Nonfarm Payroll Employment	0.356*	0.328*	0.519*	0.476*	0.356*
Durable Goods Orders	0.106*	0.060*	0.163*	0.114*	0.108*
Trade Balance	0.139*	0.244*	0.210*	0.191*	0.161*
Initial Unemployment Claims	0.021*	0.023*	0.059*	0.060*	0.033*

Notes: We estimate the exchange rate conditional mean model (1),  $R_t = \beta_0 + \sum_{i=1}^I \beta_i R_{t-i} + \sum_{k=1}^K \sum_{j=0}^J \beta_{kj} S_{k,t-j} + \varepsilon_t$ , and we report estimates of the contemporaneous response of exchange rate returns to news,  $\beta_{k0}$ . We also estimate the disturbance volatility model (2),

$$|\hat{\varepsilon}_t| = c + \psi \frac{\hat{\sigma}_{dt}}{\sqrt{288}} + \sum_{k=1}^K \sum_{j'=0}^{J'} \beta_{kj'} |S_{k,t-j'}| + \left( \sum_{q=1}^Q \left( \delta_q \cos\left(\frac{q2\pi t}{288}\right) + \varphi_q \sin\left(\frac{q2\pi t}{288}\right) \right) + \sum_{r=1}^R \sum_{j''=0}^{J''} \gamma_{rj''} D_{r,t-j''} \right) + u_t,$$

and we report estimates of the contemporaneous response of exchange rate volatility to news,  $\beta_{k0} = \gamma_k p_0(0)$ , as described in the text. Finally, we also report estimates of the cumulative volatility response,  $\sum_{\tau=0}^{12} \gamma_k p_0(\tau)$ , as described in the text.

Asterisks denote statistical significance at the five percent level.

**Table 5**  
Return and Volatility News Response Coefficients and Announcement Dummy Coefficients

Announcement	Pound/\$	Yen/\$	DM/\$	CHF/\$	Euro/\$
<b>Contemporaneous Return Response</b>					
Nonfarm Payroll					
$\beta_{k0}$	0.098*	0.085*	0.161*	0.144*	0.08*
$\theta_{k0}$	0.012	-0.011	0.029	-0.012	0.015
Durable Goods Orders					
$\beta_{k0}$	0.054*	0.026*	0.086*	0.083*	0.042*
$\theta_{k0}$	-0.021*	-0.006	-0.026*	-0.019	-0.01
Trade Balance					
$\beta_{k0}$	0.094*	0.117*	0.141*	0.126*	0.087*
$\theta_{k0}$	0.011	0.030	0.009	0.003	0.016
Initial Claims					
$\beta_{k0}$	-0.013*	-0.014*	-0.021*	-0.025*	-0.018*
$\theta_{k0}$	-0.003	-0.013*	-0.009	-0.009	-0.008*
<b>Contemporaneous Volatility Response</b>					
Nonfarm Payroll					
$\beta_{k0}$	0.0173*	0.0216*	0.0215*	0.0169*	0.015*
$\theta_{k0}$	0.0566*	0.0436*	0.0873*	0.0837*	0.0597*
Durable Goods Orders					
$\beta_{k0}$	0.014*	0.0098*	0.023*	0.0148*	0.0144*
$\theta_{k0}$	0.0042	0.0002	0.0048	0.0046	0.0043
Trade Balance					
$\beta_{k0}$	0.0226*	0.0255*	0.0214*	0.0149*	0.0153*
$\theta_{k0}$	0.0001	0.0174*	0.0162*	0.0198*	0.0141*
Initial Claims					
$\beta_{k0}$	0.0005	-0.0005	0.0039*	0.0062*	0.002
$\theta_{k0}$	0.0035*	0.0048*	0.0062*	0.0038*	0.0032*

Notes: We add to equation (1)  $J$  lags of announcement period dummies on each of  $K$  fundamentals,

$R_t = \beta_0 + \sum_{i=1}^I \beta_i R_{t-i} + \sum_{k=1}^K \sum_{j=0}^J \beta_{kj} S_{k,t-j} + \sum_{k=1}^K \sum_{j=0}^J \theta_{kj} D_{k,t-j} + \varepsilon_t$ , and we report estimates of the contemporaneous return response to news and to announcement periods,  $\beta_{k0}$  and  $\theta_{k0}$ . Asterisks denote statistical significance at the five percent

level. We also add to equation (2)  $J'$  lags of announcement period dummies on each of  $K$  fundamentals,

$|\hat{\varepsilon}_t| = c + \psi \frac{\hat{\sigma}_{dt}}{\sqrt{288}} + \sum_{k=1}^K \sum_{j'=0}^{J'} \beta_{kj'} |S_{k,t-j'}| + \sum_{k=1}^K \sum_{j'=0}^{J'} \theta_{kj'} D_{k,t-j'} + \left( \sum_{q=1}^Q \left( \delta_q \cos\left(\frac{q2\pi t}{288}\right) + \phi_q \sin\left(\frac{q2\pi t}{288}\right) \right) + \sum_{r=1}^R \sum_{j''=0}^{J''} \gamma_{rj''} D_{r,t-j''} \right) + u_t$ , and we report estimates of the contemporaneous return response to news and to announcement periods,  $\beta_{k0}$  and  $\theta_{k0}$ .

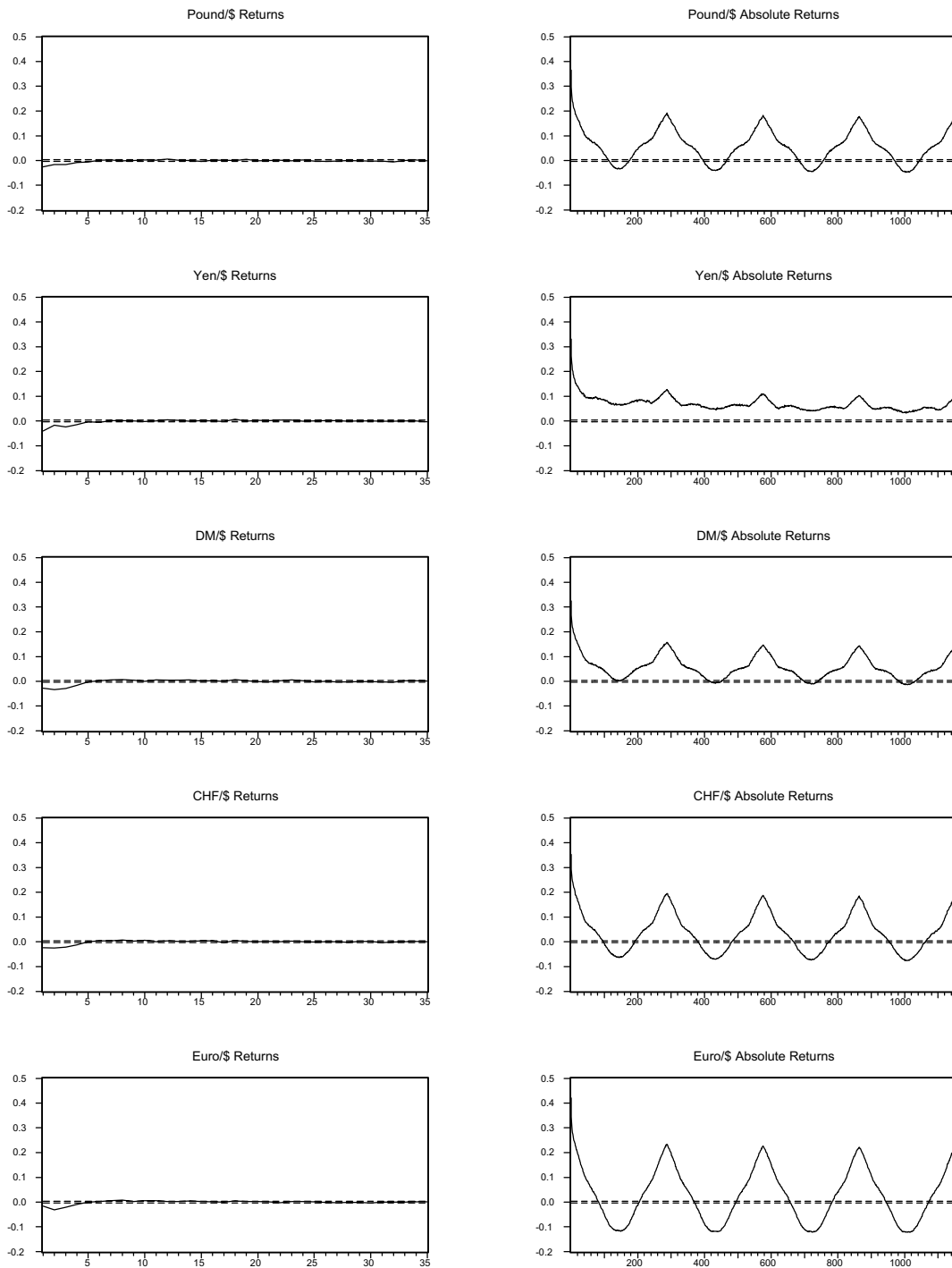
Asterisks again denote statistical significance at the five percent level.

**Table 6**  
FOMC News Response Coefficients and  $R^2$  Values

Announcement	Pound/\$		Yen/\$		DM/\$		CHF/\$		Euro/\$	
	$\hat{\beta}_k$	$R^2$	$\hat{\beta}_k$	$R^2$	$\hat{\beta}_k$	$R^2$	$\hat{\beta}_k$	$R^2$	$\hat{\beta}_k$	$R^2$
<b>FOMC</b>										
Target Federal Funds Rate	0.048*	0.229	0.050*	0.162	0.072*	0.259	0.072*	0.230	0.032	0.142

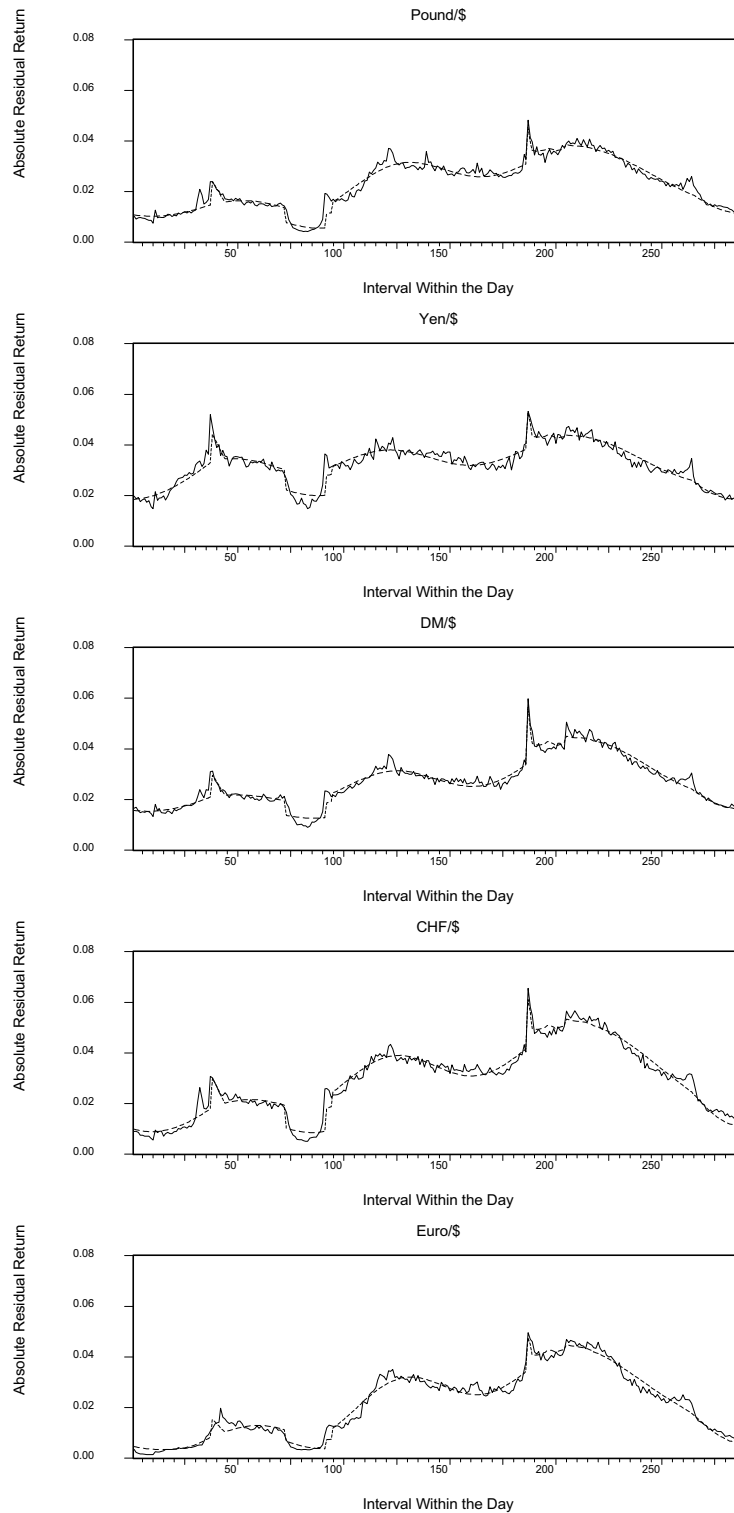
Notes: We estimate the contemporaneous exchange rate news response model,  $R_t = \beta_k S_{kt} + \varepsilon_t$ , where  $R_t$  is the 5-minute return from time  $t$  to time  $t+1$  and  $S_{kt}$  is the standardized news on the FOMC federal funds rate target made at time  $t$ . We estimate the regression using only those observations  $(R_t, S_{kt})$  such that an announcement was made at time  $t$ . We report the  $\hat{\beta}_k$  and  $R^2$  values, and we mark with an asterisk those coefficients that are statistically significant at the five percent level, using heteroskedasticity and autocorrelation consistent standard errors.

**Figure 1**  
**Sample Autocorrelation Functions**  
**Returns and Absolute Returns**



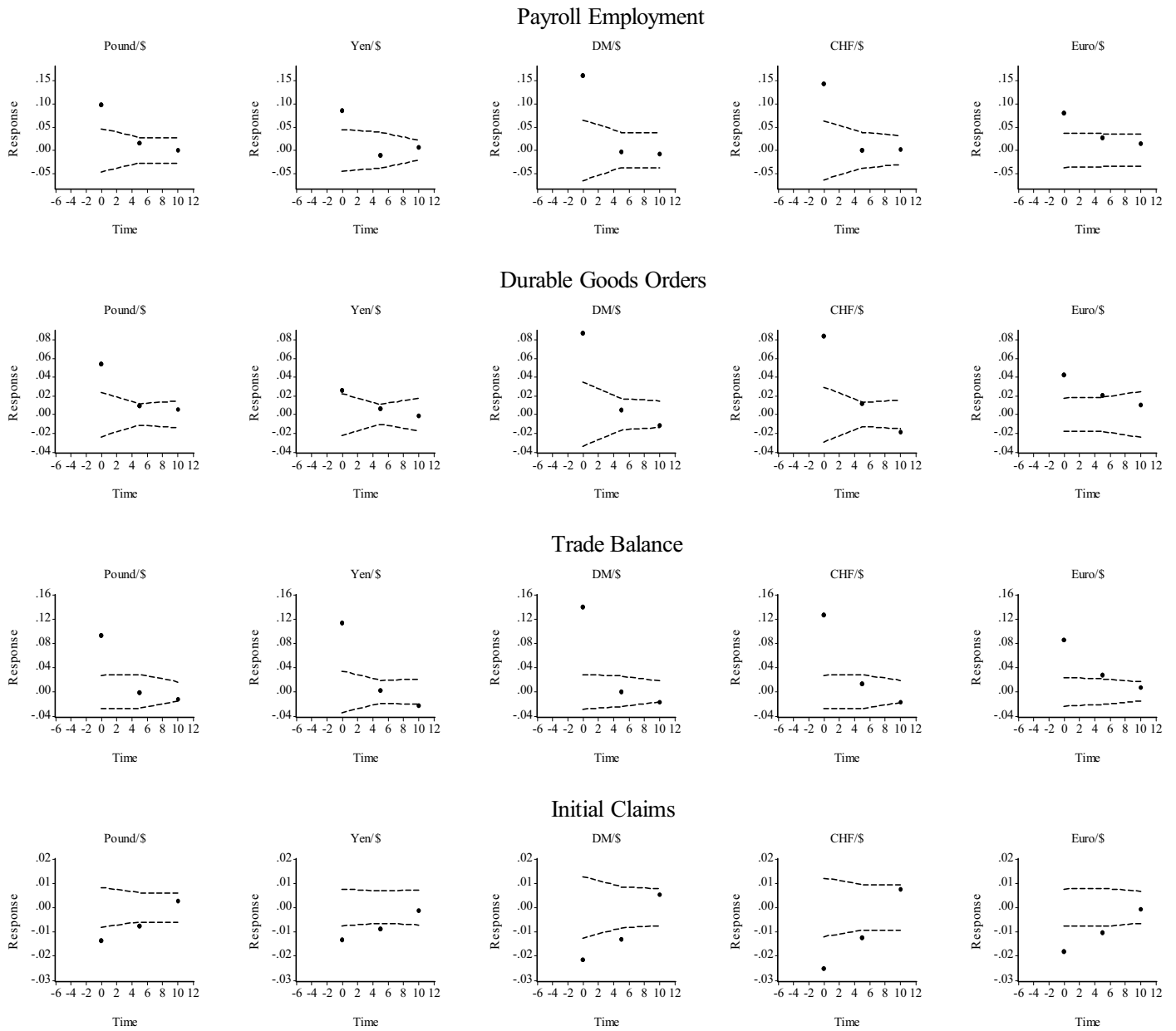
Notes: We plot the sample autocorrelations of returns and absolute returns for five currencies, together with Bartlett's approximate ninety-five percent confidence bands under the null hypothesis of white noise. In each graph, the vertical axis is the sample autocorrelation and the horizontal axis is displacement in 5-minute intervals. To avoid contamination from shifts in and out of daylight savings time, we calculate the sample autocorrelations using only days corresponding to U.S. daylight savings time.

**Figure 2**  
Actual and Fitted Intraday Volatility Patterns



Notes: The solid line is the average intraday pattern of the absolute residual return  $|\hat{\varepsilon}_t|$  over the 288 5-minute intervals within the day, where  $\hat{\varepsilon}_t$  is the residual from the exchange rate conditional mean model (1) in the text. The dashed line is the fitted intraday pattern of  $|\hat{\varepsilon}_t|$  from the exchange rate volatility model (2) in the text. To avoid contamination from shifts in and out of daylight savings time, we construct the figures using only days corresponding to U.S. daylight savings time.

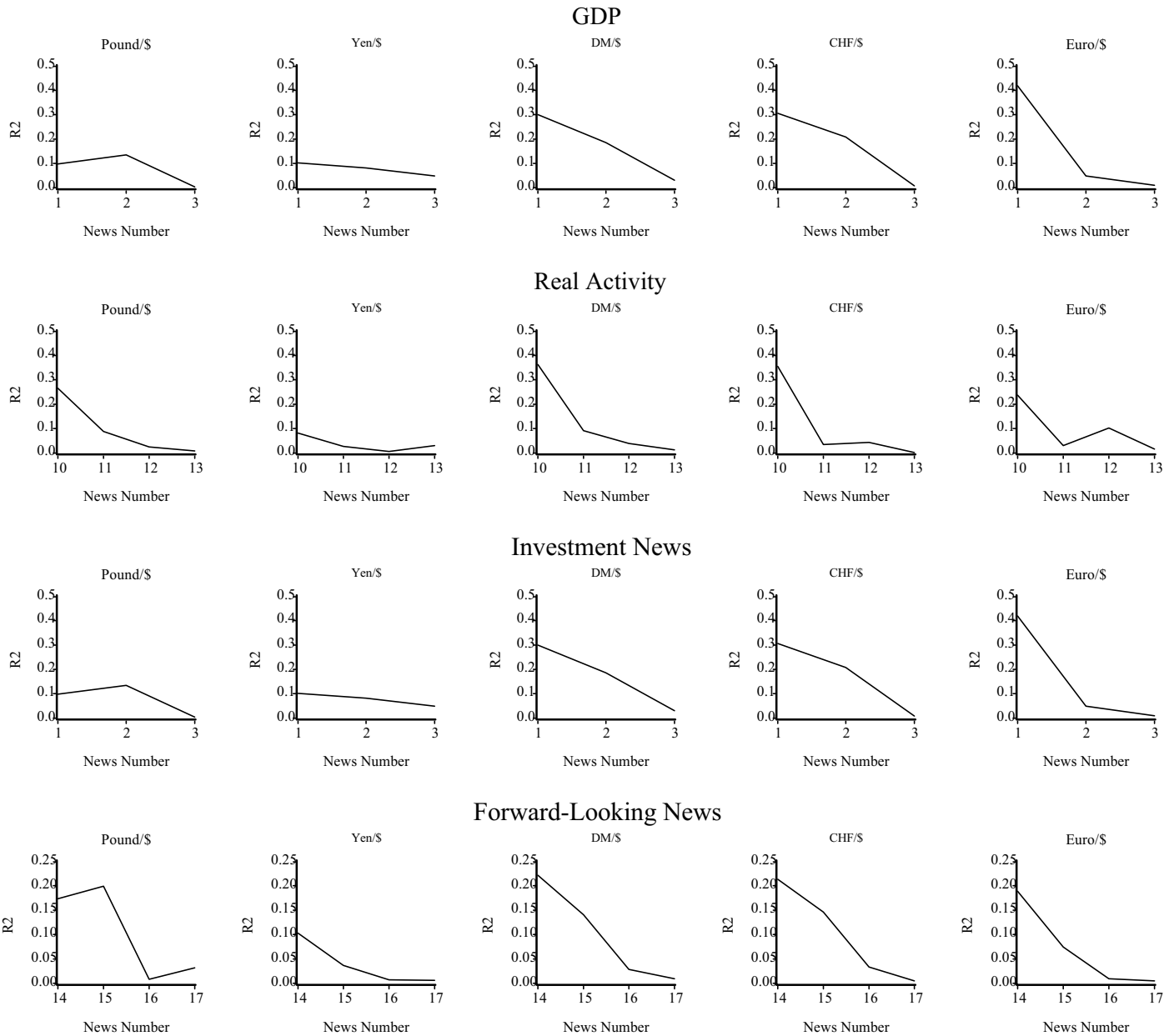
**Figure 3**  
Exchange Rate Responses to U.S. News



Notes: We graph the three news response coefficients associated with the exchange rate conditional mean regression (1), corresponding to responses at the announcement, five minutes after the announcement, and ten minutes after the announcement. We also show two standard error bands, under the null hypothesis of a zero response, obtained using the weighted least squares estimation method described in the text.



**Figure 4**  
U.S. News Effects as a Function of Release Time

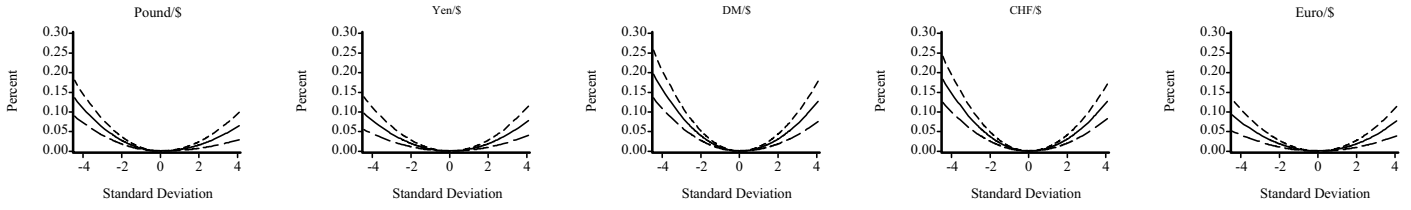


Notes: We estimate the contemporaneous exchange rate news response model,  $R_t = \beta_k S_{kt} + \varepsilon_t$ , where  $R_t$  is the 5-minute return from time  $t$  to time  $t+1$  and  $S_{kt}$  is the standardized news corresponding to announcement  $k$  ( $k=1, \dots, 17$ ) made at time  $t$ . We estimate the regression using only those observations ( $R_t, S_{kt}$ ) such that an announcement was made at time  $t$ . On the vertical axis we display the  $R^2$  values, and on the horizontal axis we display macroeconomic news announcements in the chronological order documented in Table 2. The “news numbers” are as follows:

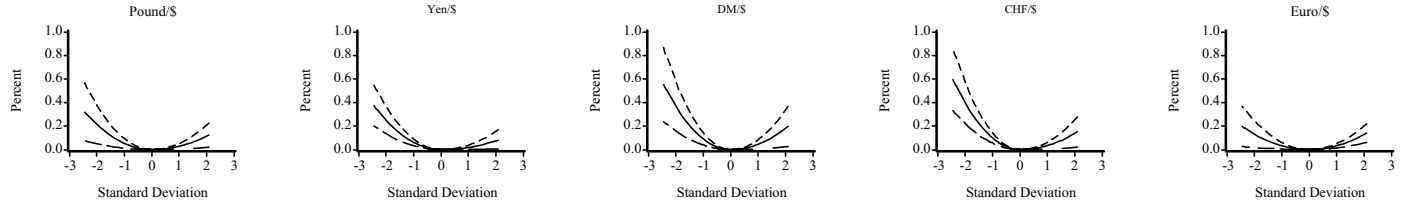
GDP	Real Activity	Investment	Forward-Looking
1- GDP Advance	4- Payroll Employment	10- Durable Goods Orders	14- Consumer Confidence
2- GDP Preliminary	5- Retail Sales	11- Construction Spending	15- NAPM Index
3- GDP Final	6- Industrial Production	12- Factory Orders	16- Housing Starts
	7- Capacity Utilization	13- Business Inventories	17- Index of Leading Indicators
	8- Personal Income		
	9- Consumer Credit		

**Figure 5**  
U.S. News Impact Curves

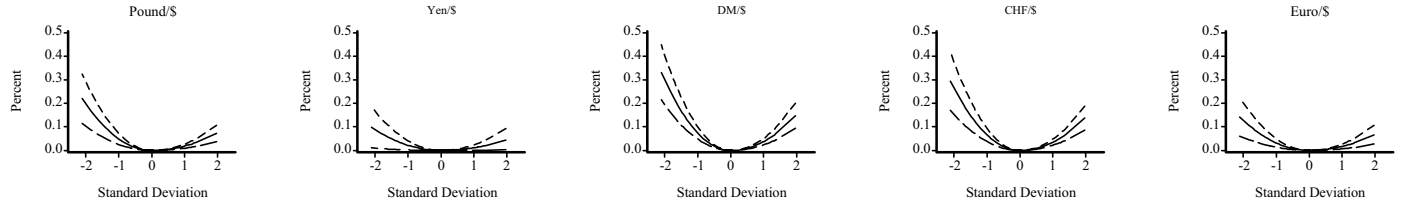
**Average Over Forty Indicators**



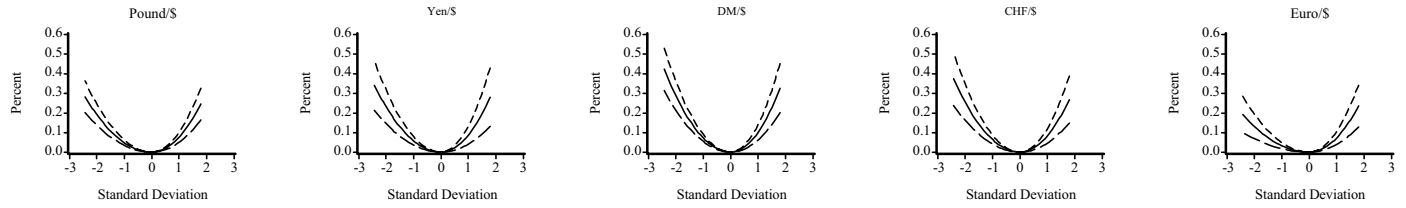
**Payroll Employment**



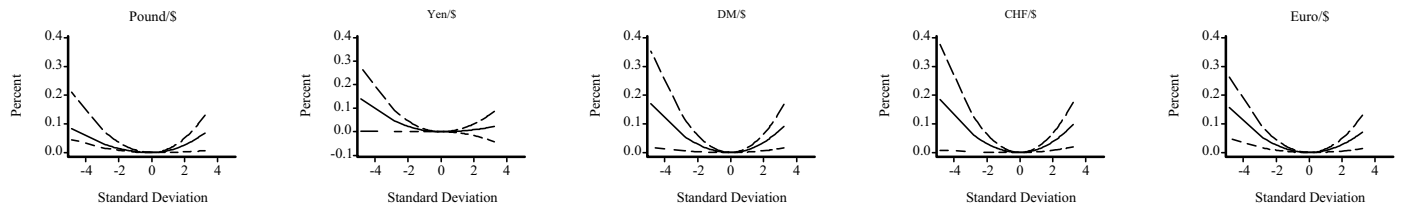
**Durable Goods Orders**



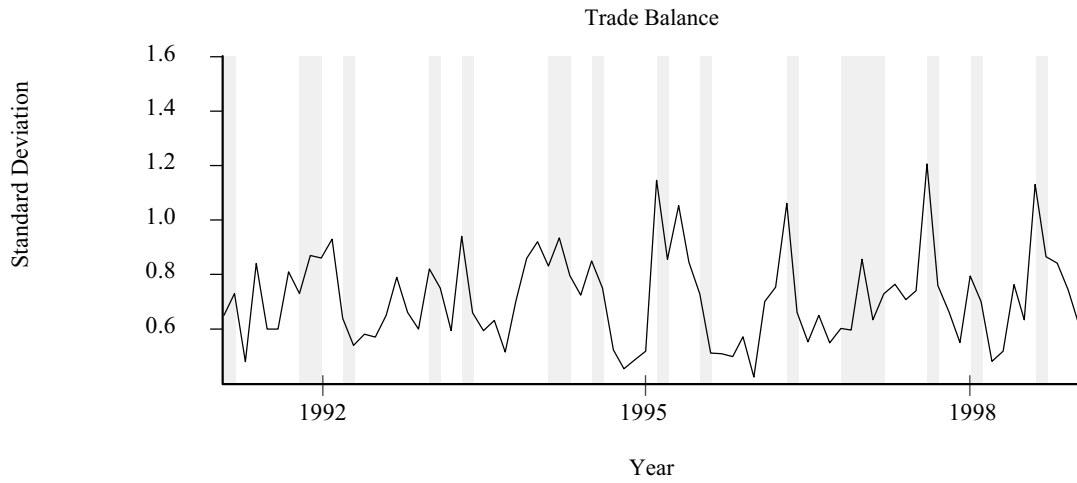
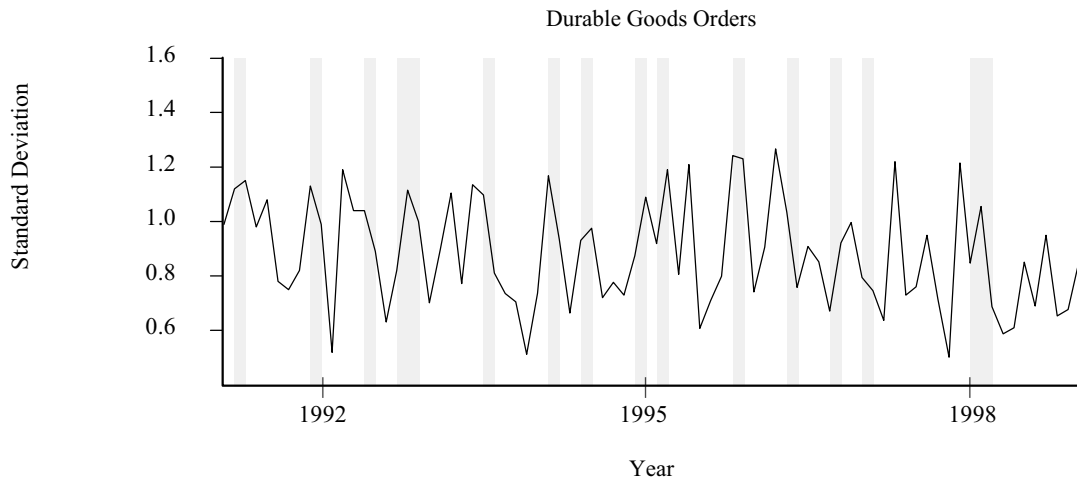
**Trade Balance**



**Initial Claims**



**Figure 6**  
Forecast Uncertainty



Notes: We plot the time series of cross-sectional standard deviations of the Money Market Services forecasts. The shaded areas denote “bad news” times. See text for details.