MACRO-AUGMENTED VOLATILITY FORECASTING

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ABSTRACT

Time-series models produce conditional volatility forecasts comparable to option implied volatilities for future horizons. The relative success of time-series models casts doubt on the necessity of forecasting conditional volatility dynamics associated with future fundamental information arrival. This study examines augmenting time-series models of conditional EUR/USD spot foreign exchange rate return volatility to incorporate predictable shocks associated with future occurrences of macroeconomic announcements. Utilizing a simple macro-augmentation procedure, the out-of-sample forecast accuracy of ARMA(p,q) models of realized volatility is significantly improved by conditioning on the occurrence of the U.S. Employment Situation announcement over the period 1987 to 2007.

INTRODUCTION

Forecasts of conditional volatility (defined as conditional variance) are necessary to assess first-order risk of holding assets over future time horizons. Conditional volatility is primarily autoregressive, but weakly related to fundamentals [1] [4] [22] [24]. Recently posited time-series models, which condition on historical evolution of volatility, produce forecasts comparable to option-implied volatility, which reflects the future expectations of market participants [18] [23] [6]. But is it possible that optimal volatility forecasts condition *solely* on the past? We consider the predetermined announcement schedules of macroeconomic indicators, which effectively forewarn investors as to when new fundamental information arrives. Fundamentally motivated volatility shocks may then be predictable on days when macroeconomic indicators are scheduled to be announced. Recent work suggests that the occurrence of macroeconomic announcements does heighten conditional *five-minute* return volatility across a number of asset classes [2] [3]. However, it is not obvious that these effects carry over to lower frequency returns, upon which many practical trading strategies are based. We ask whether investors can make better out-of-sample conditional *daily* and *monthly* volatility forecasts by conditioning on both past information and additional information about the future.

We augment the ARMA(p,q) model of realized volatility with an additive set of macroeconomic announcement date dummy variables. Utilizing return data at both the daily and five-minute sampling frequencies for the EUR/USD spot foreign exchange (FX) rate, in conjunction with twenty-one years of predetermined macroeconomic announcement dates, we are able to assess the benefit of macro-augmentation. We establish a fundamental impetus to conditional daily and monthly volatility that is distinct from autoregressive dynamics observed in financial returns.

Attention is restricted to spot FX rates because they are comparatively "cleaner" functions of macroeconomic conditions than corporate securities. While the systematic risk of corporate securities associates with macroeconomic fundamentals, the observed dependencies are small, and contradictory across time periods and authors [5] [7] [10] [11]. Furthermore, using over-the-counter spot FX market

mitigates the necessity to separately model the disparate "regular business hours" and "overnight" volatility processes that have been documented for exchange-traded contracts, such as futures [20] [13] [15] [17]. The extensive liquidity and low transactions costs of the spot FX market should in theory translate into prompt price discovery, facilitating efficient estimation of econometric models of conditional volatility.

Spot Foreign Exchange Data

Both daily and intraday FX data are required to construct the forecasts. Olsen Financial Technologies (OFT) provided five-minute mid quotes sampled in calendar time under the previous-tick method, for February 3, 1986 to December 31, 2007. We analyze the twenty year period beginning January 2, 1987. There is an average of 275 five-minute mid quotes per day. Prior to January 1, 1999, DEM/USD spot FX rates are used in place of EUR/USD spot FX rates. All intervals in which no quote was reported and weekends, holidays and special non-trading days for the New York Stock Exchange have been removed from the sample. If no price is present within a given five-minute interval, the price from the previous populated interval is used as long as the previous price is quoted within a half hour. In total, there are 8,652 intervals in which the previous mid quote is more than a half-hour old, leaving 1,457,999 filtered five-minute mid quotes. Five-minute returns are calculated as the log difference of neighboring five-minute mid quotes, and daily returns are calculated as the log difference of day-end mid quotes, where a "day" is defined as the 24-hour period beginning 21:00 GMT the night before. Realized volatilities are calculated by summing the squared five-minute returns for each day present in the filtered series.

When possible, we obtain U.S. macroeconomic announcement dates from the ArchivaL Federal Reserve Economic Data (ALFRED). However, the ALFRED database only contains historic announcement dates going back to 1987 for a limited number of U.S. macroeconomic announcements. We omit dates on which revisions are made since they are not obviously predictable. Prior work suggests which announcements provide price-relevant information [2] [3]. All announcements fall within the 24-hour trading day defined above.

Macro-Augmented ARMA(2,1) Volatility Forecasting Model

A macro-augmented ARMA(2,1) model of realized volatility explicitly accounting for daily macroeconomic announcements effects unmodeled by the standard ARMA(2,1) model takes the form:

$$\sigma^2_{MacroARMA,\, t|t-1} = \sigma^2_{ARMA,\, t|t-1} + E[RV_t - \sigma^2_{ARMA,\, t|t-1} \mid D_{k,t} : \forall k \in \{1,\ldots,K\}], \tag{1}$$

$$\text{where } E[RV_t - \sigma^2_{ARMA,\, t|t-1} \mid D_{k,t} : \forall k \in \{1,\ldots,K\}] = \eta_t + \Sigma\lambda_k D_{k,t} \tag{2}$$

Conditional daily volatility is then modeled as the standard ARMA(2,1) process plus a constant non-announcement effect (η) and K additive announcement effects ($\lambda_k\ D_{k\ ,t}$) . As formulated, the macro-augmented ARMA(2,1) model can then be estimated in two steps: estimate the standard ARMA(2,1) model; and then regress the in-sample forecast errors of the standard ARMA(2,1) model on a constant and K announcement dummies.

RESULTS

Given the surprising paucity of historic macroeconomic announcement date data spanning 1987 to 2007, the full sample analyses are restricted to ten important U.S. macroeconomic announcements. Table 1

shows the full-sample estimation results for the second-stage forecast-error-effects regressions. The announcement effects associated with the Employment Situation, Advance GDP, and PPI announcements are statistically significant at the 1% level and economically significant in that their arrivals are associated with increases in conditional daily volatility equal to roughly 54%, 26% and 33% of the sample average, respectively. These findings comply with the predictions of standard exchange rate determination models [9] [14] [19]. The positivity of these coefficients is consistent with the intuition that conditional volatility should increase with price-relevant news. To demonstrate the robustness of our findings, we also display estimation results for the GARCH(1,1) and ARFIMA(2,d,1) models in Table 1.

A potential explanation for the importance of certain announcements over others is the timing of each announcement within its informational class. Table 1 groups each of the U.S. announcements by informational class and then orders them according to relative timing within each class. As shown, the Employment Situation and PPI announcements are the first announcements within their respective informational classes, potentially explaining their strong associations with volatility shocks. The relatively minor Industrial Production announcement effect may also be explained by the fact that it is preceded by the Employment Situation announcement.

Macro-Augmented Forecast Evaluations

To test whether the observed full-sample announcement effects could have been exploited ex ante, we analyze the difference in forecast accuracy between the standard time series model and its macro-augmented counterpart. To estimate ex post conditional volatility for each day of the sample, we use realized volatility, defined as the sum of squared intraday five-minute returns, which has been shown to be an approximately optimal estimator. As measures of forecast accuracy over the *out-of-sample forecasting period* (July 8, 1997 to December 31, 2007), we use mean-squared forecast error (MSE), as well as the coefficient of determination (R^2) from univariate "information-test" regression of realized volatility on a constant and the forecast of interest.

In constructing the volatility forecasts, we first estimate each model using the first half of the sample. We then calculate the conditional volatility forecasts of each model for the one-day- and one-month-ahead forecast horizons. We then roll the end of the estimation period forward by the number of days implied by the respective forecast horizon, re-estimate the models, and construct the requisite volatility forecasts. This process is repeated until the final day of the sample is enveloped by the particular forecast horizon. The net result is two non-overlapping time series of conditional volatility forecasts. The use of non-overlapping conditional volatility forecasts mitigates concerns of induced serial correlation [8] [12] [16] [21].

Tables 2 reports the analyses for the ARMA(2,1) models of realized volatility. For the one-day-ahead horizon, Employment-Situation- and Advance-GDP-augmented forecasts provide significantly lower MSE and higher R^2 at the 10% level. For the one-month-ahead horizon, only Employment-Situation-augmented forecasts provide significantly lower MSE and significantly higher R^2 at the 5% level.

The effect of macro-augmentation on ARMA(2,1) forecasts is highly announcement specific. However, the MSE and univariate R^2 results presented in Table 2 do not differentiate between the sources of information embedded in macro-augmented forecasts. For example, if the forecasted non-announcement effect $(\hat{\eta}_t)$ is particularly informative, then it can overwhelm any contribution of the corresponding

announcement effects $\left(\hat{\lambda}_{k,t} D_{k,t+h}\right)$ to forecast accuracy. Furthermore, given the potential for "news" overlap between announcements, as well as the fact that macroeconomic announcements can sometimes occur on the same day, simultaneous examination of announcement effects within a multivariate information-test framework allows an even finer parsing of true information content. To this end, we specify separate coefficients for each forecasted announcement effect in an additional analysis and find that forecasted Employment Situation, Advance GDP, and PPI announcement effects contain unique incremental information over standard one-day-ahead ARMA(2,1) forecasts at the 5% level. For the one-month-ahead horizon, we find that forecasted Employment Situation, Housing Starts, and Retail Sales announcement effects contain unique incremental information at the 5% level.

We also examine the extent to which implied volatility (IV), extracted from the market option prices, are associated with the forecasted announcement effects of the macro-augmented ARMA(2,1) model. The results imply that IV is significantly associated with standard ARMA(2,1) forecasts as well as forecasted U.S. Employment Situation, U.S. NAPM Index, and U.S. Consumer Confidence announcement effects. Thus, assuming that IV is representative of the future volatility expectations of market participants, these results suggest that market participants not only anticipate conditional volatility shocks on days when these announcements are made, but also formulate their expectations in a manner consistent with the macro-augmented ARMA(2,1) model.

CONCLUSION

The present article examines the incremental benefit of augmenting time-series forecasts of EUR/USD FX return volatility to further condition on the predetermined schedule of macroeconomic announcements. Assuming relative efficiency in the FX price discovery process, conditional volatility should then become elevated after an announcement. We find that time-series models fail to account for conditional daily volatility shocks associated with macroeconomic announcements. The predictable timing of most macroeconomic announcements provides a straightforward manner to expand the information set utilized by time-series volatility models, and to improve out-of-sample forecast performance.

We find that macro-augmentation can significantly improve time-series forecast accuracy. Most notably, we find that one-day-ahead ARMA(2,1) forecasts that are further conditioned on the occurrence of U.S. Employment Situation announcements display significantly lower MSE and significantly higher R^2 than standard forecasts for the period January 1987 to December 2007, and that these results are robust to the estimator of ex post conditional daily volatility.

The evidence presented in this paper implies that standard time-series forecasts of the conditional volatility of EUR/USD FX returns ignore predictable announcement-driven volatility shocks, but that this deficiency can be mitigated via a relatively simple macro- augmentation procedure. Given that many trading strategies are implemented, and can be tested, at horizons longer than intraday, the findings of the present paper are of both academic and practical importance.

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TABLE 1: MACRO-AUGMENTED EFFECTS BY INFORMATION CLASS

Parameter	GARCH(1,1)	ARMA(2,1)	ARFIMA(2,*d*,1)
GDP			
$\lambda_{\text{US GDPA}}$	9.9275***	12.2200***	11.1863***
Real Activity			
$\lambda_{\text{US EMP}}$	22.3937***	22.1234***	22.5523***
$\lambda_{\text{US RS}}$	-2.7238	-2.1653	-2.8161
$\lambda_{\text{US IND}}$	6.9898*	7.7989**	8.4014**
$\lambda_{\text{US PERS}}$	0.4398	-0.3655	-0.0868
Consumption			
$\lambda_{\text{US PERS}}$	0.4398	-0.3655	-0.0868
$\lambda_{\text{US NEWH}}$	-0.5412	1.3541	1.3058
Prices			
$\lambda_{\text{US PPI}}$	11.3866***	10.7687***	11.6022***
$\lambda_{\text{US CPI}}$	2.9177	2.9143	2.2483
Forward Looking			
$\lambda_{\text{US NAPM}}$	-2.2976	-3.0436*	-2.4169
$\lambda_{\text{US HST}}$	0.3423	1.3127	1.2784

This table shows the macroeconomic announcement effects grouped by informational class and ordered according to relative timing within each class. ***, **, and * denote significance at 1%, 5% and 10%, respectively. All λ coefficients have been multiplied by 10^6.

TABLE 2: MACRO-AUGMENTED ARMA(2,1) Forecasting Results

		1-Day-Ahead		1-Month-Ahead	
Model		R2	MSE x 10^9	R2	MSE x 10^9
ARMA(2,1)		0.2738	0.9776	0.3894	138.1066
+ US CPI	Loss Function Differential	+0.0002	-0.0003	+0.0002	-0.0242
+ US EMP		+0.0079*	-0.0091*	+0.0030***	-0.6332**
+ US GDPA		+0.0012*	-0.0016*	-0.0006	+0.1424
+ US HST		-0.0000	+0.0000	-0.0001	+0.0454*
+ US IND		-0.0033**	+0.0055***	-0.0008*	+0.1844*
+ US NAPM		-0.0004	+0.0007	-0.0004	+0.1031
+ US NEWH		-0.0002*	+0.0004*	+0.0000	+0.0059
+ US PERS		-0.0011	+0.0017	+0.0003	-0.0714
+ US PPI		-0.0035*	+0.0062***	-0.0015	+0.3575
+ US RS		-0.0001	+0.0001	+0.0001*	-0.0013
+ ALL		-0.0334**	+0.0901***	-0.0017	+0.4548

This table shows the out-of-sample R2 and MSE values of the ARMA(2,1) model in the top row, and the loss function differentials of its macro-augmented counterparts in the lower rows for each forecast horizon. ***, **, and * denote that the loss function of a particular macro-augmented model is significantly different than that of the standard model at the 1%, 5% and 10% significance levels, respectively.