NEW EXCHANGE RATE ECONOMICS

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Contents

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1 Traditional Theories of Exchange Rate Determination

To introduce our presentation of recent developments in exchange rate economics we now briefly discuss the traditional asset market approach developed in the 1970s.

The models of exchange rate determination developed within the asset market approach provide descriptions of the way in which exchange rates evolve based on a given set of fundamental variables. Such variables generally include income, money and inflation figures.

This Section provides a brief review of some of the most popular models of exchange rate determination. We treat flexible and sticky price monetary models in the main, but we also mention the portfolio balance approach.

Bretton Woods

During the *Bretton Woods* era the *International Monetary System* was organised in such a way that exchange rates were substantially pegged:

- The exchange rates among the currencies of the countries which had signed the Bretton Woods agreement could vary from their central parities by no more than 1%. Changes in the central parities were possible but infrequent as the agreement was interpreted strictly.

- The System was sustainable because for a long period most currencies were not convertible and later capital controls were kept widespread and strict in most countries.

External Adjustment and International Liquidity

The international finance literature at the time was dominated by two topics: external adjustment and international liquidity.

- Since exchange rates were fixed, economists were concerned with the conditions under which current account imbalances could be eliminated.

- Moreover, because of various constrains on international capital flows, it was very difficult to finance temporary external imbalances, as too little liquidity was available in the financial markets.

Floating Exchange Rates and Exchange Rate Determination

With the move to a system of floating exchange rates the literature turned to the determination of exchange rates. However:

- According to the traditional *flows* view, the equilibrium value of the exchange rate maintains the equilibrium of the Balance of Payments, i.e. it equilibrates the flows of imports and exports: in other words, the exchange rate is said to be *the relative price of different national outputs*.

- According to the *asset market approach* developed in the early seventies, instead, the exchange rate is *the relative price of different national assets*: under the assumption of *perfect capital mobility*, which rules out significant transaction costs, capital controls and generally any obstacle to capital movements, the exchange rate adjusts instantly to equilibrate the demand and supply for stocks of national assets.

Perfect Substitutability

While all the asset market approach shares this generic definition, there exists a wide range of alternative models. I will present a simple taxonomy of these various models, based on some distinctive assumptions concerning real and financial aspects of the economy.

Definition: *Perfect substitutability* means that the composition of investors' portfolios is irrelevant as long as the expected returns of foreign and domestic bonds are equal when expressed in the same currency.

While this condition holds within the *monetary approach*, in models of the *portfolio-balance approach* domestic and foreign bonds are not perfectly substitute, in that investors have a preference towards assets denominated in the domestic currency. This preference is generally determined by several sources of risk, such as the risk of default, the volatility of exchange rates and the uncertainty on the fiscal treatment of foreign investors.

The Monetary Approach

The hypothesis of perfect substitutability has important implications for modelling exchange rates. In fact:

- According to the monetary approach domestic and foreign bonds are equivalent and can be considered as a unique asset.

- Thus, if investors can hold in their portfolios only moneys and bonds, the equilibrium of the asset markets reduces to that of three markets: those for domestic and foreign moneys and that for international bonds. We can, then, appeal to *Walras' Law* (as the equilibrium of the two money markets guaranties that of the bond market) and exclude from the analysis both domestic and foreign bonds.

Thus, since now the analysis of financial markets corresponds to that of the money markets, we refer to this branch of the asset market approach as to the monetary approach.

The Portfolio-balance Approach

Within the portfolio-balance approach investors are risk-averse and hold domestic and foreign assets in order to diversify risk. Therefore, any capital movement, which changes the composition of domestic and foreign assets held by private investors, will be possible only if there is a change in the expected relative rate of returns of these assets, which compensates for the change in the risk they bear.

In other words, according to the *portfolio-balance effect* foreign investors can be forced to hold a larger share of their wealth in domestic bonds, and hence to accept riskier portfolios, only if they obtain an increase in the expected rate of return on these assets through a devaluation of the domestic currency.

Flexible- and Sticky-price Models

A second important distinction between models of the asset market approach concerns goods markets:

- If goods prices are perfectly flexible the *purchasing power parity* holds at all times. This condition characterises the class of *monetarist* models or *flexible-price* models within the monetary approach.

- If goods prices are *sticky*:
  - Goods markets are *not* continuously in equilibrium.
  - The purchasing power parity holds only in the long-run.

We will see that this dichotomy generates different properties of the real exchange rates and real interest rates. In Figure 1 we have a graphical representation of our taxonomy.
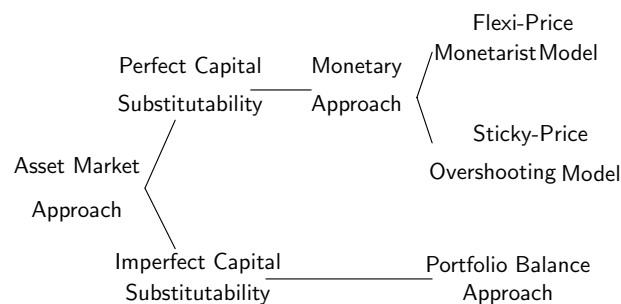
Figure 1: A taxonomy of models of exchange rate determination

The Monetarist Model

While there are several versions of the *monetarist model*, they all share four common elements:

1. An equilibrium condition for the real exchange rate, known as the *purchasing power parity* (PPP).

2. Stable demand functions for domestic and foreign real money balances.

3. The assumption of perfect substitutability, from which we derive a non-arbitrage condition for nominal interest rates and exchange rate expectations known as the *uncovered interest parity* (UIP).

4. Some treatment of exchange rate expectations, which are generally assumed to be rational.

The Purchasing Power Parity

1. While there is little doubt that the prices of commodities will always be the same when expressed in a common currency, within the monetarist framework the PPP is an equilibrium condition for the exchange rate. In the words of Frenkel (1976):

> The purchasing power doctrine (in its absolute version) states that the equilibrium exchange rate equals the ratio of domestic to foreign prices.

Then, in logs the absolute version of the PPP can be expressed as follows:

$$s_t = p_t - p_t^*, \tag{1}$$

where s indicates the spot exchange rate, p the domestic price level and the superscript $*$ a representative foreign country.

The Monetary Market Equilibrium

2. The core of the monetary approach is given by the equilibrium conditions for the money markets. While several versions have been considered in the literature, the basic element is that the demands for real money balances are stable functions. Assuming identical specifications for domestic and foreign money demands, their most common formulations are as follows:

$$m_t^d - p_t \equiv \kappa\, y_t - \lambda\, i_t, \tag{2}$$
$$m_t^{*d} - p_t^* \equiv \kappa\, y_t^* - \lambda\, i_t^*, \tag{3}$$

where m^d indicates the log of the demand for nominal money balances, y the log of the real income and i the nominal interest rate. In equilibrium, the demand for money must equal its supply:

$$m_t^d = m_t^s, \qquad m_t^{*d} = m_t^{*s}. \tag{4}$$

The Uncovered Interest Rate Parity

3. Since domestic and foreign bonds are perfect substitute, their expected rates of returns expressed in the same currency will be always equal, because risk-neutral arbitrageurs would immediately exploit and eliminate any wedge.

This uncovered interest rate parity states that the difference in the nominal interest rates of domestic and foreign bonds is equal to the expected rate of depreciation of the domestic currency:

$$i_t - i_t^* = E_t\left[s_{t+1}\right] - s_t. \tag{5}$$

Remark: Notice that the interest rates i_t and i_t^* are intended to apply within the period $(t, t+1)$. Thus, if this interval refers to a month (a week or a day) and the interest rates are annualised, the uncovered interest rate parity must be adjusted by dividing the interest rate differential by the period's length (in years).

The Derivation of a Reduced-form Relation

From the PPP and the equilibrium conditions of the money markets we can derive the following relationship for the spot rate:

$$
\begin{aligned}
s_t &= p_t - p_t^* \\
&= m_t - m_t^* - \kappa\,(y_t - y_t^*) + \lambda\,(i_t - i_t^*) \\
&= \underline{m}_t - \kappa\,\underline{y}_t + \lambda\,(i_t - i_t^*),
\end{aligned} \tag{6}
$$

where $\underline{m} = m - m^*$ and $\underline{y} = y - y^*$.

The Transmission Mechanisms

Thus, given the values for the foreign countries of m^* y^* and i^*, the domestic currency will depreciate if there is an expansion in the monetary base or an increase in the nominal interest rate and will appreciate if the domestic real income augments.

Remark: In response to an increase in the domestic money supply the demand for foreign commodities augments, depreciating the exchange rate (i.e. s_t rises.) Such depreciation raises import prices, whose increment then transfers to the domestic prices.

Remark: An increase of i is the consequence of higher inflation expectations. This increase induces a reduction in the demand for domestic money balances forcing a devaluation of the national currency, in contrast with the common opinion that an increase in the interest rate should be accompanied with an appreciation.

The Equilibrium Exchange Rate

4. Substituting in this equation the UIP we obtain the final equilibrium condition for the spot rate:

$$
s_t = \underline{m}_t - \kappa\,\underline{y}_t + \lambda\,(E_t\,[s_{t+1}] - s_t). \tag{7}
$$

This clearly shows the centrality of the expectations on the future values of the spot rate for the determination of its current value. To solve this equilibrium condition, rational expectations are called for, so by recursive substitution we can write that:

$$
s_t = \frac{1}{1+\lambda} \sum_{j=0}^{\infty} \gamma^j\, E_t\,[\underline{m}_{t+j}] - \frac{\kappa}{1+\lambda} \sum_{j=0}^{\infty} \gamma^j\, E_t\,[\underline{y}_{t+j}], \tag{8}
$$

where $\gamma = \lambda/(1+\lambda)$.

News Effects and Testable Implications

Remark: The current value of the spot rate will thus depend on the expectations of all future values of the relative money supply and the relative real income. These expectations will on turn depend on the underlying stochastic processes followed by $\underline{m}$ and $\underline{y}$. In practice, we have a situation in which "news" about fundamentals ($\underline{m}_t$ and $\underline{y}_t$) alters exchange rates.

Remark: From the uncovered interest rate parity and the PPP we conclude that the domestic real interest rate is equal to the foreign one and that the real exchange rate is constant:

$$
\begin{aligned}
r_t &= r_t^*, \\
q_t &= 0.
\end{aligned}
$$

Excess Volatility, Overshooting and Sticky Prices

In the 1970s, two important phenomena contrasted with the empirical implications of the monetarist model:

- The volatility of exchange rates exceeds that of the underlying real and monetary variables that entered their fundamental equation.

- The PPP is violated, alongside its direct consequences of:

  ○ Constant real exchange rates.

  ○ Equal real interest rates across different countries.

Sticky-price Monetary Models

In practice this suggests that the flexible-price model is built on shaky foundations and requires modification. This is done by not allowing prices to alter in response to shocks in the short-run. Only in the long-run can they adjust.

Thus, in the sticky-price (overshooting) model *à la* Dornbusch the following hypothesis are made:

- The UIP holds continuously.

- The PPP holds in long-run.

- Agents possess rational expectations.

$$\Longrightarrow$$

Sticky-price Monetary Models (cont.ed)

- Agents are rational and possess regressive expectations i.e.:

$$\dot{s}^e \;=\; \theta\,(s - \bar{s}), \qquad \theta \in (0,1) \tag{9}$$

where $\bar{s}$ is the long-run equilibrium exchange rate, θ is a coefficient and the superscript e indicates the expectation operator.

- Goods market are represented by an aggregate demand schedule and a Phillips curve relationship (which is vertical in the long-run):

$$
\begin{aligned}
y \;=\; d \;&=\; \delta\,(s - p + p^{*}) \,-\, \sigma\,i \,+\, \gamma\,y \,+\, u, \tag{10}\\
\dot{p} \;&=\; \Pi\,(y - \bar{y}). \tag{11}
\end{aligned}
$$

Long-run Analysis

In the long-run prices are fully flexible. Then, consider the effects of an increase in domestic money. Given the long-run neutrality of money we have:

- Domestic prices rise in the long-run to restore the equilibrium of the money market.

- The nominal exchange rate depreciates too. This means that the real exchange rate (and hence the long-run aggregate demand) is unchanged.

- In the long-run no interest rate will change.

This is similar to the analysis of the monetarist model, in that a rise in m forces s to increase.

Short-run Analysis

In the short-run, though, things are different as prices are sticky and cannot adjust. The response to a money supply increase must hence occur via interest rates. In fact, we have:

- The interest rate, i, must fall to ensure that three money market clear.
- The UIP then implies that there must be an expected reduction in s_t, i.e. an expected appreciation.
- Via the expectations formation, equation (9), an expected appreciation requires the exchange rate to depreciate immediately, i.e. it requires s to jump above its equilibrium level (such that it can fall towards equilibrium.)

Hence, in the short-run the exchange rate *overshoots* its final equilibrium level.

Remark: A rise in domestic interest rates will now yield an immediate appreciation of the exchange rate. This contrasts with the predictions of the monetarist model.

The Portfolio Balance Model

Prior models have assumed that domestic and foreign bonds are perfect substitutes (such that in effect there is a single, global bond market.)

Question: Is this a reasonable assumption?

If domestic agents perceive domestic and foreign bonds as different assets the exchange rate will not be solely determined by relative money supplies. Holdings of domestic and foreign assets will also matter. We will also get risk premia intruding upon the UIP relationship.

Empirical Testing: This can be accomplished by adding some terms which represent supplies of domestic and foreign assets/bonds (call them F_t and F_t^*) (also domestic and foreign wealth) to the regression formulations of equation (6).

2 Assessing Traditional Models of Exchange Rates

Given our discussion of the flex-price, sticky price and portfolio balance models of exchange rate determination we could use the following regression formulation as a general testing framework:

$$s_t = \alpha + \beta_0 (m_t - m_t^*) + \beta_1 (y_t - y_t^*) + \beta_2 (i_t - i_t^*) + \beta_3 (F_t - F_t^*) + \epsilon_t. \quad (12)$$

In terms of parameter signs we would expect that:

Model	Parameters			
Flex-price	$\beta_0 = 1$,	$\beta_1 < 0$,	$\beta_2 > 0$,	$\beta_3 = 0$
Sticky price	$\beta_0 = 1$,	$\beta_1 < 0$,	$\beta_2 < 0$,	$\beta_3 = 0$
Portfolio	$\beta_0 > 0$,	$\beta_1 < 0$,	$\beta_2 > 0$,	$\beta_3 > 0$

Results for the Monetary Models

Chronologically, the following results have been obtained for the flex-price and sticky price models:

- Results using pre-Bretton Woods data are generally supportive (for instance, see Frenkel (1976), which uses German hyperinflation data.)
- Results from the early part of the recent float are also supportive (see Dornbusch (1979)).
- Since then, though, there has been a total break down in the empirical fit of these models.
  - Frankel (1993) demonstrates poor performance of the monetarist model.
  - Backus (1984) shows that the sticky price model also works badly.
- Recently, some support has emerged for the monetary model as a long-run equilibrium specification.

On the whole, empirical results are very poor. Also, little support is obtained for more general portfolio-balance specifications.

Forecasting Exchange Rates with Fundamentals

In this respect, Meese and Rogoff (1983) derive some famous results.

Procedure: They compare *out of sample* forecasts from fundamentals models, the random walk model, the forward rate, and VAR models. Methodology implies:

1. Running rolling regressions to update the estimates of the models' parameters.

2. Constructing forecasts for the various prediction models.

3. Comparing the root mean square errors (RMSE) of such forecasts.

Main Result: Despite they allow fundamentals models to use *future* data in the construction of forecasts, nothing outperforms a random walk in terms of forecasting ability.

Implication: Thus, the best guess of next periods exchange rate is today exchange rate. In other words, no fundamental data helps in predicting exchange rates.

"News" Studies and Announcement Effects

Another class of studies is based on equation (8). This suggests that one should be able to identify jumps in exchange rates when new information comes to light.

Early studies identified "news" statistically, i.e. information is identified with residuals from regressions of fundamentals on information known at time t. Exchange rate changes were then related to such news. Their results were much more promising than previous ones.

More recently, researchers (see Andersen *et al.* (2003)) have used survey data on expectations for various macro-announcement data, plus intra-day exchange rate data to attempt to isolate responses to "news". Then, some strong and consistent results have been obtained, as unexpected money growth and trade balance are found to imply appreciation of the national currency.

Finally, notice that an indirect way to account for "news" is to look at *order flow* in the market for foreign exchange. We will discuss in details this recent research (Evans and Lyons (2002)).

3 The Microstructure of Foreign Exchange Markets

We have seen in the previous Section that the empirical analysis of the asset market approach shows how traditional models of exchange rate determination completely *fails* to explain exchange rate movements in the short-run and can only indicate long-run trends.

Thus, international finance economists have recently turned their attention to the *organisation* of foreign exchange markets.

The understanding that market microstructure theory actually studies traders' behaviour in securities markets has led economists such as Jeffrey Frankel to suggest that such a theory may guide exchange rate economics out of the "foggy swamp" it has been mired in for the past ten-twenty years.

Market Microstructure Analysis

In the words of Maureen O'Hara (1995), "market micro-structure [theory] is the study of the process and outcomes of exchanging assets under explicit trading rules".

Thus, it is suggested that the organisation and regulation of trading in securities markets has important implications for the process of price formation and more generally for all characteristics of these markets.

This consideration is true for foreign exchange markets as well and the analysis of their organisation may lead to some useful hindsights for exchange rate economics.

Markets for Foreign Exchange

Trading turn-over in foreign exchange markets amounts to an estimated total of about $1200 billion per day (See Galati *et al.* (2002)). This figure exceeds that of all other securities markets and indicates that foreign exchange markets are the largest in terms of volume of trading.

Foreign exchange markets are also the most internationally integrated, in that trading continues around the clock, i.e. 24 hours a day, while most of their activity is concentrated in the three major financial centres, which are, in increasing order of size, Tokyo, New York and London.

The Lack of Regulation

Since markets for foreign exchange by their nature are dislocated in several financial centres, practically *no* rules can be imposed on their functioning and the activity of their participants.

Therefore, their organisation is not the result of the decisions of some authorities, such as the Treasury, the Financial Service Authority and the Office of Fair Trading for the London Stock Exchange, the Security Exchange Commission for the New York Stock Exchange or the CONSOB for the Milan Stock Exchange, but the consequence of their *natural* evolution.

Spot and Other Over the Counter (OTC) Markets

FX transactions involve spot and forward contracts, but dealers trade also swaps and options.

According to Galati *et al.* (2002) roughly 30% of all transactions in foreign exchange markets are in the spot market, 10% in the forward one, whilst more than 50% involve swaps and options.

In what follows we will primarily refer to spot markets.

Market Participants

Foreign exchange markets are populated by three different types of agents: FX dealers, brokers and customers.

FX dealers, generally from the financial division of major commercial banks, trade among each others and with external customers. These may be large corporations or financial institutions.

Transactions among market participants can be *direct* or can be *mediated* by a broker.

Several estimations suggest that the inter-dealer market accounts for about 50 to 60 percent of the total volume of trading and that almost 50% of these transactions are carried out through a broker (Galati *et al.* (2002)).

Trading Mechanisms

In foreign exchange markets two different mechanisms of trading coexist:

- the <u>direct</u> market is *quote-driven* and *decentralised*,
- the <u>indirect</u> (brokered) market is *order-driven* and *quasi-centralised*.

As transactions can be completed at any time, markest for foreign exchange are also *continuous*.

We will now try to explain briefly what we mean with this terminology, while for a more extensive analysis we refer to Lyons (2001).

The Direct Market

In the direct market, transactions are the result of private bilateral "meetings" between traders. In the past these "meetings" have generally been conducted on the phone. Nowadays, though, FX dealer employ electronic communication systems, such as the Reuters 2000-1.

In the direct market, transactions are *quote-driven* because prices are fixed *before* quantities.

- In fact, clients contact single dealers, which "make the market" quoting bid-ask spreads for any specific foreign exchange they trade. These quotes specify at which prices dealers (*market makers*) will be ready to buy and to sell the specific currency.

- Then, clients can place orders to buy or sell the currency.

- Since quotes are valid for market orders not exceeding some prefixed amount, the size of these transactions is limited, even though most market makers will accept very large orders.

A Fragmented and Opaque Trading Organisation

The direct market is *decentralised* or fragmented in that transactions are completed through private bilateral deals among traders and *cannot* be observed by other market participants.

On the contrary, in other securities markets, such as the NYSE, all transactions are centralised, because trading is organised around a single market maker or according to an *open outcry system*.

Moreover, there are other decentralised markets, notably the London Stock Exchange, in which dealers are forced by institutional rules to communicate almost immediately information on their *order flows* (i.e. their sequence of transactions) to all other traders.

These mechanisms of *consolidation* are absent in the direct foreign exchange market, that hence remains fragmented and *opaque*.

The Indirect Market

The indirect market is *order-driven*. Here, in fact, prices and quantities are set *altogether*.

Moreover, transactions are not the result of simple bilateral deals, but are mediated by brokers, that is agents who do not deal on their own but operate on account of clients charging a small transaction fee.

Any broker keeps a *book* of *limit orders* placed by his clients. Limit orders placed with a broker are matched against other *market* and limit orders from other traders.

- A limit order specifies the amount of a particular currency a trader is willing to sell (buy) and the minimum (maximum) price he will accept.
- A market order indicates the intention to buy (sell) immediately a given quantity of the foreign currency at the existing *best* price.

Brokerage Services

In the past, the brokered market was operated on the phone. Traders would call a broker and ask for his *internal* spread. This means that the broker would quote the best buy and sell limit orders contained in his book and that then the trader would have the faculty to hit them.

In this way priority was (and it is still) given to buy (sell) limit orders with the best prices, rather than to the oldest ones.

Nowadays the indirect market is dominated by *electronic* brokerage services, such as the EBS and Reuters 2000-2.

Electronic Brokerage Services

The trading platforms of these electronic brokerage services share common features. In particular:

- The platform's subscribers are attached to a screen reporting the best outstanding buy and sell limit orders for a set of foreign currencies.
- All other limit orders remain in the background and are used to up-date the information available to the subscribers when a transaction is completed or one of the best orders is withdrawn.
- At any time subscribers can hit the limit orders posted on the screen or add their own ones.

Since these are centralised mechanisms of trading, the indirect market is *quasi-centralised*.

However, given that the identities of traders which complete a transaction are kept *anonymous*, in that they are not published on the platform screen, the indirect market remains partially opaque.

Liquidity versus Immediacy

You may wonder why different trading arrangements coexist in foreign exchange markets. In effect, on a purely theoretical ground, one should reckon that centralised organisations of trading should progressively outperform and exclude decentralised ones, because of their greater efficiency and scale economies.

On the other hand, there is a qualitative difference between the direct and the brokered market which responds to different needs of market participants.

- The direct market guaranties the immediacy of execution for all market orders. Even if quotes may not be favourable, clients are always able to complete a transaction with a market maker.
- In the brokered market the execution of limit orders is uncertain and may take a while, but traders benefit from the fact that they can trade at the desired price.

4 The Explanatory Power of Order Flow

Traditional models of exchange rate determination are based on two fundamental principles:

- Exchange rate determination is basically a macro phenomenon, in that exchange rate movements are uniquely determined by shifts in macro aggregates.
- Exchange rates immediately react to shifts in macro aggregates. In other words, after a variation in the price level or in output a new equilibrium value for the exchange rate is reached without any change in investors' portfolios.

The poor explanatory power of these traditional models alongside with the empirical evidence showing the importance of micro-structural aspects of the functioning of equity markets in explaining short-term movements in equity prices have turned the attention of many researchers to *order flow* in foreign exchange markets.

Order Flow

Definition: Order flow is defined as the *net* of the buyer-initiated and seller-initiated orders in a securities markets. It is the simplest measure of net buying *pressure* and it is calculated from

- the sequence of market orders reaching market makers in dealership markets,

- the sequence of market and limit orders which reach brokered markets and cross with existing posted limit orders.

Intuition: Order flow might be interpreted as the transmission link between information and exchange rates, in that it conveys information on deeper determinants of exchange rates, which foreign exchange markets need to aggregate and impound in currency values.

FUNDAMENTAL INFORMATION $\Rightarrow$ ORDER FLOW $\Rightarrow$ EXCHANGE RATES

A Simple Reduced Form Model of Order Flow and Exchange Rate Determination

Evans and Lyons (2002) consider a very simple model of exchange rate determination which makes use of the information contained in order flow. According to this model, daily exchange rate variations are determined by changes in the interest rate differential, as suggested by traditional models, and changes in signed order flow. Thus,

$$\Delta s_{t+1} \;=\; \beta_i \, \Delta(i_t - i_t^*) \;+\; \beta_z \, z_t,$$

where:

- Δs_{t+1} is the first difference in the log of the foreign exchange price within day t, $s_{t+1} - s_t$,
- $\Delta(i_t - i_t^*)$ is the first difference in the interest rate differential, $(i_t - i_t^*) - (i_{t-1} - i_{t-1}^*)$,
- and z_t is the difference between the number of buyer-initiated trades and seller initiated trades in day t.

Interpretation

To interpret this simple linear specification, consider that a positive value for z_t implies that within day t the number of buy orders exceed that of sell ones. This means that a majority of traders has purchased the foreign currency during the day indicating that they consider the foreign currency undervalued.

The order flow imbalance might reflect all that news, in the form of macro announcements, data releases, etc., which reaches foreign exchange markets and induces traders to modify their evaluations of exchange rate returns and their portfolios of assets. In synthesis:

> Order flow imbalance represents an observable *proxy* for all incoming news which anticipates future shifts in exchange rate fundamentals and hence influences the current value of foreign currencies.

Implementation

Evans and Lyons employ data pertaining to *all* bilateral transactions completed among FX dealers via Reuters Dealing 2000-1 electronic trading system in the spot DEM/USD and JPY/USD markets between May 1st and August 31st 1996.

- The data *indicates* for any transaction the exchange rate, which of the two counter-parties bought and sold and, more importantly, which initiated the transaction, allowing thus to define the corresponding direction (i.e. if a buy or a sell order) of the trade.

- The data does *not* report either the transaction *size* or the counter-parties identity.

Remark: There is very limited variability in the size of transactions in foreign exchange markets, as trades tend to be in standardised sizes. This means that very little information is lost in the observed data-set.

Remark

- The linear model proposed by Evans and Lyons can be estimated using these transaction data.

  - In this case, the interval $(t, t+1)$ does not correspond to calendar time but corresponds to transaction time, meaning that the observed data are not equally spaced in time, but refers to the random completion of new trades.

- However, the two authors consolidate the transaction data at the daily level, so that in the estimation of

$$\Delta s_{t+1} \; = \; \beta_i \, \Delta(i_t - i_t^*) \; + \; \beta_z \, z_t$$

the interval $(t, t+1)$ corresponds to 24 hours.

Notice, however, that results based on the transaction data are even stronger.

In-Sample Results

DEM/USD rate

Specification	$\Delta(i_t - i_t^*)$	z_t	$i_t - i_{t-1}$	R^2
I	0.51	2.14		0.64
	(0.26)	(0.29)		
II		2.15		0.63
		(0.29)		
III	0.62			0.01
	(0.77)			
IV		2.15	0.022	0.64
		(0.29)	(0.013)	
V			0.022	0.00
			(0.022)	

Standard errors in parentheses.

In-Sample Results (cont.ed)

JPY/USD rate

Specification	$\Delta(i_t - i_t^*)$	z_t	$i_t - i_{t-1}$	R^2
I	2.47	2.86		0.46
	(0.92)	(0.36)		
II		2.61		0.40
		(0.36)		
III	0.57			0.00
	(1.20)			
IV		2.78	0.016	0.42
		(0.38)	(0.11)	
V			-0.009	0.00
			(0.014)	

Standard errors in parentheses.

The Impact of Order Flow

Reported coefficients for the various specifications are estimated using OLS, under the normalisation that $z_t = 1$ corresponds to an imbalance of 1000 trades. In parentheses the standard errors indicate that only the coefficient β_z is significantly larger than zero.

- Both for the DEM/USD and JPY/USD regressions a positive value for the order flow, z_t, induces an appreciation of the foreign currency.

- Thus, in the case of the DEM/USD, given a value of 2.1 for the order flow coefficient, in a day where DEM buy orders exceed DEM sell orders by 1000 the German currency appreciates by 2.1%.

- Given that the average trade size in the sample for the DEM/USD spot market is $3.9 million, $1 billion net purchases of the German currency increases its value by 0.54%. Assuming that the spot rate is 1.5 DEM/USD, the value of the DEM augments by 0.8 pfenning (i.e. 0.08 DEM).

The Empirical Fit

- In all estimated specifications for the DEM/USD rate current and lag values of the interest rate differential are not significant.

- In the regression for the JPY/USD rate, the coefficient β_i is significant and correctly signed in the first specification, but does not contribute to the empirical fit of the regression.

- The coefficient of multiple correlation, R^2, in the case of the DEM/USD rate takes values larger than 0.6 when the order flow variable is included, and falls dramatically when it is excluded.

- A similar conclusion is drawn in the case of the JPY/USD rate. Here, however, the explanatory power of the order flow variable is smaller, as R^2 takes values smaller than 0.5.

Remark: Possibly, this difference is due to the different degree of diffusion of the Reuters Dealing 2000-1 system among FX dealers trading in the DEM/USD and JPY/USD markets.

Out of the Sample Empirical Forecasts

Evans and Lyons follow Meese and Rogoff (1983) methodology to study the out of sample forecasting ability of their simple linear model. The entire sample is split in two. The first 39 observations are employed as an estimation sub-sample and the following 50 are used as a forecasting sub-sample. Evans and Lyons' procedure entails the following four steps:

1. The estimation sub-sample is employed to estimate a linear regression of the exchange rate first difference on order flow and the change in the interest rate differential.

2. The estimated coefficients, β_z and β_i, are employed to derive exchange rate "forecasts" at the one-day, one-week and two weeks horizons, where *actual* values of the regressors are used in these "forecasts".

3. Squared forecasting errors are calculated for the three horizons.

4. One observation is added to the estimation sub-sample. The rolling regression procedure is repeated returning to step 1.

The Root Mean Squared Forecasting Errors (RMSE)

The root mean squared forecasting errors are calculated for the time interval between day 40 and day 89 and are compared with those obtained with a simple random walk model.

Root Mean Square Errors ($\times$ 100)

Horizon	DEM/USD rate			JPY/USD rate		
	Random Walk	Linear Model	Difference	Random Walk	Linear Model	Difference
1 day	0.44	0.29	0.15	0.40	0.32	0.08
			(0.033)			(0.040)
1 week	0.98	0.63	0.35	0.98	0.64	0.33
			(0.245)			(0.239)
2 weeks	1.56	0.96	0.60	1.34	0.90	0.45
			(0.419)			(0.389)

Out of Sample Results

Both for the DEM/USD and JPY/USD rates, the linear model presents smaller Root Mean Squared Errors than those obtained with a simple random walk.

Given the standard errors presented in parentheses, such difference is significant uniquely at the one-day horizon.

This result might not, at first sight, look particularly impressive, in that:

- the explanatory power of the model dies away pretty quickly,

- proper forecasts are not obtained, since *actual* values of the explanatory variables are used.

However, the Table reports results which are dramatically different from those obtained by Meese and Rogoff for the traditional models. Moreover, professional traders would love to be able to predict exchange rates even at the one day horizon.

Simultaneity Bias

A legitimate criticism against the linear regression proposed by Evans and Lyons refers to the issue of simultaneity bias, which emerges if exchange rate movements cause order flow.

In fact, in the case in which the exchange rate presents a *feed-back* effect on order flow the OLS estimates of the coefficients β_z is biased. Suppose, in particular, that $z_t = z_{1,t} + z_{2,t}$, where

$$z_{2,t} \;=\; \gamma \, \Delta s_{t+1}, \quad \text{while} \quad \Delta s_{t+1} \;=\; \alpha \, z_{1,t} \;+\; \epsilon_t.$$

If we run the regression

$$\Delta s_{t+1} \;=\; \beta_z \, z_t \;+\; \eta_t$$

the value of β_z is equal to

$$\beta_z \;=\; \frac{\alpha\,(1 \,+\, \gamma\,\alpha) \,+\, \gamma\,\phi}{(1 \,+\, \gamma\,\alpha)^2 \,+\, \gamma^2\,\phi} \quad \text{where} \quad \phi \;=\; \frac{\sigma_\epsilon^2}{\sigma_{z,1}^2}.$$

Simultaneity Bias (cont.ed)

Since $z_{2t,}$ is not directly observable, it is not possible to establish whether a positive value for the estimate of β_z corresponds to:

- $\alpha > 0$ (for either $\gamma \neq 0$ or $\gamma = 0$), so that order flow causes exchange rates to move (with or without a feed-back effect on order flow).

- $\alpha = 0$ and $\gamma > 0$, so that the estimated β_z assumes a positive value only because of a *positive* feed-back effect of exchange rates on order flow.

Thus, in synthesis:

> In the presence of *positive* feed-back trading rules, the results reported by Evans and Lyons are spurious and hence misleading.

5 Order Flow and Exchange Rate Returns Analysis

In order to take account of the possible feed-back effects of exchange rates on order flow, an alternative methodology can be employed. This is based on the study of a simple linear VAR model for trades and quote revisions, proposed by Joel Hasbrouck (1991) for the analysis of the NYSE.

Payne (2003) applies Hasbrouck's methodology to a transaction data-set which refers to the brokered section of the FX spot market. His study can then be considered a complement to that of Evans and Lyons, which instead analyse the direct market.

A Vector Autoregressive Approach

Payne considers all inter-dealer trades completed via Reuters Dealing 2000-2 system in the USD/DEM spot market over the week between October 6th and October 10th 1997. While this period is rather short, his data-set contains information over roughly 30,000 transactions, with a total volume of more than \$60 billion.

These figures confirm that foreign exchange markets present a huge volume of transactions and an impressive trading pace, in that several transactions are usually completed within a minute.

Differently from Evans and Lyons, Payne has access to information on the size of all transactions. This extra bit of information allows to measure more precisely the informational content of order flow. In fact, in the presence of asymmetric information, rational expectations models of asset price determination show a clear dependence of signed order size on information.

A Reduced Form VAR Model for Exchange Rate Returns and Order Flow

The empirical methodology is based on the following VAR model:

$$\begin{cases} r_t = \sum_{i=1}^{p} \alpha_i \, r_{t-i} + \sum_{i=0}^{p} \beta_{zi} \, z_{t-i} + \epsilon_{1,t}, \\[2ex] z_t = \sum_{i=1}^{p} \gamma_i \, r_{t-i} + \sum_{i=0}^{p} \delta_{zi} \, z_{t-i} + \epsilon_{2,t}. \end{cases}$$

In his study, Payne does not consolidate transactions, and hence the interval $(t, t+1]$ does not refer to a given period of time, such as the day considered by Evans and Lyons.

Indeed, Payne does not use calendar time, but an event time, where an event is any instance in which either the exchange rate best quotes (i.e. the best bid and ask prices) are revised or a transaction is completed in the Reuters Dealing 2000-2 system.

In this way, the interval $(t, t+1]$ refers to the spell of time between two subsequent events.

The Transaction Characteristics

In this simple VAR z_t is now a *vector* containing trades information. This comprises:

1. A signed trade indicator, which takes value 1 (-1) if an order to buy (sell) the US dollar is completed at time t and 0 if a quote revision takes place at time t triggered by the introduction or the cancellation of a limit order.

2. A signed trade *size* variable, to analyse the effect of volume on exchange rates.

3. A squared trade indicator, which is introduced to account for possible non linearities in the relation between price revisions and order flow.

Remarks

- Notice that this VAR specification is not entirely standard, in that the *contemporaneous* value of the order flow variables, z_t, enters into the excess return, r_t equation, when in fact these two values are determined simultaneously.

- Also notice that the excess return on the foreign currency, r_t, differs from the exchange rate variation, $s_t - s_{t-1}$, by the interest rate differential $i_{t-1}^* - i_{t-1}$. The difference is inconsequential at these very high frequencies, because over such short spells of time the period-by-period interest rate differential, $i_{t-1}^* - i_{t-1}$ is negligible. This component of the excess return is hence ignored in the calculation of r_t.

Identification Restriction and Interpretation

In the two equations which form the VAR model, the contemporaneous realisation of z_t enters into the regression for the exchange rate return. The opposite is not true, in that in the regression for z_t only lag values of the excess return are considered.

According to this formulation transactions logically *anticipate* quote revisions and hence the opposite causality is not allowed. This assumption, alongside with that the innovation terms, $\epsilon_{1,t}$ and $\epsilon_{2,t}$, are uncorrelated, permits identifying the VAR model.

The innovation term $\epsilon_{1,t}$ can be interpreted as quote revisions induced by the arrival of public information, associated with news releases and the like. The innovation term $\epsilon_{2,t}$ refers instead to unpredictable trading activity, possibly associated to private information.

The Vector Moving Average (VMA) Representation

Writing the VAR model in matrix form and inverting the VAR specification, one can derive the following VMA representation:

$$\begin{pmatrix} r_t \\ z_t \end{pmatrix} = \begin{pmatrix} a(L) & b(L) \\ c(L) & d(L) \end{pmatrix} \begin{pmatrix} \epsilon_{1,t} \\ \epsilon_{2,t} \end{pmatrix},$$

where $a(L)$, $b(L)$, $c(L)$ and $d(L)$ are infinite lag polynomials which represent the impulse response functions implied by the VAR model.

In particular, $b(L)$ represents the impact of trade innovations, $\epsilon_{2,t}$, on subsequent returns, capturing the effects of private information on exchange rates. Indeed, $\sum_{i=0}^{\infty} b_i$ indicates the long-run response of exchange rates to trade innovation and can be considered a measure of the information content of order flow.

A Variance Decomposition

The lag polynomial $b(L)$ allows to measure the information content of order flow, but does not permit assessing its contribution to the total volatility of exchange rates.

However, under the hypothesis that exchange rates can be decomposed in a random walk and a stationary process, the total volatility of the permanent component of the exchange rate process is given by the following expression:

$$\sigma_w^2 = \left(\sum_{i=0}^{\infty} b_i \right) \Omega \left(\sum_{i=0}^{\infty} b_i' \right) + \left(1 + \sum_{i=1}^{\infty} a_i \right)^2 \sigma^2, \quad \text{where}$$

Ω is the variance-covariance matrix of the order flow innovation, $\epsilon_{2,t}$, σ^2 is the variance of the exchange rate innovation, $\epsilon_{1,t}$.

An Interpretation of the Variance Decomposition

The permanent effect of a public innovation $\epsilon_{1,t} = 1$ on the exchange rate is given by 1, the contemporaneous effect, plus $\sum_{i=1}^{\infty} a_i$ and hence the variability in the permanent component of the exchange rate process that we can assign to public information is given by $(1 + \sum_{i=1}^{\infty} a_i)^2 \sigma^2$.

On the contrary, the permanent impact of an expected innovation in the order flow $\epsilon_{2,t} = 1$ on the exchange rate is $\sum_{i=0}^{\infty} b_i$, so that its contribution to the total variability of the exchange rate is given by σ_x^2, where

$$\sigma_x^2 = \left(\sum_{i=0}^{\infty} b_i \right) \Omega \left(\sum_{i=0}^{\infty} b_i' \right).$$

Thus, in synthesis, the importance of private information-based trades in determining exchange rate movements can be measured via the ratio σ_x^2 / σ_w^2.

Results

Employing only the signed trade indicator ($z_t = 1, -1, 0$) among the transaction characteristics, Payne estimates an exchange rate equation with 8 lags in z_t. Results are as follows:

- The coefficient of multiple determination, R^2, is equal to 0.25.

- The sum of the β_{zi} is positive (0.00668) and significantly different from zero, suggesting that order flow has a positive impact on exchange rates (indeed, all single coefficients β_{zi} are positive and significantly so).

- From the VMA representation it is found that the total impact of a US dollar buy order on the USD/DEM rate is equal to 0.005%, i.e. that a purchase of the American currency brings about roughly a 1 basis point increase in its value.

- From the variance decomposition it is found that more than 40% of the exchange rate variability must be attributed to unpredictable trading activity, in that $\sigma_x^2 / \sigma_w^2 = 0.41$.

Conclusions

Also notice that signed trade size and squared trade size when introduced among transaction characteristics are not significant. A possible explanation of this finding rests with the very small variability observed in the trade size variable. However, it is rather worrying for an information based argument to find no relation between trade size and price impact.

Finally, while we do not document it in details, Payne finds that time-of-the-day and liquidity effects complicate the relation between order flow and excess returns, in that the asymmetric information coefficients (the β_{iz}'s) are not stable across different level of market liquidity.

In synthesis, we conclude from his analysis that:

> Even when we take into account the possibility of feed-back trading rules, order flow imbalance is *still* a fundamental determinant of exchange rate movements.

6 Fundamentals, Order Flow and Exchange Rates

Froot and Ramadorai (2002) try to assess the relation which exists between order flow, exchange rate returns and fundamentals. With respect to the studies of Evans and Lyons (2002) and Payne (2003) there are two major differences:

- They employ a data-set of more than 6 million foreign exchange transactions obtained from State Street Corporation, a very large global asset custodian. This data-set contains records of all foreign exchange transactions for 111 currencies by more than 10,000 funds over the period between January 1st 1994 and February 9th 2001.

- They try to investigate the long-run effects of international flows on exchange rates and their relation to fundamentals. Since these are hard to observe Froot and Ramadorai employ Campbell's decomposition of permanent and transitory components of asset returns.

Aggregate Flows and Excess Returns

As a starting point Froot and Ramadorai repeat the analysis of Evans and Lyons considering the following regression:

$$r_{t+1,j}(P) = \alpha + \beta_{z,j}\, z_{t,j}(P) + \epsilon_{t,j},$$

where $r_{t+1,j}(P)$ is the P-period cumulative excess return on currency j,

$$r_{t+1,j}(P) = \sum_{i=1}^{P} r_{t+1-i,j},$$

and $z_{t,j}(P)$ is the corresponding cumulate for the signed trade size.

Remark: Because of lack of enough observations, Froot and Ramadorai do not consider simple bilateral rates: $r_{t+1,j}$ represents the excess return on currency j against a basket of major currencies; likewise, $z_{t,j}$ is the value in US dollars of all currency j inflow in the interval $(t, t+1]$.

International Flows, Excess Returns and Time Aggregation

Aggregate Flows and Excess Returns: OLS Coefficients

	$\beta_{z,j}^{1}$	$\beta_{z,j}^{5}$	$\beta_{z,j}^{20}$	$\beta_{z,j}^{60}$	$\beta_{z,j}^{120}$	$\beta_{z,j}^{240}$	$\beta_{z,j}^{400}$
Euroland	8.95	10.76	9.91	7.15	4.94	1.20	-1.37
	(0.59)	(0.45)	(0.37)	(0.34)	(0.39)	(0.57)	(0.55)
Japan	11.20	13.61	14.10	16.02	16.01	10.38	8.47
	(0.80)	(0.59)	(0.49)	(0.57)	(0.60)	(0.60)	(0.64)
United Kingdom	14.09	14.74	13.92	8.52	5.10	5.95	7.51
	(0.81)	(0.63)	(0.56)	(0.50)	(0.53)	(0.53)	(0.48)
Switzerland	5.91	7.37	5.91	4.89	7.67	7.76	1.91
	(0.52)	(0.41)	(0.34)	(0.34)	(0.40)	(0.39)	(0.38)
Canada	5.01	5.09	5.30	4.56	3.20	1.59	-0.26
	(0.78)	(0.66)	(0.50)	(0.40)	(0.33)	(0.28)	(0.32)
Australia	23.74	27.84	26.08	24.37	25.55	46.23	21.41
	(1.98)	(1.66)	(1.38)	(1.35)	(1.57)	(2.47)	(3.31)

$\beta_{z,j}^{h}$ for $h = 1, 5, 20, 60, 120, 240$ and 400 days. Standard errors in parentheses.

Flows are in US $100 millions and returns are in basis points.

The Impact of International Flows on Excess Returns

The regression slopes, i.e. the coefficients β_{zj}^h's indicate that even over very long time horizons international inflow and excess returns are positively correlated. In particular:

- For most currencies the values of these coefficients are significantly larger than zero and relative stable across various time horizons.

- On average the values of the β_{zj}^h's indicate that a \$100 million dollar net inflow results in a appreciation of 11.5 basis points (i.e. 0.115%) of the corresponding currency.

- Differences exist between currencies. While for some (notably the Australian dollar) liquidity conditions might explain the corresponding large coefficients, for others (notably the Canadian dollar and the Swiss franc) the particular nature of the data-set employed by Froot and Ramadorai might be at the root of their small coefficients.

International Flow, Excess Returns and Time Aggregation (cont.ed)

Aggregate Flows and Excess Returns: Correlation Coefficients

	$\rho_{r,z}^1$	$\rho_{r,z}^5$	$\rho_{r,z}^{20}$	$\rho_{r,z}^{60}$	$\rho_{r,z}^{120}$	$\rho_{r,z}^{240}$	$\rho_{r,z}^{400}$
Euroland	0.33	0.48	0.53	0.44	0.29	0.05	-0.07
Japan	0.31	0.47	0.56	0.55	0.54	0.39	0.33
United Kingdom	0.38	0.48	0.50	0.37	0.22	0.27	0.38
Switzerland	0.26	0.39	0.37	0.32	0.42	0.44	0.13
Canada	0.15	0.18	0.24	0.26	0.23	0.14	-0.02
Australia	0.27	0.36	0.40	0.39	0.36	0.42	0.17

$\rho_{r,z}^h$ for $h = 1$, 5, 20, 60, 120, 240 and 400 days.

Correlations Between International Flows and Excess Returns

These correlation coefficients show some very interesting regularities:

- Correlation coefficients, $\rho_{r,z}$, are positive (apart for the case of Euroland and Canada at the 400 days frequency), with maxima reaching values ranging from 0.3 to 0.6.
- Correlation coefficients tend *first* to increase with the time horizon between the 1-day and the 20 day horizon and *then* to decrease as horizons pass beyond 20-60 days.

Froot and Ramadorai interpret these results as follows:

- There is not clear evidence of a stable causal relation from flows to exchange rates, as the impact of order flow on excess returns is transitory.

- The positive correlation observed over short horizons is not related to fundamentals and could be the consequence of trend chasing activity on the part of investors.

Studying Permanent and Transitory Components of Exchange Rate Dynamics

To verify their conjecture Froot and Ramadorai combine a VAR model of excess returns, fundamentals and order flow, with a decomposition of the excess returns *à la* Campbell:

- The VAR specification is *de facto* an extension of the formulation proposed by Payne, as it includes interest rate differentials and inflation differentials alongside order flow and excess returns.

- The decomposition of the excess return allows to distinguish between innovations in exchange rates due to shifts in expected interest rate differentials (i.e fundamentals) and innovations due to changes in expected future returns.

A VAR Specification

In order to investigate how international flows interact with returns and fundamentals both in the short and in the long-run, Froot and Ramadorai consider the following VAR model for the vector $x_t = (r_t, z_t, i_t - i_t^*, \pi_t - \pi_t^*)'$:

$$x_t = \Gamma\, x_{t-1} + \epsilon_t.$$

Remark: Because of the limited number of observations a unique VAR specification is estimated for all currencies. This means that all observations are stacked together in a single series. This requires a standardisation of the order flow measure, z_t, where single currency j observations, $z_{t,j}$, are normalised by dividing all purchases of assets denominated in currency j by its standard deviation for the entire period.

Remark: Notice that the VAR specification can easily accommodate several lags simply by extending the entries of vector x_t.

Impulse Response Functions

Since Froot and Ramadorai concentrate on the short and long-run interaction between order flow, fundamentals and returns, the impulse response functions associated with this VAR specification play a paramount role in their analysis.

Given its matrix form representation, it is not difficult to invert the transition matrix (obtaining hence the VMA representation) and derive the following cumulative innovation matrix

$$\Phi(p) \equiv (\Gamma - \Gamma^{p+1})\,(I - \Gamma)^{-1},$$

which allows to determine the expected cumulative change in the vector x_t induced by the shock ϵ_t,

$$\Phi(p)\epsilon_t.$$

Impulse Response Functions (cont.ed)

- The expected cumulative innovation to the excess return induced by a shock ϵ_t is given by

$$e1'\,\Phi(p)\epsilon_t,$$

where $e1' = [1\, 0\, \cdots\, 0]$ isolates the first component of vector x_t.

- The total impulse response of the exchange rate to shock ϵ_t is given by the expected cumulative innovation in the exchange rate, $e1'\Phi(p)\epsilon_t$, plus the shock itself, $e1'\epsilon_t$, i.e.

$$e1'\,\Psi(p)\epsilon_t = e1'\left(\Phi(p) + I\right)\epsilon_t.$$

- Analogously we can identify the effects of a perturbation on order flow by substituting the vector $e1'$, with $e2' = [0\, 1\, 0\, \cdots\, 0]$. This allows to isolate the order flow shock, $e2'\epsilon_t$, the expected cumulative innovation in the order flow due to shock ϵ_t, $e2'\,\Phi(p)\epsilon_t$, and its total response function from an order flow shock, $e2'\,\Psi(p)\epsilon_t$.

Short and Long-run Impulse Response Functions

- For the analysis of the infinite horizon impulse responses, the following cumulative innovation matrices apply:

$$\Phi = \Phi(\infty) = \Gamma\,(I - \Gamma)^{-1}, \quad \text{and} \quad \Psi = \Psi(\infty) = \Phi(\infty) + I.$$

- Short and long-run effects of perturbations can then be identified via the following matrices:

$$\Phi(p) \quad \text{and} \quad \Psi(p) \quad \text{vs} \quad \Phi - \Phi(p) \quad \text{and} \quad \Psi - \Psi(p).$$

The Excess Return Decomposition

An economic interpretation of these functions can be derived from the following excess return decomposition derived by Froot and Ramadorai:

$$r_{t+1} \; - \; E_t\left(r_{t+1}\right) \; = \; \sum_{i=1}^{\infty} E_{t+1}\left(d_{t+i} - r_{t+1+i}\right) \; - \; \sum_{i=1}^{\infty} E_t\left(d_{t+i} - r_{t+1+i}\right),$$

where d_t is the real interest rate differential between time $t-1$ and t,

$$d_t \; = \; i^*_{t-1} \; - \; \pi^*_t \; - \; (i_{t-1} \; - \; \pi_t).$$

Excess Return Decomposition: Derivation

To derive this decomposition consider that the excess return over day t is $r_{t+1} = s_{t+1} - s_t + i^*_t - i_t$, the real exchange rate is $\delta_t = s_t + p^*_t - p_t$, the domestic and foreign inflation rates are $\pi_t = p_t - p_{t-1}$ and $\pi^*_t = p^*_t - p^*_{t-1}$. Then, we have that:

$$r_{t+1} \; = \; (\delta_{t+1} - \delta_t) \; + \; (i^*_t - \pi^*_{t+1}) \; - \; (i_t - \pi_{t+1}).$$

Solving forward this difference equation under the terminal condition that $\lim_{i \to \infty} E_t(\delta_{t+i}) = 0$, i.e. that in the long-run the purchasing power parity is expected to hold, we find that:

$$\delta_t \; = \; \sum_{i=1}^{\infty} E_t(d_{t+i} \; - \; r_{t+i}).$$

Subtracting the expected value of the excess return, $E_t(r_{t+1})$, from its realisation, r_{t+1}, and substituting the real exchange rate, δ_{t+1}, and its expectation, $E_t(\delta_{t+1})$, with the expression just derived, we obtain the excess return decomposition.

Cash Flow and Expected Return News

The unexpected exchange returns can be decomposed in the difference between *cash-flow* news, $\nu_{cf,t}$, and *expected-return* news, $\nu_{er,t}$, i.e.:

$$r_{t+1} \; - \; E_t\left(r_{t+1}\right) \;\; = \;\; \nu_{cf,t} \; - \; \nu_{er,t}, \quad \text{where:}$$

$$\nu_{cf,t} \;\; = \;\; \sum_{i=1}^{\infty} \Big(E_{t+1}\left(d_{t+i}\right) \; - \; E_t\left(d_{t+i}\right) \Big),$$

$$\nu_{er,t} \;\; = \;\; \sum_{i=1}^{\infty} \Big(E_{t+1}\left(r_{t+1+i}\right) \; - \; E_t\left(r_{t+1+i}\right) \Big).$$

Cash Flow and Expected Return News (cont.ed)

In other words, an exchange rate shock might be the consequence of either a fundamental shock or a shock in expected returns:

- In the former case the foreign currency appreciates if there is an increase in the present value of future interest differentials.

- In the latter it appreciates if there is a reduction in future required rates of return.

VAR Specification and Excess Return Decomposition

Given our VAR specification we can calculate these components of excess returns:

- The unexpected exchange return is equal to the exchange rate shock,

$$r_{t+1} - E_t(r_{t+1}) = e1'\epsilon_t.$$

- The expected-return news, i.e. the innovation in the present value of future excess returns, is equal to the expected infinite-horizon cumulative innovation induced by shock ϵ_t:

$$\nu_{er,t} = e1'\Phi\,\epsilon_t.$$

- This implies that cash-flow news, i.e. the innovation in the present value of future interest rate differentials, is equal to total infinite-horizon impact of shock ϵ_t:

$$\nu_{cf,t} = e1'\Psi\,\epsilon_t.$$

Short and Long-run Relationships Between Order Flow and Return

Covariances between Flows and Returns

	Excess Return $(e1'\epsilon)$	Expected ST Return Innovation $(e1'\Phi(p)\epsilon)$	Expected LT Return Innovation $(e1'(\Phi - \Phi(p))\epsilon)$	Fundamental Innovation $(e1'\Psi\epsilon)$
Unexpected Flow $(e2'\epsilon)$	Price Impact 0.278 (0.013)	ST Anticipation 0.057 (0.052)	LT Anticipation -0.282 (0.148)	Total Impact 0.054 (0.148)
Expected ST Flow Innovation $(e2'\Phi(p)\epsilon)$	ST Trend Chasing 0.292 (0.078)	ST Exp. Com. 0.030 (0.033)	Exp. Com. -0.254 (0.141)	ST CF Chasing 0.068 (0.126)
Expected LT Flow Innovation $(e2'(\Phi - \Phi(p))\epsilon)$	LT Trend Chasing -1.281 (1.039)	Exp. Com. -0.020 (0.105)	LT Exp. Com. 1.175 (1.163)	LT CF Chasing -0.126 (0.572)
Total Flow Innovation $(e2'\Psi\epsilon)$	-0.711 (1.038)	0.067 (0.097)	0.640 (1.043)	-0.004 (0.312)

Standard deviations in parentheses. LT = Long-term, ST = Short-term, CF = Cash Flow,
Exp. = Expectational, Com. = Comovement, $p = 30$ days.
Estimated values are obtained from the VAR using the excess return decomposition.

Anticipation Effects

In the Table we show estimates of the co-movement between the short and long-run components of flows and returns:

- **Price impact**: The contemporaneous comovement between order flow and excess returns, $e1'\Sigma\,e2$ (where $\Sigma = E[\epsilon_t\epsilon_t']$), is as expected significantly larger than zero.

- **Short-term Anticipation**: The comovement between current flow surprises and expected short-term *future* excess returns, $e1'\Phi(p)\Sigma\,e2$, is also positive. Even if not a significant value, this indicates that order flow *positively* anticipates short-term (1-month ahead) movements in exchange rates.

- **Long-term Anticipation:** Over longer horizon this anticipation effect changes sign, as the comovement between current flow surprises and expected long-term *future* excess returns, $e1'(\Phi - \Phi(p))\Sigma\,e2$, is negative.

Trend Chasing and Feed-back Trading Rules

- **Short-term Trend Chasing:** The covariance between expected short-term cumulative innovations in order flow and current excess returns, $e1'\Sigma\,\Phi(p)'e2$, is positive and strongly significant, indicating that some traders employ positive feedback rules over short horizons.

- **Long-term Trend Chasing**: The covariance between expected long-term cumulative innovations in order flow and current excess returns, $e1'\Sigma\,(\Phi - \Phi(p))'e2$, is strongly negative (see column 1 row 3).

These results seems to indicate that some traders employ positive feed-back rules over short-term horizons and then unwind their speculative position. As a consequence they appear to follow negative feed-back trading rules over long horizons. Such interpretation is also consistent with the difference signs of the short and long-term anticipation effects of order flow described before.

Order Flow and Fundamental Innovations

The last column considers the covariance between order flow innovations and cash-flow innovations. It shows *insignificant* values for the covariance between fundamental news and

1. flow surprises, $e1' \Psi \Sigma e2$,

2. expected short-term innovations in order flow, $e1' \Psi \Sigma \Phi(p)' e2$,

3. expected long-term innovations in order flow, $e1' \Psi \Sigma (\Phi - \Phi(p))' e2$,

4. and total innovations in order flow, $e1' \Psi \Sigma \Psi' e2$.

> Froot and Ramadorai conclude that there is no clear link between order flow and the permanent components of exchange rates. The positive impact of order flow on exchange rate is a *transitory* phenomenon *not* necessarily related to fundamental information.

Order Flow, Exchange Rates and Interest Rate Differentials

Froot and Ramadorai also analyse the short-run and long-run covariances between:

- Excess returns and interest rate differentials.

- Order flow and interest rate differentials.

Their results partially vindicates order flow. In fact, they suggest that:

- Returns are positively correlated with expected short-term future changes in interest rates.

- Order flow is positively correlated with expected short-term future changes in interest rates.

> Thus, we can differ from Froot and Ramadorai and suggest that order flow is at least related to some short term fundamental information.

7 Heterogeneous Information, Order Flow and Exchange Rates

Bacchetta and van Wincoop (2003) have offered a possible rationale for the empirical evidence outlined by Evans and Lyons, Payne, and Froot and Ramadorai.

Their basic idea is that in foreign exchange markets if risk averse traders 1) possess heterogeneous beliefs over exchange rate fundamentals and 2) observe imperfectly correlated signals on fundamentals, transitory liquidity shocks will have a persistent impact on exchange rates. This is due to:

- The usual *risk-sharing* mechanism, as investors need to be compensated for any extra risk they are forced to bear as a consequence of purchases and sales of foreign currencies.

- An *information-based* mechanism, as, in the face of the opaque structure of foreign exchange markets, investors confuse an appreciation (depreciation) of the exchange rate due to a liquidity shock with that induced by fundamental information.

The Magnification Effect of the Infinite Regress

In the case in which such confusion concerns fundamental information that becomes public in the *distant* future, the impact of order flow on exchange rates due to this information-based mechanism is *magnified* by the *infinite regress* of investors' individual beliefs. In fact:

- If investors receive private signals on fundamental variables, such as interest rate shifts or monetary aggregates, whose realisations are not imminent but distant in the future, they will try to learn from prices and quantities they observe (i.e. exchange rates and order flow) not only the fundamental value of foreign currencies, but also other investors' forecasts.

- This attempt to learn other investors' forecasts exacerbates the confusion between liquidity and fundamental shocks information, amplifying the impact of order flow on exchange rates.

The Magnification Effect and the Time Horizon

The magnification effect is absent if private signals concern *imminent* shifts in fundamentals. This is because in the case private information is short-lived the knowledge of other investors' forecasts is redundant and hence the confusion between liquidity and fundamental shocks subdues. More precisely:

- When private signals concern next period realisations of fundamental variables investors know that very soon they will all share the same fundamental information.

- If they are aware that changes to the fundamental variables to which their private signals pertain will become of public domain in the next period, investors realise that they will not be able to exploit any information they can extract from other investors' forecasts and hence will not seek to learn these forecasts.

A Model of Exchange Rate Determination with Heterogeneous Information

We now briefly discuss the basic elements of Bacchetta and van Wincoop's model.

- First we present a simplified analytical framework which represents their basic argument.

- We then discuss the properties of their model analysing the fundamentals-liquidity confusion and the magnification effect.

- Finally we present the empirical implications of this model, in the face of the empirical evidence discussed in the previous sections.

The Trading Platform

According to this framework, in the market for foreign exchange a single foreign currency is traded for the currency of a large domestic economy.

- Trading in this market is organised according to a sequence of Walrasian auctions. When an auction is called, agents simultaneously submit either market or limit orders for the foreign currency and then a clearing price (exchange rate) for the foreign currency is established.

- Indeed, foreign exchange markets are more complex than the simple Walrasian market we envisage here. However, our framework allows to capture the lack of transparency of the market for foreign exchange, in that all transactions are anonymous.

FX Dealers

In the market for foreign exchange we distinguish two classes of traders: FX dealers and customers.

- Dealers are risk averse investors which absorb any imbalance in the flow of customers' orders. They are rational investors which select optimal portfolios of domestic and foreign assets. They are supposed to be short-sighted in that their investment horizon is just one period long.

- All domestic FX dealers share the same CARA utility function of their end-of-period wealth.

- At time t they can invest in three different assets:
  - a domestic production technology,
  - domestic bonds that pay period-by-period interest rate i_t,
  - foreign bonds that pay period-by-period interest rate i_t^*.

FX Dealers' Demand for Foreign Currency

- Under these conditions the optimal demand for foreign bonds (foreign currency) on the part
of the population of domestic FX dealers is:

$$x_t \;=\; \frac{1}{\gamma \, \sigma^2}\Big(\bar{E}_t(s_{t+1}) \;-\; s_t \;+\; (i_t^* - i_t)\Big), \tag{13}$$

where:

- 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),
- $\bar{E}_t(s_{t+1})$ is the average of the conditional expectations for next period spot rate on
the part of all domestic FX dealers, s_{t+1}, given the information they possess in t,
- σ^2 is the corresponding conditional variance,
- γ is the coefficient of risk-aversion of all FX dealers' CARA utility functions.

FX Dealers's Customers and Order Flow

The clients of the FX dealers provide all the supply of foreign currency. These customers comprise
a population of liquidity trades and a group of informed agents.

- At time t, liquidity traders offer b_t units of foreign currency that they need to trade for
their liquidity needs. Thus, if b_t is positive (negative) there is a positive (negative) liquidity
shock in the FX market due to the supply (demand) of foreign currency on the part of the
liquidity traders.

- For tractability b_t is normally distributed,

$$b_t \;\sim\; N(0, \sigma_b^2).$$

- At time t, informed traders offer I_t units of the foreign currency. Their trades are correlated
with the innovation in the fundamental value, f_t, i.e. the variable that determines the
equilibrium value of the foreign currency.

The Fundamental Process

The fundamental value is given by $f_t \equiv m_t - m_t^*$, where m_t represents the log of the domestic
money supply at time t and m_t^* the equivalent aggregate for the foreign country.

- The fundamental value follows a simple AR(1) process with serial-correlation coefficient ρ,

$$f_t \;=\; \rho \, f_{t-1} \;+\; \epsilon_t^f, \tag{14}$$

where the fundamental shock, ϵ_t^f, is normally distributed and is serially uncorrelated:

$$\epsilon_t^f \;\sim\; N(0, \sigma_f^2), \quad \text{and} \quad \epsilon_t^f \;\perp\; \epsilon_{t'}^f.$$

Informed Traders Activity

While the fundamental process is observable, at time t all informed traders possess some private
information on its next period shock, ϵ_{t+1}^f, and place a market order in order to gain profits.

- In particular, we assume that this order is equal to

$$I_t \;\equiv\; -\theta \, \epsilon_{t+1}^f, \tag{15}$$

where θ is a positive constant that measures the intensity of their trading activity.

- This assumption indicates that some insiders collect information on future shifts in interest
rates before these become of public domain.

Remark: In Bacchetta and van Wincoop's original specification individual FX dealers possess
private information. However, our simplified framework captures the flavour of their analysis.

Equilibrium Conditions

- In equilibrium the market for foreign exchange clears so that:

$$x_t \;=\; z_t \;\equiv\; b_t + I_t. \tag{16}$$

- Given the production functions introduced by Bacchetta and van Wincoop, the two following equilibrium conditions in the domestic and foreign money markets prevail:

$$m_t - p_t \;=\; -\alpha\, i_t, \tag{17}$$
$$m_t^* - p_t^* \;=\; -\alpha\, i_t^*, \tag{18}$$

where p_t and p_t^* represent respectively the log of the domestic and foreign price level.

- Both countries produce a unique common good, so that purchasing power parity holds:

$$s_t \;=\; p_t - p_t^*. \tag{19}$$

A Forward Looking Spot Rate

Using (17), (18), (19), the definition of the demand for foreign currency on the part of domestic FX dealers (13) and the FX market equilibrium condition (16) we find that

$$s_t \;=\; \frac{1}{1+\alpha} \sum_{k=0}^{\infty} \left(\frac{\alpha}{1+\alpha} \right)^k \left(\bar{E}_t^k\left(f_{t+k} \right) \;-\; \alpha\, \gamma\, \sigma^2\, \bar{E}_t^k(z_{t+k}) \right), \tag{20}$$

where:

- $\bar{E}_t^k(f_{t+k})$ is the order k average rational expectation across all FX dealers of period $t+k$ fundamental value, f_{t+k}, i.e.

$$\bar{E}_t^k(f_{t+k}) \;=\; \bar{E}_t\, \bar{E}_{t+1}\, \ldots\, \bar{E}_{t+k-1}\left(f_{t+k} \right).$$

- Similarly, $\bar{E}_t^k(z_{t+k})$ is the order k average rational expectation across all FX dealers of period $t+k$ supply of foreign currency, z_{t+k}.

A Simplifying Assumption

Assumption: we suppose that:

- All FX dealers possess symmetric information.
- All FX dealers at time t can only receive signals over next period fundamental shock, ϵ_{t+1}^f.

This assumption allows to circumnavigate the infinite regress problem Bacchetta and van Wincoop study and hence obtain simple closed form solutions for the exchange rate equation (20).

- In practice, this is equivalent to impose the conditions that the order k average rational expectations of period $t+k$ fundamental value, f_{t+k}, and supply of foreign currency, z_{t+k}, are simply equal to all single FX dealers' conditional expectations of the same variables,

$$\bar{E}_t^k(f_{t+k}) = E_t(f_{t+k}) \quad \text{and} \quad \bar{E}_t^k(z_{t+k}) \;=\; E_t(z_{t+k}).$$

Expectations and Exchange Rate Determination

Under this assumption equation (20) presents the following solution:

$$s_t \;=\; \frac{1}{1+\alpha(1-\rho)}\, f_t \;+\; \frac{\alpha}{(1+\alpha)} \frac{1}{1+\alpha(1-\rho)}\, E_t\left(\epsilon_{t+1}^f \right) \;-\; \frac{\alpha}{(1+\alpha)}\, \gamma\, \sigma^2\, z_t. \tag{21}$$

Hence, to derive a rational expectation equilibrium we need to establish how FX dealers formulate their predictions of the shock in the fundamental value, ϵ_{t+1}^f. In this respect, we assume that:

- At time t all FX dealers observe a common signal, v_t, of the fundamental process, f_t.

- The signal v_t represents all the information which FX dealers can readily obtain from various official sources and publicly available data, such as newswire services, newsletters, monetary authorities' watchers and so on.

FX Dealers' Common Signal

This common signal respects the following formulation

$$v_t = \epsilon_{t+1}^f + \epsilon_t^v, \tag{22}$$

where once again the signal error ϵ_t^v is

- normally distributed,

$$\epsilon_t^v \sim N(0, \sigma_v^2),$$

- serially uncorrelated,

$$\epsilon_t^v \perp \epsilon_{t'}^v,$$

- and independent of all fundamental shocks,

$$\epsilon_t^v \perp \epsilon_{t'}^f.$$

Common Signals and Public Information

Alongside this signal all FX dealers can observe the flow of transactions that are completed in the market for foreign exchange. This is possible because in centralised platforms such as EBS and Reuters D2000-2 all transactions are immediately published on the system's computer screens.

Therefore, we can assume that:

- In any period t all FX dealers observe the supply of foreign currency, z_t.

- However, given that on all centralised platforms trades are anonymous, the average dealer cannot distinguish between liquidity orders and informative ones, i.e. between b_t and I_t.

The Projection Theorem for Rational FX Dealers

Thus, applying the projection theorem for normal distributions, the conditional expectation and the conditional variance of the fundamental shock, ϵ_{t+1}^f, are as follows:

$$E_t\left(\epsilon_{t+1}^f \mid v_t, z_t\right) = \frac{\tau_v}{\tau} v_t - \frac{\tau_y}{\tau} \frac{1}{\theta} z_t, \tag{23}$$

$$\text{Var}_t(\epsilon_{t+1}^f \mid v_t, z_t) = 1/\tau, \tag{24}$$

where τ is the conditional precision of the fundamental shock,

$$\tau = \tau_f + \tau_v + \tau_y,$$

with

$$\tau_f = 1/\sigma_f^2, \quad \tau_v = 1/\sigma_v^2 \quad \text{and} \quad \tau_y = \theta^2/\sigma_b^2.$$

The Equilibrium Spot Rate Equation

Substituting (23) into equation (21) we obtain a closed form solution for the exchange rate, i.e.

$$s_t = \lambda_f f_t + \lambda_v v_t + \lambda_z z_t, \quad \text{where} \tag{25}$$

$$\lambda_f = \frac{1}{1 + \alpha(1 - \rho)},$$

$$\lambda_v = \frac{\alpha}{1 + \alpha} \frac{\frac{\tau_v}{\tau}}{1 + \alpha(1 - \rho)},$$

$$\lambda_z = -\frac{\alpha}{1 + \alpha} \left(\frac{[1 + \alpha(1 - \rho)]\gamma\sigma^2 + \frac{1}{\theta}\frac{\tau_y}{\tau}}{1 + \alpha(1 - \rho)} \right).$$

The Role of Fundamental Shocks

Three factors enter into the closed form equation (25) for the spot rate:

- the fundamental variable, f_t,
- the public signal, v_t,
- and the order flow, z_t.

The signs of the coefficients λ_f and λ_v are positive.

- This is not surprising, if we consider that $f_t \equiv m_t - m_t^*$ and v_t is positively correlated with this relative money supply. Indeed, an increase in the relative money supply depreciates the domestic currency via the standard monetarist mechanism.

The Role of Order Flow: A Liquidity Effect

The sign of λ_z is negative, because when an order to sell foreign currency reaches the trading platform the exchange rate depreciates via both a liquidity effect and an information one:

- In the absence of informative customer orders ($\theta = 0$) FX dealers are willing to hold a larger quantity of the foreign currency only if they are compensated for the increased risk they bear. Thus, a positive z_t forces a depreciation of the foreign currency as this corresponds to a larger excess return FX dealers expect from holding foreign bonds.

  Thus, for $\theta = 0$, the order flow coefficient becomes:

  $$\lambda_z = -\frac{\alpha}{1+\alpha}\gamma\sigma^2,$$

  as it depends on the volatility of the spot rate, σ^2, and on FX dealers' risk aversion, γ.

The Role of Order Flow: An Information-based Effect

- If customer orders are informative ($\theta > 0$), even in the presence of risk-neutral FX dealers ($\gamma = 0$), an excess of sell orders might indicate an impending negative fundamental shock ($\epsilon_{t+1}^f < 0$). This induces rational FX dealers to expect an exchange rate depreciation. Consequently, they are willing to hold the same amount of the foreign currency only if a reduction in s_t re-establishes the expected excess return foreign bonds yield.

  Thus, for $\gamma = 0$, the order flow coefficient becomes:

  $$\lambda_z = -\frac{\alpha}{1+\alpha}\frac{\frac{1}{\theta}\frac{\tau_y}{\tau}}{1+\alpha(1-\rho)},$$

  which depends on the informational content of customer orders.

Heterogeneous Information and the Magnification Effect

When FX dealers observe correlated *but* different signals of the fundamental process, the impact of the order flow on exchange rates is amplified.

- If any domestic FX dealer, h, observes a private signal on the fundamental shock,

  $$v_{t,h} = \epsilon_{t+1}^f + \epsilon_{t,h}^v,$$

  other things being equal, the order flow coefficient in the equilibrium spot rate equation (25), λ_z, is *larger*, indicating that the impact of non-fundamental shocks, b_t, is *magnified*.

Long-lived Information and the Magnification Effect

Bacchetta and van Wincoop show that the impact of these non fundamental shocks is *very large*, if traders possess log-lived information.

- This is the case if at time t either informed customer observe period $t + T$ fundamental shock, ϵ_{t+T}^f (with $T > 1$), or domestic FX dealers observe private signals on the same shock,

$$v_{t,h} = \epsilon_{t+T}^f + \epsilon_{t,h}^v.$$

In both cases, in equation (20) we cannot impose the simplifying assumption that

$$\bar{E}_t^k(f_{t+k}) = E_t(f_{t+k}) \quad \text{and} \quad \bar{E}_t^k(z_{t+k}) = E_t(z_{t+k})$$

and as a consequence the impact of non fundamental shocks, b_t, on exchange rates is *greatly* magnified.

Some Empirical Implications

The empirical implications of Bacchetta and van Wincoop's model are very interesting and fundamentally in line with the results of Froot and Ramadorai. In fact:

- The Liquidity shock, b_t, presents a *transitory* effect on exchange rates:

  ○ When liquidity traders purchase a foreign currency, $b_t < 0$, the spot rate rises as FX dealers wrongly interpret the imbalance in the order flow as the consequence of a positive fundamental shock.

  ○ The initial impact is however reversed in the long-run, as FX dealers progressively learn the real nature of the shock from further observations of the order flow and the spot rate.

Some Empirical Implications (cont.ed)

- On the contrary, the fundamental shock, ϵ_{t+1}^f, presents a *persistent* effect on the value of the foreign currency. However, the initial impact is *smaller* than the total effect.

  ○ In fact, when a positive shock hits the fundamental process, $\epsilon_{t+1}^f > 0$, because of the rational confusion between liquidity and fundamental shocks, FX dealers need several observations of the spot rate to realise the extension of this positive shock.

- Under heterogeneous information, order flow variability accounts for a large share of the spot rate variance over the short-run.

  ○ In fact, under the parametric specification chosen by Bacchetta and van Wincoop, if FX dealers observe individual private signals of the fundamental shock the ratio $\text{Var}(b_t)/\text{Var}(s_{t+p} - s_t)$ varies between 70 and 10 percent for p varying from 1 to 20.

Some Empirical Implications (cont.ed)

- Under heterogeneous information, the amount of exchange rate volatility explained by fundamental variables augments over time.

  ○ More precisely, under the same parametric specification, the coefficient of multiple determination, R^2, in the regression of the spot rate variation, $s_{t+p} - s_t$, over current and lagged observations of the fundamental process, $(f_t, f_{t-1}, \ldots, f_{t-j} \ldots)$, rises with p.

- Under heterogeneous information, over short horizons the spot rate is a good *predictor* of future changes in fundamentals.

  ○ In fact, the coefficient of multiple determination, R^2, in the regression of future variations of the fundamental process, $f_{t+p} - f_{t+1}$, over current spot rate variations, $s_{t+1} - s_t$, takes values between 0 and 20 percent for $p = 1, 2 \ldots 20$.

8 News, Order Flow and Exchange Rates

In the previous Sections we have seen that at least over the short run order flow is an important determinant of exchange rate dynamics. From Bacchetta and van Wincoop's analytical framework we have learnt that order flow can affect exchange rates via

- either a portfolio balance channel, as FX dealers need to be compensated for the risk they bear when they hold foreign currencies;

- or an information channel, if order flow conveys information on fundamental shifts which affect the value of foreign currencies.

In the second scenario order flow is related to news arrivals, i.e. to information on macroeconomic variables which FX traders obtain from various official sources and publicly available data, such as newswire services, newsletters, monetary authorities' watchers and so on.

Macroeconomic Announcements and Exchange Rates

The analysis of the effects of news arrivals on spot rates dates back to the debate over the exchange rates-fundamentals disconnect stimulated in the early 1980s by Meese and Rogoff's influential results. Since then, researchers have tried to verify whether macroeconomic variables influence exchange rates, studying the effects of macro announcements on exchange rates.

- Earlier contributions (Hardouvelis (1985), Ito and Roley (1987)), that concentrated on the analysis of *daily* data, have partially vindicated the role of fundamentals, showing that news arrivals on variables such as output, price levels, etc., do affect exchange rates.

- Recently researchers (Goodhart *et al.* (1993), Almeyda *et al.* (1998), Andersen *et al.* (2003)) have studied the effects of news arrivals at *high frequencies*, also trying to explore the relation between news and order flow (Evans and Lyons (2003), Love and Payne (2003)).

News Arrivals and Spot Rates

Data on macro variables are continuously released by official and unofficial sources. According to the efficient markets paradigm, prices reflect *all* available information, so that only the *unexpected* component of these macro announcements should affect exchange rates.

- Thus, let $A_{k,t}$ represent a macro announcement variable. This is equal to the announced value of a macro indicator k, such as US GDP or German unemployment level, in the interval $(t, t+1]$ in which a public announcement is released and zero in any other interval.

- Let $E_{k,t}$ indicates the corresponding value expected by market participants at time t.

- According to the efficient markets paradigm only the unexpected component,

$$A_{k,t} \ - \ E_{k,t},$$

of the announcement variable should influence exchange rates.

Macro Announcements and News Arrivals

Andersen *et al.* (2003) have studied the effects on six major exchange rates (CHF/USD, DEM/USD, EUR/USD, GBP/USD and JPY/USD) of the unexpected components of announcements on 41 macro variables for the United States and Germany over the period between January 1992 and December 1998, employing

- Reuters data on exchange returns, r_{t+1}, observed at *5-minute* intervals;

- MMS data on money managers' *expectations* of the 41 macro variables, $E_{k,t}$.

For any indicator, k, a *standardised* news variable is defined as follows:

$$N_{k,t} \ \equiv \ \frac{A_{k,t} \ - \ E_{k,t}}{\sigma_k},$$

where σ_k is the sample standard deviation of the unexpected component of the announcement $A_{k,t}$.

The Effect of News on Spot Rates

The effect of the news variables $N_{k,t}$'s on exchange rates is evaluated estimating the following linear regression of the 5-minute return, r_{t+1} on its own lags and on contemporaneous and lagged values of the news variables:

$$r_{t+1} \;=\; \alpha_0 \;+\; \sum_{i=1}^{p} \alpha_i\, r_{t+1-i} \;+\; \sum_{k=1}^{K} \theta_{k,j}\, N_{k,t-j} \;+\; \epsilon_t. \tag{26}$$

Remark: The linear model is estimated with a two step Weighted Least Square procedure:

- Firstly, the fitted residuals, $\hat{\epsilon}_t$'s, are estimated using simple OLS.

- Secondly, the fitted residuals are employed to estimate a time-varying model of the variance, σ_t^2, of the residual, ϵ_t. The estimated time-varying variance, $\hat{\sigma}_t{}^2$ is then employed to estimate the coefficients, α_i's and $\theta_{k,j}$'s, of the linear model via WLS.

The Impact of Expected and Unexpected Macro Announcements

From this linear regression Andersen *et al.* find that:

- Both for US and German indicators, *unexpected* fundamental shocks significantly *affect* exchange rates.

- Exchange rates react *quickly* to fundamental shocks, with an immediate jump and very little movement thereafter. For example:

  - A positive (negative) one standard deviation US payroll employment shock, $N_{e,t} > 0$ ($N_{e,t} < 0$) appreciates (depreciates) the US dollar against the German currency by 0.16%.

Adding the announcement indicators, $A_{k,t}$, to the linear model (26), they also find that:

- The *expected* components of macro announcements do *not* affect exchange rates.

The Explanatory Power of News Arrivals

Most of the econometric fitness in equation (26) comes from the lagged values of the dependent variable and the contemporaneous news variables, $N_{k,t}$'s. Indeed, most of the effect of news $N_{k,t}$ on the spot rate is felt within a 5-minute interval.

Given the number of macro announcements, this amounts to a subsample of less than 0.2% of all observations. However, within this small subsample news variables show strong explanatory power, as documented by the following linear regression:

$$r_{t+1} \;=\; \theta_k\, N_{k,t} \;+\; \epsilon_t, \quad \text{for } k = 1, \ldots, 41, \tag{27}$$

where the sample is restricted to the intervals, $(t, t+1)$, in which a value for $N_{k,t}$ is observed.

- In the 41 estimations of equation (27) the coefficient of multiple correlation, R^2, often takes values around 0.3 and at times approaches 0.6.

Exchange Rate Fundamentals and Market Efficiency

From Andersen *et al.* (2003) and other empirical investigation, we conclude that:

1) Macroeconomic variables represent exchange rate fundamentals, as macroeconomic announcements affect spot rates;
2) Foreign exchange markets are semi-strong form efficient, as spot rates immediately react to news.

Order Flow and Macro Announcements

Love and Payne (2003) extend previous analysis of the effects of news arrivals on exchange rates by studying the interplay between order flow, spot rates and macro news. In particular, they study:

- The impact of news arrivals on exchange rates and order flow *separately*.

- The impact of order flow on exchange rates *around* announcement dates.

- The impact of news arrivals and order flow on exchange rates *simultaneously*.

Transaction Data

They employ transaction data which consists of all inter-dealer trades completed via Reuters Dealing 2000-2 system in the EUR/USD, EUR/GBP and GBP/USD spot markets over several months in 1999 and 2000.

- Exchange returns are sampled at the 1-minute frequency, so that several thousands observations are available for the three spot rates.

- Only the *direction* of individual trades is available, whilst no information on the size of trades is accessible.

    ○ This is different from the dataset analysed by Payne (2003), but in line with those of other studies (Evans and Lyons (2002)).

    ○ We have already seen that this lack of information is inconsequential for the study of the role of order flow.

Macro News Data

Macro news data consists of announcements on several macro indicators for the three economic areas alongside the corresponding market expectations collected by Standard and Poors.

- Since very few announcements per any macro indicator are available, for any economic area a *unique* macro news variable is obtained consolidating the data for the individual indicators. This is done in two stages:

    ○ Firstly, in the economic area C the news variable for the individual indicator k is standardised according to the familiar formulation:

    $$N_{k,t}^C \equiv \frac{A_{k,t}^C - E_{k,t}^C}{\sigma_{k,C}}.$$

    ○ Secondly, this standardised news variable is *signed* according to its effect on the value of the currency of the area.

The Direction of News

To give a sign to the news variable $N_{k,t}^C$ in the economic area C a simple linear regression of the excess return for currency C on the news variable $N_{k,t}^C$ is estimated via OLS over the entire sample period.

- If the coefficient of this linear regression is larger (smaller) than zero, positive unexpected shocks in the indicator k tend to appreciate (depreciate) currency C.

- The news variable $N_{k,t}^C$ is then signed by pre-multiplying its value by the sign of this linear coefficient.

For any economic area C a single news variable is obtained by aggregating (i.e. summing together) the *signed* standardised news variables for the individual indicators, k:

$$N_t^C = \sum_{k=1}^{K} \text{sign}(N_{k,t}^C)\, N_{k,t}^C.$$

The Impact of News Arrivals on Order Flow and Returns

First, the impact of macro news on exchange rates and order flow is studied separately.

- Returns are regressed on leads and lags of macro news variables:

$$r_{t+1}^C \;=\; \alpha \;+\; \sum_{i=-p}^{p} \theta_i^C \, N_{t-i} \;+\; \epsilon_t^C,$$

  where N_t is the vector of the three economic areas news variables, while θ_i^C is the corresponding vector of coefficient for lag (or lead) i;

- Order flows is regressed on leads and lags of macro news variables:

$$z_t^C \;=\; \lambda \;+\; \sum_{i=-p}^{p} \gamma_i^C \, N_{t-i} \;+\; \eta_t^C,$$

  where z_t^C indicates the flow of orders moving funds into currency C in the interval $(t, t+1]$.

The Impact of News Arrivals on Order Flow and Returns (cont.ed)

The results of this preliminary analysis are:

- The impact of news arrivals on exchange rates is evident:
  - Even at this very high frequency (1-minute) the reaction of the exchange rate is immediate, as the contemporaneous coefficients θ_0^C are all significantly different from zero.
  - Only the very first lag for the GBP/USD rate is significant, confirming the tremendous *pace* of foreign exchange markets.
- Surprisingly, news arrivals *also* affect order flow, with both immediate and delayed effects:
  - Indeed, all nine contemporaneous coefficients are statistically significant.
  - Moreover, some of the lag coefficients are also significantly different from zero.

The Interplay Between Macro News and Order Flow

To investigate the possibility that news arrivals alter the impact of order flow on exchange rates, Love and Payne consider the following non linear regressions of returns on leads and lags of order flow:

$$r_{t+1}^C \;=\; \alpha \;+\; \beta \, z_t^C \;+\; \sum_{C'} \sum_{i=-p}^{p} \delta_i^{C'} z_t^C \cdot I_{t-i}^{C'} \;+\; \epsilon_t^C,$$

where $I_{t-i}^{C'}$ is an indicative variable which takes the value unity if there is a macro announcement in period $t-i$ for the economic region C'.

The Interplay Between Macro News and Order Flow (cont.ed)

These non-linear regressions show that:

- Around periods of news arrivals exchange rates are *more* sensitive to order flow than during calmer times.
- Contemporaneously to the release of US (UK) news, order flow presents a significantly larger effect in the determination of the US dollar (British pound). In particular:
  - The coefficient δ_0^{US} in the regressions for the US dollar shows that the impact of order flow on exchange rates more than *doubles* with respect to normal times.
  - Similar results hold for the corresponding coefficients of the British currency.

Order Flow Intermediation of News Effects on Returns

To test whether exchange rate response to news arrivals is mediated by order flow, Love and Payne estimate a simple bivariate VAR model for each spot rates:

$$
\begin{bmatrix} r_{t+1}^C \\ z_t^C \end{bmatrix} = \begin{bmatrix} \alpha_r \\ \alpha_z \end{bmatrix} + \begin{bmatrix} \beta \\ 0 \end{bmatrix} z_t^C + \sum_{i=1}^{p} \Gamma_i \begin{bmatrix} r_{t+1-i}^C \\ z_{t-i}^C \end{bmatrix} + \sum_{j=1}^{q} \Theta_j \, N_{t-j} \, + \, \epsilon_t.
$$

Remark: It is assumed that while the contemporaneous value of the order flow, z_t^C, enters into the return equation the opposite is not true.

This identification restriction is justified by the 1-minute frequency at which variables are observed. Over such short periods of time authors deem improbable a causality link from returns to flows.

A Bivarate VAR of Order Flow and Returns

Contemporaneous Coefficients

	EUR/USD		EUR/GBP		GBP/USD	
	r_{t+1}	z_t	r_{t+1}	z_t	r_{t+1}	z_t
z_t	0.00451		0.00419		0.00304	
	(70.59)		(81.65)		(118.08)	
N_t^{EU}	0.0252	3.42	-0.00555	1.47	0.00496	2.12
	(2.17)	(2.08)	(-1.41)	(1.37)	(0.90)	(2.28)
N_t^{UK}	0.0046	1.56	-0.0198	-2.40	0.0295	6.87
	(1.47)	(1.89)	(-2.92)	(-1.75)	(3.43)	(4.77)
N_t^{US}	-0.0786	-6.55	-0.00906	-4.73	-0.0445	-5.22
	(-2.55)	(-1.90)	(-0.46)	(-2.31)	(-2.75)	(-2.22)
R^2	0.299	0.080	0.183	0.057	0.223	0.047

In parentheses t-student values.

The Effects of News Variables and Order Flow

Results from this bivariate VAR are as follows:

- As seen elsewhere, flow variables, z_t^C, possess a large and highly significant positive impact on exchange rates. Thus:

   ○ A net purchase of euros in the EUR/USD and EUR/GBP markets brings about a rise in the value of the euro.

   ○ Similarly, a net purchase of US dollars in the EUR/USD and GBP/USD markets produces a rise in the value of the dollar.

The Effects of News Variables and Order Flow (cont.ed)

- News variables, N_t^C, also have a significant impact on exchange rates and flows. Thus:

   ○ A positive value for N_t^{EU}
      - appreciates the euro against the US dollar;
      - generates positive order flow from the United States and the United Kingdom.

   ○ A positive value for N_t^{US}
      - appreciates the US dollar against the euro and the British pound;
      - generates positive order flow from Euro-land and the United Kingdom.

   ○ Interestingly, news in one area also conditions the performance of the market between the other two areas. Thus, a positive value for N_t^{US} provokes an outflow from Euro-land toward the United Kingdom and a corresponding depreciation of the euro against the British pound.

The Effects of News on Returns via Order Flows

Since news variables provoke order flow and this on its turn moves exchange rates, information conditions the values of currencies:

1. Via a direct channel, as exchange rates immediately adjust after an informative shock.

2. Via an indirect channel, as exchange rates react to imbalances between buy and sell orders.

Studying the impulse response functions of the VAR model Love and Payne are able to isolate the two components. For different horizons, these are found by:

1. Calculating the cumulative return generated by a positive news shock in area C.

2. Repeating the same calculation under the restriction that order flow is not affected by news, i.e. by introducing zeros in the second row of all the matrices of coefficients Θ_j.

3. Subtracting the result of 2. from 1..

The Effects of News on Returns via Order Flows (cont.ed)

Break-down of Information Assimilation (percentage)

	Minutes After	EUR/USD		EUR/GBP		GBP/USD	
	Announcement	Flow	Direct	Flow	Direct	Flow	Direct
EU News	0	38.17	61.83	1073.81	-973.81	57.45	42.55
	5	41.97	58.03	306.92	-206.92	77.21	22.79
	20	44.75	55.25	407.60	-307.60	85.00	15.00
UK News	0	61.37	38.63	33.65	66.35	41.50	58.50
	5	69.02	30.98	11.87	82.13	46.33	53.66
	20	89.21	10.79	11.68	82.32	47.39	52.61
US News	0	27.27	72.73	68.49	31.51	26.25	73.75
	5	29.55	70.45	72.04	27.96	21.83	78.17
	20	28.86	71.14	70.71	29.29	21.36	78.64

The Effects of News on Returns via Order Flows (cont.ed)

Apart from the case of the EUR/GBP market, where the EU news variable has an opposite effect on order flow and exchange rates and hence this decomposition makes little sense, we see that:

- 30-60% of the simultaneous impact of news on exchange rates is mediated by order flow.

- The "flow" component is significant after sometime from the macro announcement release.

Love and Payne conclude that:

> 1) Nearly 50% of public information simultaneously released to all market participants is impounded into exchange rates via order flow.
>
> 2) Efficient market theory, according to which public information should be immediately transferred to prices with *no role* for trading, is violated.

A Circulatory Issue

The analysis of Love and Payne is prone to a circulatory issue. In fact:

- The direction of news is defined on the basis of the effect of announcements on exchange rates. Thus, $N_{k,t}^C$ is positively (negatively) signed if an unexpected positive announcement $A_{k,t}^C$ augments (reduces) the value of currency C.

- The effect of news arrivals on the first moment of order flow and exchange rate is then investigated.

Love and Payne use the same sample of observations to sign the variables $N_{k,t}^C$ and to study their effects on spot rates, thus their results are *biased* in favour of a positive effect of news on returns.

The Indeterminacy of News Direction

The contradictory results of the empirical analysis of traditional models of exchange rate determination make it hard to sign news. Thus, for example, an unexpected rise in the growth rate of monetary aggregates in one country can lead to

- a depreciation of the domestic currency, if this process brings about inflation and devaluation expectations;

- an appreciation of the domestic currency, if, in the presence of a central bank reaction function, nominal interest rates are set to rise.

Thus, any empirical study of the effects of news on exchange rates and order flow is plagued by the issue of the *indeterminacy* of news direction.

Second Order Effects of News on Order Flow and Exchange Rates

In the face of these difficulties one could just concentrate on the effects of news arrival on the second moments of exchange rates and order flow. That is the route followed by Evans and Lyons (2003). In their study they employ:

- Data on all bilateral transactions between FX dealers via Reuters Dealing 200-1 electronic trading system in the spot DEM/USD and JPY/USD markets between May 1st and August 31st 1996.

- Data on macro announcements for US and German indicators derived from Reuters' newswire services.

From these sources they construct daily observations for the order flow imbalance, z_t, the exchange rate variation, Δs_{t+1}, and the number of news releases, A_t.

News, Trading Volume and Exchange Rate Volatility

Evans and Lyons consider the effects of news arrivals on the volatility of exchange rates and of order flow. In particular, they consider the following simple extension of their original model of exchange rate determination:

$$\Delta s_{t+1} \;=\; \alpha\, z_{1,t} \;+\; N_{C,t} \;+\; \epsilon_t, \quad \text{where}$$

$$z_t \;=\; z_{1,t} \;+\; z_{2,t}, \quad \text{with} \quad z_{2,t} \;=\; \gamma\,\Delta s_{t+1} \quad \text{and} \quad z_{1,t} \;=\; N_{P,t} + \eta_t.$$

Here:

- Order flow can be both informative, $z_{1,t}$, and induced by exchange rate movements, $z_{2,t}$, as a consequence of feed-back trading rules.

- Exchange rate movements can be the consequence of public information, $N_{C,t}$, or private information, $N_{P,t}$, contained in order flow.

A Different Role for Public Information

Remark: Evans and Lyons propose a different role for public information with respect to that advocated by Love and Payne:

- Public information does not affect order flow and is immediately incorporated in currency values. Only the private component of information alters exchange rates via order flow.

Remark: Evans and Lyons' notion of private information is different from the usual one.

- Foreign exchange traders do not share a common model of exchange rate determination and hence give different interpretations to macro news. Hence, a general consensus on the implications of an unexpected shock to a macro variable can be obtained only via trading.

- $N_{C,t}$ refers to the common knowledge component of news while $N_{P,t}$ subsumes all the rest.

Estimating A Model of News Arrivals, Trading Volume and Exchange Rate Volatility

Evans and Lyons do not attempt to identify $N_{C,t}$ and $N_{P,t}$. Rather, they simply assume that the corresponding variances, $\sigma^2_{C,t}$ and $\sigma^2_{P,t}$, are increasing in the pace of news arrivals:

$$\sigma^2_C = \sigma_C \cdot A_t, \quad \sigma^2_P = \sigma_P \cdot A_t.$$

Using GMM estimators they find the following parameter values and standard errors:

Parameter	α	γ	σ_C	σ_P	σ^2_ϵ	σ^2_η	R^2
Estimate	0.031	-2.051	2.791	0.168	81.375	3.795	0.326
Standard Error	0.002	0.172	0.690	0.034	10.714	0.502	

Results

Besides already established results, we see that:

- News arrivals significantly increase the volume of trading.

- The arrival of news also augments the volatility of exchange rates via both a direct public information channel and an indirect order flow one. In line with the results of Love and Payne, Evans and Lyons calculate that:

  - Roughly 70% of daily exchange rate variance due to news arrivals is via order flow.

  - Roughly 30% of daily exchange rate variance due to news arrivals is via the direct effect.

- Exchange rate movements have a *negative* feed back effect on order flow. Note that this clearly contradicts the conjecture of Froot and Ramadorai.

9 Central Bank Intervention in Foreign Exchange Markets

We now turn to central bank intervention, as this is an important component of order flow:

- Central banks routinely buy and sell currencies in spot foreign exchange markets.

- Often the declared intention of these operations is that of conditioning currency values. In this respect, their success depends on the impact that order flow has on exchange rates and its information content. Indeed, some have suggested that *foreign exchange intervention* can be effective because it carries information.

- In other words, central banks are like informed agents which trade on superior information and consequently alter securities prices. In this sense, order flow in foreign exchange markets condition exchange rates because some traders, notably central banks, possess private information.

Sterilised Intervention

When we mention foreign exchange intervention we intend *sterilised intervention*:

- Indeed, most of foreign exchange intervention is sterilised, in that when monetary authorities buy and sell currencies, the consequent change in the money supply is *offset* through an immediate open market operation.

- In effect, foreign exchange intervention represents an independent instrument of policy-making as long as it does not change the money supply, since otherwise it would be a different and less convenient way of implementing the monetary policy.

The Portfolio Balance Effect

According to a traditionally held view, sterilised intervention alters currency values via a *portfolio balance effect*, for it modifies the ratio between domestic and foreign assets held by the private sector. More specifically:

- Domestic and foreign assets are imperfect substitutes, since investors have a preference for assets denominated in their own currency.

- A purchase (sale) of foreign currencies by the central bank, which reduces (augments) the ratio between domestic and foreign assets held by the private sector, induces a depreciation (appreciation) of the national currency, because investors require a greater risk-premium to hold a larger quantity of this currency.

The Jurgensen Commission

In the early 1980s a controversy over the effectiveness of sterilised intervention emerged:

- Members of the G-5 debated if sterilised purchases and sales of foreign currencies could influence exchange rates through this *portfolio balance effect*.

- Critics of this hypothesis challenged it on the ground that either domestic and foreign assets are perfect substitutes or that the effect of sterilised intervention on the risk-premium is irrelevant.

- The Jurgensen Commission (1983), alongside other investigations (Frankel (1982), Frankel and Engle (1984), Loopesko (1984), Neumann (1984) and Rogoff (1984)), suggested that sterilised intervention had a very *small*, if any, effect on exchange rates.

The Plaza

For a long time, in line with the general opinion of the ineffectiveness of sterilised intervention, the US Federal Reserve followed a "hands-off" stance, refraining from intervening in foreign exchange markets in the first part of the 1980s.

Nevertheless,

- the excessive overvaluation of the dollar in 1985 led the monetary authorities of the United States and other leading industrial countries, notably Germany and Japan, to co-ordinate intervention operations to try to bring down the value of the US currency.

Thus,

- at the Plaza meeting of September 1985, members of the G-5 inaugurated a new period of co-ordinated and individual operations to manage exchange rates.

The Portfolio Balance Effect Revisited

- The period 1985-1990 witnessed a *reduction* in the fluctuations of the dollar with respect to the large movements of the previous five years.

- This reduction has been interpreted as confirmation of the positive results of the new intervention policy (Dominguez and Frankel (1993a)).

- The reappraisal of large-scale operations in foreign exchange markets by the main central banks and their relative success have given new life to the analysis of sterilised intervention:

  ○ Empirical studies based on more recent and accurate data conclude that central bank intervention has a *significant* short-term impact on exchange rates and is *useful* to stabilise their values.

  ○ In particular, Dominguez and Frankel (1993b) and Gosh (1992) vindicate the portfolio balance effect, showing that intervention operations influence risk-premia.

The Signalling Hypothesis

However, in the 1990s scholars have started giving more weight to a new channel of transmission of central bank intervention to exchange rates.

According to the *signalling* hypothesis (Mussa (1981)):

- Operations in foreign exchange markets by a central bank may signal changes in future monetary policy more *credibly* than just a simple announcement.

  Indeed, by purchasing (selling) foreign assets the central bank stakes its own capital in support of the future policy and hence "buys credibility".

- Sterilised intervention affects market expectations and hence the exchange rate.

Some Empirical Evidence

In the 1990s a series of empirical studies has attempted to assess the signalling role of sterilised intervention (Dominguez and Frankel (1993a, 1993c), Klein and Rosengren (1991), Dominguez (1992), Watanabe (1992), Lewis (1993), Kaminsky and Lewis (1996) and Catte *et al* (1994)).

- The conclusions of these investigations tend to support Mussa's hypothesis, as sterilised intervention is related in some way to the monetary policy and seems to condition investors' expectations.

- A survey of this strand of research is contained in Edison (1993).

A Transaction Level Study of Foreign Exchange Intervention

All cited authors have considered either daily or monthly observations of sterilised intervention.

Payne and Vitale (2003) instead employ transaction data on the intervention operations of the Swiss National Bank and conduct an event study of the effects of foreign exchange intervention on exchange rates at high frequency. Their data consists of:

- All *customer* and *intervention* operations, time-stamped to the minute, conducted by the SNB in the USD/CHF market and are recorded for the period covering 1986 to 1995.

- Tick-by-tick indicative exchange rate quotes on the USD/CHF rate over the same period.

Remark: The distinction between *customer* and *intervention* operations is crucial: while the former are triggered by the need of the Swiss government for foreign currency, the latter are aimed at influencing the value of the Swiss franc.

A Simple Test of the Signalling Hypothesis

Payne and Vitale consider simple linear regressions of the 15 minute percentage return on the USD/CHF rate on leads and lags of a signed intervention operation indicator, I_t, and a signed customer operation indicator, C_t:

$$r_{t+1} = \alpha + \sum_{j=8}^{-8} \beta_j \, I_{t+j} + \gamma_1 \, r_t + \gamma_2 \, r_{t-1} + \epsilon_t, \tag{28}$$

$$r_{t+1} = \alpha + \sum_{j=8}^{-8} \beta_j \, C_{t+j} + \gamma_1 \, r_t + \gamma_2 \, r_{t-1} + \epsilon_t. \tag{29}$$

Here I_t (C_t) is +1 in any 15 minute interval where the SNB purchased dollars (within an intervention (customer) operation) -1 in intervals when the SNB sold dollars and zero otherwise.

Figure 2: Basic Effects of Intervention and Customer Trades on the USD/CHF Rate

(a) Intervention (b) Customer trades
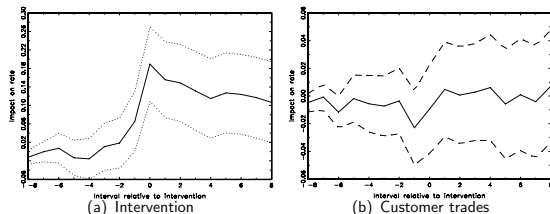
Notes: Basic effects of intervention and customer trades on the USD/CHF rate. Results are based on exchange rates and intervention events defined using a 15 minutes sampling frequency. Time is measured in 15 minute intervals relative to intervention. The dashed lines indicate the 95% confidence interval for the cumulative intervention effect.

The Effect of Interventions and Customer Trades on Exchange Rates

In these panels we present the cumulative impact on the USD/CHF rate of a purchase of US dollars on the part of the SNB. This purchase can be either on behalf of the Swiss government (right panel) or of its own initiative (left panel). We see that:

- Interventions appear to have *significant* and *persistent* effects on exchange rate levels.

- Customer trades do not alter exchange rates, as at no point is the cumulative effect of a customer trade on the USD/CHF rate significantly different from zero.

These results suggest that the exchange rate reaction to the SNB intervention activity is not the consequence of a *liquidity* or *portfolio-balance* effect. Rather, it is evidence that intervention operations "carry" information.

The Importance of the Trade Size

As a further check of the signalling hypothesis, Payne and Vitale consider two new regressions.

In the first r_{t+1} is regressed on leads and lags of the signed intervention indicator, I_t, alongside those of the signed intervention *quantity*, z_t. In the second, the leads and lags of the signed indicator are substituted with corresponding leads and lags of the *signed, squared quantity*:

$$r_{t+1} = \alpha + \sum_{j=8}^{-8} \beta_j \, I_{t+j} + \sum_{j=8}^{-8} \delta_j \, z_{t+j} + \sum_{j=1}^{2} \gamma_j \, r_{t-j+1} + \epsilon_t, \qquad (30)$$

$$r_{t+1} = \alpha + \sum_{j=8}^{-8} \delta_j \, z_{t+j} + \sum_{j=8}^{-8} \theta_j \, \text{sign}(z_{t+j}) \, z_{t+j}^2 + \sum_{j=1}^{2} \gamma_j \, r_{t-j+1} + \epsilon_t. \qquad (31)$$

Equation (30) allows to assess the relevance of the *size* of intervention. Equation (31) indicates if the relationship between intervention size and the USD/CHF return is non-linear.
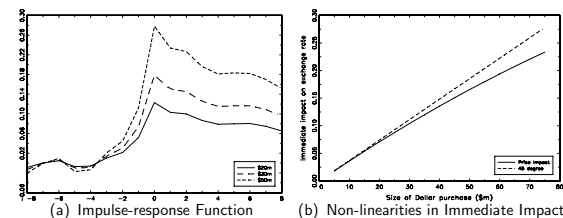
Figure 3: Size Effects of Intervention on the USD/CHF Rate

(a) Impulse-response Function (b) Non-linearities in Immediate Impact

Notes: Results are based on exchange rates and intervention events defined using a 15 minutes sampling frequency. The x-axis for panel (a) gives the (15 minute) interval relative to the intervention. In panel (a), the three selected values for the intervention size correspond to the 25th percentile, median, and 75th percentile of the distribution of intervention size. Panel (b) shows the relationship between intervention size and the change in the exchange rate. The dashed line is the exchange rate impact implied by considering the estimated linear terms in equation (30) only while the solid line is the impact generated by considering the estimated linear and quadratic terms from equation (31).

The Importance of the Trade Size (cont.ed)

Results for the first regression indicate that:

- The size of the intervention operation is important as the coefficient on current intervention, δ_0, is significantly positive, suggesting that the larger the magnitude of intervention, the larger its immediate impact on the exchange rate:

  - The estimated impact on the exchange rate of an intervention purchase of $50 million by the SNB (nearly 30 basis points) is *very very* large.

  - This impact is an order of magnitude larger than the lower bound estimated by Evans and Lyons (2002) for the impact of central bank intervention in the DEM/USD market (5 basis points for operations of $100 million).

The Persistence of Foreign Exchange Intervention Effects

To investigate the persistence of these effects Payne and Vitale also examine the results from regressions of *temporally aggregated exchange rate return* data on *aggregated intervention activity*.

They consider the following two sets of linear regressions:

$$r_{t+1}^k = \lambda_0 + \sum_{i=1}^{2} \lambda_i r_{t-i+1}^k + \lambda_3 I_t^k + \epsilon_t, \tag{32}$$

$$r_{t+1}^k = \kappa_0 + \sum_{i=1}^{2} \kappa_i r_{t-i+1}^k + \kappa_3 z_t^k + \epsilon_t, \tag{33}$$

where r_{t+1}^k is the return aggregate across k observations, while I_t^k and z_t^k are the corresponding aggregated intervention indicator and quantity.

The Persistence of Foreign Exchange Intervention Effects (cont.ed)

Intervention Effects and Aggregation

Aggregation (k)	Indicator		Quantity	
	Coeff. On I_t	t-value	Coeff. On z_t	t-value
4	0.1435	4.12	0.0027	5.84
8	0.1895	3.77	0.0027	3.10
16	0.1273	2.29	0.0020	3.09
48	0.1523	1.90	0.0025	3.02
96	0.1159	0.98	0.0019	2.06

Thus,

- The effect of SNB intervention operations is significant and *persistent*.

- The quantitative impact of these operations *falls* with the time horizon.

Summary

In brief, at least over the short-run, the signalling hypothesis seems confirmed:

- Intervention operations in foreign exchange markets represent an *expensive* instrument of policymaking.

- Because of their potential cost, they can be employed by monetary authorities to credibly convey information to market participants and hence condition market sentiment and currency values.

- Moreover, since large operations are potentially more expensive they have a bigger impact on exchange rate returns than small ones.

Secret Foreign Exchange Intervention

In a series of research papers Vitale (1997,1999,2003) has proposed a formal analysis of central bank intervention in the markets for foreign exchange. Developing market microstructure models of foreign exchange intervention, he obtains a series of interesting results.

While we refer you to these contributions for details, here we briefly indicate his main findings:

- When foreign exchange intervention is aimed at *targeting* the value foreign currencies, central banks can be more effective if they keep *secret* their intervention operations and do not declare the objectives of their activity:

  ○ This contrasts with common wisdom, according to which foreign exchange intervention must be announced and fully visible to achieve its objectives.

  ○ However, this prescription is coherent with normal practice, as most foreign exchange intervention is *concealed*.

Foreign Exchange Intervention and Monetary Policy

Even if often foreign exchange intervention and monetary policy fall under the jurisdiction of different authorities, they influence each others. In this respect, Vitale shows that:

- When foreign exchange intervention and monetary policy are *coordinated*, the former can reduce the *overshooting* of nominal and real variables in the face of a sudden shift in the objectives of the policy makers:

  ○ Specifically, in the presence of price stickiness, foreign exchange intervention can reduce the *volatility* of variables such as exchange rates, prices, output and employment levels.

  ○ In addition, the current institutional arrangements prevailing in most industrialised countries, which assign the control of foreign exchange intervention and monetary policy to different authorities, bring about a larger economic *stability*.

A Simple Market Microstructure Model of Foreign Exchange Intervention

To get an idea of how to formalise foreign exchange intervention from a market microstructure prospective, we do not follow Vitale, as he makes use of Kyle's (1985) famous, but to us unfamiliar, set-up. Rather, we resort to the analytical framework developed in Section 7.

There, we assumed that order flow in the market for foreign exchange is provided by the clients the FX dealers which set the equilibrium price for the foreign currency. These clients comprise:

- Liquidity trades, whose market orders are unrelated to the exchange rate fundamentals.

- Informed clients, which receive a common signal on future shocks to fundamentals.

Central Bank Limit Orders

Within this context it is straightforward to assume that in lieu of the informed clients a single central bank submits *limit orders* in the centralised platform on which the foreign currency is traded.

In particular, we assume that at time t the central bank places the following limit order:

$$I_t \equiv -\theta\,\epsilon_{t+1}^f \;-\; \delta\,(\bar{s} - s_t),$$

where δ is a positive constant and $\bar{s}$ is a target level for the exchange rate.

Superior Information and Exchange Rate Targeting

Thus, intervention operations contain two components:

- An *informative* component, $-\theta\,\epsilon_{t+1}^{f}$, as the central bank possesses private information on future changes in monetary aggregates:

  - Indeed, Kaminsky and Lewis (1996) show that often central banks signal future changes in monetary aggregates with purchases and sales of foreign currencies.

- A *targeting component*, in that the extra term $\delta(s_t - \bar{s})$ indicates that the central bank will purchase (sell) the foreign currency in order to sustain (reduce) its value when this is weaker (stronger) that desired:

  - Funabashi (1988) and Ito (2002) show that in several occasion G-5 central banks have set reference values for the main exchange rates and have intervened accordingly.

Simultaneity Bias and Strategic Trading

Remark: The specification we have chosen presents two advantages:

- First, it addresses the simultaneity bias which usually plagues reduced form models of the effects of foreign exchange intervention on exchange rates, as it explicitly integrates a feed-back effect of the exchange rate on the amount of intervention.

- Second, it allows the central bank to act strategically and negotiate its transactions. Indeed, nowadays central banks can place limit orders on the electronic trading platforms which dominate foreign exchange markets.

Stealth and Sunshine Targeting

Remark: An important issue with foreign exchange intervention concerns the secrecy of the target value, $\bar{s}$. In this respect, consider that:

- At the Plaza meeting of September 1985 the G-5 set reference levels for the USD/JPY and USD/DEM rates close respectively to 215 and 2.60. Likewise, at the Louvre meeting of February 1987 new reference levels were fixed at 153.5 and 1.825 respectively. In both instances these values were never publicly announced or officially endorsed.

- In the 1990s the Bank of Japan has intervened heavily and continuously to sustain the value of the US dollar against the Japanese Yen. During this decade a reference value of 125 for the USD/JPY rate has dictated the Bank of Japan's operations. Foreign exchange trades have clearly had all the required time to learn this value.

A New Equilibrium Exchange Rates

If $\bar{s}$ is common knowledge, as in the case of Japan in the 1990s, repeating the steps we described in Section 7, we obtain a new equilibrium spot rate. This is given by the following formulation:

$$s_t \;=\; \lambda_f\,f_t \;+\; \lambda_v\,v_t \;+\; \lambda_z\,z_t \;+\; \lambda_s\,\bar{s}, \tag{34}$$

where:

$$\lambda_f \;=\; \frac{1+\alpha}{(1+\alpha)[1+\alpha(1-\beta\rho)] - \alpha\beta\frac{\delta}{\theta}\frac{\tau_y}{\tau}},$$

$$\lambda_v \;=\; \frac{\alpha\,\beta\,\frac{\tau_y}{\tau}}{(1+\alpha)[1+\alpha(1-\beta\rho)] - \alpha\beta\frac{\delta}{\theta}\frac{\tau_y}{\tau}},$$

$$\lambda_z \;=\; -\,\alpha\,\frac{[1+\alpha(1-\beta\rho)]\gamma\sigma^2 + \beta\frac{1}{\theta}\frac{\tau_y}{\tau}}{(1+\alpha)[1+\alpha(1-\beta\rho)] - \alpha\beta\frac{\delta}{\theta}\frac{\tau_y}{\tau}},$$

A New Equilibrium Exchange Rates (cont.ed)

$$\lambda_s = \frac{\alpha \beta \delta \left(\gamma \sigma^2 \rho - \frac{1}{\theta}\frac{\tau_y}{\tau}\right)}{(1+\alpha)[1+\alpha(1-\beta\rho)] - \alpha\beta\frac{\delta}{\theta}\frac{\tau_y}{\tau}},$$

$$\beta = \frac{1+\alpha}{1+\alpha(1+\delta\gamma\sigma^2)}.$$

- In practice, equation (34) indicates that the stabilising activity of the central bank, $\delta(\bar{s} - s_t)$, is effecting, i.e. it alters the exchange rate, in so far as:

  ○ FX dealers are risk-averse and hence foreign exchange intervention possesses a portfolio balance effect, $\gamma \neq 0$. (This is probably the case in Japan, where the amount of foreign exchange intervention in the past few years has been huge).

Secret Target Levels and Estimation

Alternatively, one could conjecture that in the presence of risk-neutral FX dealers the stabilising activity is still effective if there is some rational confusion between the two components of the central bank's limit order.

- This can happen if its target level, $\bar{s}$, is not publicly announced and it remains private information of the monetary authorities.

Conclusions

To conclude, just notice that one can conceivably consider estimating this model via GMM if access to detailed information on exchange rates, interest rates, order flow and foreign exchange intervention is a possibility.

- It is in fact relatively simple to write unconditional moment conditions for the variables of the model (f_t, s_t, z_t and I_t).

- While in the past access to order flow and foreign exchange intervention data has been very limited, nowadays several data set are available.

- While one could consider different exchange rates and central banks, the most promising case is the Japanese one, given the continuous and heavy intervention activity of the Bank of Japan in foreign exchange markets.

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