Euro's forex role

How has the euro changed the foreign exchange market?

SUMMARY

This paper examines the primary forex statistics for the euro in relation to the German mark prior to 1999. Contrary to widespread expectations, our evidence indicates that the euro lost ground against the US dollar in forex spot trading and in some dimensions does not even match the international transaction role of the German mark. We argue that the euro changed the forex market structure and particularly increased market transparency through currency elimination. The higher market transparency exposes the dealers to higher inventory risk as his inventory imbalances are revealed more easily to other dealers. Dealers in the euro markets recover increased inventory costs through higher spreads that make the euro a less attractive transaction medium than the German mark. We explore the policy implications for the ECB, for euro outsiders and reflect upon the future of the forex market.

— *Harald Hau, William Killeen and Michael Moore*

Economic Policy April 2002 Printed in Great Britain

How has the euro changed the foreign exchange market?

Harald Hau, William Killeen and Michael Moore

INSEAD, Fontainebleau; Setanta Asset Management, Dublin; Queen's University, Belfast

1. INTRODUCTION

The international role of the euro has loomed large in the political rhetoric in favour of the single currency.[1] The creation of the euro was often portrayed as an opportunity for Europe to challenge the post-war dollar hegemony. What is the substance to this agenda more than two years into the experiment? This paper provides new statistical evidence on the international transaction role of the euro and interprets it in the light of our theoretical understanding about the microstructure of the foreign exchange (forex) market.

Traditionally, monetary theory has distinguished the transaction function of a currency from its storage function for private or official investment (central bank reserves).[2] The euro consolidated national investment opportunities into one common financial market without exchange rate risk. This is certainly an accomplishment in itself. But did the single currency also promote the international transaction function of the euro in the forex market? It is only this latter question that we examine in this paper.

This paper expresses the view of the authors and not that of Setanta Asset Management. We would like to thank Tina Kane for her help and advice during this project. Helpful comments were provided by Richard Baldwin, Oliver Burkart, Jean Dermine, Andrew Rose and three referees. The econometric estimation in this paper will form part of Killeen's doctoral thesis at Queen's University. Killeen and Moore wish to thank EBS for providing the data set. Correspondence to Harald.Hau@insead.fr or m.moore@qub.ac.uk.

[1] Charles Wyplosz (1997) calls it the hidden agenda of Europe's long-planned adoption of a single currency.

[2] We refer to Hartmann (1998a) for a good general discussion.

The forex market is special in a number of ways. Section 2 introduces the reader to its main institutional feature. We highlight decentralized market organization, illustrate the inventory management problem of a forex trader and explain why the forex market generates much larger transaction volumes than other financial markets. We also discuss how new electronic trading systems transform the existing market structure.

Section 3 presents the statistical evidence on the international role of the euro. We compare transaction volumes from the triennial survey in April 2001 and the corresponding pre-euro statistics gathered in April 1998 (BIS, 1998, 2001). The data show an important decline in euro related transaction volumes. We use additional volume data from an electronic brokerage system to identify whether the relative volume shortfall in euro rates coincides with the introduction of the euro. Section 3.2 examines evidence on transaction costs. Here we use both indicative dealer quotes from Reuters as well as transaction data from Electronic Broking Services (EBS) to access how transaction costs in the euro have changed relative to the most important predecessor currency, namely the German mark. Generally, euro rates have larger spreads and therefore higher transaction costs compared to the German mark. Moreover, the transaction costs increase coincides with the switchover to the euro in January 1999. Section 3.3 explores whether the higher euro transaction costs can be attributed either to a change in forex volatility or changes in the transaction volumes. The regression evidence suggests that both of these channels cannot explain the higher euro spreads.

How does this statistical evidence relate to our theoretical understanding of international currency dominance and the predictions made about the euro? We have addressed this question in Section 4. Most academic research on the international transaction role of the euro made reference to the so-called *vehicle currency theory*, which emphasizes the role of order processing costs (Wyplosz, 1999; Portes and Rey, 1998; Hartmann, 1998a[3]). Higher volume reduces order-processing costs, lowers transaction costs and therefore fosters the adoption of a particular currency as a vehicle for many bilateral transactions. A euro-yen transaction may thus be replaced by a euro-dollar and a dollar-yen transaction if dollar rates exhibit particularly low transaction costs. The consolidation of external liquidity of many euro-predecessor currencies into a single euro rate should have increased euro volumes and reinforced the vehicle role of the euro. Section 4.2 examines the Reuters quoted spreads in the yen–dollar–euro triangle for every full hour over the period January 1998 to August 1999. The data shows that the euro lost ground as a transaction vehicle relative to the German mark. We then discuss a variety of alternative data explanations.

Section 5 provides a new perspective on the existing statistical evidence. We call this the *market transparency hypothesis*. It argues that the currency consolidation of the euro suppressed the number of parallel markets and thereby increased transparency of the trading environment of the euro rates relative to the multiplicity of previous trading

[3] Hartmann also addresses the microstructure aspects of the vehicle currency theory.

venues. Higher market transparency can impede inter-dealer risk sharing which is crucial to forex traders. Because it is easier to identify their desired trading positions, traders find it more difficult to pass on excess inventories without suffering a capital loss. The increased inventory risk translates into larger trading spreads. The market transparency hypothesis can explain the transaction cost increase for the euro and the associated relative volume decline.

But the market transparency hypothesis has additional testable implications. A potential increase in inventory risk related to a more transparent market may be compensated by a reduced average transaction size. In Section 6.1 we present evidence on the distribution of the trade size in the pre- and post-euro period. We also conjecture that imbalances should generate larger exchange rate adjustment in a more transparent trading environment. Using order flow as a statistical measure for imbalances in desired trading positions, we analyse if such imbalances generate a larger exchange rate impact in the post-euro trading environment. The order flow sensitivities are reported in Section 6.2 and a reduced form model is estimated in Section 6.3.

Section 7 summarizes our findings and highlights the policy implications. We distinguish implications for exchange rate management by the European Central Bank (ECB), extract lessons of the first two years for euro outsiders like Britain and speculate on future developments in the forex market.

2. A FOREX MARKET PRIMER

2.1. What is special about the forex market?

We cannot designate any physical location where forex traders get together to exchange currencies. Rather, traders are located in offices of major commercial banks around the world and communicate using computer terminals, telephones and other information channels. The international scope of the forex market implies the absence of any central regulatory authority. Instead the forex market provides an example of private regulation, where market participants agree on a common set of rules governing transactions and their settlement. Hence, the forex market is certainly not a chaotic realm of lawlessness. In fact ethical and professional standards are essential in an economic environment in which a single verbal agreement on a telephone can commit millions of dollars or euros.

The forex market differs from other financial markets in a number of respects. First, it is by far the world's largest financial market in terms of transaction volume. In April 2001, the daily transaction volume in all currencies is estimated to amount to US$1173 billion a day.[4] This is gigantic even in comparison to a very active equity

[4] This and other statistics on forex market size in this paragraph are taken from the BIS (1998, 2001) surveys of the forex market undertaken in April 1998 and April 2001.

market like the New York Stock Exchange, which reaches an average daily volume of approximately US$75 billion a day. The gigantic forex volume is concentrated in relatively few currency pairs. Approximately 90% of all forex transactions involve the dollar as one of the two currencies in a transaction. Second to the dollar prior to 1999 was the German mark with a 30% representation. The nearest rival in what is now the euro-zone was the French franc with a 5% share of all transactions. The German mark dominated all other European currencies and can therefore be taken as the *de facto* predecessor currency of the euro.

Secondly, the forex market is also a market with extraordinarily low transaction costs. A common measure to express transaction costs is to calculate quoted spreads as the price difference between a buy (ask) and a sell (bid) order for a currency rate relative to the mid-price. Such quoted spreads in the forex inter-bank market can become as low as 0.5 to 1.5 basis points (a basis point is 1% of 1%, i.e. 0.0001) for the most liquid currency pairs. Quoted spreads in equity markets tend to be 50 times larger even for the most liquid stocks.

2.2. Centralized versus decentralized markets

Unlike the forex market most equity and bond markets are organized as *centralized* markets. Historically, traders gathered in one place in which buy and sell orders could meet. Such centralization has the advantage of exposing an order to the maximum number of potential counter parties. But it also has its drawbacks. By indicating his trading interest a dealer simultaneously reveals private information about his inventory or desired trading position. Centralized markets allow other traders to observe all market activity, get a sense of 'where the market goes' and what positions other traders desire. Today, electronic trading platforms have by and large taken over the role of the trading floors. This modern version of a centralized market matches buy and sell orders automatically in electronic order books. The order book allows a trader to expose his order to an even larger group of market participants, who no longer need to be physically present. But electronic trading platforms also reveal the state of the market to all market participants through the computer screen in which the buy and sell orders are listed and transactions immediately revealed. Centralized markets therefore provide maximal order exposure, but also reveal supply and demand imbalances quickly to the entire trading community.

Traditionally, forex trading took place in a *decentralized* market. The state of the market tends to be more opaque since the market operates as a network of bilateral dealer relationships. The dependence on bilateral negotiation limits the exposure of a trading interest to only one counter party at a time, but also preserves the information about the trading desire of the initiating party. Private information is therefore better protected in a less transparent decentralized market structure than in a centralized market.

Recently, two competing electronic trading platforms have emerged as a trading alternative to the traditional over-the-counter market. Both Reuters Dealing 2000–2 and Electronic Brokering Services (EBS) offer competing central market places through electronic terminals. Their combined market share increased considerably over the last 3 years. Estimates by the Bank of England (2001) suggest that electronic brokering systems were used for 66% of all transactions in 2001 up from 30% in 1998. Similarly, the Federal Reserve Bank of New York (2001) estimates the market share of electronic trading systems at 71% in 2001. The increase in electronic trading itself marks an important transformation of the forex market structure and contributes to more market transparency.

2.3. Hot potato trading and its purpose

Why does the forex market generate such gigantic trading volumes? Survey evidence for 2001 indicates that 59% of forex trading involves trading exclusively between forex dealers in commercial banks, while 41% involves transactions between a dealer and a bank customer.[5] Customers are non-dealers in non-financial firms with a volume share of less than 13% of total volume as well as financial firms like mutual, pension or hedge funds, which account for 28% of total volume. If a customer acquires a large foreign currency position from a dealer, the latter holds a risky position in his inventory. A sudden devaluation of the position amounts to a loss of the inventory value. To diminish his inventory risk, the dealer passes all or part of his position on to other dealers, who in turn may sell it to a third dealer and so on. Foreign exchange imbalances may therefore circulate like a 'hot potato' and each consecutive transaction enters into the volume count. This explains the high turnover volume in the forex market (Lyons, 1996a, 1997).

But does the 'hot potato trading' also serve an economic purpose? Two different aspects deserve to be highlighted here. First, 'hot potato trading' disseminates the inventory risk and shares it among many dealers. Shared risk is effectively lower risk. Hot potato trading is therefore a suitable risk-sharing mechanism that mutually benefits all dealers. Secondly, participation in this risk-sharing mechanism is also necessary for each dealer. In the absence of free, centralized information sources about the state of the market, trading itself represents an essential information source. Each transaction provides information about market-wide inventory imbalances and thus helps dealers to anticipate exchange rate changes. Bloomfield and O'Hara (1999) go further and argue that low market transparency increases competition for order flow that becomes more valuable as an information source if transaction prices are not revealed market wide. Spreads may therefore become extraordinarily low not only as a result of better risk sharing, but also because of more dealer competition.

[5] The share of inter-dealer trading has been declining from a volume share of 70% in 1992.

Table 1. Daily euro versus legacy turnover

	April 1998		April 2001	
	$ billion	% of global turnover	$ billion	% of global turnover
External turnover of DEM pairs	382	26.7	–	–
External turnover of other legacy pairs	251	17.6	–	–
Total legacy external turnover	633	44.3	–	–
Turnover of EUR pairs	–	–	440	37.5
Intra-legacy turnover	53	3.7		
Global turnover	1 430	100	1 173	100

Notes: The external DEM pairs consist of USD/DEM, DEM/JPY, DEM/GBP, DEM/CHF and DEM/other. The external 'other legacy pairs' consist of USD/FRF, USD/XEU and USD/other EMS. Intra-legacy turnover consists of DEM/FRF, DEM/XEU, DEM/other EMS, and other EMS/other EMS.

Source: BIS Triennial Survey 2001, Table 4.

3. THE FACTS

3.1. Trading volumes

Publicly available data on the forex market typically concern currency prices, but very limited information is available on other market statistics. An exception are the statistics on trading volume collected by survey every three years for the month of April by central banks and aggregated by the Bank for International Settlement (BIS). The most recent survey provides average daily volume for the month of April 2001 and these numbers can be compared to the last pre-euro survey from April 1998. The survey provides a volume breakdown by currency pair.

Table 1 compares the breakdown of the total daily volume in transactions involving the euro or euro legacy currencies for April 1998 and April 2001. Total spot volume decreased over the three-year period from a daily average of US$1430 billion to US$1173 billion. The dollar consolidated its dominance since it was a counterpart to 90.4% of all transactions in April 2001 compared to only 87.3% in April 1998. The euro was a counterpart in only 37.6% of all transactions with a volume of US$440 billion per day. By comparison, its predecessor currencies generated external volume with non-EMS currencies of 44.3% of total volume or US$633 billion per day. The external euro rates therefore account for 75.1% of the total volume decline registered in the forex market from 1998 to 2001. The euro not only failed to exceed the consolidated external volume but indeed fell short of aggregating the international transaction role of the legacy currencies.

A shortcoming of the BIS data is that it provides only a snapshot for two particular months. Moreover, various structural changes might have affected the forex market, which are not related to the euro. To complement the BIS volume statistics we examine monthly average volume from the most important inter-dealer brokerage system EBS. This data is available as monthly averages of daily volume for the last

Table 2. Pre- and post-euro forex spot volumes in the Electronic Broking System, EBS

	Pre-euro Jan. 98–Dec. 98 (1)	Post-euro Jan.–Dec. 99 (2)	Change (Percentage) (3)	Difference test (*t*-statistics) (4)
Non-euro pairs				
JPY/USD	29.0	25.3	−12.9%	−2.18*
CHF/USD	3.3	5.6	70.8%	4.85**
Euro pairs				
USD/DEM-EUR	45.1	37.9	−17.9%	−2.80**
JPY/DEM-EUR	7.1	4.0	−44.4%	−8.03**
CHF/DEM-EUR	5.3	3.5	−33.7%	−5.65**

Notes: Figures give daily averages in $ billions. We indicate significance at the 5% level (*) and the 1% level (**). *t*-statistics are calculated using White's adjustment for heteroscedasticity.

12 pre-euro months of 1998 and the first 12 post-euro months of 1999. We obtained data on the five currency pairs listed in Table 2. A shorter subsample of this data is graphically presented in Hau *et al.* (2002). We treat the German mark (DEM) as the predecessor of the euro. The time series USD/DEM-EUR therefore contains volumes for the dollar/DEM rate prior to 1 January 1999 and dollar/euro volumes thereafter (ISO-codes for exchange rates are: USD = US dollar, DEM = German mark, JPY = Japanese yen, GBP = pound sterling, CHF = Swiss francs, FRF = French franc, XEU = ecu and EUR = euro). Since the euro consolidated liquidity of many European legacy currencies in one external rate, one might expect euro volumes to surpass DEM volumes for pure accounting reasons. But the EBS volume data presented in Table 2 provides a surprise. Transaction volumes decrease considerably in all three euro pairs, namely the USD/DEM-EUR, the JPY/DEM-EUR and the CHF/DEM-EUR rate. The volume decrease is economically and statistically significant. The euro did not even surpass the external German mark volumes in spite of the consolidation effect. On the other hand the CHF/USD rate registered an astonishing volume increase of 71% in the year following the euro introduction.

The volume evidence from the Electronic Broking Services therefore reinforces the volume evidence from the triennial survey and suggests a decreased international transaction role for the euro. Visual inspection also shows that the volume statistics changed around January 1999 with the creation of the euro (see Hau *et al.*, 2002). We also highlight that this euro volume shortfall is not a consequence of the natural elimination of intra-EMS volume. For both the BIS and EBS data we only considered external EMS rates in the volume comparison.

3.2. Transaction costs

Low transaction costs are an important feature of an international currency. Transaction costs data is therefore essential for any evaluation of the euro's role relative to

its most important predecessor currency, the German mark. Measurement of these costs poses a number of problems. Forex dealers generally charge much higher spreads to customers than to other dealers. We therefore distinguished the customer trades from inter-dealer trades.

Customer trades amount to 41% of the volume in the forex market in 2001 (BIS, 2001). Transaction data in this market segment is generally not available. In order to access transaction costs we resort to quotes disseminated through the Reuters quote system. Dealers use the Reuters indicative quote system to advertise their quotes to forex customers. The transaction price itself depends on the customer. Larger customers may achieve more favourable prices than those provided by the Reuters quotes. But in the absence of customer transaction data, the Reuters quote data is the best available information source. Reuters quoted data is also available at relatively high frequency. Hau *et al.* (2002) analyse the best buy and sell quote in five different currency rates at every full hour for 12 months prior and 8 months after the introduction of the euro. Treating the German mark as the *de facto* euro predecessor currency, they obtain the following results. The two non-euro pairs JPY/USD (yen/dollar) and GBP/USD (pound/dollar) indicate an economically small spread decrease of 6% and 9%, respectively. It is significant in statistical terms only for the pound/dollar pair. By contrast, the three euro rates USD/DEM-EUR (for dollar/euro in 1999 and the dollar/DEM in 1998), JPY/DEM-EUR (yen/euro) and GBP/DEM-EUR (pound/euro) show economically and statistically highly significant spread increases of 40%, 62% and 195% respectively. Visual inspection of the time series confirms that the spread increase coincides with the introduction of the euro.[6] The Reuters quote data therefore suggests an important transaction cost increase for the euro relative to the German mark.

At the same time electronic brokering has gained in importance. In 1998 only 50% of all inter-dealer trades were electronically brokered and the remaining 50% were negotiated directly. This balance has shifted in favour of the two major electronic inter-dealer systems Reuters Dealing 2000–2 and EBS. In particular, EBS seems to have profited more from the increasing role of electronic brokering and its transaction data allows a valuable crosscheck of the transaction cost pattern in the Reuters quotes data. EBS transaction data was obtained for the two months of August 1998 and August 1999 in the five currency pairs listed in Table 3. The electronic brokerage system registered the last buy and sell transaction at each full hour. The hourly transaction spreads are averaged over the 24 hours and analysed as a daily transaction costs series.

Table 3 summarizes the results for the pre- and post euro period. Data on the pound/dollar rate was not available because EBS has a relatively small market share in this rate. Not surprisingly, transaction spreads in the inter-dealer market segment are considerably smaller than the Reuters quoted spreads communicated to the customer

[6] For diagrams of this data, see Hau *et al.* (2002).

Table 3. Pre- and post-euro transaction spreads in the Electronic Broking System, EBS

	Pre-euro August 1998 (1)	Post-euro August 1999 (2)	Change (3)	Difference test (*t*-statistics) (4)
Non-euro pairs				
JPY/USD	0.82	1.04	26.6%	2.13*
CHF/USD	2.03	1.28	−37.3%	−3.03**
Euro pairs				
USD/DEM-EUR	0.50	0.73	44.2%	5.76**
JPY/DEM-EUR	1.39	2.74	97%	7.44**
CHF/DEM-EUR	0.72	0.43	−39.5%	−6.76**

Notes: We indicate significance at the 5% level (*) and the 1% level (**); *t*-statistics are calculated using White's adjustment for heteroscedasticity.

segment. But our main interest concerns the transaction cost change from the pre- to the post euro period. For the JPY/USD rate we find a spread increase of 27%, but it is only marginally significant in statistical terms. The spread increase is economically and statistically more significant for the two euro pairs USD/DEM-EUR (44%) and JPY/DEM-EUR (97%). The transaction data also contains two time series involving the Swiss franc, namely the CHF/USD and the CHF/DEM-EUR rate. Both show a noticeable decrease in transaction costs suggesting a stronger role for the Swiss franc in the post-euro environment. But we also note that the Swiss franc benefited from lower volatility in August 1999 compared to August 1998.[7] Overall the transaction data confirms our conclusion about higher spreads after January 1999. This evidence on higher transacted spreads in the euro rates reinforces the conclusion obtained from the volume data about a diminished international transaction role for the euro.

Finally, we highlight an independent study[8] by Love (2001) with qualitatively similar results. He analyses transaction data in the USD/DEM-EUR market from the trading system Reuters Dealing 2000–2 for five days in October 1997 and compares the effective pre-euro spreads with the post-euro spreads from 28 September 1999 to 8 March 2000. Reuters data shows an average spread of 1.42 basis points for USD/DEM transactions relative to 2.79 basis points for USD/EUR trades. This 95% cost increase even exceeds the 44% increase found in the EBS data.[9] We therefore conclude that our qualitative inference about increased post-euro transaction costs is not specific to the EBS trading platform, but extends to the Reuters system.

[7] The standard deviation of daily returns for CHF/DEM was 4.96% in August 1998 compared to 3.38% for the CHF/EUR in August 1999, which amounts to a 32% volatility decline.

[8] We are grateful to Charles Goodhart for drawing this to our attention.

[9] The magnitude of Love's spreads is greater than ours both pre- and post-euro. This is a reflection of the different calculation method used.

3.3. The role of volume and volatility for spreads

The evidence in support of higher transaction costs in the euro relative to the DEM does not account for other economic market changes. One may reasonably expect that spreads depend on volume as well as on exchange rate volatility. Both of these spread determinants might have changed from 1998 to 1999. Higher exchange rate volatility may increase the dealers' inventory risk. As a compensation for the additional risk, dealers may require larger and more profitable spreads. We therefore expect a positive correlation between exchange rate volatility and spreads. Larger transaction volumes, particular in the customer segment, may on the other hand increase dealer-trading profits and inter-dealer competition may narrow spreads. The effect of monthly volume changes on spreads should therefore be negative.[10] Can these changes account for the increase in spreads?

We develop a simple test to examine whether simultaneous changes in volatility and volume account for the observed increase in euro related spreads documented in Section 3.2. For this purpose we construct a panel data set that measures not only spreads, but also volatility and volume. Since inventory holding periods in the forex market are short, we measure volatility at the highest available frequency, namely over hourly intervals. Both volume and realized volatility statistics are available only for three currency pairs, namely JPY/USD, USD/DEM-EUR and JPY/DEM-EUR with 20 observations for each pair.

For each of these three exchange rates, we explore the impact of the euro by estimating a one-off shift in the spread size from January 1999, controlling for volatility and volume. We also include a lagged spread to allow for a slow adjustment to the driving variables. Because the spread size affects volume as well as vice versa, *inter alia*, our estimates from this procedure might suffer from a confusion-of-causality problem, but a formal test reveals that our estimates are not affected by this problem to any significant extent (see Table A1 in the appendix for details). Tables 4 and 5 show our results.

In accordance with economic theory, we find that higher volatility tends to increase spreads and higher volume tends to decrease spreads.[11] But it is also clear that the volatility and volume statistics cannot explain the increase in the spreads for the two euro-rates for 1999. The euro-effect variable is highly significant for both the USD/DEM-EUR and the JPY/DEM-EUR currency pair, while it is insignificant for the USD/JPY rate. The unrestricted specification reveals in particular that the transaction costs in the important USD/DEM-EUR are not very dependent on either monthly volatility or volume, but a very strong one-time upward shift in transaction costs for 1999 captured by the euro-effect variable. We conclude that neither market

[10] Previous work by Bessembinder (1994) and Hartmann (1998a) distinguished between expected and unexpected volume changes. Unlike predicted volume changes, unpredictable volume changes might reflect asymmetric information and therefore increase spreads. But the distinction between expected and unexpected volume changes only matters for high frequency data. Low frequency (monthly) volume movements should be dominated by predictable components.

[11] See also Hartmann (1998) for a pure cross-sectional examination with similar results.

Table 4. Can volume and volatility changes explain the spread?

	Constant	Post-euro effect	Volume	Realized volatility	Lagged spread	Adj. R-squared	Ljung–Box Q (*p*-value)	Breusch–Pagan het. (*p*-value)
DEM-EUR/USD spread	6.25**	2.67**	−0.13	−0.01	−0.61**	0.973	4.14	2.28
	(1.11)	(0.17)	(0.31)	(0.01)	(0.08)		(0.246)	(0.131)
USD/JPY spread	5.54**	−0.08	−0.62*	0.02**	0.35**	0.794	4.09	0.51
	(1.339)	(0.11)	(0.302)	(0.003)	(0.112)		(0.251)	(0.774)
DEM-EUR/JPY spread	8.2**	1.39**	−2.57**	0.05**	0.2	0.939	6.31	3.8
	(1.75)	(0.44)	(0.65)	(0.01)	(0.15)		(0.097)	(0.051)

Notes: Standard errors in parentheses (in last two columns the figures are *p*-values). Significance at the 5% level indicated by (*) and the 1% level by (**). 'Post-euro effect' is a time dummy equal to one from January 1999 and zero before. 'Volume' is the log of the monthly average of daily EBS volumes. 'Realized volatility' is the log of the square root of the sum of the squared return of the Reuters hourly mid-price (between ask and bid price) aggregated into one monthly observation (see Andersen *et al.*, 2001 on the concept of realized volatility based on high frequency data). The Ljung–Box Q statistics test for up to third order autocorrelation. The Breusch–Pagan statistic tests for heteroscedasticitiy in the errors with respect to the constant and time dummy. We work with monthly data from January 1998 to August 1999 (i.e. 20 observations per currency pair). The equation estimated is: $\text{SPREAD}_{i,t} = \alpha_i + \beta_i \text{VOLATILITY}_{i,t} + \gamma_i \text{VOLUME}_{i,t} + \delta_i \text{TIME\_DUMMY}(1{=}99) + \text{SPREAD}_{i,t-1} + \varepsilon_{i,t}$. It is estimated with SUR.

Table 5. Explaining the spread: further statistical consideration

	Constant	Post-euro effect	Volume	Realized volatility	Lagged spread	Adj. R-squared	Ljung–Box Q (*p*-value)	Breusch–Pagan het. (*p*-value)
DEM-EUR/USD spread	7.58**	2.32**	−0.64*	0.02**	−0.5**	0.96	7.76	1.19
	(0.85)	(0.14)	(0.21)	(0.00)	(0.08)		(0.051)	(0.166)
USD/JPY spread	5.67**	−0.07	−0.64*	0.02**	0.33**	0.79	3.69	0.23
	(1.01)	(0.11)	(0.21)	(0.00)	(0.107)		(0.296)	(0.629)
DEM-EUR/JPY spread	8.79**	2.32**	−2.28**	0.04**	–	0.92	6.15	2.66
	(0.73)	(0.14)	(0.43)	(0.01)	–		(0.11)	(0.102)

Notes: We indicate significance at the 5% level (*) and the 1% level (**). The four restrictions on SUR estimation are (1) setting the USD/DEM-EUR 'Euro effect' Dummy coefficient equal that of DEM-EUR/JPY, (2) and (3) setting both USD/DEM-EUR volume and volatility coefficients equal to the respective coefficients in the USD/JPY equation and (4) setting the lagged spread in the DEM-EUR/JPY to zero. The $\chi^2(4)$ test for the restrictions is 4.63 with *p*-value 0.326.

volatility nor volume changes account for the higher transaction costs in euro-rates. Love (2001) estimates a comparable regression on Reuters Dealing 2000−2 USD/DEM-EUR data. He also finds that that volume and volatility cannot fully explain the increase in spreads following the creation of the euro.

3.3.1. Explaining the spread using daily data. The above results were obtained for monthly observations for all three currency-rates because of limited data availability. But for the USD/DEM-EUR rate we also obtained daily volume data

from EBS and can therefore repeat the spread regression for daily observations. Previous work (Bessembinder, 1994; Hartmann, 1998a) has shown that for high frequency observations a distinction between predictable and unpredictable volume becomes important; this leads us to undertake a two-step procedure. The first step uses a standard statistical procedure that permits us to separate the actual volume into a predictable component of volume and an unpredictable component (namely, an ARMA(4,4) time series model). The second step is to repeat the statistical analysis of the spread we undertook in Table 4, but this time including predictable and unpredictable volume separately (and lagged terms) in the regression.

Using this more refined procedure we find that unpredicted volume has no impact (statistically speaking) on the bid-ask spread (it was therefore excluded from the regression). Predicted volume on the other hand enters significantly and has the expected negative sign. Most importantly, the results (reported in Table A2 in the appendix) show again a positive and statistically significant euro-effect. The daily data therefore upholds our claim that there was a spread increase in 1999 unexplained by volume and volatility changes.

Finally, we quantify the spreads increase. The dummy coefficient tends to overestimate the long-run magnitude of the spread increase in the presence of negative serial autocorrelation in spreads. Correcting for this implies a total spread increase of approximately 1.54 basis points for the USD/EUR relative to the USD/DEM rate (for details see Table A3 in the appendix). This attributes a 41% increase in the spread to the creation of the euro. From Table 2, this means that the monetary union is responsible for essentially all of the spread increase in this pair between 1998 and 1999. For the JPY/DEM-EUR series spreads enlarge on average by 2.32 basis points in the post-euro period. This amounts to a 45% increase or about half the observed increase for this pair (see Table A3). We also note that the spread enlargement estimated for daily and monthly observations in the USD/DEM-EUR rate give very similar results and are therefore consistent with each other.

4. HOW TO EXPLAIN THE EVIDENCE?

4.1. The vehicle currency hypothesis

The academic debate about the international role of the euro focused on the so-called vehicle currency theory. This theory was grounded in the observation that currencies with a high volume share like the dollar are also characterized by particularly low transaction costs. It was therefore enough to emphasize the role of order processing costs for spread determination. If there are important fixed costs to a dealership presence in a particular market, then high volume markets should have, *ceteris paribus*, lower average order processing costs per unit of transaction volume. A competitive dealership market then implies that currencies with high volume should

have lower spreads. The dealers' fixed costs are recovered from more transactions, making each transaction on average cheaper.

This inverse relationship between transaction costs and volume has important implications for the emergence of a dominant international currency. A transaction from the euro into the Japanese yen could either be undertaken directly in the euro/yen currency pair, or as two consecutive transactions via the dollar as a so-called vehicle currency. In the latter case the euro balances are exchanged against the dollars and the dollars against the yen. This two-step procedure is more advantageous if the combined transaction costs in the euro/dollar and dollar/yen market are below the transaction costs in the direct euro/yen pair. Let $SPREAD_{JPY/EUR}$, $SPREAD_{USD/EUR}$ and $SPREAD_{JPY/USD}$ denote the respective percentage spreads in the three triangular currency pairs. A hypothetical 'roundtrip' of buy and immediate sell in the euro/yen rate implies transaction costs $SPREAD_{JPY/EUR}$. Undertaking the same roundtrip using both the euro/dollar and the dollar/yen market results in transaction costs $SPREAD_{USD/EUR} + SPREAD_{JPY/USD}$. The cost saving for the direct transaction relative to the intermediate use of the dollar can be expressed as

$$TSD^{USD} = SPREAD_{JPY/EUR} - SPREAD_{USD/EUR} - SPREAD_{JPY/USD},$$

where we define TSD^{USD} as the 'triangular spread differential' for the US dollar. A low value for TSD^{USD} will tend to consolidate the direct euro/yen market. If, on the contrary TSD^{USD} increases, the international currency status of the dollar is strengthened. If $TSD^{USD} > 0$, the dollar dislodges the direct euro/yen market and becomes the vehicle currency in the euro-yen-dollar triangle. Once a particular currency has vehicle currency status, it accumulates all the transactions volume of otherwise bilateral exchanges. This explains why according to the Bank for International Settlement (BIS) survey for 2001 approximately 90% of all transactions in the forex market involve the dollar. These high volumes then explain why spreads in the dollar markets are very low compared to the direct non-dollar rates.

What does the vehicle currency theory imply for the international transaction role of the euro? The monetary union is essentially interpreted as a pure liquidity consolidation of the eleven external rates in one single exchange rate.[12] This consolidation effect should increase euro relative to DEM volumes and decrease euro spreads due to scale economies. Lower spreads again have a positive feedback effect on volume and this may reduce spreads even further. The evidence on the euro volumes and spreads shows that the opposite effect was observed, namely that volumes declined and spreads increased in euro rates. This suggests that the role of scale economies in order processing have been over-estimated and that other structural effects related to the euro might be more important. But the vehicle currency theory suggests that the triangular spread differential (TSD) might be a useful statistic to explore a shift in

[12] On 1 January 2001, Greece joined as the twelfth euro member.

international currency status. We examine these statistics in more detail in the following section.

4.2. Evidence on triangular spreads

Measuring transaction costs by spreads (expressed in basis points), we can therefore define the triangular spread differential TSD as the difference between the direct spread and the sum of the two indirect spreads:

$$\mathrm{TSD}^{\mathrm{DEM\text{-}EUR}} = \mathrm{SPREAD}_{\mathrm{JPY/USD}} - \mathrm{SPREAD}_{\mathrm{JPY/DEM\text{-}EUR}} - \mathrm{SPREAD}_{\mathrm{USD/DEM\text{-}EUR}}$$

$$\mathrm{TSD}^{\mathrm{USD}} = \mathrm{SPREAD}_{\mathrm{JPY/DEM\text{-}EUR}} - \mathrm{SPREAD}_{\mathrm{JPY/USD}} - \mathrm{SPREAD}_{\mathrm{USD/DEM\text{-}EUR}}$$

$$\mathrm{TSD}^{\mathrm{JPY}} = \mathrm{SPREAD}_{\mathrm{USD/DEM\text{-}EUR}} - \mathrm{SPREAD}_{\mathrm{JPY/USD}} - \mathrm{SPREAD}_{\mathrm{JPY/DEM\text{-}EUR}}.$$

A negative triangular spread differential $\mathrm{TSD}^{\mathrm{USD}} < 0$ implies that the direct market transaction in the euro/yen pair is difficult to dislodge by two vehicle transactions involving the dollar. The larger the triangular spread differential, the more attractive it becomes to use the indirect transaction route. The vehicle differential therefore presents a direct (transaction cost-based) measure of international currency status.

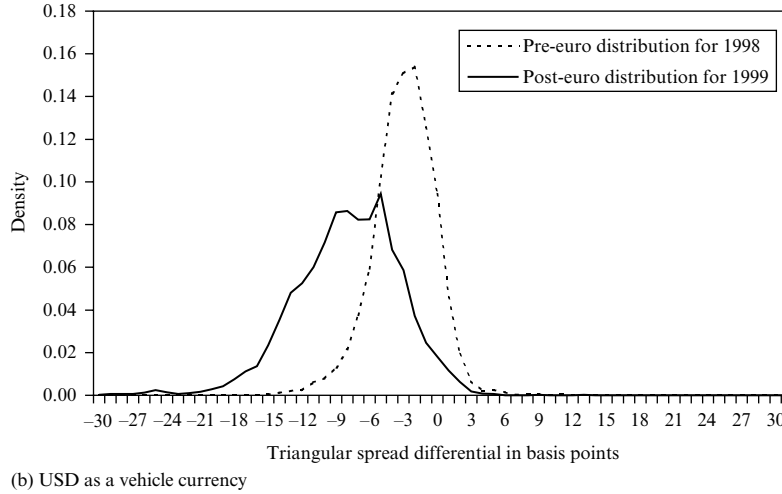
Did the triangular spread differential increase for the move from the German mark to the euro? We use 14 592 hourly spread observations based on Reuter quotes to calculate the distribution of the triangular spread differential for the above three currency pairs. Figure 1(a)–(c) plots the respective density distributions separately for the pre- and post-euro period. The vehicle differential for the euro shows a clear distributional shift to the left indicating a loss of international currency status from 1998 to 1999. No such shift can be identified for the dollar or yen triangular spread differentials. Using the euro as a vehicle is therefore on average more expensive compared to the German mark. We interpret this as evidence against an increased international transaction role of the euro relative to the German mark.

It is also interesting to verify if the loss in vehicle currency status for the DEM-EUR currency coincides with the inception of the euro in January 1999. We therefore plot monthly average triangular spread differentials for the German mark before 1998 and for the euro thereafter.

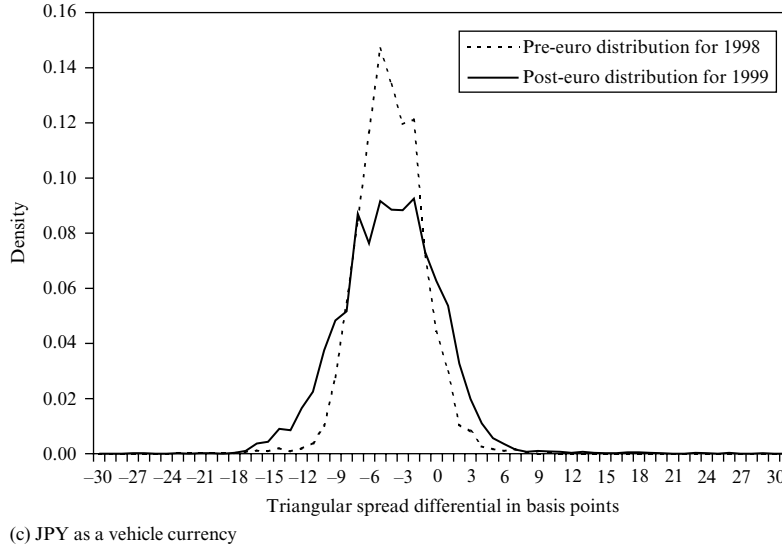
Figure 2(a) shows a clear decline by more than 2 basis points from December 1998 to January 1999. This decline further continues over the following two month to reach a level below −8 basis points. We can therefore date the reduced euro vehicle status for the beginning of 1999. The corresponding graph for the USD plotted in Figure 2(b) shows a lower triangular spread differential only for January 1999 before it bounces back to the previous value of just below 4 basis points. Finally, Figure 2(c) represents the yen as a relatively unattractive currency vehicle. But there is no change in this situation between 1998 and 1999.

The visual inspection of these graphs is supported by a statistical analysis, the results of which are presented in Table 6. This shows that the triangular spread

(a) DEM/euro as a vehicle currency



(b) USD as a vehicle currency



(c) JPY as a vehicle currency

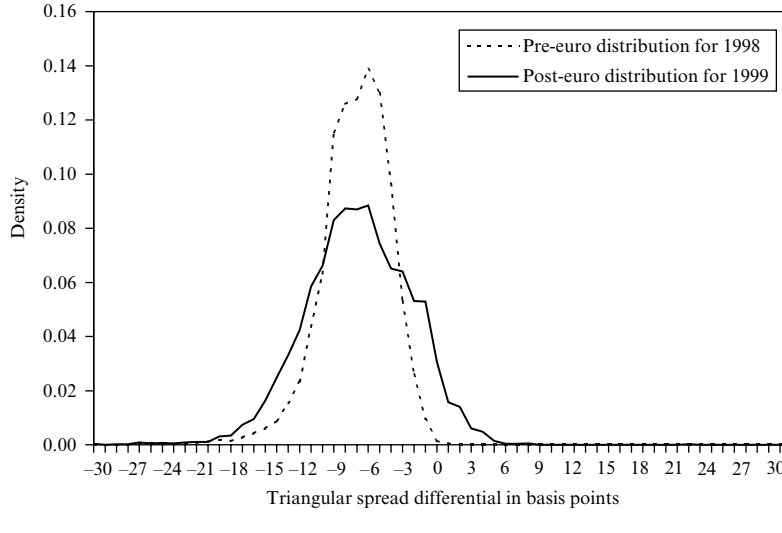


Figure 1. Pre- and post-euro TSDs

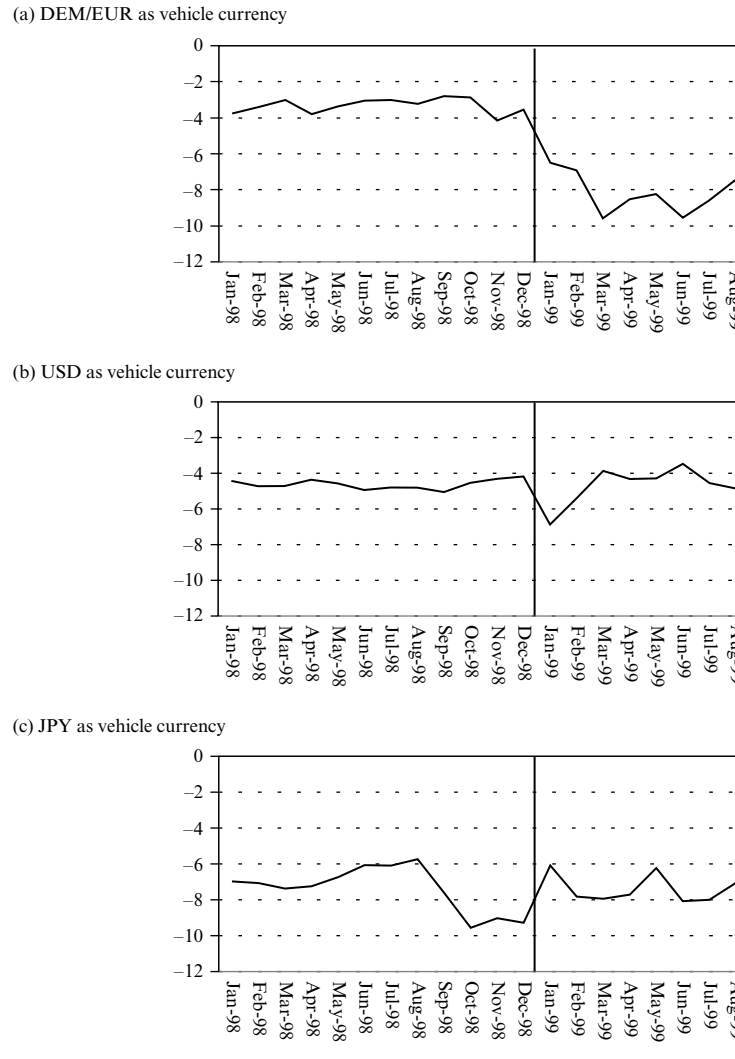


Figure 2. Time plots of TSDs: Did something change in January 1999?

differential for the euro demonstrates a statistically significant deterioration for the euro vis-à-vis the DEM. The differential for the dollar and the yen shows no statistically significant change.

4.3. Explanations unrelated to the euro

In its preliminary report on its triennial survey of foreign exchange markets (BIS, 2001), the Bank for International Settlements points to the fall in global forex turnover and states that 'The introduction of the euro, the growing share of electronic brokering in the spot interbank market and consolidation in the banking industry appear to have been the main factors driving this fall in foreign exchange market

Table 6. Testing for a change in the triangular spread differentials (TSD)

Vehicle currency pair	Pre-euro Jan. 1998–Dec. 1999		Post-euro Jan. 1999–Aug. 1999		Difference test *t*-statistics
	Mean[a]	St. Dev.	Mean	St. Dev.	
	(1)	(2)	(3)	(3)	(4)
TSD for DEM-EUR[b]	−3.45	0.006	−7.39	0.050	−22.47**
TSD for USD[c]	−4.57	0.007	−4.57	0.020	−0.01
TSD for JPY[d]	−7.61	0.010	−7.40	0.021	1.22

Notes: We indicate significance at the 5% level (*) and the 1% level (**). The *t*-statistics are heteroscedasticity consistent.

[a] To calculate mean, standard deviation and *t*-statistic we use 8670 hours of data from 1 January 1998 to 31 December 1998 and 5810 hours of data from 1 January 1999 to 31 August 1999. The time series is filtered for 24 hour and weekly seasonality effects.

[b] The DEM-EUR triangular spread differential is calculated hourly as USD/JPY spread minus the sum of the DEM-EUR/USD and DEM-EUR/JPY spreads.

[c] The USD triangular spread differential is calculated hourly as JPY/DEM-EUR spread minus the sum of the USD/DEM-EUR and JPY/USD spreads.

[d] The JPY triangular spread differential is calculated hourly as USD/DEM-EUR spread minus the sum of the JPY/DEM-EUR and JPY/USD spreads.

turnover'. The Bank goes on to explain that 'the main impact of the introduction of the euro appears to have been through the elimination of intra-EMS trading'. We argue that these three and a number of other explanations cannot account for the data described above.

The elimination of intra-EMS volume is certainly not the major structural change. According to Table 1 intra-EMS trading amounted to only 3.7% of global forex volume in 1998. The deletion of this turnover cannot explain why the *external* turnover of the euro is so much less in both absolute and proportionate terms than the aggregate *external* turnover of the legacy currencies.

The expansion of electronic brokering appears to be a more important structural change. But can it explain the evidence? It is undoubtedly true that both Reuters Dealing 2000–2 and EBS have increased their shares of the inter-dealer market. But this technological trend applies to all currency pairs. The evidence in Table 2 shows that EBS volumes in euro pairs fell disproportionately following the introduction of the euro, while the electronically brokered turnover in the dollar/swiss pair actually increased. Independently, Love (2001) also reports on the trading volume in USD/EUR compared to USD/DEM. The daily average number of DEM/dollar trades in his sample was 6027 trades per day. Euro/dollar trading volume is less than half of this number at 2864 trades per day.

We are aware of three other explanations for the data, namely the volatility, tick-size and transition hypotheses. The volatility hypothesis argues that the increase in the spreads of euro-pairs is attributable to the higher volatility of the euro. The evidence in Tables 4 and 5 shows that the sensitivity of spreads to volatility cannot explain the higher euro spreads compared to those of the DEM. The tick-size

hypothesis maintains that forex prices are quoted in nominal units of full integers called pips. Quotation in pips generates minimum price steps and the percentage value of a single price step depends on the currency denomination. If dealers continue to quote the same spread of 5 pips in the euro/dollar rate which they used to quote in the DEM/dollar rate, then the spread increases in percentage terms. The higher proportionate spreads in euro-pairs are then simply a consequence of persistent institutional quoting practices. The tick size hypothesis is essentially an argument for money illusion among professional forex traders, which is rather difficult to believe. Finally, the transition hypothesis argues that the empirical phenomena outlined here are of a transitory nature. Again, one expects the world's most liquid financial market to reach its equilibrium characteristics in less than three years.[13]

5. AN ALTERNATIVE MICROSTRUCTURE EXPLANATION

5.1. Parallel markets

The creation of the euro not only consolidated external liquidity in one single external euro rate, but it also eliminated parallel markets and therefore greatly reduced market complexity. A mutual fund manager who wanted to liquidate a large US dollar position could either sell dollars for German marks or sell dollars for French francs. Given the relative stability of the intra-EMS rates both the dollar/mark and the dollar/franc market represented parallel markets for transactions that are close substitutes. This situation is also referred to as market fragmentation.

An example for market fragmentation is the cross listing of stocks in two competing equity markets. A Dutch stock may be listed in Amsterdam as well as at the New York Stock Exchange. How does market fragmentation effect transaction costs? In a recent study on cross-listed Dutch stocks, Menkveld (2000) shows that traders prefer to trade during the overlapping period when both the markets are open. Moreover, they use the parallel market structure to split their orders and thus minimize their price impact. This allows them to reduce the risk of capital losses associated with trading large quantities in a single market.

5.2. Can market transparency be harmful?

A market is transparent if aggregate dealer imbalances and therefore their trading desires can be inferred from the market process.[14] Fragmentation of the market structure into parallel markets tends to reduce market transparency. For an individual dealer with

[13] For additional discussion on these alternative hypotheses see Section 2.5 of Hau *et al.* (2002): 'The euro as an international currency: explaining puzzling first evidence from the foreign exchange markets'.

[14] We highlight that our use of the term 'market transparency' is very different from a legal connotation of transparency which considers a market transparent if the rules governing the contractual relationships are clear.

a large inventory imbalance lower market transparency is advantageous. His desired inventory change constitutes valuable information because it may imply a future exchange rate change once it becomes publicly known. His interest is therefore to hide his trading desire in order to avoid an immediate capital loss and at the same time reduce his imbalance through trading. These two objectives are obviously conflicting. In this case parallel markets are useful because they allow him to disperse his inventory through various trading routes and render inference by other dealers more difficult.

But the dealer worries not only about the price impact of his own trades. In fact if other dealers anticipate his inventory imbalance based on the pattern of his past trades, they might engage in front running. Front running means that a competing dealer acquires a position opposite to his own and thereby accelerates the exchange rate adjustment or indeed leads to exchange rate overshooting. Assume, for example, a dealer *A* has a large positive (long) dollar position and a negative balance (short position) in euros following a client transaction. The position may be too large to reverse in a single transaction. Instead, he reduces his inventory risk by selling dollars and buying euros in a sequence of trades. Furthermore, assume all other traders have a balanced inventory. A dollar depreciation against the euro tends to follow as someone has to be induced to hold the dollar excess balances. Dealer *B* learns about this situation and buys euros for dollars prior to the dollar depreciation. He thus engages in front running. This further increases the shortage of euro balances and depreciates the dollar value. In a second step dealer *B* then sells the euro balances to dealer *A* at a much higher euro currency price and earns a trading profit. At that stage, part of the dollar depreciation is reversed. For trader *A*, front running activity implies higher trading costs and increases the benefit of hiding his own desired position. The latter task becomes easier if the market is relatively opaque. By contrast, a highly transparent market facilitates anticipation of desired positions and encourages front running.

Concerns about 'parasitic' front running have also influenced the design of centralized electronic trading systems. The Paris and Toronto stock exchanges, for example, allow dealers to conceal the size of limit orders. The order book may indicate only a proportion of the desired position, but not the full amount. Harris (1997) argues that higher market transparency is particularly problematic for markets with low transaction costs. He documents that the possibility of hiding quote size is used more frequently for stocks with low transaction costs (Harris, 1996). This suggests that market transparency changes may be particularly critical for financial markets with very low transaction costs like the forex market. The low transaction costs further encourage front running and render the transaction costs more sensitive to any change in market transparency.

5.3. Market transparency hypothesis

Did the creation of the common currency change the structure of the international forex market? Many actively traded currency rates like the USD/DEM and the

USD/FRF rate represented reasonably close trading alternatives and could therefore be considered as parallel markets. The euro consolidated these parallel markets into a single USD/EUR rate. The market transparency hypothesis asserts that this loss of parallel markets increased market transparency with respect to aggregate inventory imbalances. A forex dealer therefore finds it more costly to dispose of individual imbalances to attain his desired inventory position.

Equity traders prefer to trade a cross-listed Dutch stock at a moment when both the Amsterdam and New York stock exchange market (NYSE). Similarly, forex traders might profit from a multiplicity of parallel currency markets to reach their desired currency positions. Liquidity consolidation in a single market can be harmful because accelerated price discovery tends to make the disposal or acquisition of large forex positions more costly. We also highlight that accelerated price discovery is detrimental to inter-dealer risk sharing. The so-called hot potato trading described before is mutually beneficial only if the inventory risk is shared between dealers prior to full price discovery.

The market transparency hypothesis can explain various aspects of the data. First, it can account for the spreads increase shown in Table 3. Secondly, it implies that this increase in transaction cost should coincide with the introduction of the euro as documented in Figure 2. Thirdly, it provides an explanation why the spread increase occurred specifically for the euro rates. The German mark, as the euro predecessor, profited most from the parallel markets of the pre-euro forex system.

6. TESTING THE MARKET TRANSPARENCY HYPOTHESIS

The market transparency hypothesis has two additional testable implications. A larger inventory risk should not only lead to higher spreads, but also to a reduction of the maximum trade size to which a forex quote applies. Lower trade size limits effectively reduce the steps in which undesired inventories can accumulate and therefore reduce a trader's risk exposure. A second implication concerns the aggregate inter-dealer risk-sharing capacity of the market. Reduced aggregate risk sharing should generate a larger price impact for the net supply shocks from forex customers. Both implications are now examined in more detail.

6.1. Evidence on transaction size

Did the new post-euro market structure feature higher dealer inventory risk as the market transparency hypothesis asserts? If this is indeed the case we should expect dealers to adjust their average trade size downwards. If any quote price can be obtained only for a smaller volume, then the dealer reduces his exposure due to quote provision. We can directly verify this implication for the dollar/DEM-EUR rate for which we have two years of order flow data. We define daily average trade size as the ratio of the daily trading volume to the number of trades. Table 7 reports the average

Table 7. Pre- and post-euro trade size: DEM/EUR-USD, daily averages

	Pre-euro Jan.–Dec. 1998 (1)	Post-euro Jan.–Dec. 1999 (2)	Change % (3)	Difference test *t*-statistics (4)
Number of trades	20 933	19 768	−5.6	−2.11*
Trade size ($ millions)	2.154	1.990	−7.6	−18.8**
Trade size (DEM millions)	3.793	3.653	−3.7	−7.3**

Notes: We indicate significance at the 5% level (*) and the 1% level (**). The *t*-statistics are heteroscedasticity consistent.

daily trade size both in dollars (USD) as well as in German marks (DEM) for the pre- and post-euro regime. Both the number of trades and the volume decreased. But the volume fell more than the number of trades, implying a reduced average trade size. The average daily trade size decreases by −7.6% in dollar term and by −3.7% in German mark terms. This fall in the average trade size is statistically highly significant independently of the currency of measurement. Figure 3 provides a graphical representation of the shift of the trade size distribution from 1998 to 1999. We interpret the reduction in average trade size as the dealer response to higher inventory risk under the post-euro market structure.

6.2. Evidence on 'order flow' sensitivity

The important role of inventory risk highlighted in the microstructure literature suggests that temporary demand and supply imbalances – what is called 'order flow' in the microstructure approach to the forex market – should have a price impact if the dealers are risk averse and unwilling to buffer substantial imbalances.[15] Moreover, the market transparency hypothesis asserts that the inventory risk increases in the more transparent post-euro regime, so if the transparency hypothesis is right, the exchange rate should be more sensitive to order flow in the post-euro period.

We can test this implication by comparing the pre- to the post-euro order flow sensitivity. Order flow sensitivities have previously been estimated by Evans and Lyons (2001a), Rime (2001) and Killeen *et al.* (2001). Here we generalize the empirical specification by allowing for a one-off change in the exchange rate's order flow sensitivity subsequent to the introduction to the euro. To this end, we use a 'dummy variable' that takes on the value of zero for observations in 1998 and one for observations in 1999. Interacting this with the order flow allows us to measure the change in sensitivity.

Table 8 reports our findings. The order flow has the predicted and highly significant positive correlation with contemporaneous exchange rate changes.

[15] If a forex dealer gets an order to sell $10 million and he fulfils this, the forex volume is $10 million, but the order flow is minus $10 million since the active, or initiating side wished to sell. Order flow measures the sum of the buyer-initiated minus seller-initiated orders; a negative sum reflects net selling pressure over the period.

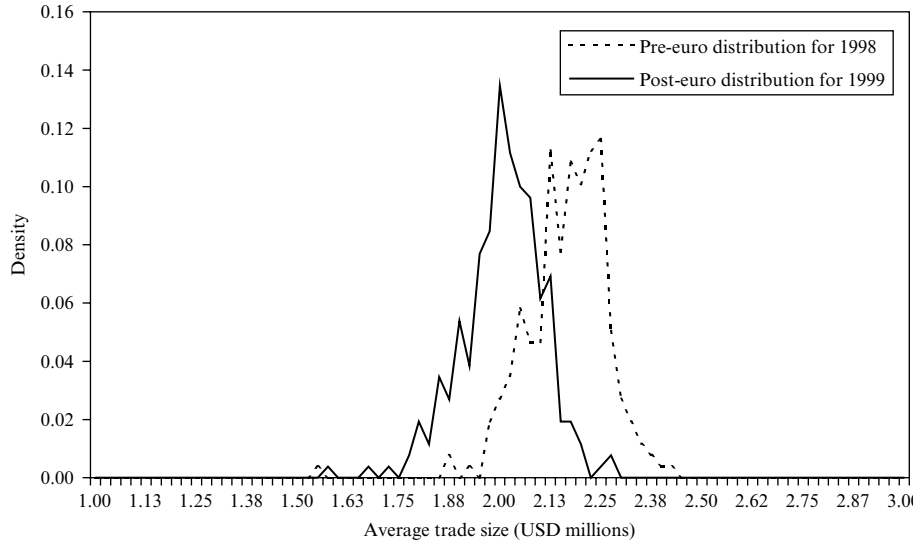


Figure 3. Pre- and post-euro of trade size distribution for USD/DEM-EUR

Table 8. Pre- and post-euro order flow sensitivity of the exchange rate

	Coefficient (1)	*t*-statistics (2)
Constant	−0.263	−6.91**
Time dummy	0.527	11.15**
Order flow	0.247	9.58**
Order flow * time dummy	0.104	2.97**
$\Delta \log E_{t-1}$	−0.080	−1.29
$\Delta \log E_{t-1}$ * Time dummy	−0.134	−1.72*

Notes: We indicate significance at the 5% level (*) and the 1% level (**). The *t*-statistics are heteroscedasticity consistent. Number of observations is 519, adjusted R-square is 0.363, Q(36) is 38.12 with a *p*-value of (0.25). The estimating equation is: $\alpha + \beta$ * Time_dummy + γ * Order_flow + δ(Order_flow * Time_dummy) + $\theta\Delta \log E_{t-1} + \sigma(\theta\Delta \log E_{t-1}$ * Time_dummy) + ε_t. We include lagged exchange rate changes $\Delta \log E_{t-1}$ as well as lagged (past) exchange rate changes interacted with the year dummy to allow for autocorrelation of the exchange rate changes and a change in this autocorrelation in 1999.

Moreover, the coefficient on the order-flow interacted with the dummy is positive and statistically highly significant, indicating that order flow sensitivity substantially increased in the post-euro period. The same order flow imbalance therefore generates a stronger contemporaneous exchange rate change for the euro than for the German mark. This suggests that the euro behaves differently from the German mark. The evidence is supportive of the market transparency hypothesis.

6.3. Allowing for feedback: reduced form model

To access the role of order flow for the exchange rate dynamics, we have to extend the sensitivity analysis of the previous section. Evidence for a stronger contemporaneous

correlation between order flow and exchange rate change in the post-euro regime does not necessarily imply a stronger long-run exchange rate effect for order flow imbalances. To obtain more insights into the dynamic interaction between the exchange rate and order flow we estimate a more general model that allows for feedback effects from exchange rate changes to order flow and can therefore capture the intertemporal response of the exchange rate to an order flow shock.

The model specification can be described as follows. The forex market conditions are summarized by two variables, namely the order flow, defined as the daily difference of buy and sell orders, and daily exchange rate change. The change in both the order flow and the exchange rate on day t depends on past order flow and past exchange rate changes. To allow a direct estimation of all coefficients our estimation procedure excludes a direct contemporaneous feedback effect from exchange rate changes on day t to order flow on the same day. This estimation requirement is typically referred to as an identification condition in econometrics.

6.3.1. Exchange rate response to a 'buy shock': the time profile. To see if introduction of the euro has changed the relationship between order flow and the exchange rate, we estimate the time series model separately for the pre-euro and post-euro period. The coefficients and the number of past state variables (lags) are estimated to provide the best possible description of the data. We find that only one lag of the two state variables is necessary to eliminate all residual autocorrelation and thus provide a good specification. (See Tables A4 and A5 in the appendix for details of the estimation).

Given the estimated interaction between the current and past exchange rate and order flow, we can trace out the dynamic impact on the exchange rate of a hypothetical 'buy shock'. We choose \$1 billion as the size of such a unit shock and compare the pre- and post-euro exchange rate change in Figure 4.[16] Comparing the solid bold line, which represents the exchange rate response for 1999 (post-euro), to the dashed bold line, which represents the pre-euro response, we see that the post-euro path is noticeably above the pre-euro path. What this means is that our estimates suggest that the euro is now *more* sensitive to large buy or sell orders. In fact, our hypothetical \$1 billion order-flow shock moves the exchange rate by only 28 basis points before the euro while the same order flow moves the rate by 46 basis points post euro (pre-euro the rate is DEM/USD; post-euro it is EUR/USD). Moreover, the exchange rate effect is incorporated within two days and the exchange rate effect is permanent thereafter for both regimes. Our estimates are of course subject to some statistical uncertainty so we also plot the 95% confidence intervals around each impulse response graph (the pre-euro interval is shown with dashed lines; the post-euro interval

[16] Technically, the so-called impulse response function at $t = k$ is the cumulative exchange rate change over k days since the shock, namely $IR(k) = \Sigma_s \Delta E_s$ (s summed over $0 \ldots k$).

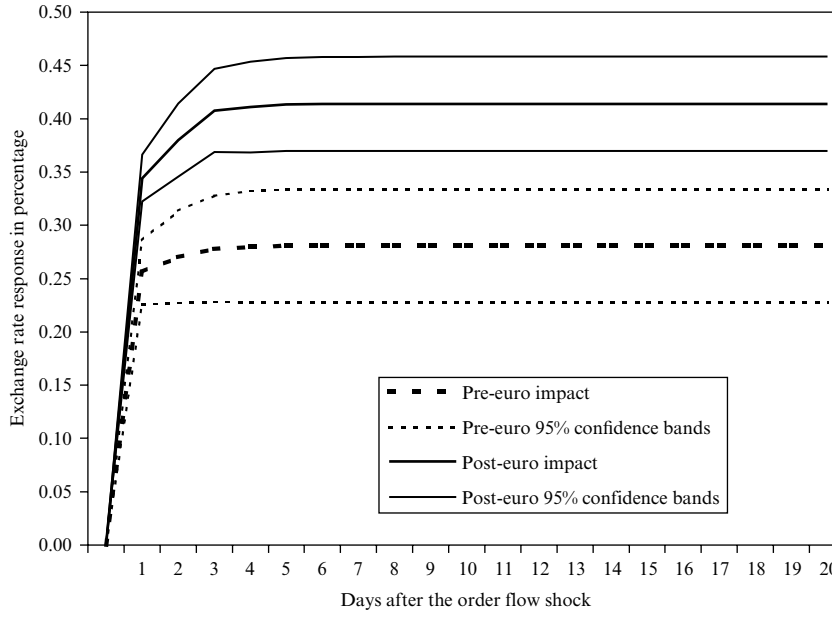


Figure 4. Pre- and post-euro exchange rate impact of a $1 billion order flow shock

with solid lines). Since the both the pre- and post-paths are outside the intervals of the other, we can be quite confident that the difference is statistically significant.

6.3.2. Technical implications of the dynamic analysis. The dynamic analysis provides three insights. First, we confirm the larger short-term impact of inventory imbalances for the post-euro period that is visible in the previous sensitivity analysis. Secondly, we find that order flow shocks have a long-run effect both in the 1998 and 1999 data. The long-run impact of order flow on exchange rates is also documented by Evans and Lyons (2001a), Lyons (2001a, b), Rime (2001), Killeen *et al.* (2001) and Froot and Ramadorai (2001). But how can order flow imbalances have long-run effects on the exchange rate? Evans and Lyons assert that order flow suitably aggregates dispersed information about (unobservable) fundamentals between two economies. If these fundamental changes are persistent, then the impulse response of a correlated order flow shock should also be persistent. But this interpretation is difficult to reconcile with our third result. The long-run order flow effect appears noticeably larger for the post-euro than for the pre-euro exchange rate regime. Can we assume that order flow is a stronger reflection of economic fundamentals in 1999 than in 1998?

Other than information about fundamentals, forex order flow may simply reflect demand shifts based on subjective valuations of foreign investment opportunities. In this latter case the exchange rate impact might be long lasting, but need not be permanent. This view seems to be supported by recent evidence by Froot and

Ramadorai (2001). Based on an exceptional data set covering 7 years of order flow in 19 currencies, they find evidence for long-lasting, but non-permanent effect of order flow shocks.

Finally, we point out that a low inventory risk-sharing capacity of the post-euro forex market may not be the only explanation for a larger exchange rate impact of order flow shocks. One might speculate that higher market transparency in 1999 reduces the incentives of informed speculators to participate in the market.[17] Incomplete appropriation of information rents has featured prominently in the theoretical finance literature (Grossman and Stiglitz, 1980). Higher market transparency and the associated information rent stealing through front-running may therefore reduce the stabilizing trading incentives of informed speculators. This could explain why order flow shocks generate larger long-run exchange rate effects. But in the absence of any data on market participation it is impossible to quantify this effect.

7. POLICY IMPLICATIONS

7.1. What did we find?

The creation of the euro generated expectations that the new currency would challenge the dollar dominance in international financial transactions (Portes and Rey, 1998; Hartmann, 1998a). We use various statistical measures to compare the international role of the euro in 1999 to the characteristics of the German mark in 1998. The evidence on both quoted and transacted spreads shows that the euro has higher transaction costs than the German mark. Moreover, the external trading volume in euro rates falls short of the aggregated volume of its composite predecessor currencies. Given that the spread increase coincides with the introduction of the euro in January 1999, it is difficult to attribute these results to general market changes unrelated to the euro.

This evidence does not support the mainstream theory about the international transaction role of currencies, known as the vehicle currency theory. The vehicle currency hypothesis interprets scale economies associated with a bigger market as the prime determinant of transaction costs and therefore a currency's international transaction role. The consolidation of liquidity in one single external euro rate should have given an advantage to the euro and strengthened its international transaction role relative to the German mark. Our evidence suggests that forex markets are more complex.

To account for the stylized facts we develop an alternative explanation called the market transparency hypothesis. It asserts that liquidity consolidation in relatively few external markets eliminates many parallel markets. This increases market

[17] For a model of endogenous market participation explaining forex volatility patterns see Hau (1998) and Jeanne and Rose (2000).

transparency and simultaneously deteriorates the inter-dealer risk-sharing opportunities provided by a slower price discovery process in the pre-euro market structure. Market transparency allows easier inference of other dealers' desired trading positions and thereby facilitates front running. Very low forex transaction costs make inventory revelation and front running a particular concern for forex dealers. They react by quoting higher spreads and reduce their trade size to limit the size of inventory imbalances. We indeed find evidence for a reduced trade size in 1999 relative to 1998.

7.2. Exchange rate management

Additional evidence concerns the effect of net supply shocks from the customer side of the market. A comparison of the pre- and post-euro forex market characteristics shows higher sensitivity of the euro exchange rate level to order flow imbalances. The same order flow imbalance therefore triggers a larger permanent exchange rate movement after 1999. This result may strengthen concerns that private capital flows generate larger exchange rate movements. The strong devaluation of the euro against the dollar over the period 1999–2001 was often perceived as favourable for European employment and growth. Political pressure on the ECB to stabilize the euro was thus constrained. But future portfolio shifts might as well produce a strong euro appreciation with stronger political pressure on ECB to actively intervene. At the same time exchange rate intervention might be more effective under the new forex structure. Evans and Lyons (2001b) claim that the sensitivity of the exchange rate to private order flow is comparable to intervention order flows by central banks. But no evidence is available to confirm the equivalence of private and official flows.

To evaluate the prospects for a more active exchange rate management, central banks have to enhance their analytical ability with new data sources. We advocate the systematic collection of high frequency order flow data in all forex market segments. Recent work by Killeen *et al.* (2001) shows that order flow analysis may also provide valuable insights with respect to the stability of exchange rate pegs. This will become particularly important if other countries desire to link their exchange rate to the euro.

7.3. Implications for euro outsiders

The observed structural change in the forex markets and the associated change in forex transaction costs concerns euro outsiders like the UK. Transactions costs measured by Reuters quoted spreads in the euro/pound rate have approximately trebled relative to preceding German mark/pound spreads. The UK decision to remain outside did not preserve a pre-euro status quo, but induced a financial segregation of the pound market from the continental European markets. This assessment makes UK non-membership more expensive in its financial and trade relations with the rest

of Europe. Since between 50% and 60% of the UK's trade is with the euro-zone, the penalty is direct and specific. If the UK joins, the remaining 40% of its trade will be penalized by the higher transactions costs between the euro and other currencies such as the dollar and yen. However, this transaction cost increase appears more modest according to our data. Overall, the transaction costs argument clearly favours UK membership. But it is also fair to say that the overall welfare costs of higher spreads are certainly very modest.

7.4. The future of forex

The forex market certainly faces further structural change. The introduction of the euro also coincides with a general trend towards electronic trading platforms in the forex market. The two leading systems, namely Reuters Dealing 2000–2 and Electronic Broking Services (EBS), are likely to increase their market share in the inter-dealer market. Also electronic forex trading is likely to expand to the customer segment of the market. The spreads in the customer segment are considerably higher than in the inter-bank market and this is the principal source of profit for bank dealers (Rime, 2001). Customer-oriented electronic trading systems can break down this segmentation. Systems like Currenex, Atriax and FXall have entered this market and claim high growth rates. The traditional currency dealer in commercial banks thus faces a disintermediation challenge similar to the floor traders in the traditional stock exchanges.

Discussion

Patrick Honohan
World Bank

This paper has the necessary ingredients: an interesting and surprising empirical finding and a fancy theory to explain it. It needs to be said at the outset, though, that some of the factual basis may not be too robust. I am also doubtful that the authors have chosen the most plausible theoretical explanation for their findings. Finally, I will raise some welfare questions that seem unresolved.

The data

This has been a period of rapid structural change in the location and technology of the forex market – having grown steadily for decades, daily average of spot forex transactions was running a third lower in April 2001 than three years earlier. Although inter-dealer trading still accounts for almost three-fifths of the total, it has been declining. Undoubtedly the growing importance of electronic brokerages in place

Table 9. Comparing volume and spread data

(a) Percentage increase in trading volumes

Source:	USD/CHF	USD/JPY	USD/DEM-EUR	JPY/DEM-EUR	CHF/DEM-EUR
BIS	−28	−11	21	25	−33
Hau *et al.*	71	−13	−18	−44	−34

(b) Percentage increase 1998−99 in DEM/EUR spreads

Source: Against:	USD	GBP	JPY	CHF
DH full year, Bloomberg	11	1	19	5
DH 2nd half, Bloomberg	2	23	26	4
DH full year, Reuters	25			
DH 2nd half, Reuters	22			
Hau *et al.* Jan.–Aug., Reuters	40	195	62	

Sources: For volume data, BIS (2001); for the spread data sources, DH for Detken and Hartmann (2000) and Hau *et al.* for main text (the first two rows of DH use Bloomberg quoted spreads; last two DH rows and Hau *et al.* use Reuters quoted spreads).

of the bilateral dealer market has been a factor here. The 1998−99 period under discussion is right during the time that all this was happening. I am inclined to believe that shifts in particular currency volumes going through one electronic brokerage, albeit the largest, cannot necessarily be taken as representative during this period.

For example, declining average deal size on EBS could reflect its capturing a larger market share through going down the food-chain, having started with the biggest transactions. More concretely the 'astonishing volume increase of 71%' reported by Hau *et al.* for the USD-CHF pair is not confirmed by the comprehensive BIS survey in April 2001, which indicates that this pair not only declined in volume overall between 1998 and 2001, but lost market share. Generally speaking there is little congruence between the volume changes reported by Hau *et al.* and those of the comprehensive BIS survey (which admittedly relates to a more recent period) (Table 9(a)). Overall, the BIS numbers indicate that volume in EUR-related trades was higher in 2001 than DM in 1998, and the share much higher; 38% as against 30%.[18]

So far as the reliability of the data on spreads are concerned, I should remark that the Hau *et al.* data for sharply increased spreads on the Euro seem to be outliers in the literature. For example, Galati and Tsatsaronis (2001) state that 'market commentary indicates that the introduction of the euro has not changed the tightness of spreads in any significant way', and they contrast the Hau *et al.* results (from a previous draft) with the results obtained by Detken and Hartmann (2000) showing

[18] The currency pattern of changes in transaction volume as reported in the BIS survey (and in particular the euro's higher-than-DM market share) reflects not only the fact that the euro embodies the other legacy currencies, as well as the DM, but also the elimination of triangular trade between other euro legacy currencies using the US dollar as a vehicle. The Euro's share of 'third currency' volume, i.e. excluding trade among the EMU currencies and the dollar, is about the same as was that of the DM.

'no significant change in bid-ask spreads after the introduction of the euro'. Actually, if we look at the Detken–Hartmann data (Table 9(b)) we do see an increase in spreads, though it is much smaller than that reported by Hau *et al.* (and Detken–Hartmann provide no information about statistical significance).

The theory

Having begun with that caveat on the factual basis of the paper let me now assume that there *was* an increase in spread and turn to the theory advanced by the authors as an explanation. This essentially states that the cause of the widening of spreads is an improvement in the transparency of the market which prevents dealers from offloading unwanted excess balances before the rest of the market wakes up to the order flow conditions and revises its quotes. In a nutshell, they are saying that spreads are wider because information has improved.

Although the effect is theoretically plausible, I find the application to the present context rather strained. To begin with, I can't see exactly how the flow of information to the market has become all that transparent. The only specific mechanism that the authors mention is the reduced possibility for dealers to park unwanted inventory in discontinued Euro legacy currencies. But just how relevant will this have been? Presumably one would have needed a fairly liquid market to carry out such manoeuvres effectively – say a market (currency pair) accounting for at least 2 or 3% of the global market. Just seven currency pairs have a 3% or better market share – the same as before the euro; if we lower the threshold to 2%, then the number of currency pairs is eight, down from nine in 1998. So I can't see that this mechanism is an important one.

Much more likely, to my way of thinking, is that information problems and uncertainty increased with the arrival of the euro. There was a degree of uncertainty about how smoothly the new operating procedures of the European Central Bank would work, for example an understandable heightened risk that liquidity conditions could have proved more volatile. Plenty of reason, then, for dealers to increase their conventional spreads with the arrival of the new currency. Indeed, according to the authors' data (as illustrated in their earlier working paper) the spreads jumped immediately in January 1999, overshooting the more modest level to which they subsequently decayed. It is hard to see how the transparency story could predict the overshoot. Heightened uncertainty is also compatible with the finding that information embodied in order flow could have become more significant, the other major non-volume piece of evidence adduced by the authors. Although I suspect that heightened uncertainty is the most likely explanation, there are two others that could just be relevant.

Mention of 'conventional' spreads should remind us that the quoted Reuters spreads are indicative only and that, according to market participants surveyed by Cheung and Chinn (2001), these spreads are normally quoted at conventional rates. (Indeed, Goodhart *et al.*, 1996, show that almost all of the quotes have spreads of

either 5 or 10 ticks.) Presumably the limit order strategies used by dealers in the electronic markets are also based on conventional schedules. Now I hesitate to mention this, but could the sudden jump in spreads possibly have something to do with the denomination? After all, quoting 1.7600/03 as bid/offer for the DEM (in terms of US dollars) gives a lower percentage spread then quoting 0.9400/03, or even 0.9400/02 for the euro. If the spreads are mostly conventional, then this might have been a relevant factor, at least in the early months.

Does it matter?

Finally, let me raise two unresolved issues about the welfare implications. At first sight, an increase in spreads (the EBS transaction spreads) from 0.5 to 0.7 basis points looks very small – sufficient to be neglected. But applied to the $1.2 trillion daily volume, this adds up to more than $50 billion per annum – a tidy sum large enough to rank with Harberger triangles if not Okun gaps. But then I realized that all of this hot potato trading that we hear about does not bear the spread (a given sequence of hot potato trades all happens on the same side of the market). I don't then know to what base the increased spread should be applied. Likely enough it is offset by the reduced or eliminated spreads in respect of other legacy currency transactions. Also, if the market is competitive and if the increased transparency moves the market price more promptly to equilibrium, then the increased spread must largely be a transfer between informed traders and dealers. The deadweight loss to liquidity traders of facing a higher spread, which would form the bulk of the social cost, might be very small indeed – and possibly offset by improved price discovery.

Julian Franks

London Business School

I am delighted to present this review in person. On two previous occasions other panel members have read my reviews in my absence. I have always wondered how close they stuck to my text and I have no way of telling since both papers remain unpublished. I have some suspicion that like the fabled 'redactor' or editor of the Old Testament they might have exercised some editorial control and blended their views with mine.

The paper provides a test of the *vehicle currency hypothesis* with respect to the euro. Thus, the lower the transaction costs the more likely it is that a currency will be used as a third party vehicle for trades between two other currencies. The authors argue that we might expect a sterling–Belgian franc transaction to go through dollars if the dollar–sterling spread and the dollar–Belgian franc spread is smaller than the sterling–Belgian franc spread. One might argue that by fixing the exchange rate of eleven other currencies the euro has reduced the transaction costs of using the euro relative to other currencies such as the DEM or the dollar, post its introduction. The alternative hypothesis, preferred by the authors, is that by fixing rates the euro has increased

transparency and has made trading more costly, resulting in larger bid ask spreads. The paper examines and compares the bid asked spreads for various currencies pre- and post-introduction of the euro, using both quotes and transactions data. It concludes that the evidence is consistent with higher spreads post-euro, and is consistent with greater transparency increasing costs.

The subject of the paper is important and the paper is interesting and readable. However, I am not convinced of the authors' central hypothesis. While their data and results are interesting I am still waiting for a credible explanation.

I will discuss four issues. First, I am not convinced that fixing the intra-EMU rates has affected transparency; it may have, but I would like more of a discussion of why we should expect it. In the equity market we observe changes in transparency in the form of changes in publication rules or in the market microstructure. Fixing rates is like merging eleven stocks – hardly the stuff of greater transparency. Moves to greater centralization of the market are not obviously the result of fixing the rates, as the authors suggest.

Even if transparency is improved, is that responsible for the increased spreads? Transactions costs may not be the only, or the most important determinant, of spreads between two currencies. For example, volatility and volumes may influence spreads. If that were the case, it may be that spreads on the euro relative to other currencies are larger than the DEM pre-fixing, and therefore we should not be surprised that the euro has not surpassed the DEM as the currency vehicle of choice. Higher volatility of the euro compared with the DEM (on its own) might be expected since the euro impounds some currencies that are weaker than the DEM and fewer, if any, that are stronger. The authors have provided some evidence that volatility and volume cannot solely explain changes in spreads in their data. The results for the Swiss franc suggest that it cannot only be transparency issues that are significantly influencing changes in spreads pre- and post-fixing, as the authors admit.

Secondly, I am much less confident than the authors that the theory and empirical evidence of bid asked spreads in the equity markets can be carried over to the currency markets. This issue is important since it is the basis of the authors' principal hypothesis. Nor am I convinced that in the equity market the evidence is balanced towards the view that greater transparency leads to higher spreads. For example, in an important paper, Pagano and Roell (1996) compare trading systems differing in their degree of transparency and find that 'greater transparency generates lower trading costs for uninformed traders on average, although not necessarily for every size of trade'; lower costs translate into smaller spreads, therefore 'the implicit bid-ask spread in a transparent auction is tighter than in a less transparent dealer market'.

In addition, although it is true that opaqueness can be desirable for block transactions they must be relatively large compared with normal order size. What is the normal order size in the foreign exchange market and how large do orders have to be before we can argue that the trade is abnormally large and therefore that less

transparency will be good for spreads? Put another way, for what size of trades is transparency 'costly'? Or, are the forex markets so deep that the costs of transparency are minor or zero? Research in the equity market on transparency controls for the size of the transaction, since transactions of normal market size should not be affected by information problems. The authors should provide more convincing evidence on this question.

Thirdly, the quotes data used by the authors is, in the absence of more information, suspect if I compare it with the transactions data provided by them (see their Table 3). The spreads based on transactions data really seem very much, if not hugely, lower. What could the differences in quotes and transactions data be attributable to? Could it be size of transaction? If it is, the quotes data might represent much smaller transactions and therefore less interesting as a data set to test transparency hypotheses. The authors' view that it could be bargaining within the spread is I believe less likely.

Finally, the authors' analysis is essentially an event study, comparing spreads pre- and post-fixing. However, when I compare post-euro spreads across the euro and non-euro zones, euro spreads do not seem much larger. Put differently, in comparing prices or transaction costs cross-sectional comparisons provide interesting comparative data. Data on additional currencies would add considerably to the cross-sectional analysis.

Richard Portes

London Business School

This paper is misconceived and misleading – just wrong. From 'puzzling first evidence' in the forex markets in 1999 the authors constructed a model and a story that ignore problems with their data and all subsequent evidence. Hau *et al.* offer an implausible explanation of a non-puzzle. They stubbornly disregard evidence from central banks and market participants and simple common sense.

First, the evidence – the data on transaction volumes and spreads. Econometrics is useless when applied to the wrong numbers. Patrick Honohan points out the great discrepancies between the BIS triennial survey data and the EBS data on volumes that Hau *et al.* use. This is hardly surprising – their Table 2 tells us that the average daily volume covered by the EBS data on DEM-EUR/USD was $37.9 billion, which is less than 10% of the total volume covered by the BIS survey. And that is the *correct* BIS survey total *spot* market volume of $387 billion – their Table 1 gives the *global* volumes (including derivatives).[19,20]

[19] The EBS data on the key EUR/USD trade cover only 3.2% of global forex market volume and 10.8% of global EUR/USD trade! Why bother? These underlie Tables 2–5, 7, 8, and A1–A5.

[20] The BIS has so far published only aggregate spot market volumes and has not yet indicated how the global currency pair turnovers break down between spot and derivatives. In 1998, the DM was much more important (relatively) in spot than in derivatives markets; if that continued with the euro, the global data could be misleading.

The EBS data they use are unrepresentative. The Bank of England (2001: p. 13) cites Citibank and concludes: 'In the spot market, initial fears that the euro's introduction would substantially diminish liquidity have proved unfounded. Volumes dropped initially, but have recovered since.' For example, the sharp initial decline in EUR/JPY turnover, of which Hau *et al.* make so much, had been almost fully reversed by early 2001. Avinash Persaud, Head of Currencies and Global Strategy for State Street Bank (source of the data used by Froot and Ramadorai, 2001), says, 'liquidity in the euro-denominated currency . . . markets is greater than in the legacy currencies'.[21]

The story on spreads is equally damaging. As Hau *et al.* admit, their Reuters quote data (Figures 1 and 2 and Table 6) are indicative quotes to customers, not effective spreads that are actually realized in inter-dealer transactions. Moreover, their EBS 'spreads' are *not* 'transaction spreads' (*pace* the title Hau *et al.* give to Table 3) – they are calculated from comparing rates in *different transactions* ('the last buy and sell transaction at each full hour'). These are not effective but rather 'pseudo' spreads – if the market clearing mid-price has moved between transactions, this will not be a 'clean' spread and could even be negative.[22]

Again, what do central banks and market participants say? Honohan cites BIS and ECB papers that flatly contradict Hau *et al.* The Bank of England (2000) says, 'euro markets are deeper and more liquid than the national currency markets . . . dealing *spreads have narrowed* in the . . . foreign exchange markets'. Citibank (quoted by the Bank of England, 2001) says, 'Initially, spreads in the [forward] euro market were wider than they had been in the Deutsche mark market, but [they] quickly tightened up to previous levels – and sometimes narrower.' The most recent ECB paper (2001) finds that 'euro-Swiss franc spreads . . . have either hardly changed compared with pre-EMU levels or are even lower . . . the increase in euro-dollar spreads is somewhat overstated by the low spreads in 1998 . . . they are now [end-2000] almost back down to the levels recorded in 1992 . . . Their modest [!] increase in 1999 might therefore have been temporary.' Hau *et al.* say, 'one expects the world's most liquid financial market to reach its equilibrium characteristics in less than three years.' Quite so, but Hau *et al.* are still back in 1999.

[21] Private communication, 24 October 2001.

[22] Honohan also suggests an alternative explanation for any initially observed rise in spreads (which Charles Goodhart confirms): Danielsson and Payne (2001) show that the modal spread for DEM/USD (pre-euro) was the minimum that the technology could record – 1 'tick' = 0.01 pfennig = 0.56 basis points. Applied to EUR/USD, this gives a minimum spread of 1.0 bp; this 'mechanical' jump in modal spread may contribute to the early rise in spreads shown in the Love (2001) and Hau *et al.* data, but one would expect it to be eroded over time – as indeed appears to have been the case. Hau *et al.* dismiss a version of this hypothesis as 'money illusion among professional forex traders, which is rather difficult to believe' (Section 4.3). Anyone who thinks the traders behave with perfect rationality should read Cheung *et al.* (1999). Love (2001), which Hau *et al.* take to support their views on spreads, uses data from only one week in the pre-euro period – a week during which Love finds a 'structural break'!

So there is no puzzle

But the authors simply ignore or dismiss all the objections to their data sets, because they want to use them to support a story. Even then, they have trouble. They don't use their data consistently – for example, their spreads regressions use the Reuters spread data with the EBS volume data! The key DEM-EUR/USD equation in Table 4 does not show the standard effects of volume and volatility (Bessembinder, 1994; Hartmann, 1999). So what do they do? They simply *impose* these effects in the corresponding regression in Table 5 (see the note to that table) and compound the offence by indicating that these coefficients, though not estimated, are 'significant'.

The 'triangular spread differentials' (TSDs) are based on the indicative Reuters quotes. And they choose the uninteresting comparison of JPY/USD direct with going through EUR as a vehicle. They devote five pages to knocking down this straw man. It is an extreme case – for the euro to take over as vehicle in this case is the 'pan-euro scenario' that Portes and Rey (1998) already explicitly ruled out as a possible equilibrium. The interesting, potentially realistic switches would be, e.g., zloty-USD-DEM versus zloty-EUR, Turkish lire-USD-DEM versus Turkish lire-EUR, etc.

It is absurd to argue that a fall in average transaction size from $2.154 million to $1.990 million, whatever its statistical significance, has any economic significance in a market in which such a transaction represents 0.0005% of total average daily transaction volume.

The 'evidence' on pre- and post-euro sensitivity of the exchange rate to order flow is indeed 'puzzling'. A model is needed here; if greater transparency reduces information asymmetry, order flow might then have *less* impact on the exchange rate. The regression itself picks up much less of the variance than a typical Evans–Lyons regression, even though Hau *et al.* have the additional interaction term. And their interpretation of the VAR leads to the conclusion that 'order flow is a stronger reflection of economic fundamentals in 1999 than in 1998' – most observers of USD/EUR would find this surprising (e.g., De Grauwe, 2000).

In the Panel version of this paper, Hau *et al.* said that 'our knowledge about the role of market transparency for market quality is limited . . . [no evidence] is available for the forex market'. Indeed. They do not specify how transparency relates to information asymmetry. They say that greater transparency implies greater inventory risk. Does moving from imperfect transparency towards perfect information (Walrasian equilibrium) raise inventory risk continuously?

Their model is misplaced

Even if the model underlying this paper were 'correct', it is misplaced. The elimination of cross-trades among the euro's predecessor currencies is supposed to have made the market more transparent, so traders found it harder to conceal large positions and hence required higher spreads to offset increased inventory risk. But those

cross-trades accounted for only 3.7% of the global forex market in 1998 – traders couldn't have been concealing much there! Excluding the 10 DEM pairs from the 55 that were eliminated by EMU, the remaining 45 pairs accounted for 0.3% of the market. So most of these markets *didn't exist* before EMU. USD/other EMS (excluding DEM) transactions were 17% of the market in 1998 – that is a lot more than intra-EMS, but even this is a small base on which to build the transparency story. And traders still have alternative markets to offload exposures (e.g., CHF or GBP pairs).

The growth of electronic brokering and institutional consolidation in the markets (fewer banks, fewer trading desks) are much more important institutional changes than the elimination of intra-EMU cross-trades, and they may have affected transparency. But they are likely to have increased rather than reduced liquidity (BIS, 2000). And in one major respect, electronic brokering has *reduced* transparency, because it brings anonymity: a dealer will not know from whom a given quote originates. The information content of an order or a quote that you know comes from Deutsche Bank is different from one coming from Banco Pastor. This is another reason, beyond those adduced by Julian Franks, against Hau *et al.*'s attempt to use equity market microstructure results to support their story. The authors ignore a key difference between equity and forex: the latter markets have no disclosure requirements.

The status of the euro as an international currency will indeed depend significantly on trading costs and liquidity in the forex markets. But it will also depend on trading costs in the markets for government bonds which are used so heavily by international investors and, more generally, on the development of euro-area financial markets. This paper misrepresents the former and ignores the latter. It has no bearing on what Hau *et al.* inappropriately call the 'vehicle currency hypothesis', and it is not helpful in assessing the prospects for the international role of the euro.

Panel discussion

Charles Goodhart confirmed the empirical results obtained by the authors as being borne out also in a recent paper of the Financial Market Group at the LSE (Love, 2001). He thought that the use of indicative spreads was problematic. He found the fact that the spread had increased to be correct, but the structural explanation unconvincing and he urged the authors to provide direct evidence on their hypothesis. However, he admitted that he could not think of a better argument to explain the empirical phenomenon. Harald Hau replied that electronic trading (which results in more centralized structures) could have been independent of the euro and could thus be an alternative explanation. He explained that the focus on the elimination of

currencies was chosen because of the time-break observed in the data that would not be easily explained otherwise.

Georges de Ménil proposed that the increased concentration of banks could be a possible explanation.

Malte Krueger asked why the effects of the euro had not been symmetric for all currencies. Harald Hau replied that the Eurosystem provided parallel markets to the German one that were not available for the dollar–yen market. He argued that the nearly fixed exchange rates would have made these markets particularly close substitutes.

Andrew Rose criticized the lack of direct evidence. He suggested interviewing traders. Moreover, he suggested analysing the period when Greece entered the EMU to confirm the results of the paper.

As a reply to the discussants, Harald Hau explained that the foreign exchange market was particularly suitable for transparency hypothesis because spreads in this market were extremely small and as shown by Harris (UCLA) markets with smaller spreads become more information-sensitive. Moreover, strategic behaviour would rationalize why traders split up orders. Finally, evidence from the stock market, which shows that trade concentrates in periods of time-overlap of different market places, suggests that transparency and strategic behaviour might very well play a role also in the foreign exchange market. Michael Moore explained that the different results obtained using BIS data and the data used by the authors occur because of different measures contained in the BIS data. Taking these differences into account, the main empirical message would be borne out by both data sources. Both Michael Moore and William Killeen confirmed that the volume of euro trades had dropped. William Killeen mentioned that all that was needed for strategic behaviour to occur was that currencies were less than perfectly correlated. Moreover, Richard Lyons' work on order flows mentioned by the discussants was an entirely different study using different data for a different time period.

APPENDIX

Table A1. Hausman test for endogeneity of volume and volatility

Equation	Test statistics (1)	*p*-value (2)
USD/DEM-EUR Spread	0.54	0.99
JPY/USD Spread	0.01	1.00
JPY/DEM-EUR Spread	0.02	1.00

Notes: The Hausman test is a chi-squared test with the null hypothesis that the regressors are endogenous, hence correlated with the error terms. The test statistics compare the OLS coefficient estimates in each of the spread equations [Regressors: Constant, Time Dummy, Volume, Volatility and Spread(-1)] to the instrumental variable estimates [Instruments: Constant, Time Dummy, Volume (-1) , Volatility(-1) and Spread(-1)].

Table A2. High frequency spread regressions for the USD/DEM-EUR rate

Dependent Variable: DEM-EUR/USD Spread	Coefficients (1)	Std. error[a] (2)	*t*-statistics (3)
Constant	4.65	1.09	4.26**
Time Dummy (1 = 1999)	0.69	0.09	7.71**
USD/DEM-EUR Expected Volume(−3)[b]	−0.26	0.10	−2.57*
USD/DEM-EUR Spread (−1)	0.34	0.06	5.68**
USD/DEM-EUR Spread (−2)	0.15	0.05	2.79**

Adjusted R-Squared = 71.7%

F-test[c]	*F*-statistic	*p*-value
F(20,431)	19.02	0.52

Test	Test statistics	*p*-value
Ljung–Box Q (25)	20.77	0.71
Breusch–Pagan het.[d]	4.58	0.03*

Notes: We indicate significance at the 5% level (*) and the 1% level (**). The data are daily (4 January 1998–31 August 1999, 431 observations).

[a] Standard errors are computed from heteroscedasticity consistent matrix.

[b] Defined as the fitted values of ARMA(4,4) process of Log Cash Volumes. Unexpected volume (lagged) was found to have the correct (positive) sign but was insignificant at the 95% confidence level. Realized volatility (contemporaneous and lagged) was also insignificant.

[c] *F*-test of null hypothesis that the following variables should be excluded from a general dynamic model with five lags: Realized volatility (0, −1, −2, −3, −4, −5), Unexpected volume (0, −1, −2, −3, −4, −5), Expected volume (0, −1, −2, −4, −5) and Spread (−3, −4, −5).

[d] The Breusch–Pagan statistic tests for heteroscedasticity in the errors with respect to the constant and time dummy.

Table A3. Estimation of the long-run time dummy effect

Equation	Long-run coefficient	Standard error	*t*-statistics
(a) Monthly data: January 1998–August 1999 (20 observations)			
USD/DEM-EUR spread[a]	1.543	0.065	−27.3**
JPY/USD spread[a]	−0.109	0.165	−0.659
JPY/DEM-EUR spread[b]	2.321	0.142	16.3**
(b) Daily data: 4 January 1998−31 August 1999 (431 observations)			
USD/DEM-EUR spread[c]	1.365	0.0918	14.87**

Notes:

[a] Long-run coefficient for the regime change is derived from the restricted SUR equation. It is defined by term: Time Dummy Coeff. /[1-Spread(-1) Coeff.].

[b] Long-run coefficient for regime change is the same as the coefficient in the restricted SUR equation since there are no dynamics in the yen/dollar equation.

[c] Long-run coefficient for the regime change is defined by term: Time Dummy Coeff. /[1-Spread(-1) Coeff–Spread(-2) Coeff].

Table A4. VAR model for the pre-euro period

(a) USD/DEM-EUR equation

Variable	Coefficient	Standard error	*t*-statistics
Constant	−0.092	0.047	−1.94
Log diff. DEM-EUR/USD (−1)	0.04	0.068	0.60
Net order flow (−1)[a]	0.064	0.035	1.79[b]
Adjusted R-squared = 1.29%			
	Test	*p*-value	
Ljung–Box Q-statistic (25)[c]	38.40	0.05	
Breusch–Pagan het.	0.33	0.57	

(b) Net order flow[a] equation

Variable	Coefficient	Standard error	*t*-statistics
Constant	0.663	0.088	7.5**
Log diff. DEM-EUR/USD (−1)	−0.04	0.126	−0.321
Net order flow (−1)[a]	0.265	0.066	3.97**
Adjusted R-squared = 5.80%			
	Test	*p*-value	
Ljung–Box Q-statistic (25)	20.22	0.74	
Breusch–Pagan het. test[d]	18.50	0.00**	

Notes: We indicate significance at the 5% level (*) and the 1% level (**). The *t*-statistics are heteroscedasticity consistent. We use daily data: 4 January 1998–31 December 1998 (260 observations).

[a] Net order flow is defined as buy initiated minus sell initiated trades measured in DM billions per day, with euros converted to DMs at the January 1999 fixed rate.

[b] The *t*-statistic on lagged order flow in the exchange rate equation is significant at 10%.

[c] Ljung–Box Q-statistic (25) test identifies cumulative autocorrelation up to order 25. The null hypothesis is no autocorrelation in the errors.

[d] The Breusch–Pagan statistic tests for heteroscedasticity in the errors with respect to the constant and time dummy.

Table A5. VAR model for the post-euro period

(a) USD/DEM-EUR equation

Variable	Coefficient	Standard error	*t*-statistics
Constant	−0.179	0.044	−4.02**
Log diff. DEM-EUR/USD (−1)	−0.372	0.082	−4.52**
Net order flow[a] (−1)	0.174	0.042	4.13**
Adjusted R-squared = 7.40%			
Ljung–Box Q-statistic (25)[b]	19.67	0.76	
Breusch–Pagan het.	16.11	0.00**	

(b) Net order flow[a] equation

Variable	Coefficient	Standard error	*t*-statistics
Constant	−0.333	0.087	−3.8**
Log diff. DEM-EUR/USD (−1)	−0.277	0.161	−1.72
Net order flow (−1)[a]	0.355	0.082	4.31**
Adjusted R-squared = 7.00%			
	Test	*p*-value	
Ljung–Box Q-Statistic (25)[b]	24.53	0.49	
Breusch–Pagan het.[c]	11.05	0.00**	

Notes: We indicate significance at the 5% level (*) and the 1% level (**). The *t*-statistics are heteroscedasticity consistent.

[a] Net order flow is defined as buy initiated minus sell initiated trades measured in DM billions per day, with euros converted to DMs at the January 1999 fixed rate.

[b] Ljung–Box Q-statistic (25) test identifies cumulative autocorrelation up to order 25. The null hypothesis is no autocorrelation in the errors.

[c] The Breusch–Pagan statistic tests for heteroscedasticity in the errors with respect to the constant and time dummy.

REFERENCES

Andersen, T.G., T. Bollerslev, F.X. Diebold and P. Labys (2001). 'The distribution of realized exchange rate volatility', *Journal of the American Statistical Association*, 96, 42–55.

Bacidore, J. and G. Sofianos (2001). 'NYSE specialists trading in non-US stocks', Working Paper 2000-05, NYSE.

Bank of England (2001). 'The foreign exchange and over-the-counter derivatives markets in the United Kingdom', available at http://www.bankofengland.co.uk/statistics/bis-survey/fxotcsum01.pdf

Bessembinder, H. (1994). 'Bid-ask spreads in the interbank foreign exchange markets', *Journal of Financial Economics*, 35(3), 317–348.

BIS (Bank for International Settlements) (1998). 'Central bank survey of foreign exchange and derivative market activity in April 1998'.

—— (2001). 'Central bank survey of foreign exchange and derivative market activity in April 2001'.

Black, S. (1991). 'Transactions costs and vehicle currencies', *Journal of International Money and Finance*, 3, 209–222.

Bloomfield, R. and M. O'Hara (1999). 'Market transparency: Who wins and who loses?', *Review of Financial Studies*, 12(1), 5–35.

Bollerslev, T. and I. Domowitz (1993). 'Trading patterns and prices in the interbank foreign exchange market', *Journal of Finance*, 48, 1421–1443.

Bollerslev, T. and M. Melvin (1994). 'Bid-ask spreads and volatility in the foreign exchange market: An empirical analysis', *Journal of International Economics*, 36(3–4), 355–372.

Boothe, P. (1998). 'Exchange rate risk and the bid-ask spread: A seven-country comparison', *Economic Inquiry*, 25, 485–492.

Cheung, Y.-W. and M.D. Chinn (2001). 'Currency traders and exchange rate dynamics: A survey of the US market', *Journal of International Money and Finance*, 20(4), 439–471.
Cheung, Y.-W., M.D. Chinn and I. Marsh (1999). 'How do UK-based foreign exchange traders think their market operates?', CEPR Discussion Paper 2230.
Copeland, T. and D. Galai (1983). 'Information effects and the bid-ask spread', *Journal of Finance*, 1457–1469.
Danielsson, J. and R. Payne (2001). 'Measuring and explaining liquidity on an electronic limit order book', at http://risk.lse.ac.uk/rr/files/JD-RP-01-2-22-982870682-7.pdf
Detken C. and P. Hartmann (2000). 'The euro and international capital markets', *International Finance*, 3(1), 53–94.
Evans, M. and R. Lyons (2001a). 'Order flow and exchange rate dynamics', *Journal of Political Economy*, forthcoming.
—— (2001b). 'Portfolio balance, price impact and secret intervention', NBER Working Paper 8356, July 2001.
Federal Reserve Bank of New York (2001). 'The foreign exchange and interest rate derivatives market survey: turnover in the United States', available at http://www.newyorkfed.org/pihome/triennial/fx_survey.pdf.
Flood, M., R. Huisman, K. Koedijk and R. Mahieu (1999). 'Quote disclosure and price discovery in multiple-dealer financial markets', *Review of Financial Studies*, 12(1), 37–59.
Froot, K.A. and T. Ramadorai (2001). 'Currency returns, institutional investor flows, and exchange rate fundamentals', mimeo, Department of Economics, Harvard University.
Galati, G. and K. Tsatsaronis (2001). 'The impact of the euro on Europe's financial markets', BIS Working Papers 100, July.
Gemmill, G. (1996). 'Transparency and liquidity: A study of block transactions in the London Stock Exchange under different publication rules', *Journal of Finance*, 1765–1790.
Giavazzi, F., J.-P. Danthine and E.-L. von Thadden (2000). 'European financial markets after EMU', CEPR Discussion Paper, no. 2413, London, April 2000.
Glassman, D. (1987). 'Exchange rate risk and transactions costs: evidence from bid-ask spreads', *Journal of International Money and Finance*, 6, 481–490.
Goodhart, C., T. Ito and R. Payne (1996). 'One day in June 1993: A study of the working of Reuters 2000–2 electronic foreign exchange trading system', in J. Frankel *et al.* (eds.), *The Microstructure of Foreign Exchange Markets*, University of Chicago Press, Chicago, 107–179.
Grossman, S.J. and J.E. Stiglitz (1980). 'On the impossibility of informationally efficient markets', *American Economic Review*, 70, 393–408.
Harris, L. (1996). 'Does a large minimum price variation encourage order exposure?', University of Southern California Working Paper.
—— (1997). 'Order exposure and parasitic traders', University of Southern California Working Paper.
Hartmann, P. (1998a). *Currency Competition and Foreign Exchange Markets: The Dollar, the Yen and the Euro*, Cambridge University Press, Cambridge.
—— (1998b). 'Do Reuters spreads affect currencies' differences in global trading activity?', *Journal of International Money and Finance*, 17(5), 757–784.
—— (1999). 'Trade volumes and transaction costs in the foreign exchange market', *Journal of Banking and Finance*, 23, 801–824.
Hau, H. (1998). 'Competitive entry and endogenous risk in the foreign exchange market', *Review of Financial Studies*, 11(4), 757–787.
Hau, H., W. Killeen and M. Moore (2000). 'The euro as an international currency: Explaining puzzling first evidence', CEPR Discussion Paper 2510, July 2000.
—— (2002). 'The euro as an international currency: Explaining puzzling first evidence from the foreign exchange markets', forthcoming, *Journal of International Money and Finance*.
Huang, R.D. and H.R. Stoll (1997). 'The components of the bid-ask spread: A general approach', *Review of Financial Studies*, 10, 995–1034.
Huang, R.D. and R.W. Masulis (1999). 'FX spreads and dealer competition across the 24-hour trading day', *Review of Financial Studies*, 12, 61–93.
Jeanne, O. and A. Rose (2000). 'Noise trading and exchange rate regimes', CEPR Discussion Paper, No. 2142, NBER Working Paper, No. 7104.
Killeen, W., R. Lyons and M. Moore (2001). 'Fixed versus flexible: Lessons from the EMS order flow', NBER Working Paper No. w8491, available at http://haas.berkeley.edu/~lyons.

Love, R.E. (2001). 'Analysis of spreads in the euro/dollar and deutsche mark/dollar foreign exchange markets', mimeo, Financial Markets Group, London School of Economics.
Lyons, R.K. (1995). 'Tests of micro structural hypotheses in the foreign exchange market', *Journal of Financial Economics*, 39, 321–351.
—— (1996a). 'Foreign exchange volume: Sound and fury signifying nothing?', in J. Frankel *et al.* (eds.), *The Microstructure of Foreign Exchange Markets*, University of Chicago Press, Chicago.
—— (1996b). 'Optimal transparency in a dealer market with an application to foreign exchange', *Journal of Financial Intermediation*, 225–254.
—— (1997). 'A simultaneous trade model of the foreign exchange hot potato', *Journal of International Economics*, 275–298.
—— (2001a). 'New perspective on FX markets: order-flow analysis', *International Finance*, 303–320.
—— (2001b). *The Microstructure Approach to Exchange Rates*, MIT Press, Cambridge, MA.
Madhavan, A., D. Porter and D. Weaver (2000). 'Should securities markets be transparent?', University of Southern California Working Paper.
Menkveld, A.J. (2000). 'Splitting orders in fragmented markets: Evidence from cross-listed stocks', mimeo, Tinbergen Institute, Amsterdam.
Pagano, M. and A. Roell (1996). 'Transparency and liquidity: A comparison of auction and dealer markets with informed trading', *Journal of Finance*, 2, 579–611.
Payne, R. (1999). 'Informed trade in spot foreign exchange markets: An empirical investigation', mimeo, Financial Markets Group, London School of Economics.
Portes, R. and H. Rey (1998). 'The emergence of the euro as an international currency', *Economic Policy*, 26, 307–343.
Rime, D. (2001). 'Four essays on the microstructure of foreign exchange, series of dissertations no 2-2001', Norwegian School of Management.
Sarno, L. and M.P. Taylor (2000). 'The microstructure of the foreign exchange market', mimeo, Department of Economics, University of Oxford.
Viswanathan, S. and J. Wang (2000). 'Why is inter-dealer trading so pervasive in financial markets?', mimeo, Fuqua School of Business.
Wyplosz, C. (1999). 'An international role for the euro?', in J. Dermine and P. Hillion (eds.), *European Capital Markets with a Single Currency*, Oxford University Press, Oxford.