An Empirical Study of Liquidity and Information Effects of Order Flow on Exchange Rates

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FX Market Microstructure

FX markets have for many year been an economics-free zone. Even simple, uncontroversial models fail to fit the data. *Then came FX market microstructure.*

What is it?

"Market microstructure is the area of finance that studies the process by which investors latent demands are ultimately translated into prices and volumes" Madhavan (2000)

Why now?

Research in equity market microstructure well-established High quality data beginning to become available from two sources

1) Electronic Inter-dealer markets (EBS and Reuters 2000-2)

2) Global Custodians

Why all the fuss?

1) Equity market microstructure important, but never claimed to *explain* movements in equity prices. In FX the lack of any other models has lead to disproportionate interest in microstructure

2) Overall order flow in FX markets dwarfs all other markets - surely that means something?

3) R^2's of over 50%

The Role of Order Flow

What is order flow?

Key concept in FX microstructure models is order flow.
Defined as the difference between the number or value of buy orders and the number or value of sell orders. Of course number of buy and sell trades equal, but the number of buyer-initiated and seller-initiated need not be the same

What can it 'explain'?

The first paper in the area can be summarised by the following regression result for daily data.

$$\begin{aligned} \Delta DEM_t = \ & 0.51\Delta(i_t - i_t^*) + \ 2.14\Delta X_t \\ & \quad (0.26) \qquad\quad (0.29) \end{aligned}$$

X = order flow, Standard errors in brackets

High explanatory power but what's the process going on here?

The Role of Order Flow

The Strong Flow-Centric View Currency movements are caused by investors revealing private information in trading. Thus order flow causes permanent price movements

The Weak Flow-Centric View Flows contain information on deviations from fundamentals (i.e. liquidity effects). Thus flows do produce currency moves but only temporary ones

The Fundamentals Only View Correlation between currency moves and order flow simply reflects the fact that both are influenced by fundamentals

How can we decide which view is correct?

Need a structural model

Bacchetta Van Wincoop Model

We employ a variant of the Bacchetta & Van Wincoop (2003) model

Nice features

- Model that has both a plausible representation of fundamentals and microstructure features

Nice features we don't have

- Infinite regress means that huge FX volatility can be created by second-guessing (Magnification effect)

Nice features we have that aren't in the model

- Closed form solution!
- Informed and uninformed traders
- Look at order *flow* rather than stock

FX Dealers

$$x_t \quad = \quad \frac{1}{\gamma\,\sigma^2}\left(\bar{E}_t(s_{t+1}) \;-\; s_t \;+\; (i_t^* \;-\; i_t)\right), \tag{1}$$

s_t is the log of the spot exchange rate (i.e. the number of units of the domestic currency for one unit of the foreign one) σ^2 indicates the corresponding conditional variance, γ is the coefficient of risk-aversion of all FX dealers' CARA utility functions.

Order flow

$$z_t \;=\; z_{t-1} \;+\; o_t. \tag{2}$$

z_t is the same as x_t

Order flow has a liquidity trader component b_t and informed trader component I_t

$$o_t \;=\; b_t \;+\; I_t. \tag{3}$$

Since order flow presents some evidence of serial correlation we assume that its liquidity component, b_t, follows an AR(1) process,

$$b_t \;=\; \rho_b\, b_{t-1} \;+\; \epsilon_t^l, \tag{4}$$

Fundamentals

$$f_t \equiv m_t - m_t^*$$

$$f_t \quad = \quad \rho_f\, f_{t-1} \;+\; \epsilon_t^f, \tag{5}$$

Informed traders have some information about future fundamentals

$$I_t \quad \equiv \quad -\,\theta\,\epsilon_{t+1}^f, \tag{6}$$

and to close the model we have these conditions from our simple monetary model

$$m_t \;-p_t \quad = \quad -\alpha\, i_t, \tag{7}$$

$$m_t^* \;-\; p_t^* \quad = \quad -\alpha\, i_t^*, \tag{8}$$

As in both countries a unique common good is produced, the purchasing parity condition holds:

$$s_t \quad = \quad p_t \; - \; p_t^*. \tag{9}$$

Solution

$$\begin{aligned} s_t \quad = \quad & \frac{1}{1+\alpha(1-\rho_f)}\, f_t \; + \; \frac{\alpha}{(1+\alpha)}\, \frac{1}{1+\alpha(1-\rho_f)}\, E\left(\epsilon_{t+1}^f \mid \Omega_t\right) \\ & - \; \alpha\, \gamma\, \sigma^2\, z_t \; - \; \gamma\, \sigma^2\, \frac{\alpha^2\, \rho_b}{1+\alpha(1-\rho_b)}\, E\left(b_t \mid \Omega_t\right). \end{aligned} \tag{10}$$

But still need to derive how FX dealers form expectations of future fundamentals and liquidity order flow

For future fundamentals dealers weigh up the information they get from public sources v_t and from order flow

$$v_t \quad = \quad \epsilon_{t+1}^f \; + \; \epsilon_t^v, \tag{11}$$

they can strip out the predictable part of order flow

$$E\left(b_t \mid \Omega_{t-1}\right) \; = \; \rho_b\, E\left(b_{t-1} \mid \Omega_{t-1}\right). \tag{12}$$

$$E\left(\epsilon_{t+1}^f \mid \Omega_t\right) \quad = \quad \frac{\tau_v}{\tau_{\epsilon,t}}\, v_t \; - \; \frac{\tau_{y,t}}{\tau_{\epsilon,t}}\, \frac{1}{\theta} \left(o_t \; - \; E\left(b_t \mid \Omega_{t-1}\right) \right), \tag{13}$$

$$\mathrm{Var}\left(\epsilon_{t+1}^f \mid \Omega_t\right) \quad = \quad 1/\tau_{\epsilon,t}, \tag{14}$$

where $\tau_{\epsilon,t}$ is the conditional precision of the fundamental shock. This precision is equal to

$$\tau_{\epsilon,t} = \tau_f + \tau_v + \tau_{y,t},$$

where $\tau_f = 1/\sigma_f^2$, $\tau_v = 1/\sigma_v^2$, $\tau_{y,t} = \theta^2 \tau_{b,t-1}$, $\tau_{b,t-1} = 1/\sigma_{b,t-1}^2$ and $\sigma_{b,t-1}^2$ is the conditional variance of the liquidity order flow, b_t, given the information FX dealers possess at the end of period $t-1$.

Eventually we get to the closed form solution for s_t

$$s_t \; = \; \lambda_{s,-1}\, s_{t-1} \; + \lambda_f\, f_t \; + \; \lambda_{f,-1}\, f_{t-1} \; + \; \lambda_z\, z_t \; + \; \lambda_{z,-1}\, z_{t-1} \; + \; \lambda_o\, o_t \; + \; \lambda_{o,-1}\, o_{t-1} \; + \; \lambda_v\, v_t, \tag{15}$$

where

$$\begin{aligned}
\lambda_{s,-1} &= \rho_b \frac{\tau_y}{\tau_\epsilon}, \\
\lambda_f &= \frac{1}{1+\alpha\,(1-\rho_f)}, \\
\lambda_{f,-1} &= -\,\rho_b \frac{1}{1+\alpha\,(1-\rho_f)}\,\frac{\tau_y}{\tau_\epsilon} \;=\; -\,\lambda_{s,-1}\,\lambda_f, \\
\lambda_z &= -\,\alpha\,\gamma\,\sigma^2, \\
\lambda_{z,-1} &= \alpha\,\gamma\,\rho_b\,\frac{\tau_y}{\tau_\epsilon}\,\sigma^2 \;=\; -\,\lambda_{s,-1}\,\lambda_z,
\end{aligned}$$

$$\begin{aligned}
\lambda_o &= -\,\frac{\alpha}{1+\alpha}\left[\alpha\gamma\sigma^2\left(\frac{\rho_b(1+\alpha)}{1+\alpha(1-\rho_b)}\right)\left(\frac{\tau_f+\tau_v}{\tau_\epsilon}\right) \;+\; \frac{\frac{1}{\theta}}{1+\alpha(1-\rho_f)}\,\frac{\tau_y}{\tau_\epsilon}\right], \\
\lambda_{o,-1} &= \frac{\alpha}{1+\alpha}\,\rho_b\left(\frac{\frac{1}{\theta}}{1+\alpha(1-\rho_f)}\right)\frac{\tau_y}{\tau_\epsilon}, \\
\lambda_v &= \frac{\alpha}{1+\alpha}\left(\frac{1}{1+\alpha(1-\rho_f)} \;-\; \alpha\,\gamma\,\sigma^2\,\theta\,\frac{\rho_b(1+\alpha)}{1+\alpha(1-\rho_b)}\right)\frac{\tau_v}{\tau_\epsilon}.
\end{aligned}$$

If we take differences, we obtain the following expression for the variation in the exchange rate:

$$\begin{aligned}
s_t \,-\, s_{t-1} \;=\;& \lambda_{s,-1}\,(s_{t-1} \,-\, s_{t-2}) \;+\; \lambda_f\,(f_t \,-\, f_{t-1}) \;+\; \lambda_{f,-1}\,(f_{t-1} \,-\, f_{t-2}) \;+\; \lambda_z\,o_t \;+ \\
& \lambda_{z,-1}\,o_{t-1} \;+\; \lambda_o\,(o_t \,-\, o_{t-1}) \;+\; \lambda_{o,-1}\,(o_{t-1} \,-\, o_{t-2}) \;+\; \lambda_v\,(v_t \,-\, v_{t-1}), \qquad (16)
\end{aligned}$$

The Data

- All inter-dealer trades in EUR/USD undertaken through the two electronic limit order book trading systems Electronic Broking Services (EBS) and Reuters D2000-2 (D2)
- Using 2001 data from the BIS triennial survey as a guide we can estimate that these two electronic platforms represent about 60% of all inter-dealer order flow in EUR/USD and perhaps 33% of total order flow.
- Bid and ask prices and an indicator of the number of buy and sell transactions from both trading systems at a five minute frequency over the period August 2000 to mid-January 2001.
- supplement that information both with some daily estimates (on average trade size and euro-area and US interest rates) and with five-minute interest rate data collected from the LIFFE 3-month EURIBOR futures contract.

Table 1: Summary Statistics for order flow, exchange rate and interest rate data

	Mean	Std. Dev.	ρ	prob.
	Daily frequency			
Order flow				
All Transactions	-54	270	0.19	0.04
EBS	-87	154	0.13	0.16
D2	33	178	0.22	0.02
Returns	0.0003	0.75	0.01	0.27
Interest Rates	0.0195	0.06	0.16	0.11
	Hourly Frequency			
Order flow				
All Transactions	-5	61	0.229	0.00
EBS	-8	38	0.115	0.000
D2	3	47	0.092	0.001
Returns Rate	0.006	0.22	0.026	0.35
Interest Rates	0.0003	0.0087	-0.06	0.04
	5-minute Frequency			
Order flow				
All Transactions	-0.4	13.0	0.199	0.00
EBS	-0.7	10.8	-0.01	0.28
D2	0.3	11.1	0.167	0.00
Returns	0.000006	0.0007	-0.035	0.00
Interest Rates	0.00003	0.004	-0.136	0.00

Notes: Table shows the mean, standard deviation, first-order correlation coefficient and the p value of the Box-Ljung statistic for first-order autocorrelation for a number of series. Order flow is defined as the number of buys minus the number of sells. Returns are the percentage change in the USD/EUR exchange rate observed over the period. Interest rates are the percentage point change in the Euro-US interest rate 3-month interest rate differential at the daily frequency and the percentage point change in the Euribor 3-month forward rate (interpolated from the 3 and 6 month Euribor futures contract traded on LIFFE) at higher frequencies. Intra-daily data are shown for the European trading day (7am to 6pm, UK time) excluding the change from the end of one trading day to the beginning of the next

Table 2: EBS and Reuters 2002-2 Compared

	EBS	D2
Average number of trades per day	11020	2627
Average trade size	$3.14 million	$1.84 million
Average bid-ask spread	0.014%	0.051%
Occasions when bid-ask spread is zero or less	5.51%	2.13%
Occasions when bid-ask spread is less than zero	0.26%	0.31%
Occasions when bid is above ask of other platform	0.58%	0.63%
Average absolute deviation in mid price	0.014%	0.014%
Hasbrouck Indicator of information share	47%-94%	6%-53%

figures refer to European trading session between 7.00am and 6.00pm. Calculations based on five minute data frequency. Average trade size derived from daily EBS volume data for EBS and Payne 2003 for D2. Hasbrouck indicator based on identifying contribution to underlying common trend of each set of prices (see Hasbrouck(1995)

Table 3: GMM estimates of the model parameters, USD/EUR market (all transactions).

	5-minute Interval				**Hourly Interval**				**Daily Interval**			
Parameter	**Value**	**S.E.(1)**	**S.E.(2)**	p**-val**	**Value**	**S.E.(1)**	**S.E.(2)**	p**-val**	**Value**	**S.E.(1)**	**S.E.(2)**	p**-val**
ρ_b	0.180	0.017			0.373	0.058			-0.002	-0.026	-0.070	0.82
α	0.320	0.082			0.627	0.102			1.706	0.735	1.190	0.00
γ	7056.384				187.524				3.593		7.070	0.00
θ	0.032	0.028			1.118	0.0.718			0.359	0.364	1.084	0.21
τ_f	42347.748				42715.100				102.678			
τ_y	6.727				316.244				1.828			
τ_v	459.225				100.730				13.255			
σ^2	9.089E-05				0.0133				0.351			
	R^2 0.063				R^2 0.484				R^2 0.685			
	P.O.R. 0.000				P.O.R. 0.010				P.O.R. 0.318			

Notes: The dependent variable is the percentage change in the spot exchange rate, while the signed order flow variable, o_t, is normalised to units of 1000 trades. Therefore, a value of $o_t = 1$ corresponds to an excess of 1000 sell orders in period t. The fundamental value f_t is equal to the annualised interest rate differential, $\alpha(i_t^* - i_t)$, for the daily data. At higher frequencies f_t is proxied by $-\alpha i_t$. P.O.R. stands for probability value of over-identifying restrictions, The parameter value ρ_f is restricted to be equal to 1. The first set of Standard errors (S.E.(1)) are from GMM estimation whilst the second set of standard errors (S.E.(2)) and p-values are from the Monte Carlo procedure described in the text. p-values are the probability of parameter values being less than zero.

Table 4: GMM estimates of the model parameters, USD/EUR market (daily data).

	EBS Transactions				**D2 Transactions**			
Parameter	**Value**	**S.E.(1)**	**S.E.(2)**	p**-val**	**Value**	**S.E.(1)**	**S.E.(2)**	p**-val**
ρ_b	0.035	0.047	0.083	0.31	-0.011	0.044	0.060	0.76
α	2.322	1.166	1.338	0.01	3.241	0.567	1.096	0.00
γ	5.674		1.581	0.00	2.961		3.82	0.000
θ	0.204	0.158	0.101	0.01	0.005	0.090	0.255	0.70
τ_f	55.463				28.456			
τ_y	1.941				0.001			
τ_v	6.801				11.270			
σ^2	0.210				0.328			
	R^2 0.384 P.O.R. 0.775				R^2 0.65 P.O.R. 0.077			

Notes: As for Table 3.

Table 5: Trade impact on EBS and Reuters D2000-2.

Trade Size	EBS	D2
1000	2.702	3.205
$1 Billion	0.935	1.742

Notes: Size equal to 1000 means an excess of 1000 sell orders on buy orders within a trading day, while size equal to $1 billion indicates an excess of sell orders on buy orders for the value of $1 billion. The impact of a $1 billion order is estimated using average trade sizes derived from daily EBS volume data for EBS and Payne (2003) for D2. See Table 2.

Table 6: Estimated size of Euro Interventions

Date	ECB	Fed	BoJ	BoE	BoC
22 September	$5.5bn	$1.5bn	$1.5bn	$0.085bn	$0.11bn
3-6 November	$4.6bn				
9 November	$1.2bn				

Notes: Data derived from figures reported by each Central Bank and/or Finance Ministry. All figures except ECB refer purely to intervention operations. ECB figures include non- intervention related FX transactions by the ECB - these are usually very small

Table 7: Impact of Euro Interventions

	22 Sep.	3 Nov.	6 Nov.	10 Nov.	Average
Size of Intervention	-$8.7bn	-$2.3bn	-$2.3bn	-$1.2bn	-$3.625bn
Actual Impact:					
on Exchange Rate	-2.413%	-0.653%	0.834%	-0.568%	-0.700%
on Order Flow	-800	-289	-141	-227	-364
on Order Flow ($)	-$2.3bn	-$0.835bn	-$0.407bn	-$0.656bn	-$1.05bn
on Interest Rates	-0.1bp	-0.7bp	-4bp	2.2bp	-0.7bp
Predicted Impact:					
of Order flow on Exchange Rate	-1.753%	-0.633%	-0.308%	-0.496%	-0.798%
of Interest Rates on Exchange Rate	-0.003%	-0.068%	-0.155%	0.100%	-0.021%
Total	-1.756%	-0.701%	-0.463%	-0.396%	-0.819%

Notes: Actual impacts are the difference between levels predicted by the model had intervention not occurred, and the actual changes that did occur. Predicted Impacts on the exchange rate shows how the actual impact of the intervention on order flow and interest rates should have impacted the exchange rate according to the model. Order flow is the estimated order imbalance created by the intervention expressed both as a number of trades and as a dollar value using the estimates in Table 2. Exchange rate effects are expressed as the percentage change in the dollar vs. the euro and interest rate changes are the change in US interest rates relative to euro rates expressed in basis points. The interventions on the 3rd and 6th of November are assumed to be of equal size.

CONCLUSIONS

- We come down firmly in the weak flow-centric camp. Order flow has an important impact on exchange rates but that impact is all to do with liquidity and not with information of fundamentals.
- We come down (less firmly) in the portfolio balance camp for intervention. We can explain the impact of intervention pretty well simply through its impact on order flow - Intervention trades are not special
- what we do not have such strong evidence on is the persistence of liquidity shocks. In our model they are permanent since they is no group of traders that attempt to exploit mis-pricing
- similarly, on intervention we need a large sample before we can tell what is going on