Trade Deficit Announcements and Exchange Rate Volatility: Evidence from the Spot and Futures Markets

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INTRODUCTION

Recent empirical research[1] has shown that foreign exchange markets respond to monthly announcements of forecast and actual U.S. trade deficit figures [see Madura and Tucker (1992) for a survey]. The link between exchange rates and trade data announcements has been explained in several ways. Hardouvelis (1988) has suggested that trade deficits are autocorrelated,[2] so that trade deficits are leading indicators of expected deficits. Therefore, higher trade deficits are expected to be followed with an increase in the supply of the dollars, thus leading to a dollar depreciation. Furthermore, approaching a politically sensitive level of the trade balance may trigger interventions by the Fed and other

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[1]See Aggarwal and Schrim (1992); Hogan, Melvin, and Roberts (1991); Hogan and Melvin (1992); Hardouvelis (1988); Deravi, Gregorowicz, and Hegji (1988); and Irwin (1989); Madura and Tucker (1992).

[2]See Hogan et al. (1991) for further evidence on the autocorrelation of trade deficits.

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central banks to depreciate the dollar [Deravi et al. (1988); Hogan et al. (1991)]. Hogan et al. (1991) suggested that larger than expected trade deficits may encourage protectionist sentiment among policy makers which could in turn lead to the imposition of trade sanctions against foreign trade partners. Consequently, expected import sanctions would lead to an increase in the price level and a fall in the value of the dollar.

The objective of this study is to provide an extension to the literature by analyzing the effects of trade deficit announcements on the joint distribution of the spot and futures price changes. A bivariate GARCH error correction model is employed to investigate whether or not there is an asymmetric response of the spot and the futures rates to the magnitude and the sign of trade deficit surprises. In addition, this study examines whether or not trade deficits and trade surpluses have asymmetric effects on the currency price changes and volatility.

Several key findings result from this study. The effects of the magnitude of trade deficit surprises are not uniform across the spot and the futures markets and across currencies. With the exception of the Canadian dollar (CD), an unexpected trade deficit is associated with a dollar depreciation in the spot and futures markets vis-a-vis the British pound (BP), the German mark (DM), the Japanese yen (JY), and the Swiss franc (SF). Evidence suggests that the magnitude and sign of unanticipated trade deficit announcements have asymmetric effects in spot and futures markets. It is found that the effects of the magnitude of the trade deficit surprises on the time varying exchange rate volatility are more pronounced for dollar/yen exchange rates than for other currencies. This supports the hypothesis that persistent U.S. trade deficits with Japan promotes protectionist sentiment among policy makers to drive down the value of the dollar, thus increasing the exchange rate uncertainty. Trade deficit surprises are positively associated with larger impacts on the futures prices. Also, larger than expected trade deficits are more likely to be associated with an increase in the exchange rate volatility than are smaller than expected trade deficits. This implies that the information content of announcements matters.

These results are important for studying the link between the rate of information flow and asset price volatility.[3] This study finds that the financial market volatility may rise or fall depending on the information content of news. In general, pessimistic news is expected to raise exchange rate volatility while optimistic news could reduce exchange

[3]See Papers by Clark (1973); Epps and Epps (1976); and Tauchen and Pitts (1983).

rate volatility. The implication is that the management of exchange rate exposure must incorporate both the magnitude and the direction of changes in currency prices and volatility when important official announcements are made public. In particular, changes in currency prices and volatility surrounding official announcements suggest that the risk minimizing hedge ratio must be changing; and, therefore, a dynamic hedging strategy may be incorporated to minimize the foreign exchange exposure. Overall, the evidence of a significant impact of the announcements on currency price changes and volatility could be important for market participants in understanding how macroeconomic information contributes to asset price volatility.

REVIEW OF THE LITERATURE

Most studies on the link between trade deficits and exchange rates specify the following regression equation (Hogan, et al. (1991)):

$$\Delta \ln S_t = a + bFE_t + u_t \qquad (1)$$

where $\ln S_t$ is the natural logarithm of the daily exchange rate (dollar/foreign currency) and FE_t is the percentage forecast error of trade data announcements. FE_t is defined as [(Actual - Forecast)/Forecast)] where Actual is the monthly U.S. trade deficit figure released by the U.S. Department of Commerce (USDOC) and Forecast is the survey median forecast of trade balance by the Money Market Services (MMS). A positive value for b would indicate that unexpected trade deficits are associated with a dollar depreciation. Hardouvelis (1988) did not find any significant link between balance of trade news and the spot exchange rates for the BP, CD, DM, JY, SF, French franc (FF), and the Italian lira (IT) for the 1980–1984 period. However, for the 1980–1982 period (during which the Fed's target was M1 rather than interest rate), he found a significant link between short-term interest rates and trade deficit news. Deravi et al. (1988) studied the spot and forward rates for the BP, CD, FF, DM, JY, and SF for the period 1980–1987. They concluded that trade deficit news did not have an impact on exchange rates before August 1984, but did have an effect during the period from March 1985 to July 1987. Irwin (1989) reported that trade news had an impact on the foreign exchange rate market only after 1984. Hogan et al. (1991) found that trade deficit news was associated with a dollar depreciation against the DM, JY, and the IT. Madura and Tucker (1992) found that trade deficits were directly associated with the currency options' implied standard deviation for the BP, CD, DM, JY, and the SF.

Those studies may share several potential shortcomings. First, they concentrated on the first moment (the mean) of the exchange rate distribution, leading many to wonder whether or not the second moment (the variance) is also affected by trade deficit news. According to Ross (1989), the evidence of a link between information and the variance of an asset's price is also useful for drawing inferences on the impact of news on financial markets. Second, prior studies used monthly spot exchange rate data, for which the amount of risk in the distributions of the exchange rate is constant over time.[4] However, it has been shown that the assumption of conditional normality and constant variance is inappropriate for daily data [Baillie and Bollerslev (1990)]. Third, prior studies focused on a single (usually the spot) market. However, the futures market's response to news could differ from the spot market's reaction because of market depth, daily settlement, and expiration effects.[5] Finally, the literature failed to show whether or not the information content of trade announcements matters. If trade deficits reflect pessimistic views regarding the overall competitiveness of the U.S. economy, then larger than expected trade deficits are more likely to be associated with a dollar depreciation and an increase in volatility.[6] By contrast, smaller than expected trade deficits may resolve uncertainty and should therefore be associated with a dollar appreciation and a decline in volatility.

In the next section, using a bivariate GARCH error correction model, this study empirically tests whether trade deficit news elicits asymmetric response in price changes and volatility in spot and the futures markets. This article makes several contributions to the literature. First, the bivariate GARCH model offers a unique opportunity to examine simultaneously the effects of trade deficit

[4]Hogan and Melvin (1992) is an exception.

[5]Although Madura and Tucker (1992) estimated separate regressions to examine the effects of trade data announcements on changes in the currency spot price and the currency implied standard deviation (ISD), these regressions were not estimated jointly in a full information model. Since the spot, forward, futures, and options markets are linked through the no-arbitrage condition, one would expect that the effects are distributed across all markets.

[6]A larger than expected trade deficit could also suggest the central bank may be forced to intervene in the market to depreciate the dollar. This point will be addressed later in the article.

surprises on spot and futures price changes and volatility without imposing restrictions on the direction of the causality between the markets. Second, the bivariate specification enables one to capture feedback effects which occur between the futures and spot markets when new information arrives [see Chan, Chan, and Karolyi (1991)]. Third, the bivariate GARCH model allows one to formally test Samuelson's (1965) finding that news events may have different impacts on spot and futures prices depending on assumptions made about the return generating process of the primary asset. Econometrically, this specification produces more efficient parameter estimates and hence more powerful tests about the impact of trade deficit news on volatility than does single equation estimation. Fourth, the model allows for cointegration between the spot and the futures markets. The theory of cointegration [see Engle and Granger (1987)] states that if two variables move together in the long run then there exists an error correction representation of the common relationship. Since spot and futures prices are cointegrated, ignoring the error correction term in the return generating equations would in fact yield inconsistent estimates. Finally, this study offers a useful way to model the differential response of volatility to positive and negative surprises.

A BIVARIATE GARCH ERROR CORRECTION MODEL OF EXCHANGE RATE VOLATILITY

The second moments of $\ln S_t$ and $\ln F_t$ can be parametrized with the following bivariate GARCH model previously applied in Chan et al. (1991), Kroner and Sultan (1993), and Schwert and Seguin (1991).[7]

$$\begin{aligned}\Delta \ln S_t &= \alpha_0 + \alpha_1(\ln F_{t-1} - \ln S_{t-1}) + \alpha_2 FE_t + \epsilon_s \\ \Delta \ln F_t &= \beta_0 + \beta_1(\ln F_{t-1} - \ln S_{t-1}) + \beta_2 FE_t + \epsilon_f \qquad (2)\end{aligned}$$

[7]The bivariate specification of the spot and futures rates is not new in the literature. For example, Chan, Chan, and Karolyi (1991) and Kroner, Hogan, and Sultan (1994) used the bivariate specification of the spot and the futures price changes to examine the effects of program trading on the S&P 500 spot and futures volatility. Baillie and Myers (1991) and Kroner and Sultan (1993) used the bivariate specification to derive time changing hedge ratios in the commodities futures and currency futures markets, respectively.

$$\begin{bmatrix} \epsilon_s \\ \epsilon_f \end{bmatrix} | \psi_{t-1} \sim N(0, H_t) \tag{3}$$

$$H_t = \begin{bmatrix} h_{s,t} \\ h_{sf,t} \\ h_{f,t} \end{bmatrix} = \begin{bmatrix} \tau_s \\ \tau_{sf} \\ \tau_f \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} \epsilon_{s,t-1}^2 \\ \epsilon_{s,t-1}\epsilon_{f,t-1} \\ \epsilon_{f,t-1}^2 \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{bmatrix} h_{s,t-1} \\ h_{sf,t-1} \\ h_{f,t-1} \end{bmatrix} \tag{4}$$

where $\Delta \ln S_t$ and $\Delta \ln F_t$ are changes in the natural logarithms of daily spot and futures prices in level, $(\ln F_{t-1} - \ln S_{t-1})$ is the error correction (EC) term, FE_t is the percentage forecast error of trade deficit announcements, and ϵ_s and ϵ_f are the residuals from the spot and futures equations. Notice that the EC term preserves the basic relationship between the spot and the futures rates which states that the futures rate is equal to spot rate adjusted for the interest rate differential between the home country and the foreign country. As Brenner and Kroner (1992) have demonstrated, if the domestic and foreign interest rates move together, then the interest rate differential will be stationary and $\ln S_t$ and $\ln F_t$ will be cointegrated with a cointegrating vector $(1,-1)$. As Engle and Granger (1987) note, if two variables are cointegrated, then omitting the error correction term amounts to model misspecification.[8]

The theoretical basis for the preceding GARCH model of asset price volatility is nested in the existing literature which relates asset price volatility to the rate of flow of information. For example, Clark (1973), Epps and Epps (1976), and Tauchen and Pitts (1983) modeled the joint distribution of price volatility and market volume as a mixture of normal distributions. They concluded that an increase in the rate of flow of information increases trading activity and price volatility.

[8]The relationship between the spot and the futures is derived from the covered interest rate parity:

$$\ln F_t = \ln S_t + (\ln i_t - \ln i_t^*)$$

where i and i^* are home and domestic interest rate, respectively. The implication of a cointegrating relationship among these four variables is that in the short run they are allowed to deviate from one another but in the long run they move together. As Brenner and Kroner (1992) have noted, if the interest rate differential $(\ln i - \ln i^*)$ is stationary, then it follows that lnF and lnS are cointegrated with the cointegrating vector $(1,-1)$. Hence, the error correction representation of the bivariate system does preserve the fundamental pricing relationship between the spot and the futures rates.

Econometrically, model misspecification through failure to account for information may lead to spuriously significant a_{ij} and b_{ij}. Lamoureux and Lastrapes (1990) suggested that by including information in the variance equation(s), one may correct for such model misspecification. In the empirical section of this article, balance of trade news is included in the variance equations to examine if it is a significant determinant of the observed nonlinearity in the exchange rate movements.

If FE_t is included in the H_t matrix, eq. (4) may be rewritten as:

$$H_t = \begin{bmatrix} h_{s,t} \\ h_{sf,t} \\ h_{f,t} \end{bmatrix} = \begin{bmatrix} \tau_s \\ \tau_{sf} \\ \tau_f \end{bmatrix} + \begin{bmatrix} a_{11} & 0 & 0 \\ 0 & a_{22} & 0 \\ 0 & 0 & a_{33} \end{bmatrix} \begin{bmatrix} \epsilon_{s,t-1}^2 \\ \epsilon_{s,t-1}\epsilon_{f,t-1} \\ \epsilon_{f,t-1}^2 \end{bmatrix} + \begin{bmatrix} b_{11} & 0 & 0 \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{bmatrix} \begin{bmatrix} h_{s,t-1} \\ h_{sf,t-1} \\ h_{f,t-1} \end{bmatrix} + \begin{bmatrix} \theta_s \\ \theta_{sf} \\ \theta_f \end{bmatrix} [FE_t] \quad (5)$$

where, to economize on parameters of the GARCH model, H_t is assumed to be block diagonal.[9] a_{11} and a_{33} are ARCH coefficients for the residuals of s_t and f_t. a_{22} measures the extent of covariance between the residuals. A significant a_{22} would indicate time varying covariances. Similarly, b_{11} and b_{33} are GARCH coefficients, and b_{22} is the covariance between the residuals from the spot and the futures equations. θ_is are coefficients of FE_t in the conditional covariance matrix. For example, a positive and significant value for θ_s would imply that FE_t is associated with time varying volatility of the spot equation. Also, θ_{sf} measures the joint impact of FE_t on the conditional covariance between the spot and futures exchange rates.

EMPIRICAL EVIDENCE

The Data

Exchange rates are natural logarithms of daily spot and futures prices of the BP, CD, DM, JY, and the SF in terms of the U.S. Dollar. Daily closing prices (from February 1980 to April 1989) are from Dunn and Hargitt, Inc. The sample contains 2334 daily observations. To avoid problems due to expiration effects of futures contracts, this study rolls over to the nearby contract two weeks prior to the expiration of the cur-

[9]The H_t matrix contains 21 parameters and convergence of a nonlinear system with this many parameters is often problematic. By assuming H_t, the number of parameters is reduced to 9.

rent contract. The daily spot rates are matched with prices of the nearby futures contracts. Actual trade balance data are monthly U.S. trade deficit figures released by the USDOC. Forecast trade balance data are monthly survey median forecasts of the trade balance compiled by the MMS.[10] The percentage forecast error of trade announcements (FE_t) is defined as: [(Actual - Forecast)/Forecast)]. If FE_t is positive, it would imply that the unexpected trade deficit has increased. For days when there are no trade data announcements, FE_t is assigned a value of 0.

Descriptive Statistics

Descriptive statistics for the trade deficit figures and exchange rates are reported in Table I. The U.S. trade balance was in a persistent deficit during the period of the study. The size of the average monthly deficit was \$8.66 billion. The average MMS forecast was quite similar at \$8.31 billion. However, as Figure 1 shows, on many occasions the actual deficit and the MMS forecast differed. These surprises may have affected the dollar's exchange rate vis-a-vis the major currencies.

Although not reported here, tests for cointegration reveal that the spot and the futures rates are cointegrated [see Kroner and Sultan (1993)]. Therefore, the bivariate specification of the spot and the futures should contain an error correction term. The results of diagnostic tests on the distributions of the exchange rates are reported below. The unconditional distributions of $\Delta \ln S_t$ and $\Delta \ln F_t$ are non-normal, as indicated by high skewness and kurtosis. Skewness ranges from a low of -0.13 (CD futures) to a high of 0.59 (JY futures), suggesting asymmetric distributions. Kurtosis values suggest that the distributions of the exchange rates are leptokurtic. Based on the Bera-Jarque[11] statistics the hypothesis of normality for these exchange rates is rejected.

Tests for autocorrelation are conducted by estimating the Ljung–Box Q statistics on the first 24 lags. The critical value for these statistics at the 95% level is 36.42. The Q(24) shows that the null hypothesis of no autocorrelation cannot be rejected except for the spot rates of the DM, JY, and SF. Ljung–Box Q (24) statistics for the preceding three exchange rates marginally exceed the critical χ^2. Ljung–Box Q^2 (24) suggests time dependence in the second moments.

[10]The trade data announcements for the sample period occurred at different times. Prior to October 1983, the announcements were made at 2:30 P.M. Eastern Standard Time (EST). Since then the announcements are made at 8:30 P.M. EST. The daily closing data are not adjusted to reflect this. See Hogan et al. (1991) for survey release dates. Many thanks to Ked Hogan for the survey data.

[11]The Bera-Jarque statistic is a test for normality which is distributed as χ_2^2 and therefore has a 95% critical value of 5.99.

TABLE I
Descriptive Statistics

Variable	μ	σ	*Skewness*	*Kurtosis*	*Bera-Jarque*	*Q(24)*	$Q^2(24)$
Trade Deficit							
Actual	8.66	4.86	0.04	−4.12	5.79		
Forecast	8.31	4.57	−0.12	−4.56	11.46		
Exchange Rates							
BP Spot	−0.010	0.75	0.17	6.02	898.40	22.27	508.78
BP Futures	−0.010	0.75	0.25	5.95	872.77	19.21	463.33
CD Spot	−0.001	0.27	0.02	8.43	2867.61	26.67	383.33
CD Futures	−0.001	0.29	−0.13	8.53	2978.27	32.11	307.50
DM Spot	−0.003	0.75	0.34	5.33	574.29	42.42	201.34
DM Futures	−0.003	0.75	0.39	5.31	578.41	30.16	260.25
JY Spot	0.025	0.68	0.25	5.18	487.72	43.99	209.06
JY Futures	0.026	0.71	0.59	7.29	1923.47	34.30	82.15
SF Spot	−0.001	0.81	0.30	4.92	393.48	41.34	215.19
SF Futures	−0.001	0.86	0.42	5.29	576.66	18.71	201.76

Descriptive statistics are reported using 2334 daily observations for the period February 1980 to April 1989. μ is the mean and σ is the standard deviation. Actual is the monthly U.S. trade deficit released by the U.S. Department of Commerce (USDOC) and Forecast is the survey median forecast of the trade deficit compiled by the Money Market Services (MMS). The balance of trade figures are reported in billions of U.S. dollars. The exchange rates are in log-differenced form. Q(24) and $Q^2(24)$ are the Ljung–Box test statistics for 24th order serial correlation in the levels and in squares. The Ljung–Box test statistic is distributed χ^2_{24} under the null hypothesis of no serial correlation. The critical value at the 95% significance level is 36.42. The Bera-Jarque Wald statistic is a test for normality. Under the null hypothesis of normality, the critical χ^2_2 value is 5.99. The Bera-Jarque statistic is calculated as follows:

$$n\left[\frac{\text{Skewness}^2}{6} + \frac{(\text{Kurtosis} - 3)^2}{24}\right]$$

where n is the number of observations.

Overall, the descriptive statistics provide convincing evidence that daily exchange rate movements are not normally distributed and that variance/covariances are changing over time. The GARCH model, which permits time changing volatility, is suitable for modeling such nonlinear distributions.

Exchange Rate Response to the Magnitude of Trade Deficit Surprises

GARCH models are estimated using the Berndt, Hall, Hall, and Hausman (BHHH) procedure.[12] The first model is:

$$\begin{aligned}\Delta \ln S_t &= \alpha_0 + \alpha_1(\ln F_{t-1} - \ln S_{t-1}) + \alpha_2 FE_t + \epsilon_s \\ \Delta \ln F_t &= \beta_0 + \beta_1(\ln F_{t-1} - \ln S_{t-1}) + \beta_2 FE_t + \epsilon_f \qquad (6)\end{aligned}$$

[12]To improve the convergence properties of the BHHH algorithm, the exchange rates are multiplied by 100. Many thanks to Ken Kroner for providing the GARCH program.

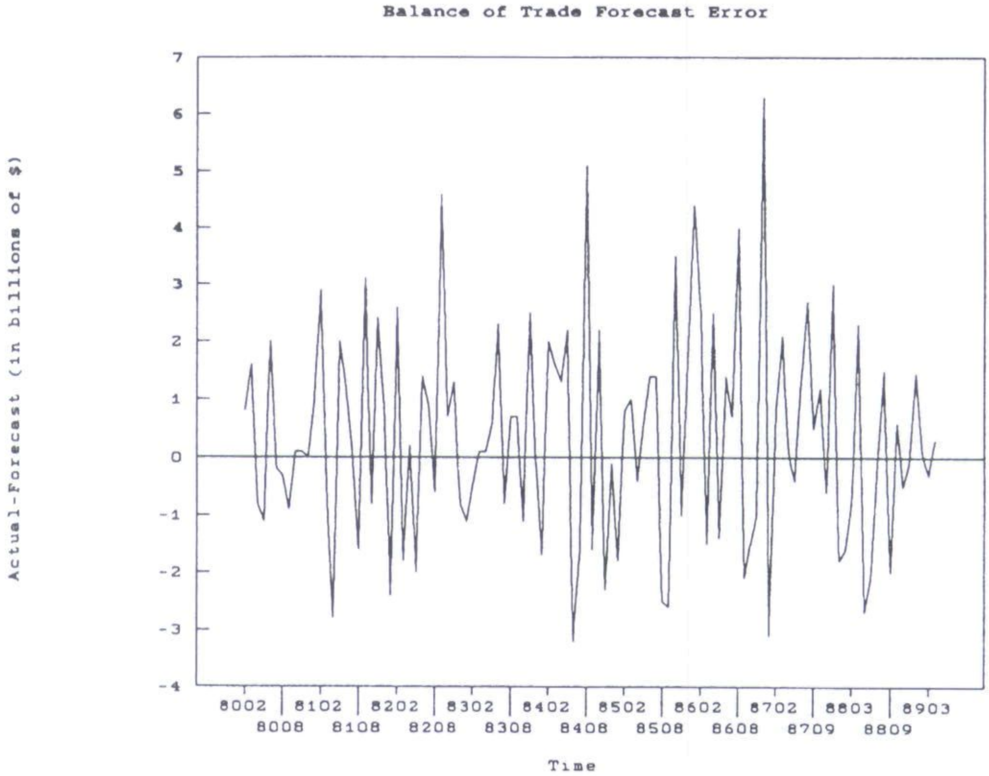

FIGURE 1
Balance of Trade Forecast Error. Figure 1 plots the difference between the monthly actual and forecast trade deficit values. Actual is the monthly U.S. trade deficit released by the U.S. Department of Commerce (USDOC) and Forecast is the survey median forecast of the trade deficit. The survey is compiled by Money Market Services (MMS). The balance of trade figures are reported in billions of U.S. dollars. During the sample period (February 1980 to April 1989) the monthly average the U.S. trade deficit was equal to \$8.66 billion.

$$H_t = \begin{bmatrix} h_{s,t} \\ h_{sf,t} \\ h_{f,t} \end{bmatrix} = \begin{bmatrix} \tau_s \\ \tau_{sf} \\ \tau_f \end{bmatrix} + [A] \begin{bmatrix} \epsilon^2_{s,t-1} \\ \epsilon_{s,t-1}\epsilon_{f,t-1} \\ \epsilon^2_{f,t-1} \end{bmatrix} + [B] \begin{bmatrix} h_{s,t-1} \\ h_{sf,t-1} \\ h_{f,t-1} \end{bmatrix} + \begin{bmatrix} \theta_s \\ \theta_{sf} \\ \theta_f \end{bmatrix} [FE_t] \tag{7}$$

where $\theta_s = \theta_{sf} = \theta_f = 0$ are the linear restrictions placed on the parameters of FE_t in the H_t. The matrices $[A]$ and $[B]$ are defined in eq. (5). Since preliminary diagnostics reveal the presence of excess kurtosis in the errors, the bivariate GARCH models are estimated by maximizing the log-likelihood, assuming a conditional bivariate elliptical t-distribution, of the following form,

$$f(\epsilon_t) = \frac{\Gamma\frac{(n+\nu)}{2}}{\Gamma\left(\frac{\nu}{2}\right)\left(\sqrt{\pi(\nu-2)}\right)^n} |H_t|^{-\frac{1}{2}}\left[1 + \frac{1}{\nu-2}\epsilon_t' H_t^{-1}\epsilon_t\right]^{-\frac{n+\nu}{2}} \quad (8)$$

where n is the number of variables, v denotes the degrees of freedom, and H_t is obtained from eq. (7). According to Bollerslev and Woolridge (1992), maximizing the above log-likelihood improves statistical inferences since the resulting standard errors of the coefficients are robust to excess kurtosis. Note that although H_t is assumed block diagonal, the diagonal elements of the matrix may not be sufficient to model the time varying volatility of the spot and the futures rates. Therefore, it may be necessary to include off diagonal elements to ensure that the standardized squared residuals (ϵ_{it}^2/h_{lit}) are free of autocorrelation.

As shown in Table II, the error correction (EC) terms are generally significant at the 5% confidence level. Therefore, EC terms are included in subsequent regressions to avoid model misspecification. The coefficients of FE_t are positive and significant at the 5% confidence level in all but the CD spot and futures rates. The results are similar to those reported elsewhere. Hogan et al. (1991) also found positive and significant values for the coefficient of FE_t in the spot equation for the BP, DM, and JY. Among the currencies in this study, the DM spot turns out to be the most sensitive to trade deficit surprises, followed by the SF spot, JY spot, and BP spot. Among the futures rates, the SF futures rate is the most sensitive to trade deficit news, followed by the JY futures, DM futures, and BP futures.

Surprisingly, the results suggest that spot price changes are generally more sensitive to FE_t than are futures prices. Given that futures are important instruments for stabilizing the underlying spot market, one would expect the futures prices to be more sensitive to news. Also, given that the size of the interbank market, where the spot currency trading takes place, largely outweighs the futures market, these results are quite surprising.

Additional diagnostics suggest that the GARCH specification fits the data well. a_{ij} (ARCH coefficients) and b_{ij} (GARCH coefficients) are significant in most cases. Furthermore, the Ljung–Box Q statistics suggest that the standardized residuals are white noise in all cases.[13] The reciprocal of the degrees of freedom term (1/v) suggests the inappropriateness of assuming conditional normality. For instance, the degrees of freedom is 4.65 (BP). This implies that the British pound standardized residuals cannot be assumed normal. Since the bivariate GARCH model estimates standard errors that are robust to excess kurtosis, the assumption of a conditional *t*-distribution is appropriate. Overall, Table II shows that with the exception of the CD spot and futures rates, most major exchange rates are quite sensitive to trade deficit surprises. Furthermore, the results show that spot price changes tend to be surprisingly more sensitive to information shocks than futures markets.

Table III presents estimates from bivariate GARCH models which do not impose any restrictions on the θ_s, θ_{sf}, and θ_f. Again, with the exception of the CD spot and futures, FE_t is positively linked to spot and futures price changes for all currencies. The coefficients of FE_t are significant at the 5% confidence level in 8 out of 10 cases. In terms of sensitivity, the DM spot and futures turn out to be the most sensitive, followed by the spot and futures exchange rates of the SF, JY, and BP.

Table III also reports a positive link between FE_t and the H_t. For example, FE_t is positively associated with the variance of the spot exchange rate of the DM, JY, and SF. With respect to the variance of the futures exchange rates, FE_t has positive coefficients for the BP, DM, and JY. Finally, with the exception of the Canadian dollar, FE_t is positively linked to the conditional covariance of the spot and the futures exchange rates for all currencies in the sample.

The log-likelihood statistics from the unconstrained models are greater for all five currencies, compared to the previous results reported in Table II. This suggests that useful information may be obtained by including FE_t in the H_t. However, log-likelihood ratio tests show that, with the exception of the Japanese yen, the increases are not significant. Based on λ_2, the null hypothesis that FE_t *does not* belong in the conditional covariance matrix cannot be rejected for all but the Japanese yen. The evidence of a positive link between FE_t and the volatility in the dollar/yen spot and futures rates is worth noting given the recent rise in protectionist sentiment against Japanese exports

[13]Although not reported here to conserve space, several alternative specifications were tried to model the bivariate exchange rate distributions. These included restricting the GARCH model to only diagonal elements of the [*B*] matrix and estimating higher order GARCH models. However, the present specification is chosen on the basis of the evidence of white noise properties in the standardized residuals.

into the United States. This may be also consistent with the hypothesis that the Fed intervenes when trade deficits unexpectedly rise. Hence, one would expect the conditional volatility of the dollar/yen spot and futures rates to be most sensitive to the U.S. trade deficits announcements.

The results in Table III may be compared with the evidence reported in Madura and Tucker (1992). They found that trade deficits are associated with an increase in the currency options' implied standard

TABLE II

Exchange Rate Response to the Magnitude of Trade Deficit Surprises (Trade Deficit Surprises in the Conditional Mean Equations)

	(BP)	*(CD)*	*(DM)*	*(JY)*	*(SF)*
α_0	−0.0273	−0.0071	−0.0066	0.016	0.0004
	(−2.0476)[a]	(−1.6826)[b]	(−0.2985)	(0.9268)	(0.0163)
β_0	−0.041	−0.0214	0.0818	0.0479	0.0774
	(−3.0276)[c]	(−4.7823)[c]	(3.7536)[c]	(2.7438)[c]	(2.9995)[c]
ECM_s	−0.05	−0.0546	−0.0266	−0.0459	−0.0261
	(−2.083)[a]	(−3.8409)[c]	(−0.9649)	(−2.4668)[a]	(−1.1621)
ECM_f	−0.1516	−0.1761	−0.1738	−0.1124	−0.1261
	(−6.2434)[c]	(−11.6451)[c]	(−6.4600)[c]	(−6.0671)[c]	(−5.5261)[c]
$FE_{t,s}$	0.3501	0.0665	0.5178	0.4384	0.5172
	(2.5119)[a]	(1.495)	(4.1282)[c]	(3.5841)[c]	(3.4743)[c]
$FE_{t,f}$	0.226	0.0095	0.2896	0.3599	0.3737
	(1.8014)[b]	(0.2117)	(2.4604)[a]	(3.179)[c]	(2.6144)[c]
τ_s	0.0185	0.0038	0.0217	0.0228	0.0352
	(1.663)[b]	(3.5084)[c]	(2.2299)[a]	(2.3943)[a]	(1.9273)[b]
τ_{sf}	0.0212	0.0007	0.0241	0.0263	0.0448
	(3.4556)[c]	(3.118)[c]	(3.4756)[c]	(3.9687)[c]	(3.6031)[c]
τ_f	0.0367	0.0026	0.0425	0.0367	0.0731
	(2.5478)[a]	(2.2669)[a]	(3.3291)[c]	(3.1702)[c]	(3.2841)[c]
a_{11}	0.0994	0.1751	0.1563	0.1886	0.1374
	(6.6026)[c]	(8.3171)[c]	(8.1343)[c]	(7.1684)[c]	(6.6791)[c]
a_{22}	0.0971	0.0995	0.1313	0.1609	0.1395
	(7.0085)[c]	(8.3228)[c]	(7.7504)[c]	(7.2134)[c]	(7.4076)[c]
a_{33}	0.1096	0.1042	0.129	0.1751	0.1519
	(6.7755)[c]	(6.8707)[c]	(7.0899)[c]	(7.4126)[c]	(7.3411)[c]
b_{11}	0.1858	0.0183	0.3402	0.1789	0.1408
	(1.5169)	(0.2161)	(5.5998)[c]	(2.3544)[a]	(1.5417)
b_{12}	0.7414	0.8965	0.5591	0.6908	0.7551
	(5.7236)[c]	(9.5074)[c]	(8.6777)[c]	(8.5552)[a]	(7.5126)[c]
b_{22}	0.8843	0.9043	0.857	0.8408	0.8412
	(54.5227)[c]	(94.6868)[c]	(45.6751)[c]	(43.0869)[c]	(38.0273)[c]
b_{32}	0.9132	1.0704	0.8596	0.8685	0.8641
	(29.2258)[c]	(34.1834)[c]	(28.9222)[c]	(29.1227)[c]	(24.3929)[c]
1/v	0.2148	0.2022	0.2078	0.2701	0.2355
	(14.2354)[c]	(14.3855)[c]	(13.8964)[c]	(17.4695)[c]	(15.7739)[c]
λ_1	−2573.7231	1497.8801	−2735.7394	−2110.7252	−3253.6568

continued

TABLE II (Continued)

	Post Estimation Diagnostics with Standardized Residuals			
	Skewness	*Kurtosis*	*Q(24)*	*Q^2(24)*
BP Spot	−0.1258	4.6228	16.2602	28.5474
BP Futures	−0.1319	4.2881	10.4351	24.7781
CD Spot	−0.4125	7.0984	16.8380	23.6602
CD Futures	−0.5196	6.5368	31.9140	12.8991
DM Spot	0.0882	4.1954	32.8646	20.3832
DM Futures	0.1507	4.1124	28.4239	19.3563
JY Spot	0.2442	5.4250	29.5732	20.3407
JY Futures	0.4287	6.8219	21.4649	22.3700
SF Spot	0.1152	4.1502	31.5817	27.2087
SF Futures	0.1715	3.9996	20.9806	19.4877

The bivariate conditional mean equations are:

$$\Delta \ln S_t = \alpha_0 + \alpha_1(\ln F_{t-1} - \ln S_{t-1}) + \alpha_2 FE_t + \epsilon_s$$
$$\Delta \ln F_t = \beta_0 + \beta_1(\ln F_{t-1} - \ln S_{t-1}) + \beta_2 FE_t + \epsilon_f \tag{T1}$$

where the independent variables in the mean equations are $\ln F_{t-1} - \ln S_{t-1}$ (error correction term) and the percentage forecast error of the monthly trade announcements (FE_t). FE_t is defined as (Actual-Forecast)/Forecast. The position of the independent variable(s) in the bivariate system is indicated by the subscripts: s (spot), f (futures), and sf (covariance). The bivariate conditional variance–covariance equations are:

$$H_t = \begin{bmatrix} h_{s,t} \\ h_{sf,t} \\ h_{f,t} \end{bmatrix} = \begin{bmatrix} \tau_s \\ \tau_{sf} \\ \tau_f \end{bmatrix} + \begin{bmatrix} a_{11} & 0 & 0 \\ 0 & a_{22} & 0 \\ 0 & 0 & a_{33} \end{bmatrix} \begin{bmatrix} \epsilon^2_{s,t-1} \\ \epsilon_{s,t-1}\epsilon_{f,t-1} \\ \epsilon^2_{f,t-1} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} & 0 \\ 0 & b_{22} & 0 \\ 0 & b_{32} & 0 \end{bmatrix} \begin{bmatrix} h_{s,t-1} \\ h_{sf,t-1} \\ h_{f,t-1} \end{bmatrix} \tag{T2}$$

The results are obtained by jointly estimating eqs. (T1) and (T2). t-statistics are reported in parentheses. Significance levels are indicated as follows: [a](5%), [b](10%), [c](1%). λ_1 is the log-likelihood value. Standardized residuals are estimated as ϵ_t/h_t where h_t is the conditional variance of each exchange rate. Q statistics denote Ljung–Box statistics for serial correlation. The critical value at the 95% is 36.42.

deviation for the BP, CD, DM, JY, and the SF. This suggests that trade deficits convey a pessimistic outlook regarding the competitiveness of the U.S. exporting sectors. If unexpected trade deficits trigger protectionist sentiment among policy makers, then market participants may view dollar denominated assets to be riskier. Therefore, unexpected trade deficits may be associated with increases in the conditional volatility of the exchange rates.

Exchange Rate Response to the Sign of Trade Deficit Surprises.[14]

It is possible that, in addition to the magnitude, the exchange rates may also respond to the sign of the trade deficit surprise. To show this, the

[14]This section has greatly benefitted from discussions with Mike Melvin.

TABLE III

Exchange Rate Response to the Magnitude of Trade Deficit Surprises (Trade Deficit Surprises in the Conditional Mean and Variance/Covariance Equations)

	(BP)	*(CD)*	*(DM)*	*(JY)*	*(SF)*
α_0	−0.0258	−0.0066	−0.0117	0.0171	0.002
	(−1.9438)[a]	(−1.574)	(−0.5318)	(0.9925)	(0.0771)
β_0	−0.0396	−0.021	0.079	0.0505	0.0778
	(−2.9368)[b]	(−4.7313)[b]	(3.6504)[b]	(2.8883)[b]	(3.0022)[b]
ECM_s	−0.0451	−0.053	−0.0202	−0.0459	−0.0275
	(−1.8918)[a]	(−3.7362)[c]	(−0.7375)	(−2.4483)[c]	(−1.2217)
ECM_f	−0.1454	−0.175	−0.1706	−0.1141	−0.1266
	(−5.9952)[b]	(−11.6044)[b]	(−6.3934)[b]	(−6.0801)[b]	(−5.5183)[b]
$FE_{t,s}$	0.4657	0.0557	0.6721	0.4882	0.5566
	(2.807)[b]	(1.1441)	(4.5865)[b]	(4.0106)[b]	(2.9474)[b]
$FE_{t,f}$	0.3673	0.0067	0.4542	0.3868	0.3969
	(2.1681)[c]	(0.119)	(3.1094)[b]	(3.0698)[b]	(2.1568)[c]
τ_s	0.0177	0.0038	0.0221	0.024	0.032
	(1.51)	(3.6144)[b]	(2.4001)[c]	(2.7465)[b]	(1.7161)[a]
τ_{sf}	0.0237	0.0006	0.0244	0.0252	0.0429
	(3.6029)[b]	(2.937)[b]	(3.6044)[b]	(4.0431)[b]	(3.6327)[b]
τ_f	0.0422	0.0023	0.0435	0.0318	0.071
	(2.8819)[b]	(2.1249)[c]	(3.4946)[b]	(3.0405)[b]	(3.2837)[b]
a_{11}	0.1079	0.1739	0.1546	0.183	0.135
	(6.7352)[b]	(8.4241)[b]	(8.1221)[b]	(7.3508)[b]	(6.6388)[b]
a_{22}	0.104	0.0989	0.1316	0.1538	0.1357
	(7.147)[b]	(8.3732)[b]	(7.7855)[b]	(7.3312)[b]	(7.4316)[b]
a_{33}	0.115	0.1042	0.1314	0.1678	0.1465
	(6.8702)[b]	(6.962)[b]	(7.2446)[b]	(7.5559)[b]	(7.3369)[b]
b_{11}	0.1189	0.0253	0.3746	0.1906	0.083
	(1.0461)	(0.2964)	(8.0412)[b]	(2.5861)[b]	(0.8849)
b_{12}	0.8043	0.8864	0.5202	0.6719	0.8221
	(6.6192)[b]	(9.3872)[b]	(10.7041)[b]	(8.7269)[b]	(7.8894)[b]
b_{22}	0.8731	0.905	0.8544	0.8413	0.8456
	(50.6519)[b]	(96.511)[b]	(45.569)[b]	(44.1219)[b]	(39.7688)[b]
b_{32}	0.8985	1.073	0.8548	0.8771	0.8686
	(28.2098)[b]	(34.7664)[b]	(29.3515)[b]	(30.6143)[b]	(25.1132)[b]
$FE_{t,s}$	0.1307	0.0033	0.202	0.3481	0.3732
	(1.1122)	(0.3279)	(1.7492)[a]	(3.0572)[b]	(2.062)[c]
$FE_{t,sf}$	0.1682	0.0112	0.2079	0.2801	0.2952
	(1.6942)[a]	(1.4556)	(1.8791)[a]	(2.6366)[b]	(2.0373)[c]
$FE_{t,f}$	0.1975	0.0105	0.2168	0.2479	0.2707
	(1.8252)[a]	(1.033)	(1.7521)[a]	(2.1172)[c]	(1.4438)
$1/v$	0.2142	0.2008	0.2065	0.2626	0.2339
	(14.2743)[b]	(14.3517)[b]	(13.7454)[b]	(17.003)[b]	(15.6762)[b]
λ_1	−2570.4598	1502.2472	−2731.8466	−2103.5202	−3250.0696
λ_2	6.5200	8.7400[a]	7.7800	14.4200[b]	7.2000

continued

TABLE III (Continued)

	Post Estimation Diagnostics with Standardized Residuals			
	Skewness	*Kurtosis*	*Q(24)*	*$Q^2(24)$*
BP Spot	−0.1174	4.5863	16.5951	28.9095
BP Futures	−0.1269	4.2763	10.4552	25.6088
CD Spot	−0.4164	7.1328	16.7032	22.9713
CD Futures	−0.5055	6.5114	31.7630	13.2568
DM Spot	0.0805	4.1854	33.1660	19.9702
DM Futures	0.1439	4.0801	29.2295	19.9711
JY Spot	0.2028	5.0867	30.8419	20.7335
JY Futures	0.4199	6.7631	22.1839	23.3102
SF Spot	0.1030	4.1272	31.5125	26.5042
SF Futures	0.1607	3.9693	21.2007	19.9607

The bivariate conditional mean equations are:

$$\Delta \ln S_t = \alpha_0 + \alpha_1(\ln F_{t-1} - \ln S_{t-1}) + \alpha_2 FE_t + \epsilon_s$$
$$\Delta \ln F_t = \beta_0 + \beta_1(\ln F_{t-1} - \ln S_{t-1}) + \beta_2 FE_t + \epsilon_f \tag{T3}$$

where the independent variables are $\ln F_{t-1} - \ln S_{t-1}$ (error correction term) and the percentage forecast error of the monthly trade announcements (FE_t). FE_t is defined as (Actual-Forecast)/Forecast. The position of the independent variable (*s*) in the bivariate system is indicated by the subscripts: *s* (spot), *f* (futures), and *sf* (covariance). In the bivariate conditional variance–covariance FE_t is also included. The resulting equations are:

$$H_t = \begin{bmatrix} h_{s,t} \\ h_{sf,t} \\ h_{f,t} \end{bmatrix} = \begin{bmatrix} \tau_s \\ \tau_{sf} \\ \tau_f \end{bmatrix} + \begin{bmatrix} a_{11} & 0 & 0 \\ 0 & a_{22} & 0 \\ 0 & 0 & a_{33} \end{bmatrix} \begin{bmatrix} \epsilon^2_{s,t-1} \\ \epsilon_{s,t-1}\epsilon_{f,t-1} \\ \epsilon^2_{f,t-1} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} & 0 \\ 0 & b_{22} & 0 \\ 0 & b_{32} & 0 \end{bmatrix} \begin{bmatrix} h_{s,t-1} \\ h_{sf,t-1} \\ h_{f,t-1} \end{bmatrix} + \begin{bmatrix} \theta_s \\ \theta_{sf} \\ \theta_f \end{bmatrix} [FE_t] \tag{T4}$$

The results are obtained by jointly estimating eqs. (T3) and (T4). *t*-statistics are reported in parentheses. Significance levels are indicated as follows: [a](10%), [b](1%), [c](5%). λ_1 is the log-likelihood value. Standardized residuals are estimated as ϵ_t/h_t where h_t is the conditional variance of each exchange rate. Q statistics denote Ljung–Box statistics for serial correlation. The critical value at the 95% is 36.42. λ_2 is the log-likelihood ratio test for the hypothesis H0: $\theta_s = \theta_{sf} = \theta_f = 0$. The critical value (95%) for the χ^2 with 3 degrees of freedom is 7.81.

following bivariate GARCH model is estimated:

$$\Delta \ln S_t = \alpha_0 + \alpha_1(\ln F_{t-1} - \ln S_{t-1}) + \alpha_2 FE_t + \alpha_3 D_s + \epsilon_s$$
$$\Delta \ln F_t = \beta_0 + \beta_1(\ln F_{t-1} - \ln S_{t-1}) + \beta_2 FE_t + \beta_3 D_f + \epsilon_f \tag{9}$$

$$H_t = \begin{bmatrix} h_{s,t} \\ h_{sf,t} \\ h_{f,t} \end{bmatrix} = \begin{bmatrix} \tau_s \\ \tau_{sf} \\ \tau_f \end{bmatrix} + [A] \begin{bmatrix} \epsilon^2_{s,t-1} \\ \epsilon_{s,t-1}\epsilon_{f,t-1} \\ \epsilon^2_{f,t-1} \end{bmatrix} + [B] \begin{bmatrix} h_{s,t-1} \\ h_{sf,t-1} \\ h_{f,t-1} \end{bmatrix} + \begin{bmatrix} \theta_s \\ \theta_{sf} \\ \theta_f \end{bmatrix} [FE_t] + \begin{bmatrix} \gamma_s \\ \gamma_{sf} \\ \gamma_f \end{bmatrix} [D] \tag{10}$$

TABLE IV

Exchange Rate Response to the Sign of Trade Deficit Surprises

	(BP)	*(CD)*	*(DM)*	*(JY)*	*(SF)*
α_0	−0.0258	−0.0065	−0.0054	0.0187	−0.0004
	(−1.9559)[a]	(−1.5375)	(−0.2453)	(1.077)	(−0.0162)
β_0	−0.04	−0.0207	0.0827	0.0515	0.0756
	(−2.9815)[b]	(−4.6865)[b]	(3.8312)[b]	(2.9462)[b]	(2.9357)[b]
ECM_s	−0.0477	−0.053	−0.0267	−0.0467	−0.0257
	(−2.0043)[c]	(−3.7275)[b]	(−0.9695)	(−2.4865)[c]	(−1.1375)
ECM_f	−0.1484	−0.1747	−0.1741	−0.1144	−0.1249
	(−6.1408)[b]	(−11.5749)[b]	(−6.4566)[b]	(−6.1273)[b]	(−5.4511)[b]
$FE_{t,s}$	−0.1935	−0.0024	−0.2602	0.0176	−0.319
	(−0.7594)	(−0.036)	(−1.1925)	(0.097)	(−1.0878)
$FE_{t,f}$	−0.4275	−0.0566	−0.5499	−0.0899	−0.5335
	(−1.6472)[a]	(0.6514)	(−2.3879)[c]	(−0.4581)	(−1.8923)[a]
D_s	0.3474	0.0222	0.4652	0.2562	0.4864
	(4.6685)[b]	(0.9815)	(6.7856)[b]	(4.1413)[b]	(5.7907)[b]
D_f	0.4102	0.0191	0.502	0.2872	0.5293
	(5.3401)[b]	(0.7556)	(7.5248)[b]	(4.3993)[b]	(6.6578)[b]
τ_s	0.0214	0.0038	0.0187	0.0285	0.0303
	(1.7313)[a]	(3.6311)[b]	(1.9733)[a]	(2.8818)[b]	(1.6582)[a]
τ_{sf}	0.0277	0.0006	0.0235	0.0303	0.0418
	(3.856)[b]	(2.9366)[b]	(3.7112)[b]	(4.3244)[b]	(3.6247)[b]
τ_f	0.0431	0.0023	0.0394	0.0334	0.0682
	(2.8721)[b]	(2.0661)[c]	(3.2539)[b]	(3.0194)[b]	(3.2641)[b]
a_{11}	0.1124	0.1744	0.1561	0.1841	0.1354
	(6.8097)[b]	(8.4064)[b]	(8.1899)[b]	(7.2749)[b]	(6.6912)[b]
a_{22}	0.1099	0.1001	0.1304	0.159	0.136
	(7.2877)[b]	(8.3946)[b]	(7.866)[b]	(7.3784)[b]	(7.5148)[b]
a_{33}	0.1211	0.105	0.1255	0.1766	0.1471
	(7.0181)[b]	(6.9586)[b]	(7.0105)[b]	(7.5807)[b]	(7.412)[b]
b_{11}	0.0975	0.0253	0.287	0.1167	0.0853
	(0.9131)	(0.2965)	(3.663)[b]	(1.5086)	(0.8882)
b_{12}	0.8175	0.8856	0.6238	0.743	0.8221
	(7.1049)[b]	(9.3884)[b]	(7.2683)[b]	(8.8763)[b]	(7.7247)[b]
b_{22}	0.8612	0.904	0.8571	0.8299	0.8464
	(47.0017)[b]	(95.9279)[b]	(48.4203)[b]	(41.3298)[b]	(40.2249)[b]
b_{32}	0.8906	1.0731	0.8644	0.8702	0.87
	(27.1786)[b]	(34.9292)[b]	(29.2941)[b]	(29.1397)[b]	(25.5234)[b]
$FE_{t,s}$	0.1612	0.0037	0.1666	0.2404	0.3311
	(0.9743)	(0.2624)	(1.291)	(1.4161)	(1.2879)
$FE_{t,sf}$	0.2172	0.0139	0.2023	0.2968	0.3166
	(1.6764)[a]	(1.2499)	(1.5773)	(2.0207)[c]	(1.5798)
$FE_{t,f}$	0.2551	0.0168	0.2386	0.3661	0.3273
	(1.5035)	(1.0774)	(1.48)	(1.95)[a]	(1.2696)
D_s	0.0142	0.001	0.0253	0.0554	−0.0106
	(0.2778)	(0.2057)	(0.4971)	(1.2099)	(−0.1345)
D_{sf}	−0.0121	0.001	0.0143	0.0186	−0.0195
	(−0.2792)	(0.2983)	(0.3232)	(0.416)	(−0.2855)
D_f	−0.0266	0.001	0.0017	−0.0133	−0.0237
	(−0.4843)	(0.1875)	(0.0326)	(−0.2422)	(−0.2989)

continued

TABLE IV (Continued)

	(BP)	(CD)	(DM)	(JY)	(SF)
$1/v$	0.2149	0.2006	0.207	0.2643	0.2315
	(14.3022)[b]	(14.3084)[b]	(13.8304)[b]	(16.9279)[b]	(15.6235)[b]
λ_1	−2554.9438	1502.1655	−2714.5904	−2091.3123	−3235.4761
λ_2	31.0400[b]	0.1600	34.5200[b]	24.4200[b]	29.1800[b]

Post Estimation Diagnostics with Standardized Residuals

	Skewness	*Kurtosis*	$Q(24)$	$Q^2(24)$
BP Spot	−0.4195	7.1328	16.514	22.6348
BP Futures	−0.5010	6.4695	30.7720	13.2419
CD Spot	−0.0900	4.6353	17.2970	27.6609
CD Futures	−0.0953	4.3238	11.2837	23.1264
DM Spot	0.1173	4.1932	33.1936	17.6263
DM Futures	0.1874	4.0781	28.8183	16.9738
JY Spot	0.2029	4.9012	30.8245	22.4799
JY Futures	0.4319	6.6075	22.5019	21.4196
SF Spot	0.1341	4.1221	30.7496	23.5624
SF Futures	0.1927	3.9432	22.5814	18.6271

The bivariate conditional mean equations are:

$$\Delta \ln S_t = \alpha_0 + \alpha_1(\ln F_{t-1} - \ln S_{t-1}) + \alpha_2 FE_t + \alpha_3 D_s + \epsilon_s$$

$$\Delta \ln F_t = \beta_0 + \beta_1(\ln F_{t-1} - \ln S_{t-1}) + \beta_2 FE_t + \beta_3 D_f + \epsilon_f \qquad \text{(T5)}$$

where the independent variables are $\ln F_{t-1} - \ln S_{t-1}$ (error correction term), the percentage forecast error of the monthly trade announcements (FE_t), and D which is set equal to 1 (−1) if FE_t is positive (negative) and 0 otherwise. FE_t is defined as (Actual-Forecast)/Forecast. The position of the independent variable (s) in the bivariate system is indicated by the subscripts: s (spot), f (futures), and sf (covariance). In the bivariate conditional variance−covariance FE_t and D are included. The resulting equations are:

$$H_t = \begin{bmatrix} h_{s,t} \\ h_{sf,t} \\ h_{f,t} \end{bmatrix} = \begin{bmatrix} \tau_s \\ \tau_{sf} \\ \tau_f \end{bmatrix} + \begin{bmatrix} a_{11} & 0 & 0 \\ 0 & a_{22} & 0 \\ 0 & 0 & a_{33} \end{bmatrix} \begin{bmatrix} \epsilon^2_{s,t-1} \\ \epsilon_{s,t-1}\epsilon_{f,t-1} \\ \epsilon^2_{f,t-1} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} & 0 \\ 0 & b_{22} & 0 \\ 0 & b_{32} & 0 \end{bmatrix} \begin{bmatrix} h_{s,t-1} \\ h_{sf,t-1} \\ h_{f,t-1} \end{bmatrix} + \begin{bmatrix} \theta_s \\ \theta_{sf} \\ \theta_f \end{bmatrix} [FE_t] + \begin{bmatrix} \gamma_s \\ \gamma_{sf} \\ \gamma_f \end{bmatrix} [D] \qquad \text{(T6)}$$

The results are obtained by jointly estimating eqs. (T5) and (T6). t-statistics are reported in parentheses. Significance levels are indicated as follows: [a](10%), [b](1%), [c](5%). λ_1 is the log-likelihood value. Standardized residuals are estimated as ϵ_t/h_t where h_t is the conditional variance of each exchange rate. Q statistics denote Ljung−Box statistics for serial correlation. The critical value at the 95% is 36.42. λ_2 is the log-likelihood ratio test for the hypothesis H0: $\theta_s = \theta_{sf} = \theta_f = 0$. The critical value (95%) for the χ^2 with 3 degrees of freedom is 7.81. λ_2 is the log-likelihood ratio test for the hypothesis H0: $\theta_s = \theta_{sf} = \theta_f = \gamma_s = \gamma_{sf} = \gamma_f = 0$. The critical value (95%) for the χ^2 with 6 degrees of freedom is 12.59.

where a dummy variable (D) is added which is set equal to 1 (−1) if FE_t is positive (negative) and 0 otherwise. The results in Table IV suggest that FE_t is only marginally significant in affecting the conditional mean of the futures rate for the BP, DM, and SF. On the other hand, with the exception of the Canadian dollar, the dummy (D) has a positive and significant coefficient in the mean equations for the remaining currencies. t-statistics indicate that the coefficients are significant at the 1% confidence level. In contrast with Table III, the dummy variable D is associated with a larger coefficient in the futures market than the spot. This finding may be consistent with the fact that the size of the spot foreign exchange market is quite large compared to the currency futures markets. Therefore, it is possible that the effects of news would be associated with a larger magnified change in the currency futures prices than the spot prices.

With respect to volatility, the only significant impact of FE_t is found in the case of JY which is expected in light of previous results. FE_t is positively linked to the conditional covariance between the spot and the futures residuals for the JY (significant at 5%). For the remaining currencies, the link between FE_t and H_t is not statistically significant. Finally, Table IV shows that there is no significant link between D and H_t.

These results are consistent with the literature, on balance of trade surprises and Fed interventions. Deravi et al. (1988) claim that the Fed has a trade balance target, so that unexpected trade deficits are likely to encourage the Fed to actively intervene to drive down the value of the dollar. Since intervention data are not available, most of the analysis is limited to drawing inferences.[15] Although the study by Hogan et al. (1991) offered convincing evidence of indirect effects of Fed interventions, their results are also subject to the usual criticism that actual Fed interventions data are not used. These results suggest that positive trade deficit surprises are associated with dollar depreciations vis-à-vis major currencies, which could be due to Fed interventions.[16]

Asymmetric Response of Exchange Rates to Trade Deficits and Trade Surpluses

An interesting issue which has been ignored in the literature is whether or not deficits and surpluses have symmetric effects on the exchange rates. For example, Madura and Tucker (1992) found that trade deficit announcements, regardless of their sign, were positively associated with the currency ISDs. It is argued in this article that the level of uncertainty in asset prices may be associated with the information content of an announcement. If a given piece of news does not resolve uncertainty,

[15] Data limitation continues to impede empirical work involving official interventions in the foreign exchange markets [see Dominquez and Frankel (1990)].

[16] The assumption that the Fed intervenes in the foreign exchange market with every deficit announcements cannot be empirically supported due to lack of reliable data. Early in the sample period (March 1981 to July 1983), the Fed is reported to have followed a policy of no intervention [see Hogan et al. (1991)]. No adjustments are made to reflect this policy switch.

then the conditional volatility of asset prices may rise. Assuming larger than expected trade deficits create pessimistic views regarding the overall competitiveness of the U.S. economy, then greater trade deficit surprises are more likely to be positively linked with the time varying volatility. The opposite may be true for unexpectedly small trade deficits.[17]

The following model is estimated to examine the effects of the information content of trade news:

$$\begin{aligned} \Delta \ln S_t &= \alpha_0 + \alpha_1(\ln F_{t-1} - \ln S_{t-1}) + \alpha_2 DEF_t \\ &\quad + \alpha_3 SUR + \alpha_4 D_s + \epsilon_s \\ \Delta \ln F_t &= \beta_0 + \beta_1(\ln F_{t-1} - \ln S_{t-1}) + \beta_2 DEF \\ &\quad + \beta_3 SUR + \beta_4 D_f + \epsilon_f \end{aligned} \tag{11}$$

$$\begin{aligned} H_t = \begin{bmatrix} h_{s,t} \\ h_{sf,t} \\ h_{f,t} \end{bmatrix} &= \begin{bmatrix} \tau_s \\ \tau_{sf} \\ \tau_f \end{bmatrix} + [A] \begin{bmatrix} \epsilon^2_{s,t-1} \\ \epsilon_{s,t-1}\epsilon_{f,t-1} \\ \epsilon^2_{f,t-1} \end{bmatrix} \\ &\quad + [B] \begin{bmatrix} h_{s,t-1} \\ h_{sf,t-1} \\ h_{f,t-1} \end{bmatrix} + \begin{bmatrix} \theta_s \\ \theta_{sf} \\ \theta_f \end{bmatrix} [DEF_t] \\ &\quad + \begin{bmatrix} \gamma_s \\ \gamma_{sf} \\ \gamma_f \end{bmatrix} [SUR] + \begin{bmatrix} \delta_s \\ \delta_{sf} \\ \delta_f \end{bmatrix} [D] \end{aligned} \tag{12}$$

where, instead of FE_t, two variables (*DEF* and *SUR*) are included in the mean and in the H_t. These variables are defined as follows. *DEF* is set equal to FE_t when FE_t is positive. Otherwise, *DEF* is set equal to zero. On the other hand, if FE_t is negative, *SUR* is set equal to FE_t, and zero otherwise.[18] So, when FE_t is positive, *DEF* is expected to be associated with a depreciation of the dollar. Similarly, when FE_t is negative, *SUR* is expected to be associated with an appreciation of the dollar. Recall that larger than expected trade deficits are assumed

[17]Notice that, FE_t can be positive, negative, or equal to zero. A positive value implies a larger than expected trade deficit. A negative value, on the other hand, does not mean that trade surplus has increased because during this period the U.S. ran a persistent trade deficit vis-a-vis its major trading partners. Rather, it implies a smaller than expected trade deficit.

[18]To check for possible multicollinearity, Pearson correlation coefficients among various combinations for *D*, FE_t, *DEF*, and *SUR* are estimated. These values are (pairs of variables are in parentheses): 0.65 (FE_t, *D*), 0.48 (*D*, *SUR*), 0.48 (*D*, *DEF*), and 0.01 (*SUR*, *DEF*). The correlation coefficients are significant at the 1% significance level. These correlations suggest that multicollinearity should not be a concern.

to be pessimistic news and smaller than expected trade deficits are optimistic news regarding the future outlook for the export sector. So, *DEF* is expected to be positively associated with the conditional variance/covariance whereas *SUR* is expected to be negatively linked to the conditional variance/covariance.

Table V shows that no further insights are gained by including *DEF* and *SUR* in the mean equations. However, based on the conditional H_t matrix, the results imply that the information content of trade announcements has significant impact on volatility. *DEF* is positively associated with the conditional variance and covariance of the spot and the futures for all currencies except the Canadian dollar. With few exceptions, the coefficients are generally significant at varying confidence levels. Among the currencies, the volatility of the dollar/yen rates is most sensitive to unexpected trade deficits. On the other hand, *SUR* is associated with a decrease in the conditional variance of the British pound spot and futures exchange rates. For the remaining currencies, the link between *SUR* and exchange rate volatility is insignificant. As expected, the dummy (D) in the mean equations is positive and significant for all currencies except the Canadian dollar. In the covariance matrix (H_t), D is insignificant.

In terms of statistical significance, the results are quite robust. Further diagnostics show that the bivariate GARCH specification of the exchange rates fits the data well. The standardized residuals are free of autocorrelation.

Overall, the results indicate that trade deficit news has different impacts on spot and futures markets. This suggests that market participants' interpretation of the news determines to a large extent what will be the impact of the news on the markets. In general, this article indicates that both the spot and the futures exchange rates clearly respond to the magnitude of trade deficits surprises as well as to the sign of trade deficit surprises. The results also suggest that the foreign exchange markets experience swings in volatility during periods when official announcements are made public. In particular, evidence of changes in currency prices and volatility surrounding official announcements suggests that the risk minimizing hedge ratio must be changing during this time and therefore a dynamic hedging strategy should be incorporated to minimize the foreign exchange exposure.[19]

[19]See Baillie and Myers (1991) and Kroner and Sultan (1993) for dynamic hedging when the covariance matrix is changing with time.

TABLE V
Asymmetric Response of Exchange Rates to Trade Deficits and Trade Surpluses

	(BP)	*(CD)*	*(DM)*	*(JY)*	*(SF)*
α_0	−0.024	−0.0054	−0.0061	0.0194	0.0071
	(−1.7602)[a]	(−1.2631)	(−0.2731)	(1.1176)	(0.2804)
β_0	−0.0394	−0.0199	0.0847	0.0527	0.081
	(−2.8477)[b]	(−4.425)[b]	(3.8889)[b]	(3.0036)[b]	(3.1411)[b]
ECM_s	−0.0488	−0.0532	−0.0217	−0.044	−0.0302
	(−2.0055)[c]	(−3.7466)[b]	(−0.7827)	(−2.2643)[c]	(−1.3224)
ECM_f	−0.1501	−0.1751	−0.1731	−0.1128	−0.1288
	(−6.0919)[b]	(−11.6223)[b]	(−6.3972)[b]	(−5.8336)[b]	(−5.559)[b]
DEF_s	−0.3384	−0.0348	−0.4371	−0.2278	−0.4447
	(−0.95)	(−0.4026)	(−1.1901)	(−0.7173)	(−0.9766)
DEF_f	−0.5939	−0.0916	−0.7783	−0.3703	−0.6288
	(−1.5738)	(−0.9224)	(−2.4236)[c]	(−1.0391)	(−1.2394)
SUR_s	0.254	0.2347	0.2733	0.6786	0.1102
	(0.4063)	(1.1941)	(0.5582)	(1.5611)	(0.1796)
SUR_f	−0.0381	0.1455	−0.0526	0.6114	−0.0804
	(−0.0608)	(0.8178)	(−0.1423)	(1.2137)	(−0.12)
D_s	0.3539	0.0046	0.4441	0.2109	0.4739
	(3.8553)[b]	(0.1649)	(5.4666)[b]	(2.9539)[b]	(5.1008)[b]
D_f	0.4272	0.0068	0.4863	0.2431	0.5123
	(4.4598)[b]	(0.2415)	(6.9004)[b]	(3.0599)[b]	(5.3742)[b]
τ_s	0.0125	0.0036	0.017	0.0235	0.0265
	(0.9331)	(3.4194)[b]	(1.965)[a]	(2.4691)[c]	(1.3976)
τ_{sf}	0.0285	0.0005	0.0213	0.0258	0.042
	(3.7802)[b]	(2.2789)[c]	(3.2581)[b]	(4.0476)[b]	(3.56)[b]
τ_f	0.0438	0.0019	0.036	0.0286	0.0647
	(2.8858)[b]	(1.7775)[a]	(3.0891)[b]	(2.745)[b]	(3.2064)[b]
a_{11}	0.1061	0.1724	0.1495	0.1816	0.1385
	(6.7656)[b]	(8.3966)[b]	(8.4407)[b]	(7.3089)[b]	(6.826)[b]
a_{22}	0.1052	0.0979	0.1287	0.1579	0.1388
	(7.3921)[b]	(8.3532)[b]	(8.0682)[b]	(7.5365)[b]	(7.7349)[b]
a_{33}	0.1162	0.1031	0.126	0.1748	0.148
	(7.1428)[b]	(6.9192)[b]	(7.2935)[b]	(7.7435)[b]	(7.5969)[b]
b_{11}	0.0073	0.0387	0.3873	0.0471	−0.0164
	(0.0731)	(0.4441)	(6.9849)[b]	(0.7329)	(−0.2151)
b_{12}	0.9222	0.8692	0.5075	0.8122	0.9228
	(8.1587)[b]	(9.0448)[b]	(8.6892)[b]	(11.0976)[b]	(10.2172)[b]
b_{22}	0.8494	0.9027	0.853	0.8213	0.8301
	(45.1867)[b]	(94.2959)[b]	(47.1623)[b]	(42.7436)[b]	(38.5016)[b]
b_{32}	0.8765	1.0776	0.8637	0.8592	0.8566
	(26.1561)[b]	(34.8103)[b]	(30.1446)[b]	(29.3889)[b]	(25.3231)[b]
DEF_s	0.4862	0.0036	0.6904	0.9222	0.8175
	(1.9512)[a]	(0.2166)	(2.6682)[b]	(2.807)[b]	(2.1847)[b]
DEF_{sf}	0.5904	0.0184	0.5311	1.0963	1.093
	(2.8379)[b]	(1.3413)	(2.2424)[c]	(3.6123)[b]	(2.9783)[b]
DEF_f	0.6815	0.0256	0.4248	1.3057	1.4032
	(2.417)[c]	(1.2255)	(1.6439)[a]	(3.3599)[b]	(2.8004)[b]
SUR_s	−0.7408	−0.0596	−0.3557	−0.336	−0.4974
	(−2.0085)[c]	(−1.1971)	(−1.1961)	(−0.9599)	(−1.0251)

continued

TABLE V (Continued)

	(BP)	*(CD)*	*(DM)*	*(JY)*	*(SF)*
SUR_{sf}	−0.7245	−0.0305	−0.169	−0.4358	−0.716
	(−2.2288)[c]	(−1.2432)	(−0.6201)	(−1.1991)	(−1.5213)
SUR_f	−0.8854	−0.0196	−0.0912	−0.5446	−0.9144
	(−2.2012)[c]	(−0.3904)	(−0.3022)	(−1.1674)	(−1.4936)
D_s	0.06	0.0088	0.0319	0.0586	0.0076
	(1.2343)	(1.6151)	(0.5569)	(1.1405)	(0.0914)
D_{sf}	0.0341	0.0039	0.0197	0.0285	0.0027
	(0.7209)	(1.0864)	(0.4109)	(0.5576)	(0.0359)
D_f	0.0387	0.0004	0.0108	0.0004	−0.001
	(0.7411)	(0.0619)	(0.2036)	(0.006)	(−0.011)
1/v	0.2098	0.1982	0.1987	0.258	0.2276
	(13.6412)[b]	(14.18570)[b]	(13.0704)[b]	(16.1403)[b]	(15.0455)[b]
λ_1	−2542.3475	1507.21300	−2703.5207	−2075.4589	−3223.3611

Post Estimation Diagnostics with Standardized Residuals

	Skewness	*Kurtosis*	*Q(24)*	*Q^2(24)*
BP Spot	−0.0448	4.7866	16.0350	25.4003
BP Futures	−0.0527	4.3961	11.0724	23.8535
CD Spot	−0.3846	7.0540	15.5603	25.3781
CD Futures	−0.4857	6.5218	30.1243	13.5141
DM Spot	0.1403	4.2370	30.6565	15.8756
DM Futures	0.2059	4.0678	28.7802	18.1402
JY Spot	0.1924	4.9374	30.3100	21.4280
JY Futures	0.4416	6.9378	22.9536	18.5487
SF Spot	0.1525	4.1654	28.9442	22.2671
SF Futures	0.2092	3.9514	22.7982	20.3392

The bivariate conditional mean equations are:

$$\Delta \ln S_t = \alpha_0 + \alpha_1(\ln F_{t-1} - \ln S_{t-1}) + \alpha_2 DEF_t + \alpha_3 SUR + \alpha_4 D_s + \epsilon_s$$
$$\Delta \ln F_t = \beta_0 + \beta_1(\ln F_{t-1} - \ln S_{t-1}) + \beta_2 DEF + \beta_3 SUR + \beta_4 D_f + \epsilon_f \tag{T7}$$

where the independent variables are $\ln F_{t-1} - \ln S_{t-1}$ (error correction term), DEF, SUR, and D. The construction of DEF and SUR is as follows. If FE_t is positive, DEF is set equal to FE_t, and zero otherwise. If FE_t is negative SUR is set equal to FE_t and zero otherwise. The position of the independent variable (*s*) in the bivariate system is indicated by the subscripts: *s* (spot), *f* (futures), and *sf* (covariance). In the bivariate conditional variance-covariance DEF, SUR, and D are included. The resulting equations are:

$$H_t = \begin{bmatrix} h_{s,t} \\ h_{sf,t} \\ h_{f,t} \end{bmatrix} = \begin{bmatrix} \tau_s \\ \tau_{sf} \\ \tau_f \end{bmatrix} + \begin{bmatrix} a_{11} & 0 & 0 \\ 0 & a_{22} & 0 \\ 0 & 0 & a_{33} \end{bmatrix} \begin{bmatrix} \epsilon^2_{s,t-1} \\ \epsilon_{s,t-1}\epsilon_{f,t-1} \\ \epsilon^2_{f,t-1} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} & 0 \\ 0 & b_{22} & 0 \\ 0 & b_{32} & 0 \end{bmatrix} \begin{bmatrix} h_{s,t-1} \\ h_{sf,t-1} \\ h_{f,t-1} \end{bmatrix}$$
$$+ \begin{bmatrix} \theta_s \\ \theta_{sf} \\ \theta_f \end{bmatrix} [DEF_t] + \begin{bmatrix} \gamma_s \\ \gamma_{sf} \\ \gamma_f \end{bmatrix} [SUR] + \begin{bmatrix} \delta_s \\ \delta_{sf} \\ \delta_f \end{bmatrix} [D] \tag{T8}$$

The results are obtained by jointly estimating eqs. (T7) and (T8). *t*-statistics are reported in parentheses. Significance levels are indicated as follows: [a](10%), [b](1%), [c](5%). λ_1 is the log-likelihood value. Standardized residuals are estimated as ϵ_t/h_t where h_t is the conditional variance of each exchange rate. *Q* statistics denote Ljung–Box statistics for serial correlation. The critical value at the 95% is 36.42.

CONCLUSIONS

The objective of this study is to examine the exchange rate response to trade deficit announcements in the context of a bivariate GARCH error correction framework. By analyzing the joint distribution of the spot and the futures rates, this study examines whether or not there is asymmetric response of the spot rate and the futures rate to trade deficit forecast errors and to the positive and the negative trade deficit surprises.

Several important findings are presented. No strong generalizations are possible regarding a uniform impact of trade deficit surprises on exchange rates. Rather, the effects are distributed unevenly across the spot and the futures markets and across currencies. During the period from February 1980 to April 1989, unexpected trade deficits are associated with dollar depreciations in the spot and the futures markets vis-à-vis the British pound, the German mark, the Japanese yen, and the Swiss franc. There is evidence that depending on the information content of news, spot market response to trade deficit announcements has differed from the futures market's response. While the spot market shows a greater sensitivity to the magnitude of unexpected trade deficits than futures markets, the opposite is true under alternative specification where sign of trade deficit surprises is considered. Also, the effects of the magnitude of trade deficit surprises on the time varying exchange rate volatility are more pronounced for dollar/yen exchange rates than for other currencies. This supports the hypothesis that persistent U.S. trade deficits with Japan promotes protectionist sentiment among policy makers to drive down the value of the dollar, thus increasing the exchange rate uncertainty. Finally, larger than expected trade deficits are more likely to be associated with an increase in the exchange rate volatility than are smaller than expected trade deficits. This implies that the information content of trade announcements does matter.

Overall, the evidence demonstrates that the effects of trade data announcements on key currency prices and volatility are not symmetric. For future research, one may extend the analysis presented in this article to examine the behavior of the risk premium in currency prices given trade data announcements. It would be worthwhile also to examine if trade deficit and trade surpluses have differential impacts on currency spot and currency options prices and their volatility.

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