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Private Information and the Monetary Model of Exchange Rates: Evidence from a Novel Data Set

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Abstract

We propose an exchange rate model which is a hybrid of the conventional monetary specification and the Evans-Lyons microstructure approach. It argues that the failure of the monetary model is principally due to private preference shocks which render the demand for money unstable. These shocks to liquidity preference are revealed through order flow. We estimate a monetary model augmented with order flow variables, using a unique data set: almost 100 monthly observations on inter-dealer order flow on dollar/euro and dollar/yen. The augmented monetary, or "hybrid", model exhibits out of sample forecasting improvement over the monetary and random walk specifications.

JEL classification: D82; E41; F31; F47
Keywords: Exchange rates; Monetary model; Order flow; Microstructure; Forecasting performance

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1. Introduction

One of the most enduring problems in international economics is the 'exchange rate disconnect' puzzle. Numerous structural or arbitrage approaches have been tried. Prominent among them are:

a) the sticky price monetary model

b) the Balassa-Samuelson model

c) the portfolio balance model

d) purchasing power parity

e) uncovered interest parity.

The in-sample and forecasting goodness of fit of these models were evaluated by Cheung, Chinn and Garcia Pascual (2005 (a) and (b)). Their conclusions are not unfamiliar:

> "the results do not point to any given model/specification combination as being very successful. On the other hand, some models seem to do well at certain horizons, for certain criteria. And indeed, it may be that one model will do well for one exchange rate, and not for another."

Recently, Gourinchas and Rey (2007) have used the external budget constraint to devise a sophisticated measure of external imbalance which has forecasting power for exchange rate changes over some horizons.[1] However, the framework seems to be limited to some of the institutional features of the US dollar and is ex-ante silent on the timing and the composition of external adjustment between price and quantity. The most theoretically and empirically startling innovation in the literature has been the introduction of a finance microstructure concept – order flow – to explain

[1] See an extended analysis on bilateral exchange rates using this framework in Alquist and Chinn (2008).

exchange rate movements. In a series of papers Evans and Lyons[2] (2002, 2005, 2008), have shown that order flow contemporaneously explains a significant proportion of the high-frequency variation in exchange rates. Though their theoretical framework is also very convincing, it has been difficult to evaluate its merit at standard macroeconomic frequencies because of the proprietary nature of the data. This paper fills this gap as it presents results on almost 100 monthly observations of order flow nested within a conventional framework[3].

In Section 2 we discuss the theoretical motivation for the hybrid monetary fundamentals-order flow model we adopt. In Section 3 we outline the characteristics of the data we employ in this study. Section 4 replicates the Evans and Lyons (2002) results at the monthly frequency, confirming the fact that the order flow data we use (and the sample period examined) are representative. Our empirical methodology and basic in-sample results are discussed in Section 5. The next section reports some of the robustness tests implemented. Section 7 reports the preliminary results of our out-of-sample validation exercises that demonstrate the predictive power of the hybrid model. The final section makes some concluding remarks.

2. Theoretical Background

The central assertion of the paper is that at least one of the parameters of the utility function is privately known and can only be revealed through trading. To fix ideas, consider the following variation on the standard monetary model: Let the utility function be the following special case of a CES function:

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[2] These are just examples of their work. For a fuller account, see http://www9.georgetown.edu/faculty/evansm1/Home%20page.htm

[3] Berger et al. (2006) also obtained access to a long run of EBS order flow data. – 6 years from 1999 to 2004 but they do not integrate this into the conventional monetary analysis.

$$E_0 \sum_{t=0}^{\infty} \delta^t \frac{\left[\left(C_t^j\right)^{\frac{\theta-1}{\theta}} + e^{\frac{\beta_t^j}{\theta}} \left(\frac{M_t^j}{P_t^j} \right)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}}{\frac{\theta}{\theta-1}} \tag{1}$$

Where $j = H, F$ for home and foreign respectively; C_t^j is consumption at time t; M_t^j is nominal money balances and P_t^j is the price of C_t^j. θ, δ and β_t^j are parameters. The CES parameter, θ, and the discount rate, δ, are common knowledge but the parameter governing the demand for money is idiosyncratic and follows a unit root process as follows:

$$\beta_t^j = \beta_{t-1}^j + \varepsilon_t^j \tag{2}$$

Where ε_t^j is an i.i.d. random error with the property that $Cov\left(\varepsilon_r^H, \varepsilon_s^F\right) = 0 \quad \forall r, s$.

The idea that preference shocks can used to explain asset pricing is not eccentric. This is the main concept behind Campbell and Cochrane (1999) which has already been applied to an exchange rate setting by Moore and Roche (2002, 2005, 2007, 2008) as well as Verdelhan (2007).

Equation (1) is maximised subject to the budget constraint:

$$W_t^j = P_t^j C_t^j + M_t^j - M_{t-1}^j + \frac{B_t^j}{1 + i_t^j} \tag{3}$$

Where i_t^j is the nominal return on one period riskless bonds and B_t^j is the number of bonds held. W_t^j is wealth, the only state variable and the control variables are C_t^j, M_t^j and B_t^j., The equation of motion for W_t^j is:

$$W_{t+1}^j = P_t^j Y_t^j + B_t^j + M_t^j \tag{4}$$

Where Y_t^j is labor income.

The solution to this is straightforward and the demand for money (using lowercase symbols to represent the natural log of a variable) is[4]:

$$m_t^j - p_t^j = \beta_t^j + c_t^j - \theta r_t^j \tag{5}$$

Denoting the home price of foreign currency as s_t and using PPP, $s_t = p_t^H - p_t^F$, we have:

$$s_t = \left[\left(m_t^H - m_t^F\right) - \left(c_t^H - c_t^F\right) + \theta\left(r_t^H - r_t^F\right)\right] - \left\{\beta_t^H - \beta_t^F\right\} \tag{6}$$

The terms in the square brackets on the right hand side of equation (6) constitute a standard way of expressing the monetary model. The novel feature is the final term in curly brackets. Assuming the substitution semi-elasticity of the demand for money, θ, is 'small', variations in velocity for each country's will be largely driven by β_t^j. The 'exchange rate disconnect' puzzle is here explained by instability in the demand for money itself. Since the parameters β_t^j (and their relation), are unknown in advance, they can only be revealed though the act of trading itself i.e. through foreign exchange order flow. This is a simplified way of thinking about the role in exchange rate determination of portfolio balance shocks as put forward by Flood and Rose (1999). More specifically, shocks to liquidity demands is one of the motivations offered for the link between order flow and exchange rate in the seminal paper by Evans and Lyons (2002). The contention of this paper is that cumulative shocks to liquidity demand, as specified by equation (2), are captured by cumulative foreign exchange order flow. Bjonnes and Rime (2005) and Killeen, Lyons and Moore (2006) provide evidence that exchange rate levels and cumulative order flow are

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[4] In equations (5) and (6), $r_t^j = Log\left(\frac{i_t^j}{1+i_t^j}\right)$.

cointegrated in high frequency data. If equation (6) were correct, exchange rate levels should be cointegrated with *both* cumulative order flow *and* the traditional vector of 'fundamentals' of the monetary model at *all* frequencies. It has been impossible to test this up to this point because of lack of data.[5]

3. Data

The data is monthly from January 1999 to January 2007 (see the Data Appendix for greater detail, and summary statistics). Two currency pairs are considered: dollar/euro and dollar/yen.

The most novel aspect of the data is the long span of order flow data. That data was obtained from Electronic Broking Services (EBS). This is one of the two major global inter-dealer foreign exchange trading platforms. It dominates spot brokered inter dealer trading in dollar/yen and is responsible for an estimated 90% of dollar/euro business in the same category. The two series are:

- Order Flow: Monthly buyer initiated trades net of seller initiated trades, in millions of base currency (OFEURUSD, OFUSDJPY)
- Order Flow Volume: Monthly sum of buyer-initiated trades and seller-initiated trades, in millions of base currency.

For dollar/euro, the base currency is the euro while the dollar is the base currency for dollar/yen. In the empirical exercise, we standardize the data by converting OFEURUSD into dollar terms so that the order flow variable enters into each equation analogously.[6] In some of the robustness checks, the order flow variables are

[5] In the subsequent analysis, we allow for sticky prices, so that inflation enters in separately from interest rates. This specification is sometimes termed the "sticky price monetary model" or "real interest differential model".
[6] OFUSDJPY is multiplied by a negative sign to generate the corresponding yen variable.

normalized by volume (also adjusted into dollar terms). The untransformed order flow and order flow volume data are depicted in Figures 1 and 2.

The other data are standard. Monthly data were downloaded from the IMF's *International Financial Statistics*. The exchange rate data used for prediction are end-of-month. The exchange rate data used to convert order flow, as well as the interest rate data, are period average, which is most appropriate given the order flow data are in flow terms. In our basic formulation, money is M2 (the ECB-defined M3 for Euro area), income is industrial production, inflation is 1 month log-differenced CPI, annualized.[7]

The key variables, the exchange rates and transformed order flow series are displayed in Figures 3 and 4 for the dollar/euro and dollar/yen, respectively. Note that in these graphs, the exchange rates are defined (dollar/euro and dollar/yen) and order flow transformed so that the implied coefficient is positive.

4. Replicating the Evans-Lyons Results

In order to verify that the results we obtain are not driven by any particular idiosyncratic aspects of our data set, we first replicate the results obtained by Evans and Lyons (2002). They estimate regressions of the form (7).

$$\Delta s_t = \beta_0 + \beta_1 (i_t - i_t^*) + \beta_2 (of_t) + \beta_3 (\Delta of_t) + u_t \tag{7}$$

Where *i* are short term nominal interest rates and *of* is order flow. The estimates we obtain are reported in Table 1. Several observations are noteworthy. First, the

[7] As noted in Section 6, we also check to see if the results are robust to use of M1 as a money variable, different inflation rates (3 month or twelve month differences of log-CPI), or real GDP (at the quarterly frequency). M1 and real GDP are also drawn from *IFS*.

proportion of variation explained goes up substantially when order flow in levels is included.

Second, the interest differential coefficient is only statistically significant (with the anticipated sign[8]) when the order flow variables are omitted, and then only in the dollar/euro case. Inclusion of the order flow variables reduce the economic and statistical significance of the interest rate differential in this case. In short, any suspicion that the Evans-Lyons result is an artefact of high-frequency data is firmly dispelled. The results are, however, consistent with those of Berger et al. (2006) who argue that the Evans Lyons result is relatively weaker at lower frequencies.

5. Empirics

We implement the rest of the portion of the paper in the following manner.

a) The Johansen Procedure is applied to test for cointegration between the exchange rates, cumulative order flow and conventional monetary model fundamentals (here taken to be the sticky-price model determinants – money, income, interest and inflation rates).
b) The dynamic OLS procedure of Stock and Watson (2003) is used to obtain the long run coefficients.
c) The implied error correction model is estimated.
d) Out of sample forecasts for different models are compared

[8] The negative slope is consistent with a sticky price monetary model story, though not, of course with uncovered interest parity.

5.1 Testing for Cointegration

The first step in the cointegration test procedure is to determine the optimal lag length. We evaluated the VAR specifications implied by the monetary model and the monetary model augmented by the order flow variable (in this case cumulated). We term this latter version the "hybrid" model.

The Akaike Information Criterion typically selects a fairly short lag length of one or two lags in the VAR specification. However, these specifications also typically exhibit substantial serial correlation in the residuals, according to inspection of the autocorrelograms up to lag 12. In contrast, the residuals appear serially uncorrelated when four lags are included in the VARs. Hence, we opt to fix on the four lag specification.[9]

We applied the Johansen (1988) maximum likelihood procedure to confirm that the presence of cointegration, and to account for the possibility of multiple cointegrating vectors. Table 2 reports the results of our tests.

The first three columns of Table 2 pertain to specifications including only sticky price monetary fundamentals. Columns 4-6 pertain to the monetary model augmented with cumulative order flow. Columns [1] and [4] pertain to model specifications allowing a constant in the cointegrating equation, columns [2] and [5] to ones allowing a constant in both the cointegrating equation, and in the VAR, and columns [3] and [6] allowing intercept and trend in the cointegrating equation, and a constant in the VAR (in all but columns [1] and [4], deterministic time trends are allowed in the data).

[9] Only in the USD/JPY hybrid model case does a 3 lag specification appear plausible. To maintain consistency across specifications, we retain the four lag specification in all cases.

The numbers pertain to the implied number of cointegrating vectors using the trace and maximal eigenvalue statistics (e.g., “2,1” indicates the trace and maximal eigenvalue statistics indicate 2 and 1 cointegrating vectors, respectively). Since the number of observations is not altogether large relative to the number of coefficients estimated in the VARs, we also report the results obtained when using the adjustment to obtain finite sample critical values suggested by Cheung and Lai (1993). Hence, “Asy” entries denote results pertaining to asymptotic critical values, and “fs”, to finite sample critical values.

Inspection of Table 2 confirms that that it is fairly easy to find evidence of cointegration using the 5% marginal significance level. The specification selected by the AIC for the monetary model is one that omits a constant in the VAR equation for the dollar/euro, and one including a constant in both the cointegrating vector and the VAR for the dollar/yen. In the case of the hybrid model, there is again some diversity of results. For the dollar/euro, there seems to be some argument for a trend in the cointegrating relationship, while no trend appears in the cointegrating vector for the dollar/yen.

Table 2 also indicates that it is quite easy to obtain evidence of cointegration – and indeed cointegration with multiple long run relationships – using the asymptotic critical values. We opt to put greater weight on the finite sample critical values.

The resulting conclusions are highly suggestive that there is one cointegrating vector in almost all cases. Hence, we proceed in our analysis assuming only one cointegrating vector.[10] This conclusion points to an important role for cumulative order flow in determining long term exchange rates but only in combination with monetary fundamentals.

5.2 Estimating the Long Run Relationships and the Error Correction Models

We estimate the cointegrating relationship using dynamic OLS (Stock and Watson, 1993), which is appropriate if there is one cointegrating vector. The procedure involves running a regression involving two leads and lags of first differences of the right hand side variables.

$$s_t = X_t \Gamma + \delta\tau + \sum_{i=-2}^{+2} \Delta X_{t+i} B + u_t \qquad (8)$$

Where *X* is a vector of monetary fundamentals and cumulative order flow, τ is a time trend (which is suppressed in some specifications). Using these estimates, error correction terms are defined thus:

$$ECT_t = (s_t - (X_t \hat{\Gamma} + \hat{\delta}\tau)) \qquad (9)$$

And then incorporated into single equation error correction models.[11]

$$\Delta s_t = \Delta X_{t-1} + \varphi ECT_{t-1} + v_t \qquad (10)$$

Where φ should take on a negative value, significantly different from zero, if the exchange rate responds to disequilibria in the fundamentals.

In the results that are reported, a standardized specification incorporating one lag of first differenced monetary fundamentals, is used. One could adopt a general-to-

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[10] Note that while we could rely upon the Johansen procedure to obtain estimates of the long run and short run coefficients, we decided to rely upon the DOLS procedure, in large part because the estimates we obtained via this method were so implausibly large, and sensitive to specification. In addition, Stock and Watson (1993) present simulation results that indicate that DOLS estimates are less dispersed than Johansen estimates.

[11] In some specifications, order flow is entered in contemporaneously, including the one that incorporates cumulative order flow in the cointegrating relationship.

specific methodology with the objective of identifying a parsimonious specification. Typically, such an approach leads to error correction models with short lags (a lag or at most two of first differenced terms), with perhaps income and inflation variables omitted. In order to maintain consistency of specifications across models, we opt to present the results of models incorporating only one lag of the differenced monetary fundamentals.

5.3 Long- and Short-Run Coefficients

The results of estimating these equations for the dollar/euro and dollar/yen are reported in Tables 3 and 4, respectively.[12] Turning first to Table 3, columns [1]-[3], one finds little evidence that the exchange rate reacts to the long run monetary fundamentals (note that while order flow is included in columns [2] and [3], these are not in the cointegrating relation). So while order flow is important in determining the rate of exchange rate depreciation (notice that the adjusted R-squared rises from 1% to 26%), it does not appear in the level of the dollar/euro rate.

The cointegration tests suggest that cumulative order flow does enter into the cointegrating relationship, and that furthermore, there is a deterministic time trend in the cointegrating relation. The specification in column [8] conforms to that specification.

That specification, allowing the cumulative order flow to enter into the long run relationship, explains a large proportion of variation in the exchange rate change

[12] We rely upon a single equation estimation methodology focused on the exchange rate as the dependent variable, which is appropriate if the "fundamentals" are weakly exogenous. We tested for this condition, and this is typically the case, especially when inflation is measured as the three month change.

(30%). Moreover, the exchange rate responds in an economically and statistically significant way to disequilibria as measured by the error correction term.

Turning to the dollar/yen results in Table 4, we can dispense with the specifications incorporating the time trends in the cointegrating vector, given the results of the Johansen tests. The specifications excluding cumulative order flow from the cointegrating vector (columns [1]-[3]). Notice that the specification incorporating contemporaneous order flow is quite successful, in so far as the adjusted R-squared is quite high. Order flow is itself highly significant.

The specification in column [4] is that consistent with the test statistics for the hybrid model. In addition to a significant short run coefficient, cumulative order flow also enters in significantly.

To sum up the results from this section, there does appear to be significant evidence of a long run relationship between exchange rates and monetary fundamentals augmented by cumulative order flow. Even when cumulative order flow might be argued to not enter into the long run relationship (i.e., in the case of the dollar/yen), it is clear that order flow enters into the short run relation.

6. Robustness Tests

We have investigated a number of variations to the basic specifications, to check whether the empirical results are robust.

- Order flow vs. normalized order flow
- M1 vs M2

- 3 month vs. 1 month inflation
- Quarterly vs. monthly data

We deal with each of these issues in turn.

Order flow issues. The order flow variables are included in dollar terms. It is reasonable to scale net order flow variable by the *volume* of order flow. The results in the Evans and Lyons regressions are basically unchanged. Using this normalized order flow variable in the hybrid model specifications (conforming to columns [2]-[3] and [6]-[7] in Tables 3 and 4) does not result in any appreciable change in the results.[13]

Money measures. While the substitution of narrow money for M2 results in slightly different results, particularly with respect to the short- and long-run coefficients on the money variable, the impact on the general pattern of estimates is not significant. In particular, the coefficient on the cumulative order flow variables remain significant.

Quarterly data. At the cost of considerable reduction in the number of observations, one can switch to quarterly data. The benefit is that one can then use real GDP as a measure of economic activity, rather than the more narrow industrial production variable. As a check, we re-estimated the error correction models (both in a constrained version, using nonlinear least squares, and in an unconstrained version using OLS). What we find is that we recover the same general results as that obtained

[13] Another point related to order flow is that net order flow is positive in the raw data. This can be ascribed to a data recording error. As long as the *level* of order flow enters in the level in the error correction specification, then only the constant is affected. However, when the cumulated order flow enters into the long run relationship, a deterministic trend is introduced. We can address this by allowing a deterministic trend in the data. A direct way to address this issue is by demeaning the raw order flow data. Using demeaned order flow has no impact on the order flow coefficient, but changes substantially the long run coefficient on cumulated order flow.

using the monthly data. While money coefficients remain wrong-signed (as do income variables for the yen), the order flow and cumulative order flow variables show up as economically and statistically significant.

7. Out-of-sample Forecasting

As is well known, findings of good in-sample fit do not often prove durable. Hence, we adopt the convention in the empirical exchange rate modeling literature of implementing "rolling regressions." That is, estimates are applied over an initial data sample up to 2003(12) , out-of-sample forecasts produced, then the sample is moved up, or "rolled" forward one observation before the procedure is repeated. This process continues until all the out-of-sample observations are exhausted.[14] To standardise the results, we generate our forecasts for the monetary model from the simple specifications of column (1) in both Tables 3 and 4. For the hybrid model, we use column (4) from both Tables. In effect, this means that we are leaving out the deterministic time trend in all cases, including, of course the random walk benchmark.

Forecasts are recorded for horizons of 1, 3, and 6 months ahead. We could evaluate forecasts of greater length, but we are mindful of the fact that the sample we have reserved for the out of sample forecasting constitutes only three years worth of observations.

Instead of implementing the two-stage procedure outlined in Section 5, we collapse the procedure into a one-step non-linear least squares estimation of an unconstrained error correction model, with one lag of each of the first differences of all variables.

[14] Note that this is sometimes referred to as a historical simulation, as the ex post realizations – as opposed to ex ante values – of the right hand side variables are used. In this sense, our exercise works as a model validation exercise, rather than a true forecasting exercise.

One key difference between our implementation of the error correction specification and that undertaken in some other studies involves the treatment of the cointegrating vector. In some other prominent studies, the cointegrating relationship is estimated over the entire sample, and then out of sample forecasting undertaken, where the short run dynamics are treated as time varying *but the long-run relationship is not.* This approach follows the spirit of the Cheung, Chinn and Garcia Pascual (2005b) exercise.

The results for the dollar/euro are reported in Table 5.1. The first two rows pertain to the no-drift random walk forecast. The next two blocks of cells pertain to the monetary model, and the hybrid model. The final block is the Evans-Lyons model, which we include for purposes of comparison. Note that the Evans-Lyons model does not incorporate a long run relationship incorporating cumulated order flow.[15]

Turning first to the dollar/euro exchange rate, notice that monetary model does very badly relative to the random walk over this sample period. The ratio of the monetary model to the random walk RMSE (the Theil U-statistic) is 2.6, 2.3 and 3.3 at the 1, 3 and 6 month horizons. In contrast, the mean error is smaller for the hybrid model at all horizons, and Theil statistic (vis a vis the random walk) is much smaller: 1.3, 0.9, and 1.0. The relative performance of these forecasts (random walk, monetary, hybrid) are shown in Figures 5 and 6 for the dollar/euro exchange rate.

[15] The particular specification we use conforms to columns [3] and [7] in Table 1.

Perhaps more remarkable, the RMSE for the hybrid model is smaller than the random walk at the 3 and 6 month horizons. Given the upward bias in the model-based RMSE versus the random walk RMSE (see Clark and West, 2007), this suggests an improvement vis à vis the random walk benchmark.[16]

The results are slightly different in the case of the dollar/yen. There, by the RMSE criterion, the hybrid model substantially outperforms the monetary model at the 1 and 3 month horizons, and ties at the 6 month horizon.[17] However, the Evans-Lyons specification in this case does best, with the lowest Theil statistic at horizons of 3 and 6 months ahead. Nevertheless, at the 1 month horizon, the hybrid model still outperforms the random walk.

8. Conclusion

We have laid out a simple and transparent framework in which non-stationary private liquidity preference shocks give rise to instability in the demand for money and the apparent failure of the monetary model of exchange rates. Cumulative order flow tracks these shocks and provides the 'missing link' to augmenting the explanatory power of conventional monetary models. We show that the hybrid model beats both the monetary model *and* a random walk in a simple forecasting exercise. Berger et al. (2006) concluded that while order flow plays a crucial role in high-frequency exchange rate movements, its role in driving long-term fluctuations is much more limited. We contend that this conclusion is premature.

[16] The Diebold and Mariano (1995) and West (1996) test statistic does not indicate significant differences in the RMSEs.
[17] Although the monetary model consistently underperforms, in the sense that it consistently underpredicts the USD/JPY exchange rate.

In summary, we find substantial evidence to support our proposition that order flow is an important variable in exchange rate determination, whose role can be rationalized on the basis of a straightforward macroeconomic model.

Data Appendix

For the conventional macroeconomic variables, monthly frequency data were downloaded from *International Financial Statistics* (accessed November 4, 2007).

End of month data used for exchange rates when used as a dependent variable. Interest rates are monthly averages of daily data, and are overnight rates (Fed Funds for the US, interbank rates for the euro area, and call money rate for Japan). In the basic regressions, money is M2 (the ECB-defined M3 for Euro area), although specifications using M1 were also estimated. Income is proxied by industrial production, while inflation is 1 month log-differenced CPI in the basic regressions. Specifications were also estimated using 3 month and 12 month log-differenced CPI as a measure of inflation. Money, industrial production and CPIs are seasonally adjusted.

Order flow was obtained from Electronic Broking Services (EBS). In order to make the specifications consistent across currencies, the order flow data is converted to dollar terms by dividing by the period-average exchange rate (for OFEURUSD) and by putting a negative in front (for OFUSDJPY). Hence, the exchange rates are defined (USD/EUR, USD/JPY) and order flow transformed so that the implied coefficient is positive.

In some unreported regressions, the order flows are normalized by volume. Order flow volume was also converted to dollar terms, in the same manner that order flow was converted.

For the quarterly regressions (not reported), we use end-of-period exchange rates, and the last month of each quarter for interest rates and inflation rates. The income variable is US GDP (2000$), and for Euro area and Japan, GDP volume (1995 ref.).

Table A1: Summary Statistics for Dollar/Euro

Sample: 1999M01 2007M01

	LXEU	M2_EU	Y_EU	I_EU	PI1_EU	Z1EU	CUMZ1EU
Mean	0.077	-0.018	-0.015	0.005	0.006	0.011	0.622
Median	0.086	-0.007	-0.017	0.005	0.005	0.011	0.633
Maximum	0.309	0.016	0.019	0.028	0.143	0.033	1.079
Minimum	-0.172	-0.102	-0.053	-0.020	-0.102	-0.018	0.008
Std. Dev.	0.143	0.029	0.018	0.016	0.043	0.009	0.344
Skewness	-0.196	-1.370	-0.018	-0.042	0.351	-0.461	-0.208
Kurtosis	1.647	3.869	1.956	1.328	4.612	3.426	1.684
Observations	97	97	97	97	97	97	97

Note: Order flow variables here expressed in trillions of USD per month.

Table A2: Summary Statistics for Dollar/Yen

Sample: 1999M01 2007M01

	LXJP	M2_JP	Y_JP	I_JP	PI1_JP	Z1JP	CUMZ1JP
Mean	-4.743	-4.774	0.015	0.034	0.030	-0.013	-0.701
Median	-4.755	-4.759	0.013	0.036	0.035	-0.013	-0.697
Maximum	-4.627	-4.623	0.065	0.065	0.128	0.006	-0.020
Minimum	-4.897	-4.933	-0.027	0.010	-0.062	-0.033	-1.283
Std. Dev.	0.063	0.093	0.020	0.018	0.045	0.008	0.362
Skewness	-0.189	-0.217	0.464	0.068	-0.257	-0.028	0.027
Kurtosis	2.473	1.756	2.972	1.512	2.457	2.744	1.839
Observations	97	97	97	97	97	97	97

Note: Order flow variables here expressed in trillions of USD per month.

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Table 1: Evans-Lyons specification, 1999M02-2007M01

coefficient	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	USD/EUR				USD/JPY			
constant	0.003	**-0.012**	**-0.009**	0.003	0.005	**0.023**	**0.030**	0.005
	0.003	0.005	0.005	0.003	0.006	0.004	0.007	0.006
Int. diff.	**-0.410**		-0.270	**-0.405**	-0.172		-0.186	-0.170
	0.169		0.182	0.171	0.147		0.145	0.140
OF		**1.179**	**1.080**			**1.799**	**1.807**	
		0.333	0.333			0.301	0.312	
Δ OF				0.392				**1.114**
				0.258				0.156
adj.R sq.	0.05	0.16	0.17	0.06	0.01	0.34	0.35	0.24
N	96	96	96	96	96	96	96	96

Notes: Top entry is the OLS regression coefficient while the bottom entry is the Newey-West robust standard error. **Bold face** denotes coefficients significant at the 10% marginal significance level. Int. Diff. is the money market interest differential, OF is order flow in trillions of USD.

Table 2: Johansen Cointegration Test Results, 1999M04-2007M01

		[1]	[2]	[3]	[4]	[5]	[6]
		Monetary Fundamentals			Hybrid		
USD/EUR	asy	***1,1***	3,1	1,1	4,2	4,1	**4,2**
	fs	***1,1***	1,1	1,1	1,1	1,1	**2,1**
USD/JPY	asy	2,2	***2,1***	1,1	2,1	***1,1***	1,1
	fs	2,2	***1,1***	1,1	1,1	***0,1***	0,1

Notes: Implied number of cointegrating vectors using Trace, Maximal Eigenvalue statistics. "Asy" ("fs") denotes number of cointegrating vectors using asymptotic (finite sample) critical values (Cheung and Lai, 1993). Columns [1] and [4] indicate a constant is allowed in the cointegrating equation and none in the VAR; columns [2] and [5] indicate a constant is allowed in the cointegrating equation and in the VAR; columns [3] and [6] indicate an intercept and trend is allowed in the cointegrating equation and a constant in the VAR. ***Bold italics*** denotes the trend specification with the lowest AIC for single cointegrating vector case. All results pertain to specifications allowing for 4 lags in the levels-VAR specification.

Table 3: USD/EUR Monetary/Order Flow Hybrid Exchange Rate Regression Results, 1999M04-2007M01

coefficient	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
constant	0.001	-0.016	-0.005	**-0.013**	0.001	**-0.015**	-0.005	**-0.014**
	0.003	0.004	0.004	0.005	0.003	0.004	0.004	0.005
$\Delta money_{t-1}$	-0.625	**-1.266**	**-0.760**	**-1.195**	-0.703	**-1.299**	**-0.819**	**-0.942**
	0.451	0.424	0.446	0.434	0.456	0.434	0.455	0.450
$\Delta income_{t-1}$	-0.037	0.027	-0.043	-0.135	-0.264	-0.141	-0.253	-0.074
	0.344	0.334	0.314	0.333	0.354	0.344	0.323	0.336
$\Delta int\ rate_{t-1}$	2.405	**2.549**	2.456	**2.648**	2.236	**2.394**	2.283	**2.684**
	1.800	1.257	1.742	1.084	1.613	1.113	1.568	1.175
$\Delta infl\ rate_{t-1}$	-0.033	-0.022	-0.019	0.017	-0.014	-0.008	-0.001	0.032
	0.049	0.039	0.050	0.036	0.044	0.036	0.046	0.036
$\Delta\ ex\ rate_{t-1}$	**0.156**	**0.220**	0.065	**0.240**	**0.182**	**0.237**	0.098	**0.229**
	0.090	0.072	0.111	0.071	0.091	0.072	0.113	0.071
ECT_{t-1}	-0.057	-0.043	-0.053	**-0.104**	**-0.118**	**-0.088**	**-0.110**	**-0.084**
	0.038	0.030	0.038	0.031	0.041	0.032	0.039	0.029
money	**-3.928**	**-3.928**	**-3.928**	-0.420	0.161	0.161	0.161	-4.356
	0.489	0.489	0.489	1.337	1.522	1.522	1.522	3.109
income	**5.514**	**5.514**	**5.514**	**5.119**	**6.276**	**6.276**	**6.276**	**4.363**
	2.793	2.793	2.793	2.556	2.538	2.538	2.538	2.356
int rate	**-8.292**	**-8.292**	**-8.292**	-2.954	-4.356	-4.356	-4.356	**-4.496**
	3.020	3.020	3.020	2.609	2.882	2.882	2.882	2.695
infl rate	1.123	1.123	1.123	-0.314	0.252	0.252	0.252	-0.893
	1.019	1.019	1.019	1.027	0.899	0.899	0.899	0.872
OF_{t}		**1.491**		**0.316**		**1.436**		**1.564**
		0.306		0.109		0.299		0.313
OF_{t-1}			**0.611**				**0.554**	
			0.301				0.291	
Cum OF				**1.473**				**1.248**
				0.299				0.561
time					**0.049**	**0.049**	**0.049**	-0.171
					0.019	0.019	0.019	0.106
adj.R sq.	0.01	0.26	0.04	0.30	0.06	0.29	0.08	0.30
N	94	94	94	94	94	94	94	94

Notes: Top entry is coefficient; robust standard error is bottom entry. Estimates from two step procedure. Coefficients on level variables (excluding order flow) are obtained using DOLS(2,2). Other coefficients are estimated from second stage error correction model. Time trend coefficient pertains to the cointegrating equation. **Bold face** denotes significance at 10% msl. Variables in ***bold italics*** are in the cointegrating relationship.

Table 4: USD/JPY Monetary/Order Flow Hybrid Exchange Rate Regression Results, 1999M04-2007M01

coefficient	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
constant	-0.004	**0.019**	**-0.008**	**0.023**	**-0.005**	**0.018**	**-0.010**	-0.004
	0.003	0.004	0.004	0.004	0.002	0.004	0.004	0.005
$\Delta money_{t-1}$	0.373	0.462	0.301	0.366	0.104	0.259	0.024	0.074
	0.452	0.335	0.471	0.355	0.436	0.332	0.453	0.457
$\Delta income_{t-1}$	**0.543**	**0.415**	**0.521**	0.273	**0.551**	**0.412**	**0.527**	**0.581**
	0.233	0.198	0.228	0.196	0.233	0.198	0.228	0.236
$\Delta int\ rate_{t-1}$	**5.007**	**4.180**	**4.826**	**4.010**	**5.504**	**4.475**	**5.314**	**5.515**
	1.313	1.044	1.286	1.125	1.325	1.037	1.315	1.329
$\Delta infl\ rate_{t-1}$	**-0.087**	**-0.080**	**-0.084**	**-0.081**	**-0.098**	**-0.087**	**-0.095**	-0.080
	0.035	0.029	0.035	0.030	0.035	0.029	0.035	0.034
$\Delta\ ex\ rate_{t-1}$	**0.184**	**0.272**	**0.238**	**0.221**	**0.185**	**0.265**	**0.246**	**0.199**
	0.105	0.092	0.119	0.094	0.104	0.092	0.119	0.103
ECT_{t-1}	**-0.188**	**-0.160**	**-0.187**	**-0.079**	**-0.193**	**-0.153**	**-0.193**	**-0.201**
	0.042	0.041	0.043	0.034	0.042	0.037	0.044	0.039
money	-0.134	-0.134	-0.134	**3.689**	2.327	2.327	2.327	2.441
	0.121	0.121	0.121	2.249	1.695	1.695	1.695	1.663
income	**-1.947**	**-1.947**	**-1.947**	0.000	**-1.949**	**-1.949**	**-1.949**	**-2.395**
	0.480	0.480	0.480	0.000	0.405	0.405	0.405	0.624
int rate	**-0.543**	**-0.543**	**-0.543**	**2.512**	0.737	0.737	0.737	0.522
	0.288	0.288	0.288	1.498	0.910	0.910	0.910	0.921
infl rate	0.299	0.299	0.299	0.586	0.395	0.395	0.395	0.210
	0.384	0.384	0.384	0.485	0.448	0.448	0.448	0.441
OF_t		**1.816**		**0.914**		**1.776**		0.005
		0.286		0.551		0.283		0.007
OF_{t-1}			-0.313				-0.350	
			0.298				0.299	
Cum OF				**1.790**				-0.716
				0.296				0.870
time					-0.094	-0.094	-0.094	-0.210
					0.064	0.064	0.064	0.154
adj.R sq.	0.16	0.48	0.15	0.43	0.17	0.48	0.17	0.18
N	94	94	94	94	94	94	94	94

Notes: Top entry is coefficient; robust standard error is bottom entry. Estimates from two step procedure. Coefficients on level variables (excluding order flow) are obtained using DOLS(2,2). Other coefficients are estimated from second stage error correction model. Time trend coefficient pertains to the cointegrating equation. **Bold face** denotes significance at 10% msl. Variables in ***bold italics*** are in the cointegrating relationship.

Table 5.1: USD/EUR Out of Sample Forecasting Performance, 2004M02-07M01

model	statistic	1 month	3 month	6 month
random walk	mean error	-0.001	-0.005	-0.011
	std error	0.004	0.011	0.020
monetary	mean error	-0.015***	-0.039***	-0.078***
	std error	0.006	0.014	0.027
	Theil	2.580	2.290	3.309
hybrid	mean error	-0.001	-0.001	-0.001
	std error	0.006	0.012	0.020
	Theil	1.323	0.912	0.995
Evans-Lyons	mean error	-0.010	-0.024	-0.062***
	std error	0.007	0.014	0.021
	Theil	1.960	1.786	2.201

Notes: Mean error for out-of-sample forecasting. Newey-West robust standard errors. ***(**) denotes significance at 1%(5%) marginal significance level. Theil U-statistic is the ratio of the model RMSE relative to random walk RMSE. A U-statistic > 1 indicates the model performs worse than a random walk.

Table 5.2: USD/JPY Out of Sample Forecasting Performance, 2004M02-07M01

model	statistic	1 month	3 month	6 month
random walk	mean error	0.004	0.010	0.018
	std error	0.003	0.009	0.015
monetary	mean error	0.013***	0.027***	0.045***
	std error	0.005	0.010	0.018
	Theil	1.434	1.733	1.972
hybrid	mean error	0.000	0.003	0.005
	std error	0.004	0.010	0.025
	Theil	0.640	0.938	2.088
Evans-Lyons	mean error	0.000	0.003	0.005
	std error	0.004	0.008	0.015
	Theil	0.683	0.654	0.761

Notes: Mean error for out-of-sample forecasting. Newey-West robust standard errors. ***(**) denotes significance at 1%(5%) marginal significance level. Theil U-statistic is the ratio of the model RMSE relative to random walk RMSE. A U-statistic > 1 indicates the model performs worse than a random walk.

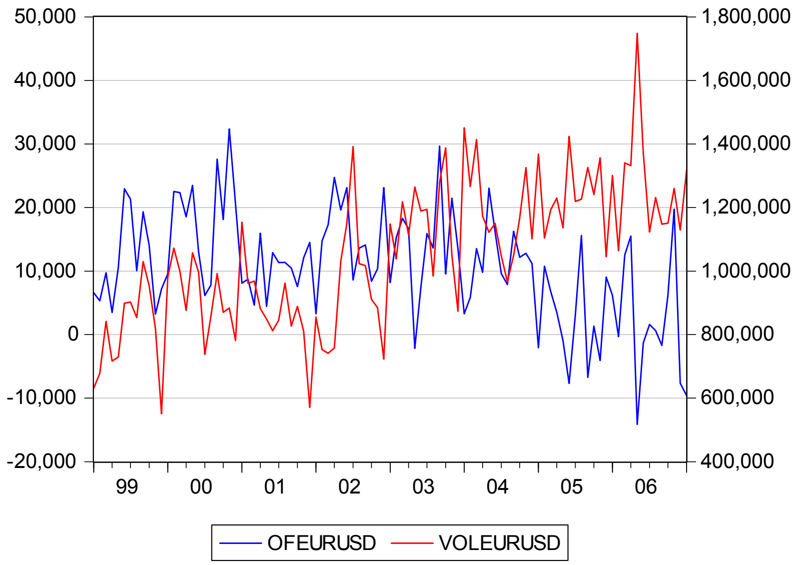

Figure 1: EUR/USD monthly order flow and order flow volume, in millions of euros.

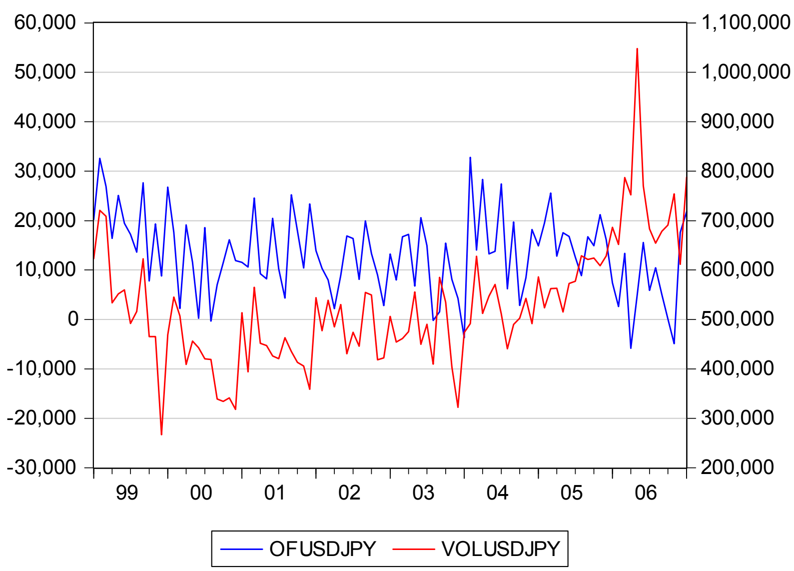

Figure 2: USD/JPY monthly order flow and order flow volume, in millions of dollars.

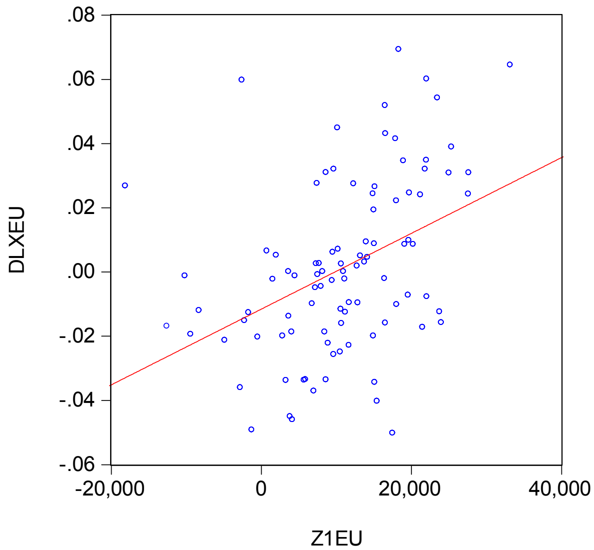

Figure 3: First difference of log USD/EUR exchange rate and monthly net order flow in millions of USD (purchases of euros)

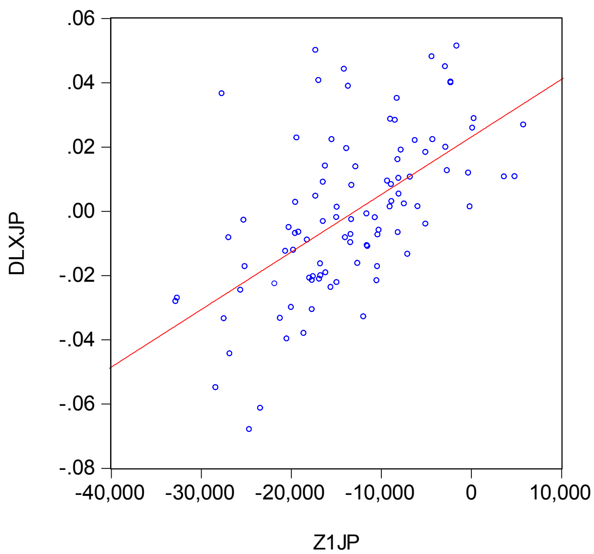

Figure 4: First difference of log USD/JPY exchange rate and monthly net order flow in millions of USD (purchases of yen)

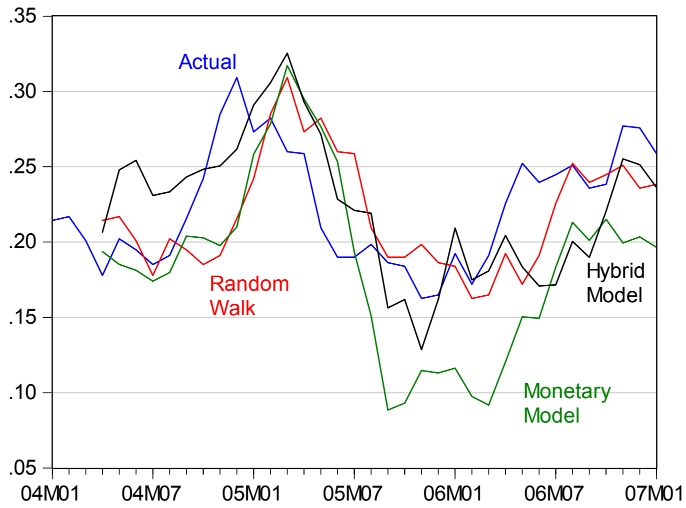

Figure 5: Out-of-sample forecasts of USD/EUR, 3 month horizon

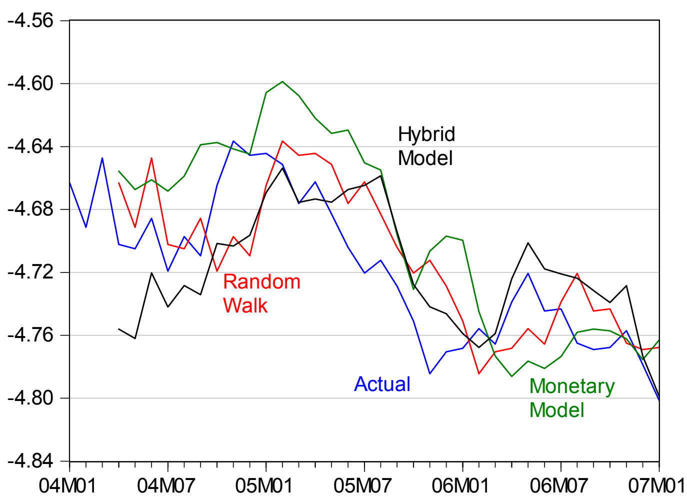

Figure 6: Out-of-sample forecasts of USD/JPY, 3 month horizon