ESF EXPLORATORY WORKSHOP (REF: EW05-330)

High Frequency Econometrics and the Analysis of Foreign Exchange Markets

SCIENTIFIC REPORT

Web Page: http://www2.warwick.ac.uk/fac/soc/wbs/research/wfri/prog2005/esf/

Warwick Business School, University of Warwick, June 26th,27th 2006

Organised by Mark Salmon, Nikolaus Hautsch and Lucio Sarno

1. Executive Summary

The ESF Exploratory Workshop on **High Frequency Econometrics and the Analysis of Foreign Exchange Markets** was held at the University of Warwick, (Warwick Business School) on June 26th,27th 2006.

The workshop was largely supported by the ESF with all additional costs beyond the allocated grant of 14,000 Euro covered by the Financial Econometrics Research Centre (FERC) at Warwick Business School through an award from the Bank of England's research funds.

The organisers were Professor Mark Salmon (Warwick Business School), Professor Nikolaus Hautsch (University of Copenhagen) and Professor Lucio Sarno (Warwick Business School).

The workshop brought together leading experts in two major areas of academic research which are both undergoing rapid development; the econometric analysis of high frequency data drawn from financial markets and the " New Micro Exchange Rate Economics". The emphasis of the new micro approach to foreign exchange markets is to analyse the determinants of exchange rates from the (micro) forces and characteristics of the markets themselves rather than the traditional approach which has employed macro fundamentals as providing the explanation for the movements in exchange rates. As such the new micro approach puts emphasis on the behaviour of the different types of participants in these markets, dealers, customers etc. and their individual transactions. Econometricians have at the same time been developing new statistical tools for analysing transaction level data and order book data in which we have access to all possible transactions undertaken by the different agents emphasised in the new micro approach to FX markets. Bringing the leading exponents of these two separate groups of academics together for the workshop proved to be enormously successful and the workshop was highly productive in stimulating discussion.

The meeting was introduced by Professor Mark Salmon and by Dr.Dalina Dumitrescu for the European Science Foundation who explained the purpose of the Exploratory workshop series and the role of the ESF in general within European Research. The meeting consisted of 8 sessions with 16 papers presented over the two days. The papers were all state of the art and hence recent an in fact a number had been specifically prepared for the workshop. There was a wide mix of topics between purely theoretical econometrics and finance or economic theory and applied research. Each presentation was limited to half an hour followed by 5 minutes from an invited discussant and then 10 minutes allocated to general discussion. A number of comments were made at the time of the workshop and afterwards to the effect that people greatly valued the level of the discussion and the open manner in which the debate took place. This made for a very enjoyable and relaxed atmosphere given the physical environment with plenty of space in the lecture room and break out area where refreshments were available throughout the workshop.

It was decided that we did not wish to pursue a publication from the workshop as it was too premature but that a number of collaborations were formed during the meeting that were likely to become highly beneficial in the future.

2. Scientific Program

All of the papers presented at the workshop can be found on the following web page:

http://www2.warwick.ac.uk/fac/soc/wbs/research/wfri/prog2005/esf/programme/

The 16 papers presented can be grouped as follows;

- **High Frequency Econometrics Theory,** Nikolaus Hautsch, Ingmar Nolte with Valeri Voev, Kim Christensen, Neil Shephard with Barndorff-Nielsen, Hansen and Lunde
- **New Micro Theory of FX Markets** Philippe Bacchetta with Eric van Wincoop, Harald Hau with Michael Moore and Peter Dunn ,Richard Lyons
- **Order Book Theory** Jeremy Large, Albert Menkveld with Thierry Foucault
- **Empirical Analysis of High Frequency Data** Winfried Pohlmeier with Ingmar Nolte and Katrazyna Bien, Joachim Grammig with Erik Theissen and Oliver Wuensche, David Veredas with Roberto Pascual, Lukas Menkhoff and Maik Schmelin, Mark Salmon with Roman Kozhan, Lucio Sarno with Pasquale Della-Corte and Ilias Tsiakas, Dagfinn Rime with Elvira Sojli and Lucio Sarno.

A brief description of each presentation, the subsequent discussion and the critical results follows.

Nikolaus Hautsch
'Generalized Autoregressive Conditional Intensity Models with Long Range Dependence'

Nikolaus Hautsch presented results generalizing Russell's (1999) autoregressive conditional intensity model in several directions. First, he proposed a framework which nests both proportional intensity structures as well as accelerated failure time structures. Second, the process dynamics are extended to allow for long range dependence in the intensity process. Third, he accounted for spill-over effects between consecutive trading days by incorporating inter-day dynamics. Fourth, a semiparametric extension of the Burr hazard rate for the modeling of the baseline intensity component was suggested. Applications of univariate and bivariate versions of the model to trade intensities and price change intensities based on the IBM stock traded at the New York Stock Exchange illustrated the usefulness of the proposed extensions. Significant long memory effects are observed. Furthermore, evidence for non-stationary patterns in the intensity series was presented. In contrast, the inter-day dynamics were found to be weak and only identifiable on a sufficiently long time series. Moreover, the presence of acceleration effects and a rejection of proportional intensity structures was observed. Finally, it turned out that a semiparametric specification of the baseline intensity component is necessary to capture the distributional properties of the date. The latter is particularly important for trade durations.

Ingmar Nolte
Latent Factor Panel Intensity Model

Trading behavior of investors is influenced by a broad set of decision variables. If we were able to observe this complete information set, we could fully characterize the time varying correlation structure across individuals based on this observable information. Individual investment opportunity sets as well as unobservable macroeconomic factors are just two examples of information which is not observed by the econometrician. Time varying latent factors can be used to approximate this unobservable information and improve the characterization of the correlation structure across individuals.
In this talk Ingmar Nolte introduced latent factors to panel intensity models, which were used to investigate the stochastics of trading decisions of investors for multiple assets over time. This framework allows for a rigorous exploration of financial decision making theories such as rational expectations and behavioural finance theories.
The model that was proposed can be viewed on the one hand as an extension of the stochastic conditional intensity (SCI) model of Bauwens & Hautsch (2005) to panel data and as an augmentation of the class of panel survival models by a latent factor. The intensity based specification is chosen to allow for an intuitive incorporation of time varying covariates. The latent factor is assumed to evolve on an arrival process resulting from aggregation of individual arrival processes. A simulated maximum likelihood (SML) technique was used to estimate the model. Due to the complexity of the model an adjustment of the efficient importance sampling method of Richard & Zhang (2005) was also employed.
The model should serve to analyze the trading behavior of retail investors in the foreign exchange market with the help of an trading activity data-set of OANDA FXTrade, which allows to race every action of around 5000 investors in up to 30 currency pairs over the period from 1st October 2003 to 15th May 2004.

Philippe Bacchetta with Eric van Wincoop
Incomplete Information Processing: A Solution to the Forward Premium Puzzle

The uncovered interest rate parity equation is the cornerstone of most models in international macro. However, the equation does not hold empirically since the forward discount, or interest rate differential, is negatively related to the subsequent change in the exchange rate. This forward discount puzzle implies that excess returns on foreign currency investments are predictable. In this presentation the authors investigated the extent to which incomplete information processing can explain this puzzle. They considered two types of incompleteness: infrequent and partial information processing. They calibrated a two-country general equilibrium model to the data and show that incomplete information processing can fully match the empirical evidence. It can also account for several related empirical phenomena, including that of 'delayed overshooting'. They showed that incomplete information processing is consistent both with evidence that little capital is devoted to actively managing short-term currency positions and with a small welfare gain from active portfolio management. The gain is small because exchange rate changes are very hard to predict. The welfare gain is easily outweighed by a small cost of active portfolio management.

Harald Hau with Michael Moore and Peter Dunne
International Order Flows: Explaining Equity and Exchange Rate Returns

Macroeconomic models of equity and exchange rate returns perform poorly. The proportion of daily returns that these models explain is essentially zero. Instead of relying on macroeconomic determinants, the authors model equity price and exchange rate behavior based on a concept from microstructure – order flow. International order flows are derived from belief changes of different investor groups in a two country setting. They obtained a structural relationship between equity returns, exchange rate returns and their relationship to home and foreign market order flow. To test the model they constructed daily aggregate order flow data from all equity trades in the U.S. and France from 1999 to 2003. Almost 60 percent of the daily returns in the S&P100 index was explained jointly by exchange rate returns and aggregate order flows. The model implications were also validated for intraday returns.

Richard Lyons
Myths About the Micro Approach to Exchange Rates

Richard Lyons addressed four common misconceptions about micro-based research on exchange rates: (1) public news arrivals account for most exchange rate variation; (2) allocative trades do not convey information; (3) order flow is easy to measure; and (4) transactions obviously drive prices. Though few people subscribe to all four, most people subscribe to at least one. The presentation attempted to dispell these misconceptions and substantial discussion was created by the presentation with partial agreement with the arguments put forward.

Winfried Pohlmeier
Estimating Liquidity Using Information on the Multivariate Trading Process

The dynamic multivariate density of discrete bid and ask quote changes and their associated depths was analysed accounting for the contemporaneous relationship between these trading marks by exploiting the concept of copula functions. The author showed how to model truncations of the multivariate density in an easy way. A Metropolized-Independence Sampler was applied to draw from the dynamic multivariate density. The samples drawn served to construct the dynamic density function of the quote slope liquidity measure, which enables us to quantify time varying liquidity risk. He then analysed the influence of decimalization on the NYSE on liquidity.

Joachim Grammig with Erik Theissen and Oliver Wuensche
Time and the Price Impact of a Trade – A Structural Approach

This paper revisits the role of time in measuring the informational content of trades. Using a VAR methodology and NYSE data, Dufour and Engle (2000) showed that duration between trades carry informational content with respect to the price impact of a trade. This talk draws on their work, but addresses the issue within the framework of a structural model. Specifically, the authors extended Madhavan/Richardson/Roomans' microstructure model to account for time varying trade intensities. They estimated the model on a cross section of stocks traded on one

of the largest European stock markets, and also for the NYSE traded Dow Jones stocks. Our results provide contrasting evidence regarding the informational content of time. Although they also found that ”time matters” in that the informational content of a trade increases with the duration since the last trade, the informational content is quite different. While Dufour and Engle's results provided evidence for the hypothesis that ”no trade means no information”, which is in line with Easley/O'Hara's (1992) microstructure model, their results suggest that in an automated order book market with no dedicated market makers the impact of time on the price impact of trades is more in accord with the predictions from the Admati/Pfleiderer (1988) model.

David Veredas with Roberto Pascual
Does the Open Limit Order Book Explain Informational Volatility?

This talk evaluated the informational content of an open limit order book by studying its role in explaining long run volatility. The authors separated liquidity-driven (transitory) volatility from information-driven (long run) volatility using a dynamic statespace co-integration model for ask and bid quotes. They found that changes in immediacy costs, for trades of different sizes, precede posterior fluctuations in long run volatility, even after controlling for the incoming order flow; the book is less informative for large-caps; its informativeness decreases with time aggregation, and the book beyond the best quotes adds explanatory power to the best quotes.

Lukas Menkhoff
Whose Trades Convey Information?

Information is a property of *traders* and not necessarily of *trades*. Accordingly, Lukas Menkhoff analyzed *traders*' characteristics in an electronic limit order market via anonymous trader identities. He used six indicators of informed trading in a cross-sectional multivariate approach to identify traders with high price impact. More information is conveyed by those traders' trades who – simultaneously – use medium-sized orders (practice stealth trading), have large trading volume, are located in a financial center, trade early in the trading session, at times of wide spreads and when the order book is thin. These variables tentatively have a declining marginal effect on identification of informed traders.

Mark Salmon with Roman Kozhan
Can we Predict Exchange Rates in Real Time; an Application of Genetic Technical Analysis Using the Structure of the Order Book

This presentation examined the predictability of exchange rates on a transaction level basis using both past transaction prices and the structure of the order book. Formal tests for the ability of genetically derived trading rules, that may be likened to technical rules, were applied to one week of tick-by-tick data on the USD-DM exchange rate drawn from Reuters DM2002 electronic trading system. The Pesaran-Timmermann test showed clear ability to predict directional changes in the exchange rate and the economic value of predictability taking account of transaction costs was shown to be significant out-of-sample using the Anatolyev-Gerko test. These conclusions rested critically however on the frequency of trades which was controlled by what the authors referred to as an inertia parameter. If the trading system is

allowed to trade at every instant then it fails to show profitability but when trades are made only when prices changes are of a sufficient magnitude then significant profitability appears under transaction costs. These conclusions were confirmed using White's Reality Check. Surprisingly the authors did not find strong evidence that exploiting the order book structure aids predictability.

Lucio Sarno with Pasquale Della-Corte and Ilias Tsiakas
Fundamentals, the Forward Bias and Volatility: an Economic Evaluation of Exchange Rate Predictability

This talk provided a comprehensive evaluation of the short-horizon predictive ability of economic fundamentals and forward premia on monthly exchange rate returns in a framework that allows for volatility timing. The authors implemented Bayesian methods for estimation and ranking of a set of empirical exchange rate models, and constructed combined forecasts based on Deterministic and Bayesian Model Averaging. More importantly, they assessed the economic value of the in-sample and out-of-sample forecasting power of the empirical models, and found two key results: (i) a risk averse investor will pay a high performance fee to switch from a dynamic portfolio strategy based on the random walk model to one which conditions on the forward premium with stochastic volatility innovations; and (ii) strategies based on combined forecasts yield large economic gains over the random walk benchmark. These two results were shown to be robust to reasonably high transaction costs.

Kim Christensen
Asymptotic Theory of Range Based Estimation of Quadratic Variation of Discontinuous Semi-martingales

Kim Christensen proposed using realized range-based estimation to draw inference about the quadratic variation of jump-diffusion processes. He constructed a new test of the hypothesis that an asset price has a continuous sample path. Simulated data showed that his approach is efficient, the test is well-sized and more powerful than a return-based t-statistic for sampling frequencies normally used in empirical work. Applied to equity data, he found that the jump process is not as active as reported in previous work.

Neil Shepherd
Designing Realized Kernels to Measure the ex-post Variation of Equity Prices in the Presence of Noise

This presentation by Neil Shephard showed how to use realised kernels to carry out efficient feasible inference on the ex-post variation of underlying equity prices in the presence of simple models of market frictions. The issue is subtle with only estimators which have symmetric weights delivering consistent estimators with mixed Gaussian limit theorems. The weights can be chosen to achieve the best possible rate of convergence and to have an asymptotic variance which is close to that of the maximum likelihood estimator in the parametric version of this problem. Realised kernels can also be selected to (i) be analysed using endogenously spaced data such as that in databases on transactions, (ii) allow for market frictions which are endogenous, (iii) allow for temporally dependent noise. The finite sample performance of the

estimators was reported using simulation, while empirical work illustrated their use in practice.

Jeremy Large
Price Tick and Welfare when Assets Trade on a Penny

Using a stochastic sequential game, Jeremy Large modelled an electronic limit order book that *trades on a penny*, meaning its bid-ask spread is almost always the price tick size. By deriving flow-equality features of dynamic ergodic equilibrium, it deduces the buy-side's strategy and welfare, while bypassing altogether their complex forecasting problem. Per agent, this welfare decreases with tick size {but is actually invariant to potentially beneficial measures like increased or more consistent trading volumes, more sophisticated trading, or modified queuing rules. Depths adjust producing equilibrium effects which exactly offset these. He advocated narrowing the tick, but anticipates resistance from sell-side traders.

Albert Mekveld with Thierry Foucault
Competition for Order Flow and Smart Order Routing Systems

Albert Mekveld reported on joint work with Thierry Foucault that studied changes in liquidity following the introduction of a new electronic limit order market when, prior to its introduction, trading is centralized in a single limit order market. They also studied how automation of routing decisions and trading fees affect the relative liquidity of rival markets. The theoretical analysis yielded three main predictions: (i) consolidated depth is larger in the multiple limit order markets environment, (ii) consolidated bid-ask spread is smaller in the multiple limit order markets environment and (iii) the liquidity of the entrant market relative to that of the incumbent market increases with the level of automation for routing decisions (the proportion of "smart routers"). They tested these predictions by studying the rivalry between the London Stock exchange (entrant) and Euronext (incumbent) in the Dutch stock market. The main predictions of the model were supported.

Andreas Heinen with Walid Ben Omrane
The Information Content of Individual FX Dealers' Quoting Activity

The authors investigated the information content of dealers' quoting activity as measured by the frequency of price revisions in the Euro/Dollar foreign exchange market. They used a multivariate double autoregressive conditional Poisson model designed for time series of count data and found that dealers react differently to the same news announcements, some dealers increasing their activity, whilst others decrease it in response to the same news. They attributed this to the heterogeneous interpretation of the news content by individual traders and to the significant influence of some dealers on others. They also found very significant interaction between dealers' quoting activity, which suggests that dealers monitor the quoting activity of others to infer their private information and their interpretation of public news announcements.

Dagfinn Rime with Elvira Sojli and Lucio Sarno
Exchange Rate Dynamics and Order Flow; a re-examination

This paper investigated a range of questions related to the linkages between order flow and exchange rates using 12 months of high-frequency data for four major exchange rates. The main results were that: i) order flow is intimately related to exchange rate movements across all the exchange rates examined; ii) the link between exchange rates and order flow is significantly enhanced, both statistically and economically, by portfolio re-balancing effects via cross-currency order flows; iii) order flow impacts exchange rate movements gradually, which allows the design of simple forecasting exchange rate models that display satisfactory out-of-sample performance; iv) a significant amount of order flow variation can be explained using macroeconomic news suitably constructed from survey data.

3. Assessment of the results, contribution to the future direction of the field

The final discussion session which is obligatory in an ESF exploratory workshop was found to be particularly useful and the following issues were raised with regard to future directions and what we had learnt from the workshop.

New research objectives identified:-

1. There is a need to study the relationship between order flow and risk premia
2. We need to consider the role of policy in these market based models through the integration of policy and the development of policy related market models
3. We need to identify the role of policy instruments in market models
4. We need to integrate these market models more closely with standard finance perhaps through stochastic discount factor -FX asset pricing models.
5. We need to consider the relationship with other asset markets
6. We need to consider how market models relate to new EK open economy models
7. We need to work more on expectation formation in market models
8. Information Structures need to be recognised in the data sets we employ
9. We need to consider multiple time frames in same model
10. Links to O'Hara information (PIN) models need to be explored
11. What are sources of ER volatility?
12. We need high frequency – low frequency and long high frequency datasets

What did we learn?

1. We have major problems getting disaggregate data of the form that is appropriate to properly test the theory currently being developed and so more effort must be put into data sourcing
2. We gained a greater understanding of the relationships between Microstructures → High frequency data → Asset pricing
3. Also between SDF's → Risk premia
4. We have gained a better appreciation of the need to extract information from noise
5. Many were grateful for being exposed to new econometric methods

6. It was recognised that there was too much data description in current high frequency econometric work and more effort should be devoted to testing economic theory and models.
7. We recognised the need to consider the entire set of linkages from macro → market → macro

This discussion has continued after the workshop and an active virtual network has spontaneously become established continuing the discussion started at the end of the Exploratory workshop. We have also discussed the possibility of formally applying for an ESF Research Networking Programme or an action under the Framework Programme. We are currently actively pursuing these possibilities.

4. Final Programme

Monday 26th June 2006

9.00 Coffee

9.10 Introduction by Mark Salmon and the European Science Foundation Dr. Dalina Dumitrescu

Chair Lucio Sarno

9.15 Nikolaus Hautsch (University of Copenhagen)
Generalised autoregressive conditional intensity models with long range dependence

10.00 Ingmar Nolte (Konstanz) with Valeri Voev
Latent factor panel intensity model

10.45 Coffee

11.00 Philippe Bacchetta (Gerzensee) with Eric van Wincoop
Incomplete information processing: a solution to the forward premium puzzle

11.45 Harald Hau (INSEAD) with Michael Moore and Peter Dunn
International order flows: explaining the equity and exchange rate returns

12.30 Richard Lyons (Haas School of Business)
Myths about the micro approach to exchange rates

1.15 Lunch

Chair Mark Salmon

2.00 Winfried Pohlmeier (Konstanz) with Ingmar Nolte and Katrazyna Bien
Estimating Liquidity Using Information on the Multivariate Trading Process

2.45 Joachim Grammig (Univeristat Tubingen) with Erik Theissen and Oliver Wuensche
Time and the price impact of a trade - A structural approach

3.30 Tea

4.00 David Veredas (ECARES-Universite Libre de Bruxelles) with Roberto Pascual
Does the open limit order book explain informational volatility?

4.45 Lukas Menkhoff (Hannover) and Maik Schmelin
Whose trades convey information?

5.30 Finish

7.00 **Meet at Rootes Reception for dinner at Harringtons, Kenilworth - transport provided**

Tuesday 27th June 2006

Chair Nikolaus Hautsch

9.30 Mark Salmon (Warwick) with Roman Kozhan
Can we predict exchange rates in real time; an application of genetic technical analysis using the structure of the order book

10.15 Lucio Sarno (Warwick) with Pasquale Della-Corte and Ilias Tsiakas
Fundamentals, the forward bias and volatility: an economic evaluation of exchange rate predictability

11.00 Coffee

11.30 Kim Christensen (Aarhus School of Business)
Asymptotic theory of range based estimation of quadratic variation of discontinuous semi-martingales

12.15 Neil Shephard (Oxford) with Barndorff-Nielsen, Hansen and Lunde
Designing realised kernels to measure the ex-post variation of equity prices in the presence of noise

1.00 Lunch

Chair Mark Salmon

2.00 Jeremy Large (Oxford)
Price Tick and Welfare when Assets Trade on a Penny

2.45 Albert Menkveld (Vrije Univeristeit Amsterdam) with Thierry Foucault
Competition for order flow and smart order routing systems

3.30 Tea

4.00 Dagfinn Rime (Norges Bank) with Elvira Sojli and Lucio Sarno
Exchange Rate Dynamics and Order Flow; a re-examination

4.45 ESF: Concluding Discussion … Future Directions … outstanding research issues

6.00 Finish

Conference Dinner at Radcliffe House meet 7.00

5.Statistical information on participants

Nationalities:

UK	6
Danish	1
German	6
Swiss	1
Norwegian	1
Italian	3
Greek	2
Dutch	2
USA	3
Russia	1

Total 26 (ESF Representative not included)

Gender repartition:

Female participants: 2 Male participants: 24

6 Final List of Participants

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