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The euro as an international currency: explaining puzzling first evidence from the foreign exchange markets

Harald Hau [a,*], William Killeen [b], Michael Moore [c]

[a] *INSEAD, Fontainebleau, France*
[b] *BNP Paribas Asset Management, London, UK*
[c] *Queen's University, Belfast, UK*

Abstract

This paper presents evidence that the bid-ask spreads in euro rates increased relative to the corresponding bid-ask spreads in the German mark (DM) prior to the creation of the currency union. This comes with a decrease in transaction volume in the euro rates relative to the previous DM rates. The starkest example is the DM(euro)/yen rate in which the spread has risen by almost two-thirds while the volume decreased by more than one third. This outcome is surprising because the common currency concentrated market liquidity in fewer external euro rates and higher volume tends to be associated with lower spreads. We propose a microstructure explanation based on a change in the information environment of the FX market. The elimination of many cross currency pairs increased the market transparency for order flow imbalances in the dealership market. It is argued that higher market transparency adversely affects the inventory risk sharing efficiency of the dealership market and induces the observed euro spread increase and transaction volume shortfall.

JEL classification: F31; G14; G15; D8

Keywords: Vehicle currency; Market transparency; Spread determination; Transacton costs

* Corresponding author. Department of Finance, INSEAD, Boulevard de Constance, 77305 Fontainbleau Cedex, France. Tel.: +33-1-6072-4000; fax: +33-1-6072-4045.

E-mail address: Harald.Hau@insead.fr (H. Hau).

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1. Introduction

A key feature of an international currency is a dominant role in the global foreign exchange (FX) market.[1] It has long been realized that this role can by far surpass a country's relative importance in international trade. Examples are the asymmetric role of the dollar in global foreign exchange trading or of the German mark (DM) for European currency pairs. This observation lead to the notion of a "vehicle currency," which emerges from currency competition as a predominant transaction medium because of network externalities and scale economies translating high transaction volume into lower transaction costs. This vehicle currency perspective is underpinned by evidence on the inverse long-run relationship between transaction costs and transaction volume across different foreign exchange markets (Hartmann, 1998a, 1998b, 1999).[2] The creation of the euro implied a liquidity consolidation of many external rates in a single euro rate. The euro could therefore hope to surpass the German mark as a vehicle currency in the global FX market.[3]

The first part of our paper examines the outcome of the "euro experiment" for the FX market in the first one to two years of the montary union. We examine evidence both on external bid-ask spreads and transaction volumes in the pre- and post-euro environment and find that both criteria indicate a diminished role of the euro relative to the German mark. We can summarize our empirical findings in three points:

> **Stylized Fact 1 (Euro Transaction Costs)**. The euro is characterized by higher transaction costs in the dollar, yen and sterling markets. Quoted spreads increased from approximately 3.76 to 5.26 basis points for the dollar rate, from 5.1 to 8.3 basis points for the yen rate and from 3.1 to 9.2 basis points for the sterling rate. Other evidence strongly suggests that this widening extends to effective spreads.
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> **Stylized Fact 2 (Non-euro Transaction Costs)**. The increase in the cost of euro transactions, relative to DM transactions, occurred against a background of constant or even declining costs in dollar markets, other than the euro/dollar market.
>
> **Stylized Fact 3 (Transaction Volume)**. A unique data set for brokered interdealer trades shows lower euro transaction volumes compared to the previous DM volumes. The decrease in the role of euro transactions, compared to DM transactions, occurred against stable or even increasing transaction volumes in dollar markets, other than the euro/dollar market.

[1] The international role of a currency has additional dimensions. These include its use in the broad range of financial asset transactions, in international trade invoicing and in central bank activities. This paper is concerned only with FX trading. For a more general discussion of the international role of the euro we refer to Detken and Hartmann (2000), Giavazzi et al. (2000) and Kool (2000).

[2] Other important work includes Glassman (1987), Black (1991), Bollerslev and Domowitz (1993), and Boothe (1988)

[3] For such a scenario prediction see Portes and Rey (1998). Based on security market size they find it plausible that the euro would expand the role of the German mark (DM) as a regional vehicle currency and could challenge the dollar's supremacy as the world's principal international currency.

To put these results into perspective it is useful to recall previous forecasts about the euro's transaction role relative to the German mark. Hartmann (1998) derives total volume forcasts for spot trading using data by the Bank for International Settlements (1996). Based on a scenario which excludes the United Kingdom from participation, the statistics in Table 1 were presented as plausible outcomes. The elimination of intra-EU volume (Row (2)) reduces the overall euro volume (Row (4)) relative to the DM volume (Row (1)) and is not fully compensated by the consolidation of external liquidity (Row (3)) in one common currency. However, our own evidence suggests that in reality the external euro volume itself decreased relative to the external volume of the DM in spite of the volume boost from external consolidation. This is a rather surprising result.

The second part our paper interprets these puzzling findings and develops a stylized model consistent with the evidence. We argue that the evidence requires a refinement of the existing vehicle currency perspective for currency unions. The positive effect of liquidity consolidation and the long-run inverse volume-spread relationship may well be at work. But this conventional linkage documented for existing currency pairs may have been dominated by a second effect specific to the creation of a currency union. The currency union reduced the number of currencies and therefore changed the information environment of the foreign exchange market. The consolidation of liquidity in a single euro rate increased "market transparency." By market transparency we mean the knowledge of an individual dealer about the positions and trading desires of all other market participants. Higher market transparency in turn may reduce interdealer risk sharing and increase inventory risk for the dealers. We demonstrate that the equilibrium outcome may be higher spreads and lower volume.

The role of market transparency in FX trading has to be appreciated in the light of two key market characteristics. First, the FX market is characterized by low market transparency. The dealership structure limits information revelation on transaction prices to own party trades. Moreover, there exists a wide range of asset substitutes which makes if difficult to discern position and trading desires of other market participants. A short spot position in DM and a long spot position in dollars can be hedged in different instruments (like forwards and futures) or through different cross rates, for example buying dollars for French francs (FF) and simultaneously buying FF for DM. Second, inventory risk management concerns in the FX market are more

Table 1
Forecast of total spot volume in euro relative to the DM[a]

		Daily trading volumes (billions US$)
Legacy DM volume	(1)	268.3
Elimination of intra-EU volume	(2)	−69.8
Additional external liquidity	(3)	+42.9
Euro volume	(4)	241.4

[a] Source: Hartmann (1998, table 4.3)

important than in other dealership markets. The average time span for the inventory cycles of a foreign exchange trader may be as short as 15 minutes. Inventory risk is therefore a crucial determinant of trader behavior and FX spread quotation (Bollerslev and Melvin, 1994; Lyons, 1995, 1996).

The creation of the euro implies that all internal cross rates disappear, while external markets are consolidated in a single rate. The reduced number of trading venues is likely to accelerate the information revelation process and increases public information about excess balances held by other dealers. But an important benefit of a dealership market is interdealer inventory risk sharing after large customer orders. The high interdealer trading volumes indicate this important market function. Accelerated information revelation may be harmful to the dealers as it tends to undermine inventory risk sharing. A low transparency environment allows dealers to pass excess balances to other dealers prior to information revelation and price change. A high transparency environment on the other hand may imply a price change prior to full risk sharing. In the latter case the dealer takes a big concentrated loss on his excess balances which he did not manage to diffuse to other uninformed dealers. He can only protect himself against the increased inventory risk by quoting larger spreads. The higher market transparency induced by the currency union may therefore explain the evidence on higher spreads for the euro (Stylized Fact 1). But higher spreads decrease the role of the euro as a vehicle currency without adverse effect for the dollar rates (Stylized Fact 2). The lower transaction volumes in the euro rates follows from the conventional inverse relationship between transaction costs and volume (Stylized Fact 3).

The role of changing market transparency under a currency union is difficult to formalize. We provide a very stylized model representation which extends the Copeland and Galai (1983) model to a system of three currencies. This allows us to examine the case of a merger of two currencies in a union and compare the prior market characteristics to those after the union formation. The model is designed to illustrate the benefit of interdealer risk sharing in a system of multiple currencies. We show under which conditions a dealer faced with inventory imbalances from client order flow uses cross hedging opportunities in the adjunct currency pairs to manage his inventory risk. A long position in dollars and a short position in DM can for example be hedged by simultaneously selling French francs for dollars and buying French francs for DM. The maintained model assumption about market transparency is that inventory sharing in the same currency pair is possible only at the full information price, while adjunct markets provide the risk sharing options prior to complete price adjustment. This captures the admittedly extreme case in which dealers have full information about excess balances in one currency pair (in which they may specialize) and none in the adjunct markets. The more general message is that differential information about excess balances in markets with substitutable assets will naturally foster risk sharing. If these risk sharing opportunities decrease or disappear or in the currency union, we obtain a market with higher spreads and possibly lower volume (in spite of the liquidity consolidation) as observed for the external euro currency pairs.

The role of market transparency for the spread determination is a very recent concern for the design of equity markets. Evidence that higher market transparency can increase spreads has recently been provided by Bloomfield and O'Hara (1999) in an experimental setting.[4] It is interesting to note that some stock exchanges try to offer a choice to market participants about the desired degree of market transparency. The limit order books of the Paris and Toronto stock exchange for example allows traders to post a part of their limit order in the form of a hidden order which does not appear on the otherwise public limit order book. Harris (1996) shows that hiding trading desires becomes more prevalent as the trade size increases. But his evidence also shows that higher transaction costs (measured by minimum tick size relative to asset price) reduce a dealer's desire to hide orders. This suggests that the inventory costs of increased market transparency may therefore be particularly high in the FX market in which a low spread (compared to equity markets) encourages frontrunning. Madhavan et al. (2000) study the effects of greater transparency in the Toronto Stock Exchange (TSE) before and after the limit order book was publicly disseminated. This natural experiment allows them to isolate the effects of transparency while controlling for stock-specific factors and for type (floor or automated) of trading system. They find that transparency had detrimental effects on execution costs and liquidity.

Our paper is organized as follows. The empirical Section 2 starts with a discussion of the foreign exchange market structure and the data sources. Section 2.3 describes the structural break in transaction costs in the external euro rates relative to the previous corresponding DM rates. Section 2.4 uses unique data on brokered interdealer transactions to highlight the reduced euro turnover. Section 3 provides a theoretical microstructure framework for interpreting this evidence. Section 4 summarizes our conclusions.

2. Evidence

2.1. Foreign exchange market structure

The data and the evidence are difficult to understand without reference to the FX market structure. A brief overview of the market structure is therefore useful.[5] There are three different types of trades in the FX market. These can best be classified by type of counterparty. We distinguish customer dealer trades, direct interdealer trades and brokered interdealer trades. Dealers are employed in about 100 banks worldwide. The customers are non-dealers in financial firms, non-financial firms and central banks. Financial firms include both leveraged institutions such as hedge funds and unleveraged institutions such as mutual funds.

Customer dealer trades amount to approximately 20% of the volume in the former dollar/DM market. Most interdealer order flow is concentrated in about 10 of the

[4] See also Flood et al. (1999) for an experiment of different design and results.
[5] This account is based on Lyons (1999).

100 participating institutions. Direct interdealer trades amount to approximately 40% of the market transactions. The third category, namely brokered interdealer trades, covers the remaining 40% of the total turnover. There are two main interdealer broking systems, namely Reuters Dealing 2000-2 and Electronic Broking Services (EBS). We estimate that EBS brokers 40–50% of the market.

Before EMU two currencies, the dollar and the DM, almost completely dominated world foreign exchange markets. For April 1998, BIS (1999) reported that 98% of the total spot inter-dealer turnover involved either the dollar or the mark or both currencies and that cross transactions involving none of the two vehicle currencies were a negligible share of wholesale spot trading. Substantially the same point can be made about the inter-bank FX swap market. The situation is somewhat different for the outright forward FX market, in which currency distribution tends to be slightly more uniform. However, this segment is also the smallest of the three categories, accounting for only 5% of the aggregate inter-dealer volume in spot, forward and swap transactions and even less when options are added to the aggregate.

2.2. Data sources

Our evidence draws from two distinct data sources. For the evidence on transaction costs we rely on indicative quotes from the Reuters information system. These quotes combine the Reuters FXFX and WXWY pages and were purchased from Olsen & Associates in Zurich.[6] This first data source reflects the customer-dealer segment of the market. The evidence on transactions volumes is based on data obtained directly from EBS. The volume data concerns the brokered inter-dealer market.

2.2.1. Reuters indicative quote data

The Reuters indicative quote data is generated by traders who submit electronic quotes 24 hours a day. The submission of quotes incurs no obligation on the dealer to ‘make a market’ subsequently. Our data set contains the best bid and ask quotes for a set of currency pairs at each full hour. This allows us to construct a bid-ask spread at hourly frequency which we expressed in basis points relative to the mid-price. Available are eight currency pairs, namely dollar/yen (January 1998–August 1999), dollar/sterling (January 1998–August 1999), dollar/DM (January 1998–December 1998), DM/yen (January 1998–December 1998), sterling/DM (January 1998–December 1998), euro/dollar (January 1999–August 1999), euro/sterling (January 1999–August 1999) and euro/yen (January 1999–August 1999). Each month of data represents approximately 744 spread observations. The Reuter data source has been used in previous academic research.[7] Lyons (1995, 1996) as well as Goodhart et al. (1996) have criticized the use of this data to proxy actual interbank spreads. First,

[6] The Reuters FXFX page itself only contains a subset of the available quotes. In addition the FXFX page only displays Dollar pairs. A subset of DM (now Euro) quotes is displayed on the Reuters WXWY page. Our data set represents *all* available quotes. However, to avoid confusion, we follow the convention of referring to this data as FXFX.

[7] We refer to Hartmann (1998a) for a more complete discussion of the Reuters FXFX data.

they are not transactable prices. Second, while quoted spreads usually "bracket" true spreads in the interbank market, they are typically two to three times as wide as transaction spreads. Third, quoted spreads are less likely to bracket true spreads when volatility is highest since there are limits to how frequently the indications can change. While the use of indicative quotes for high frequency spread inference is therefore controversial, low frequency quoted spread measures are more difficult to dismiss as good proxies to actual transaction costs. Goodhart et al. (1996) finds a close enough approximation of indicative quotes to underlying firm quotes at frequencies longer than an hour. All the inference in this paper is concerned with the average spread over monthly periods.

2.2.2. EBS volume data

The EBS data consists of monthly averages of daily spot market transaction volume in eight currency pairs. These are dollar/yen (January 1998–October 1999), dollar/Swiss franc (January 1998–October 1999), dollar/DM (January 1998–December 1998), DM/yen (January 1998–December 1998), DM/Swiss franc (January 1998–December 1998), euro/dollar (January 1999–October 1999), euro/yen (January 1999–October 1999), and euro/Swiss franc (January 1999–October 1999). EBS has different market shares in different currency pairs. Using the BIS survey as a benchmark for 1998, we estimate that EBS has captured 40–50% of the brokered interdealer market. This means that we are effectively measuring at most 20% of the total spot forex volume. Nevertheless, we believe that the time series dimension of the EBS volume data provides a useful measurement of the overall volume evolution around the introduction of the euro.[8] We highlight that the brokered inter-dealer market is of increasing importance (Lyons, 1999) and anecdotal evidence suggests that EBS is enhancing its share of the brokered inter-dealer market. This is relevant since we are presenting evidence of *declining* euro volumes in relation to its legacy currencies.

2.3. Transaction costs

For simplicity we refer to the euro as the successor of the DM. The mnemonic USD/DEM-EUR for example refers to the dollar/DM rate for the period prior to

[8] For a similar analysis see Goodhart et al. (1996) and Payne (1999), who use data from EBS's direct competitor in the brokered interdealer market, Reuters Dealing 2000-2. Goodhart et al. have detailed information from that source on just one day's trading. Payne has similar information for a five day period. Goodhart et al. suggest that brokered interdealer market segment is a reasonable proxy for total spot volume. The most reliable source on transactions volume is the survey carried out by the Bank for International Settlements. However, this data is only available for a single month on a triennial basis. In conclusion the EBS data is as good a picture of forex volumes as we are likely to obtain for the 1998-99 period that we are examining.

January 1999 and to the dollar/euro rate thereafter.[9] Table 2 shows transaction cost statistics for two non-euro currency pairs and three euro currency pairs. We provide statistics for both the mean in panel A and the median in panel B. The skewdness of the quote distribution may make the median a more robust statistic which is less sensitive to abnormally high spread realizations. Column (1) states the mean or median quoted spreads for 1998, while column (2) reports the mean or median spreads for the 8 months following the introduction of the euro. Before testing for differences we filter each spread series for hourly intraday seasonalities and week-end effects.[10] Tests statistics for equality of the mean and median in the pre- and post-euro period are reported in column (4). For a discussion of the median test we refer to Siegel and Cassellan (1988).

The non-euro pairs USD/JPY and GBP/USD show a small decrease in mean spread of 6 and 9%, respectively. The *t*-statistics reported in Table 2, panel A, column (4) indicate that this decrease is statistically significant only for the GBP/USD rate. The corresponding statistics for the median in panel B indicate a decrease of 17 and 8%, respectively, and are both statistically significant. A graphical illustration of the spread for the USD/JPY is provided by the solid line in Fig. 1, which plots monthly average spreads. These and the spreads in subsequent figures are calculated by taking averages of the unfiltered hourly spread data for each month. Spreads increased in the second part of 1998 and then declined in the first part of 1999. Fig. 2 shows the spread decline for the GBP/USD currency pair. It is very modest and hard to detect in the time series plot. We conclude that the two non-euro pairs show evidence for either constant or decreasing spreads between 1998 and 1999.

The three euro pairs show very different spread evidence. Table 2, column (3) reveals that USD/DEM-EUR, JPY/DEM-EUR, and GBP/DEM-EUR all show a substantial increase in mean and median spreads between 1998 and 1999. The mean spread increase is 40% for the dollar market, 62% for the yen rate and a dramatic 195% increase for the sterling rate. Both the mean and median spread increase are statistically highly significant. The time series plots, again based on monthly averages, are provided in Figs. 3, 4, and 5, respectively. The increase in both the dollar and sterling spreads exactly coincide with the introduction of the euro. While we find some gradual decrease in the spread for the sterling rate in the spring of 1999, this decline shows no tendency to revert to the original spread of less than 4 basis points.

Finally, we obtained from an anonymous referee summary statistics on mean and median spreads for a more recent period from September 2000 to January 2001.[11] The mean or median spreads are reported in Table 2, column (5) and are qualitatively

[9] The other time series mnemonics are USD/JPY for Dollar/Yen; USD/CHF for Dollar/Swiss Franc, GBP/USD for Sterling/Dollar, JPY/DEM-EUR for Yen/DM and Yen/Euro, GBP/DEM-EUR for Sterling/DM and Sterling/Euro and CHF/DEM-EUR for Swiss Franc/DM and Swiss Franc/Euro.

[10] For a discussion of these effects in Reuter's quoted FX spreads, see Huang and Masulis (1999).

[11] We note that this source contains for the same time period very low spread observation of 5.63 and 3.28 basis points for the CHF/USD and DEM-EUR/CHF, respectively. Unfortunately, we were unable to obtain spread data on these pairs for 1998 and 1999.

Table 2

Pre- and post-euro FX spot transaction cost comparison. We use Reuters data from Olson & Associates on the best indicative bid and ask quotes in the FX spot market measured at every full hour to calculate the hourly percentage spreads (in basis points) as [log(ask)−log(bid)]×10,000. Reported are the mean and median spreads in five currency pairs for 8760 hours of pre-euro trading (January 1998–December 1998, column (1)) and 5832 hours of post-euro trading (January 1999–August 1999, column (2)). Column (4) provides the test statistics for the difference in transaction costs between the pre- and post-euro regime after filtering for intraday and weekend seasonalities. The t-statistics are calculated using White's correction for heteroscedasticity with no allowance for autocorrelation. They were also calculated allowing for autocorrelation of up to 5th order. However the inferences are not substantially affected. The median test has a chi-square distribution, $\chi^2(1)$, under the null of median equality and critical values given by 3.84 (5%) and 5.99 (1%). Column (5) reports the mean spread for an additional period (September 2000–January 2001) provided by an anonymous referee. We indicate significance of the difference in mean and median at the 5% level (∗) and the 1% level (∗∗)

Panel A: Mean Spreads

Currency	Pre-Euro Jan. 98–Dec. 98 (1)	Post-Euro Jan. 99–Aug. 99 (2)	Change (Percentage) (3)	Difference test (*t*-Statistics) (4)	Recent period Sept. 00–Jan. 01 (5)
Non-euro pairs					
USD/JPY	6.05	5.71	−6%	−0.71	5.52
GBP/USD	5.37	4.89	−9%	−4.48∗∗	4.49
Euro pairs					
USD/DEM-EUR	3.76	5.26	40%	21.70∗∗	4.75
JPY/DEM-EUR	5.12	8.30	62%	17.10∗∗	7.35
GBP/DEM-EUR	3.12	9.20	195%	73.55∗∗	8.80

Panel B: Median Spreads

Currency	Pre-Euro Jan. 98–Dec. 98 (1)	Post-Euro Jan. 99–Aug. 99 (2)	Change (Percentage) (3)	Difference test $\chi^2(1)$ (4)	Recent period Sept. 00–Jan. 01 (5)
Non-euro pairs					
USD/JPY	6.25	5.16	−17%	118.0∗∗	4.62
GBP/USD	5.93	5.46	−8%	247.6∗∗	3.54
Euro pairs					
USD/DEM-EUR	3.30	4.69	42%	3423.0∗∗	5.31
JPY/DEM-EUR	4.49	8.04	79%	1572.8∗∗	5.50
GBP/DEM-EUR	3.35	7.80	133%	9189.8∗∗	8.29

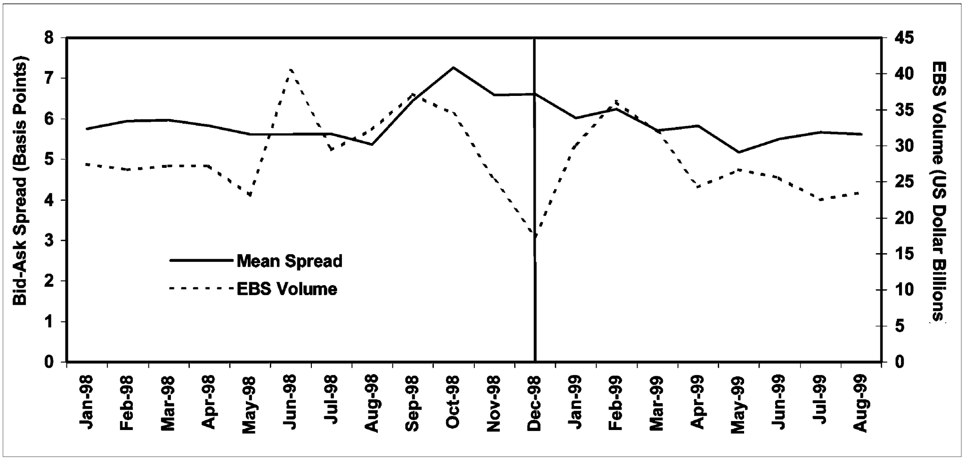

Fig. 1. For the currency pair USD/JPY (Dollar/Yen) we plot monthly averages of hourly percentage bid-ask spreads (in basis points) based on Reuters indicative quote system and monthly average of daily volumes in the electronic broker system EBS (in billions of US dollars).

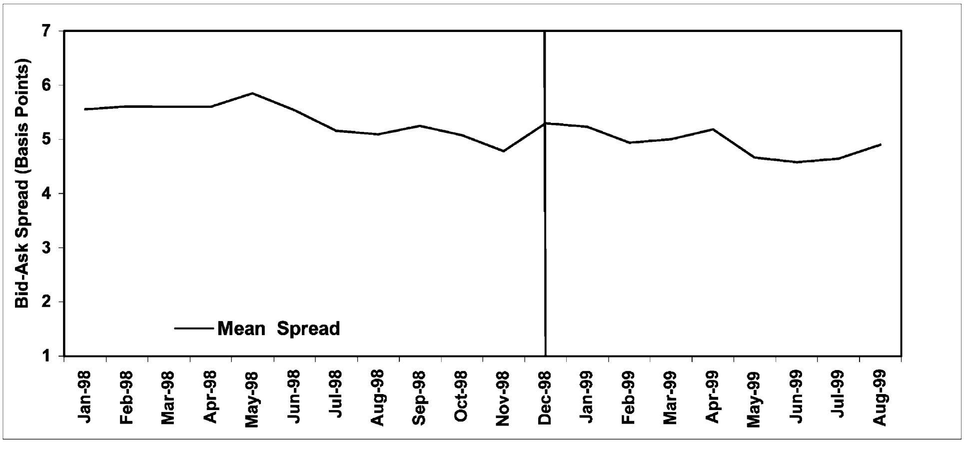

Fig. 2. For the currency pair GBP/USD (British Pound/Dollar) we plot monthly averages of hourly percentage bid-ask spreads (in basis points) based on Reuters indicative quote system.

similar to the spreads for the 8 month period following the euro introduction. This data confirms that the spread increase for the euro currency pairs was indeed long lasting and not a transition problem. We conclude that foreign exchange transactions are more costly in the euro than in the preceding DM rates.[12]

[12] Historical spread data are also available for April 1992 (Hartmann, 1998a). These spreads are generally low and comparable to the pre-euro spreads reported here. Detken and Hartmann (2000) also report results on pre- and post-euro spreads. Their evidence from Reuters is qualitatively similar to ours. They also report data from Bloomberg. Both appear to be drawn only from end-of-day quotes. The intraday data in the present paper are much richer and in general more reliable than end-of-day quotes.

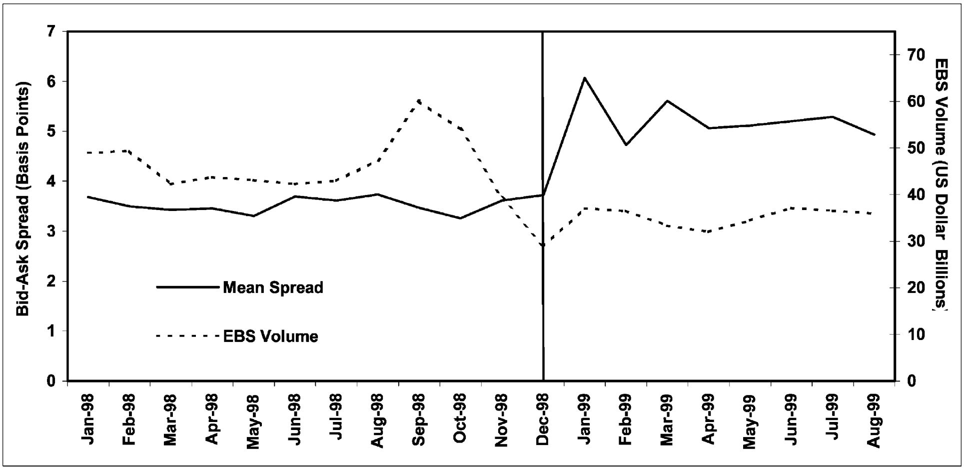

Fig. 3. For the currency pair USD/DEM-EUR (Dollar/DM-Euro) we plot monthly averages of hourly percentage bid-ask spreads (in basis points) based on Reuters indicative quote system and monthly average of daily volumes in the electronic broker system EBS (in billions of US dollars).

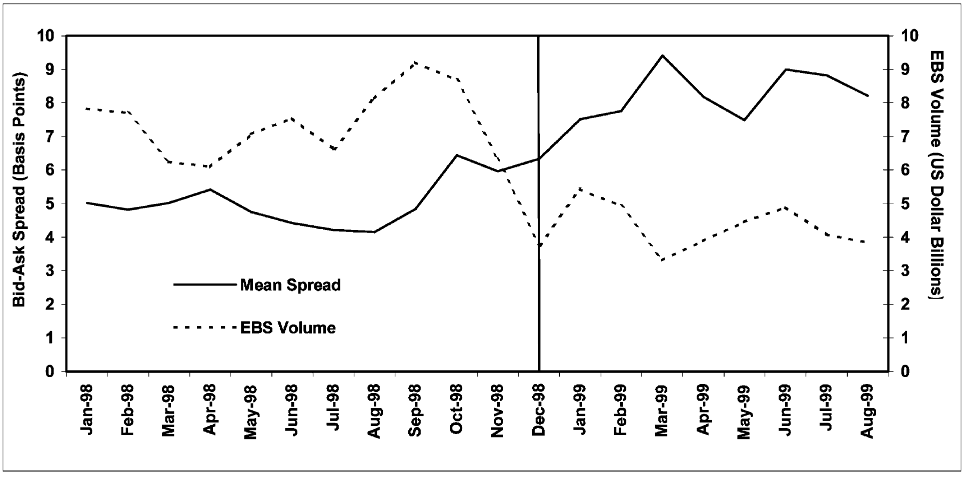

Fig. 4. For the currency pair JPY/DEM-EUR (Yen/DM-Euro) we plot monthly averages of hourly percentage bid-ask spreads (in basis points) based on Reuters indicative quote system and monthly average of daily volumes in the electronic broker system EBS (in billions of US dollars).

2.4. Transaction volume

Table 3 documents the change in EBS brokered transaction volume before and after the euro creation. In Panel A, the monthly volume series are converted into

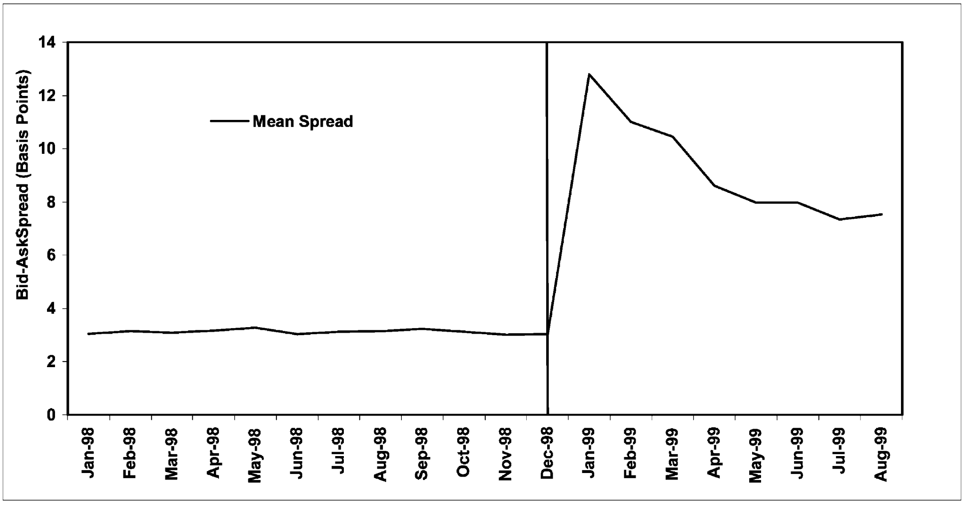

Fig. 5. For the currency pair DEM-EUR/GBP (DM-Euro/British Pound) we plot monthly averages of hourly percentage bid-ask spreads (in basis points) based on Reuters indicative quote system.

billions of US dollars at the end of the month exchange rate. A time series plot, in row order of currency pair, is provided by Figs. 1, 6, 3, 4, and 7.[13]

First, we look at the two non-euro currency pairs. From Panel A of Table 3, USD/JPY mean volume fell by a modest 5% after the introduction of the euro. The scored line in Fig. 1 indicates temporary volume changes without any large long-run change. Volume peaked in the summer and fall of 1998. This coincides with the Russian financial crisis, the difficulties of Long Term Capital Management (LTCM) and the surge in the value of the yen. However, by the summer of 1999 USD/JPY volume had recovered. Second, USD/CHF mean volume almost doubled between the two years. This pair has moved ahead of both CHF/DEM-EUR and JPY/DEM-EUR. Fig. 6 illustrates the intertemporal increase in volume, which coincides with the introduction of the euro.

More interesting still are the three euro currency pairs for which volume data are available. The most surprising currency pair is USD/DEM-EUR (Fig. 3). Panel A of Table 3 shows that euro/dollar mean volume is 22% lower than the mean dollar/DM volume. This is striking given that the DM rate is only one of many legacy currencies in the monetary union. In fact statistics from the Bank for International Settlements (1999) shows that in April 1998, global turnover in all market segments in dollar/DM was $290.5 billion per day while turnover in aggregate dollar/other

[13] For completeness, Panel B displays the volumes for euro-pairs in euros. This addresses the possibility of valuation bias. There is, however, no substantive difference.

Table 3
Pre- and post-euro FX spot transaction volume comparison. FX spot market transaction volumes are stated for different currency pairs in the electronic brokerage system EBS. We estimate the market share of EBS to represent approximately 40–50% of all electronically brokered trades and 20% of all FX spot transactions for the listed currency pairs. The data is available to us as monthly averages of total daily transaction volume. The monthly averages are converted into US dollar volumes at end of the month exchange rates for Panel A To avoid any valuation bias, the volumes are also calculated in euros for the three euro pairs in Panel B. In the latter panel, for 1998, the volumes were first converted into DM using the end of month exchange rate. The DM-euro conversion rate was then used to complete the task. Column (1) provides the mean volume for the 12 months of pre-euro trading (January 98–December 98) and column (2) reports the mean volume for the consecutive 8 post-euro months (January 99–August 99). The mean volume change from the pre- to the post-euro period is given in column (3) and the difference test in column (4). The *t*-statistics are calculated using White's correction for heteroscedasticity with no allowance for autocorrelation. They were also calculated allowing for autocorrelation of up to 3rd order. However the inferences are not substantially affected. We mark significance at the 5% level (*) and the 1% level (**)

Panel A: Volumes Expressed in US Dollars

Currency	Pre-euro Jan. 98–Dec. 98 (1)	Post-euro Jan. 99–Aug. 99 (2)	Change (Percentage) (3)	Difference test (*t*-Statistics) (4)
Non-euro pairs				
USD/JPY	29.0	27.6	−5%	−0.69
CHF/USD	3.3	5.9	80%	4.91**
Euro pairs				
USD/DEM-EUR	45.2	35.4	−22%	−6.15**
JPY/DEM-EUR	7.1	4.4	−38%	−4.09**
CHF/DEM-EUR	5.3	3.5	−34%	−3.39**

Panel B: Volumes of Euro Pairs Expressed in Euros

Currency	Pre-euro Jan. 98–Dec. 98 (1)	Post-euro Jan. 99–Aug. 99 (2)	Change (Percentage) (3)	Difference test (*t*-Statistics) (4)
Euro pairs				
USD/DEM-EUR	40.5	32.7	−19%	−4.37**
JPY/DEM-EUR	6.4	4.0	−37%	−5.97**
CHF/DEM-EUR	4.7	4.0	−15%	−5.31**

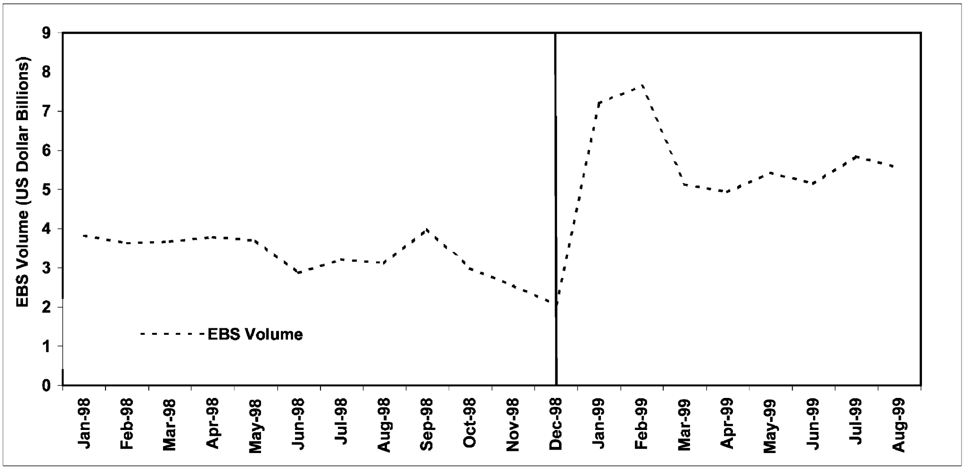

Fig. 6. For the currency pair USD/CHF (Dollar/Swiss Franc) we plot monthly averages of daily volumes in the electronic broker system EBS (in billions of US dollars).

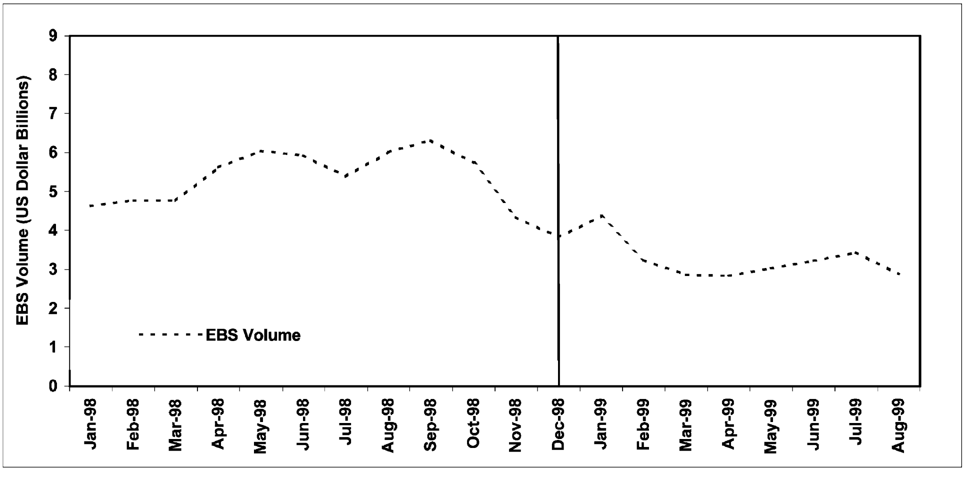

Fig. 7. For the currency pair CHF/DEM-EUR (Swiss Franc/DM-Euro) we plot monthly averages of daily volumes in the electronic broker system EBS (in billions of US dollars).

EMS pairs amounted to $250.3 billion per day.[14] The qualitative importance of liquidity consolidation of former non-DM legacy dollar pairs cannot be dismissed lightly. Despite the merging of these legacy pairs into a common euro/dollar pair, we register an astonishing overall volume decrease in the USD/DEM-EUR series

[14] This figure is obtained as the sum of Dollar/French Franc, Dollar/Ecu and Dollar/'other EMS' in the BIS survey. A number of caveats need to made about this remark. The above BIS figures refer to all market segments. It also includes forward and swap as well spot volumes. If only spot volumes are considered, Dollar/DM falls to $142.3 billion per day while the sum of the other three falls to $35.1 billion per day.

for 1999. Second, JPY/DEM-EUR mean volume fell by 38% between 1998 and 1999. The scored line in Fig. 4 shows that volume fell from its fall 1998 peak, but unlike USD/JPY, it never recovered. Finally, CHF/DEM-EUR mean volume decreased by 34% between 1998 and 1999. Like the other two euro pairs, Fig. 7 again shows an autumn 1998 peak with no recovery in 1999. Panel A of Table 2, column (4) reports t-statistics for the equality of the mean trading volume in the pre- and post-euro environment. The volume shortfall in the euro pairs relative to previous DM volumes is statistically significant in all three cases.

In summary, the EBS transactions volume shows a pattern of lower volumes in euro pairs relative to the corresponding legacy DM pairs. Generally, euro volumes failed to recover from the late autumn 1998 decline in FX spot volumes unlike non-euro currency volumes.

2.5. Five alternative hypotheses

The following section examines five alternative hypotheses which we believe cannot account for the above evidence. We discuss them briefly before proposing our own explanation.

The *competition hypothesis* claims the spread increase is due to reduced market maker competition in the FX market. Following a formal question in the European Parliament concerning the widening of spreads for the sterling/euro rate, the EU Commission launched an investigation for anti-competitive market practises.[15] No evidence could be produced.[16] In the light of our own evidence we find the competition hypothesis implausible for a number of reasons. First, it is unclear why reduced quote competition should coincide with the euro introduction between December 1998 and January 1999. Second, any market exit of FX dealers should lead to a general spread increase for all rates. Why such spread increase is limited to the euro currency pairs would remain unexplained. Third, Huang and Masulis (1999) show that the sensitivity of the quoted spread with respect to entry is relatively low.[17]

The *tick size hypothesis* interprets the spread increase as the consequence of behavioral quoting practices in the FX market. The legacy sterling/DM rate for example was quoted in DM with a spread of 5 DM pips or 0.0005 DM. In contrast, sterling/euro is quoted in sterling with a spread of 3 sterling pips. Because of the change in the nominal unit of measurement, the nominal spread is closer to zero in terms of pip integers. Traders may be under the illusion of lower spreads and stick to the previous nominal pip-based spreads. We find this value illusion difficult to believe. No formal constraint exists to quote fractions of pips. Also, economic stakes in the market seem too high for market makers not to learn about this simplistic value illusion.

The *volatility hypothesis* attributes the rise in the euro spreads and the parallel

[15] See also Financial Times, 29.10.99 and 20.12.99.

[16] See EU Commission (1999).

[17] Compare Huang and Masulis (1999), Fig. 2, p. 75.

decline in volume to an exogenous increase in FX volatility. While FX volatility changes are common, why should they occur only for euro rates unless they are endogenous to the regime shift under the currency union? Increased market transparency and accelerated price revelation may indeed increase FX volatility. Less efficient dealer risk sharing in the more transparent post-euro regime can increase the price impact of client order flow, thus generating higher volatility. Madhavan et al. (2000) show that price volatility increased in the Toronto stock market following a regulatory shift to higher pre-trade transparency. This endogenous effect is obviously difficult to distinguish from other euro-specific volatility shocks. Hence, the volatility statistics summarized in Table 3 allow different interpretations, although their computation is straightforward. The hourly data frequency of the Reuters data allows us to measure pre- and post-euro volatility directly as realized volatility (see Andersen et al., 2001) using a total of 14,992 observations for each currency pair. Table 4, column (1) presents the pre-euro volatility and column (2) the post-euro volatility, where we defined volatility as the log of the sum of the squared return changes over hourly intervals measured at midprice. Fig. 8 plots the correponding time series of monthly realized volatility for JPY/DEM-EUR, USD/DEM-EUR and GBP/DEM-EUR. The two non-Euro pairs show a decrease and the three euro pairs an increase of post- to pre-euro FX volatility. But only for the GBP/DEM-EUR market do we find a statistically significant volatility increase. Therefore, the overall case for the volatility hypothesis appears weak. Detken and Hartmann (2000) make a similar point about exchange rate volatility.

The *vehicle currency hypothesis* argues that in contrast to the DM, the euro is more often exchanged indirectly via the dollar against third currencies. We concede

Table 4
Pre- and post-euro FX volatility. We use Reuters data from Olson & Associates on the best indicative bid and ask quotes in the FX spot market measured at every full hour to calculate FX volatility for five currency pairs as half the log of the sum of squared return changes on hourly midprice (Andersen et al., 2001). Reported are the realized volatility for 8760 hours of pre-euro trading (January 1998–December 1998, column (1)) and 5832 hours of post-euro trading (January 1999–August 1999, column (2)). Column (4) provides the heteroskedastic consistent t-statistics for a test of equal volatility across the two regimes. These are calculated using White's correction for heteroscedasticity with no allowance for autocorrelation. They were also calculated allowing for autocorrelation of up to 3rd order. However the inferences are not substantially affected. We mark significance at the 5% level (∗) and the 1% level (∗∗)

Currency	Pre-euro Jan. 98–Dec. 98 (1)	Post-euro Jan. 99–Aug. 99 (2)	Change (Percentage) (3)	Difference test (*t*-Statistics) (4)
Non-euro pairs				
USD/JPY	1.5	1.3	−23%	−1.76
GBP/USD	0.9	0.8	−9%	−1.06
Euro pairs				
USD/DEM-EUR	1.0	1.1	10%	0.94
JPY/DEM-EUR	1.3	1.4	7%	0.55
GBP/DEM-EUR	0.8	1.0	24%	2.02∗

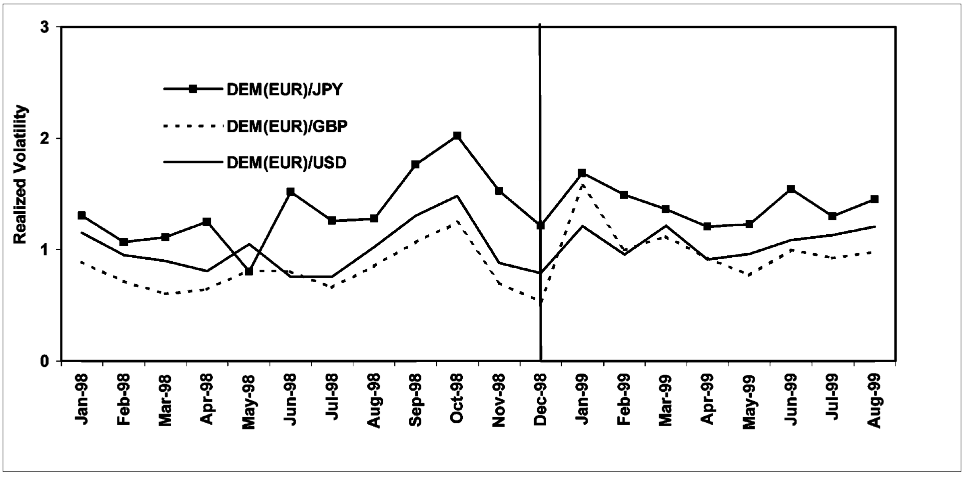

Fig. 8. For the three currency pairs DEM-EUR/JPY, DEM-EUR/GBP and DEM-EUR/USD we plot monthly realized volatility measured as the log of the mean squared hourly returns of the midprice in the Reuters indicative quote system.

that the vehicle currency theory allows in principle for multiple equilibria (Hartmann, 1998a). But it is not clear to us why the euro should not inherit the vehicle currency status of the DM. Also, any explanation based on multiple equilibria gives no insight as to *why* we see an equilibrium transition. We prefer to focus on testable explanations of a causal nature. However, the most compelling reason for rejecting the vehicle currency hypothesis is that it requires at the very least that USD/DEM-EUR volumes should have risen and its spreads fallen. In fact, precisely the opposite has occurred.

This is not to exclude a vehicle currency story entirely. The data in Tables 1 and 2 clearly show an increase in the liquidity of CHF/USD and GBP/USD. This is consistent with the idea that transactions originating in sterling and the Swiss franc have become more likely to use the dollar as a vehicle than before the creation of the euro. This does not account for why the euro has a smaller vehicle role than the DM. There is still a need to explain what triggered the change in vehicle status.

The *transition hypothesis* argues that the observed rise in euro-spreads vis-á-vis the legacy DM spreads is simply a disequilibrium phenomenon. For example, many small banks in various European countries had lost home currency business against the dollar and the DM. They may have initially tried to switch their trading activity to USD/EUR, GBP/EUR or JPY/EUR. Because of their information disadvantages compared to the established market participants, they may have quoted larger spreads in order to protect themselves against more informed traders. But overall this reorientation of market making activity should have increased competition in the remaining currency pairs and reduced their spreads. Furthermore, we provide evidence in column (5) of the two panels of Table 1, that the wider spreads in euro-pairs have been sustained up to two years after the introduction of the euro. Admittedly, there is some indication that the spread increase has been reduced in its magnitude but even that caveat is somewhat ambivalent.

3. A microstructure explanation

This section presents a microtheoretical interpretation of the stylized euro characteristics. We start with an intuitive description of the central idea in Section 3.1. Section 3.2 presents the model with endogenously determined spreads and volume. It is a generalization of the Copeland and Galai model (1983) to a multicurrency system with risk averse market makers. The multicurrency system is represented by a triangular system of three currencies and three cross rates. The currency union corresponds to the case in which two of the currencies merge and the triangular system collapses to a single bilateral exchange rate. In Section 3.3 we solve for the external equilibrium spread under the currency union. Section 3.4 solves for the equilibrium spread in the more complicated triangular currency system which corresponds to the pre-euro setting. Section 3.5 extends the model to the general case in which the degree of information asymmetry differs across different currency pairs. This provides an interesting additional perspective on the spread increase in the euro.

3.1. An informal discussion

Microstructure theory has distinguished three components of spread determination: Inventory holding costs, information costs and order processing costs.[18] We are not aware of any reason which could plausibly explain a sudden exogenous shock to the bank cost function for FX market making.[19] We therefore focus on the two remaining spread components.

Our main argument is that the inventory costs for FX dealers has increased under the currency union. The currency union has not only concentrated foreign exchange liquidity in a single external euro rate, but also decreased the number of currency pairs and therefore the complexity of the FX market. We argue that this has increased market transparency. Market transparency in turn can be detrimental to the interdealer risk sharing function. Dealers receiving potentially informative client order flow tend to disseminate these flows in interdealer trades. The relatively high volume of such "hot potato trading" and the short time spans for inventory holding cycles highlight the importance of interdealer risk sharing. If a more transparent market makes it easier to identify the aggregate imbalances, the information revelation and price adjustment process accelerate and may preempt the full dissemination of the excess balances prior to price adjustment. Trading losses are then concentrated in the

[18] See for example Huang and Stoll (1997) or Sarno and Taylor (2000) for a survey.

[19] The introduction of the Euro coincided with the use of the TARGET clearing system. However, the apparent success of the TARGET system points to a possible decrease in order processing costs for euro rates.

account of the dealer with the original inventory imbalance. This increases inventory risk and requires higher equilibrium spreads as a compensation for this risk.

The stylized model presented in the following section is designed to capture the key role of inventory risk sharing in a multidealer market. We start from a triangular system with three currency spot markets, for example the dollar/DM, the DM/French franc and the dollar/French franc rate. For simplicity, we assume that dealers specialize in a particular currency pair. Dealers in the same pair know about inventory imbalances in their own currency pair, but not about imbalances in the two other markets. A dealer with inventory imbalances can therefore use the two other rates in a triangular system to diffuse his position through cross rate hedging.[20] We are able to characterize the equilibrium spreads and trading volumes for a symmetric multicurrency system and compare them to the case in which two of the currencies merge in a currency union. The triangular system then collapses to the bilateral one. Dealers then no longer have the option to pass imbalances to the uninformed dealers in other currency rates. The loss in interdealer risk sharing results in higher equilibrium spreads and possibly lower transaction volume in spite of the liquidity consolidation. This corresponds to our observations about the euro.

Our model incorporates asymmetric information between clients and dealers. The equilibrium spread reflects the respective information costs as a separate spread component. But the information cost component of the spread does not change with the currency union as long as the adverse selection problem from quote provision is the same for dealers in all currency pairs. This latter assumption need not be fulfilled. Some currency rates may be subject to more informative order flow than others. If for example order flow in intra-European rates (prior to the currency union) was relatively less informative, then the corresponding hedging activity could reduce the equilibrium spread in the dollar/DM rate. This externality could disappear with the currency union and imply higher dollar/DM spreads. We treat such “asymmetry in information asymmetry” across currencies as an extension in Section 3.5.

In what follows, we restrict our modelling effort to cross currency hedging behavior in spot rates. But our argument about the relationship between market transparency and spread determination carries over to all kinds of other hedging strategies involving forwards or swaps in so far as they are carried out in a non-transparent dealership market. With the euro arrival, the number of derivative markets was also drastically reduced and liquidity and information concentration occurs in fewer rates. Therefore, our argument is not contingent on any particular FX instrument.

3.2. A simple model

Let there be a triangular market in three currency exchange rates denoted *AB*, *AC* and *BC*.[21] These currency rates might for example represent the dollar/DM rate, the

[20] Such cross hedging (undertaken possibly in derivatives) appears to have been an important element of the pre-euro market structure. Its noteable feature is the high proportion (88%) of the trading volume that took the form of outright forwards and swaps in dollar markets with legacy currencies other than the DM. However, our model considers hedging only through the spot markets.

[21] The case of only three currencies allows a very simple formulation of the idea that parallel markets

DM/FF rate and the dollar/FF rate. The three markets are decentralized dealership markets. However, it takes time to find a trading partner who is willing to trade. We capture the non-simultaneous nature of the interdealer market by assuming that the market in currency pair *AB* is open in period 1, while markets for the currency pairs *AC* and *BC* are open only in period 2. We assume that currency balances in each currency pair can be liquidated in period 3 at prices P^L_{AB}, P^L_{AC} and P^L_{BC}, respectively.[22] Trader *AB* is the market maker in currency pair *AB* and quotes a bid-ask spread s_{AB} in the currency rate *AB* around a midprice P^M_{AB} in period 1.We assume that the three spreads are quoted independently of trade-size.[23] Similarly, traders *AC* and *BC* are market makers in currency pairs *AC* and *BC*, respectively, and quote bid-ask spreads s_{AC} and s_{BC} around midprices P^M_{AC} and P^M_{BCM} respectively. To begin with, let *AB* be the currency pair in which temporary imbalances arise. They are related to a stochastic shock ε to the liquidation price P^L_{AB}, such that

$$P^L_{AB} = P^M_{AB} + \varepsilon.$$

We assume that the shock ε has mean zero and variance σ^2_ε. The shock to the currency pair *AB* can have two distinct sources. It can be related to a value change for the currency *A* (state *a*) or alternatively to a value change for the currency *B* (state *b*). For example an appreciation of the dollar/DM rate can come either as appreciation of the DM against both dollar and FF or as an appreciation of the DM and the FF against the dollar. We assume for simplicity that both states *a* and *b* are distinct and occur with equal probability of 1/2. Therefore,

$$P^L_{AC} = \begin{cases} P^M_{AC} + \varepsilon & \text{if } a \\ P^M_{AC} & \text{if } b \end{cases}$$

and

$$P^L_{BC} = \begin{cases} P^M_{BC} & \text{if } a \\ P^M_{BC} + \varepsilon & \text{if } b \end{cases}.$$

In period 1 the trader in the currency pair *AB* faces informed and uninformed currency demand. Currency demand from informed traders is denoted $X^I(s)$ and demand from uninformed traders (noise traders) is denoted $X^U(s)$. We make simple closed form assumptions about this demand, namely

$$X^I(s) = f(s)\chi^I,$$
$$X^U(s) = f(s)\chi^U,$$

where χ^I and χ^U are independent random variables which can take on the values -1

might be less transparent and therefore provide marginal hedging benefits. Moving from $n>3$ to $n+1$ markets should still provide a *marginal* hedging benefit for a trader with excess balances. But this situation requires a more elaborate modelling effort.

[22] The three periods are best considered as a sequence of intra-day trading. There is no time preference between them.

[23] Traders cannot condition on trade size.

and 1 with equal probability 1/2. The function $f(s)>0$ is assumed to be continuous and decreasing in the spread $s\in(0,\infty)$ and has a maximum at zero. This captures in reduced form the inverse relationship between spreads and both informed and uninformed currency demand. We also assume that χ^I is informative about price innovations ε. This is captured by a negative covariance of informed demand and the price innovation given by[24]

$$\mathrm{Cov}(\varepsilon,\chi^I) = -\gamma < 0.$$

The quoting trader *AB* incurs losses in his trades with the better informed clients. But he can use the two other currency markets *AC* and *BC* to hedge against losses from the informed demand. We assume that in period 2 trader *AB* can choose to sell 50% of his excess demand short in the currency rates *AC* and *BC*. This is referred to as the cross currency hedging option (h=1). Alternatively, trader *AB* may decide not to hedge and keep his excess balances until liquidation in period 3. He cannot pass on the imbalances to a trader in his own currency pair *AB* because dealers in the same market are assumed to have full information about the inventory shock and adjust their quotes accordingly in the second trading round. Spread quotation by (uninformed) traders in markets *AC* and *BC* by contrast has not yet incorporated the information about the inventory shock realization and therefore provide attractive hedging opportunities. But we also restrict the hedging options of trader *AB* in markets *AC* and *BC* in order to simplify the analysis. We assume that he can hedge only 50% of his excess balance which amounts to optimal risk allocation between the three traders.[25] But we highlight that the attractiveness of the hedging option clearly depends on the endogenous size of the spreads s_{AC} and s_{BC}. Finally, we have to specify the risk aversion of the traders. Let their utility depend only on the expected profit and its variance, namely

$$U(\Pi_i) = E(\Pi_i)-\frac{1}{2}\rho \ \mathrm{Var}\ (\Pi_i),\ i = AB,AC,BC$$

where the parameter ρ governs his risk aversion.[26]

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[24] This covariance can be illustrated as follows: If P_{AB} is the DM price of dollars, then $\varepsilon>0$ is a DM depreciation and $\chi^I>0$ is a DM customer purchase.

[25] Traders generally have an incentive to hedge more than 50% of their informative excess balances *as long as* the spreads s_{AC} and s_{BC} do not adjust, which they would of course as trader *AB* overexploits the information signal in his excess demand. We abstract from this dimension of spread adjustment process by limiting the hedging possibilities to 50% of the excess balances. This happens to coincide with the optimal level of intertrader risk sharing. But other suboptimal intertrader risk sharing outcomes still support our conclusions as long as at least some marginal improvement in intertrader risk sharing is achieved through the existance (or only improvement) of the cross hedging opportunity. For a more elaborate theoretical analysis see Viswanathan and Wang (2000).

[26] The utility function of the market makers is a "Selten utility" defined in the first and second moment of profits. Since the order-flow shocks in the model are the product of a binomial and normal random variable, the formulation does not reduce to CARA preferences.

3.2.1. The triangular system

In the above exposition the supply and price shock originates in the currency rate *AB* with distinct states *a* and *b*. Generally, the order flow shock might occur first in any of the three currencies, allowing for states *a*, *b* and *c*. For simplicity, we assume a symmetric set-up in which the supply shock and price change ε originates with equal probability 1/3 in each of the three currencies. Moreover, traders are assumed not to know at the moment of spread determination in which of the three currencies *A*, *B*, or *C* the supply shock occurs. This is formally equivalent to a set-up in which traders have to choose first their spread s and then are assigned by nature one of the three cross rates. A lack of information with respect to the origin of the supply shock is equivalent to not allowing any conditioning of the spread s on the respective currency pairs *AB*, *AC*, or *BC*. The maximization problem of the traders in the triangular currency system therefore amounts to setting a single spread $s \in (0,\infty)$ and choosing a hedging strategy $h \in \{0,1\}$ so as to maximize

$$\frac{1}{3}U(\Pi_{AB}) + \frac{1}{3}U(\Pi_{AC}) + \frac{1}{3}U(\Pi_{BC}). \tag{1}$$

We denote the solution for the equilibrium spread by s^T.

3.2.2. The currency union

The introduction of the euro is represented by a union of the currencies *A* and *C*. The triangular currency system therefore collapses to a single rate *AB*. We assume for simplicity that the exogenous demand per trader does not change. The trader *AB* faces the same demand as before and the trader *BC* is now quoting in currency *AB* with a currency demand of the same information features as before, only that it is now in currency rate *AB*. Trader *AC* and his demand disappear. Since by assumption no currency cross rates exist and excess balances are revealed to the second trader in same currency, hedging opportunities are absent in period 2.[27] This implies that h=0 and the two remaining traders choose a spread $s \in (0,\infty)$ to maximize $U(\Pi_{AB})$.

The equilibrium spread in this case is denoted by s^U. The simple set-up allows for a straightforward comparison to the equilibrium spread s^T in the triangular system.

It is clear that even after the introduction of the euro, traders had other cross hedging opportunities at their disposal. The Swiss franc and the British pound for example continued to provide such options. The somewhat stylized opposition of a trilateral versus a single rate currency system ignores this aspect for expositional simplicity. But we underline that our qualitative argument depends only on a marginal decrease of hedging opportunities (due to the currency union) and the fact that these hedging opportunities contributed to the opaqueness of the true aggregate excess balance of all market makers.

[27] We could also assume that the two traders in *AB* can still share their inventory risk. But since they are only two traders (instead of three as before) spreads would still be higher. In this case the spread increase would not be explained by increased market transparency, but by a decrease in the risk sharing capacity of the market.

3.3. External spreads of the currency union

We start solving for the optimal spreads in the currency union in which no (intra-union) cross currency hedging exists. The expected profit of a trader who quotes a bid-ask spread consists of two components. First, the trader earns spread profits denoted Π^S on the exogenous informed and uninformed transaction volume. We can evaluate these profits relative to the midprice which is also the (unconditional) expected liquidation price. Formally, for expected spread profits relative to the mid-price of $s/2$ we obtain

$$E(\Pi^S) = \frac{s}{2}E[|X^I| + |X^U|] = \frac{s}{2}[|X^I| + X^U|] = sf(s).$$

A higher spread increases spread profits linearly in s, but decreases volume in the term $f(s)$ as $\mathrm{d}f(s)/\mathrm{d}s<0$. The second component of the expected profit is the directional loss from providing a bid-ask spread to informed traders. We can quantify these expected directional profits $E(\Pi^D)$ as the covariance of the excess balances $X^E=X^I+X^U$ with the consecutive exchange rate change ε, hence

$$E(\Pi^D) = E(X^E\varepsilon) = E[(X^I + X^U)\varepsilon] = -\gamma f(s).$$

Finally, we have to take into account the risk aversion of the traders. The excess balances X^E in the stylized set-up can take only one of three values, namely

$$X^E = \begin{cases} 2f(s) & p = \frac{1}{4} \\ 0 & p = \frac{1}{2}. \\ -2f(s) & p = \frac{1}{4} \end{cases}$$

The unconditional variance follows as the weighted average of the conditional variances, therefore

$$\mathrm{Var}(\Pi^D) = \frac{1}{4}\mathrm{Var}[2f(s)\varepsilon] + \frac{1}{4}\mathrm{Var}[-2f(s)\varepsilon] = 2\sigma_\varepsilon^2 f(s)^2.$$

We note that the variance of the spread profit Π^S is zero. Total utility of a trader under a currency union follows as

$$U(\Pi_{AB})^{h=0} = sf(s)-\gamma f(s)-\rho\sigma_\varepsilon^2 f(s)^2.$$

In an equilibrium with competitive entry the traders should be indifferent between quote provision and no quote provision. This implies that in equilibrium trader utility should be zero. This in turn implies the competitive spread under a currency union. Proposition 1 summarizes the result.

Proposition 1 *Under a currency union the competitive external spread* s^U *is defined by the equation*

$$s^U = \gamma + \rho\sigma_\varepsilon^2 f(s^U), \tag{2}$$

where γ *measures the covariance of informed trader demand with consecutive exchange rate changes,* ρ *characterizes the risk aversion of the trader,* σ_ε^2 *the variance of exchange rate changes and f(s) captures the (inverse) relationship between spread size and currency demand. Expected volume (per trader) is given by*

$$E(Vol) = 2f(s^U).$$

Proof. Follows directly from $U(\Pi_{AB})^{h=0} = 0$. ■

Fig. 9 provides a graphical illustration. The left-hand side of Eq. (2) is represented as a 45 degree line. The decreasing line represents the right-hand side and the intersection marks the competitive equilibrium spread s^U. The comparative statics are intuitive and straightforward. An increase in γ, representing more information in the order flow, shifts the second line upwards and increases the equilibrium spread.[28] The same holds for a higher risk aversion parameter ρ and higher exchange rate volatility captured by σ_ε^2.

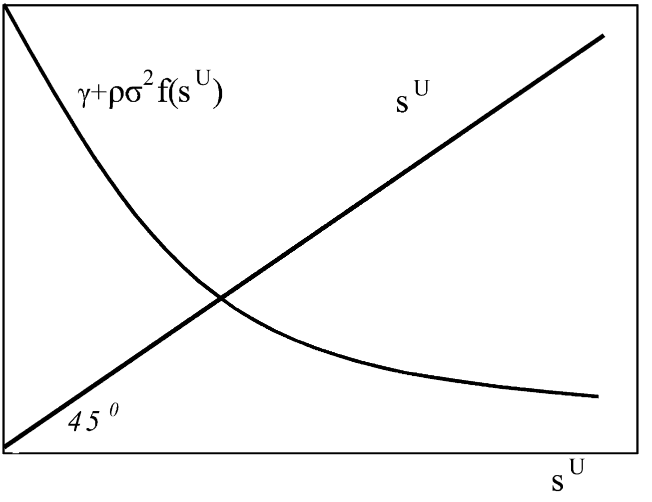

Fig. 9. The equilibrium relationship for the competitive spread $s^U = \gamma + \rho\sigma^2 f(s^U)$ in a system with two currencies is illustrated by plotting the right- and left-hand side of the equation. The intersection characterizes the equilibrium spread s^U which depends on the adverse selection parameter γ capturing the information cost component of spreads and the inventory cost component given by a product of trader risk aversion ρ, exchange rate variance σ and the currency demand $f(s^U)$ assumed to be decreasing in the spread s^U.

[28] Naturally, any comparative statics exercise with respect to the reduced form parameter γ is problematic. In a structural model an increase in γ might also increase the order flow from informed agents.

3.4. Spreads in the triangular system

Next we analyze the triangular currency system in which cross currency hedging is possible. We proceed in three steps. First we show under which conditions the trader *AB* desires to hedge half of his excess balances with contrarian positions in the two other currencies. This will be an optimal strategy only if the spread in the currency pairs AC and BC are below a certain threshold. In a second step we derive the competitive spread in the triangular system if trader *AB* hedges (h=1). Finally, we show that the resulting competitive spread is indeed low enough to make traders want to hedge in period 2. This justifies the hedging assumption in the derivation of the competitive spread level and completes the equilibrium argument. The appendix generalizes the derivation to an arbitrary postive hedging share μ for the excess balances with $0<\mu<1$. The main text treats the simpler case where μ=0.5.

The following proposition characterizes the cross currency hedging condition:

Proposition 2 *In the competitive triangular currency system with a spread* s^T, *the trader who is experiencing excess balances desires a cross currency hedge if*

$$s^T < \gamma + \frac{3}{2}\rho\sigma_{\varepsilon}^{2}f(s^T). \tag{3}$$

Proof. The trader prefers a hedged over an unhedged position if

$$U(\Pi_{AB})^{h=1} - U(\Pi_{AB})^{h=0} > 0.$$

Under the assumption that trader *AB* can hedge 50% of his excess balances X^E in period 2, we obtain

$$E(\Pi^S) = \frac{s}{2}E\left[\frac{1}{2}|X^I + \frac{1}{2}|X^U|\right] = \frac{1}{2}sf(s),$$

$$E(\Pi^D) = E\left(\frac{1}{2}X^E\varepsilon\right) = -\frac{1}{2}\gamma f(s),$$

$$\mathrm{Var}(\Pi^D) = \frac{1}{2}\sigma_\varepsilon{}^2 f(s)^2,$$

for the spread profit, the expected directional profit and the profit variance, respectively. The expression for the spread profit is obtained from two components. The first is the spread profit for the dealer *AB* from receiving his customer order flow. This is the same as in the currency union, namely

$$E(\Pi^{S1}) = \frac{s}{2}E[|X^I + |X^U|] = sf(s).$$

The second component is the spread loss from partial cross hedging of 50% of the excess supply. These (negative) profits are given by

$$E(\Pi^{S2}) = 2\left\{-\frac{s}{2}E\left[\frac{1}{2}|X^I + X^U|\right]\right\},$$

$$= -\frac{s}{2}E[|X^I + X^U|],$$

$$= -\frac{1}{2}sf(s),$$

where the pre-multiplication by 2 is due to the dual cross hedge. The total spread related expected profits are therefore

$$E(\Pi^S) = E(\Pi^{S1}) + E(\Pi^{S2}) = \frac{1}{2}sf(s).$$

Calculating the trader utility for h=1 implies

$$U(\Pi_{AB})^{h=1} = \frac{1}{2}sf(s) - \frac{1}{2}\gamma f(s) - \frac{1}{4}\rho\sigma_\varepsilon^2 f(s)^2,$$

and subtracting the utility for $h = 0$ calculated previously directly implies the inequality (3). ■

By hedging, a trader foregoes spread income (Π^S), but reduces his losses from liquidity provision to informed traders (Π^D), and also lowers his inventory risk. He desires to hedge if spreads are sufficiently low. A more informative currency demand, higher risk aversion or higher exchange rates volatility increase his hedging benefit. We can determine a critical spread threshold at which expression (3) holds with equality. At this spread trader *AB* is just indifferent between hedging and not hedging. Next we conjecture that the equilibrium spread in the triangular currency system is lower than the threshold spread. This implies that trader *AB* hedges through acquisition of short positions $-1/2X^E$ in both currency pairs *AC* and *BC*. It is straightforward to determine the utility of traders *AC* and *BC* under hedging. Traders *AC* and *BC* experience the same excess supply shock from trader *AB*. They both earn a spread profit given by

$$E(\Pi^S) = \frac{s}{2}E\left[\frac{1}{2}|X^E|\right] = \frac{1}{4}sf(s).$$

Also their exchange rate risk and the information content of their hedging demand are the same. Trader *AC* for example faces exchange rate risk in the state a, while trader *BC* faces risk in the complementary state b. Both states have by assumption the same probability ($p_a = p_b = 1/2$). The expected loss from the informative excess demand amounts to

$$E(\Pi_{AC}{}^D) = p_a E\left(\frac{1}{2}X^E\varepsilon|a\right) = -\frac{1}{4}\gamma f(s),$$

$$E(\Pi_{BC}{}^D) = p_b E\left(\frac{1}{2}X^E\varepsilon|b\right) = -\frac{1}{4}\gamma f(s),$$

and inventory risk follows as[29]

$$\mathrm{Var}(\Pi^D) = \frac{1}{4}\sigma_\varepsilon^2 f(s)^2.$$

The utility of traders AC and BC under hedging is therefore given by

$$U(\Pi_{AC})^{h=1} = U(\Pi_{BC})^{h=1} = \frac{1}{4}sf(s) - \frac{1}{4}\gamma f(s) - \frac{1}{8}\rho\sigma_\varepsilon^2 f(s)^2.$$

Finally, we have to take into consideration that currency imbalances need not arise in the currency rate AB, but happen with equal probability 1/3 in each of the three cross rates. This amounts to a simple permutation of the trader indices. Each trader therefore has an expected utility given by expression (1). The competitive entry condition (zero equilibrium utility for traders) implies the following proposition.

Proposition 3 *In the competitive triangular currency system the equilibrium spread s^T is characterized by*

$$s^T = \gamma + \frac{1}{2}\rho\sigma_\varepsilon^2 f(s^T). \tag{4}$$

Spreads in the triangular currency system are lower than in the currency union. Expected volume (per trader)

$$E(Vol) = 2f(s^T),$$

is higher than for the external currency union rate.

Proof. Expression (1) set equal to zero implicitly defines s^T. First we have to verify that under this spread s^T hedging is indeed optimal for trader AB as conjectured. We note that the right-hand side of Eq. (4) is smaller than the right-hand side of Eq. (3) for all s, therefore s^T is smaller than the hedging threshold $s*$ and it is optimal for traders to hedge. Second, the right-hand side of Eq. (4) is also smaller than the right-hand side of Eq. (2), which implies $s^T < s^U$. Expected volume (per trader) decreases as $\mathrm{d}f(s)/\mathrm{d}s < 0$. ■

For the special case in which the demand of informed traders loses its information content (γ=0), the equilibrium spread in the triangular system is exactly half the currency union spread. Generally, a higher information content of the informed demand component (higher γ) tends to diminish the relative difference of the spreads in the two systems. This follows from the fact that cross currency hedging facilitates collective risk sharing, but does not provide alleviation for the adverse selection problem which spread quoting traders face relative to the informed market demand. This illustrates in a simple manner that all economic benefits of the multicurrency

[29] This variance is calculated as the probability weighted average of the conditional variance of $1/2\varepsilon X^E$ conditioned on the three realizations of X^E and the two independent realizations a and b of the cross rate changes.

over the single currency system are due to the improved risk sharing characteristics of the former. Asymmetric information, while a building block of spread determination, does not alter spreads with the move to a single currency. This is straightforward since the degree of information asymmetry (in the order flow) was assumed to be the same for each trader across the two regimes. We relax the latter assumption in Section 3.5.

The aggregate trade volume for the currency union is smaller than the sum of the turnover for the two pre-union rates *AB* and *AC*. If the external currency demand is strongly price elastic in the spread *s*, it is possible that the currency turnover of the union is even below the turnover in an individual rate in spite of the liquidity concentration. The evidence presented in Section 2 suggests that this was indeed the case for the euro relative to the DM.

3.5. Asymmetries in the information asymmetry

An interesting extension of the model is to assume that the precision of the informed demand differs across the three markets, for example $\gamma_{AB}=\gamma_{BC}>\gamma_{AC}$. Exchange rate stabilization within the EMS system might have considerably reduced the scope of asymmetric information with respect to intra EMS rate (here *AC*). Let $\bar{\gamma}$ denote the average covariance of the informed demand shock χ^I and the currency rate change ε,

$$\bar{\gamma} = \frac{1}{3}(\gamma_{AB} + \gamma_{AC} + \gamma_{BC}).$$

In this case the individual spreads in each currency should reflect the severity of the adverse selection problem for the spread quoting traders. However, since the trader with the excess balances transfers a proportion of this adverse selection risk to the two other traders, they are affected more if the excess balances come from traders *AB* or *BC* than if they come from trader *AC*. The information component of the spread in each currency is therefore a weighted average of the own market adverse selection risk and adverse selection risk in the cross currency transfers. Let the transformed adverse selection parameter be defined by

$$\tilde{\gamma}_{AB} = \frac{3}{4}\bar{\gamma} + \frac{1}{4}\gamma_{AB}.$$

The transformed adverse selection parameter $\tilde{\gamma}_{AB}$ collapses to γ_{AB} for $\gamma_{AB}=\gamma_{AC}=\gamma_{BC}$. Generally, the term $\tilde{\gamma}_{AB}$ captures the adverse selection externality in the triangular currency system. The derivation is straightforward. Market maker *AB* keeps 50% of the excess order flow and eliminates the rest through hedging. This implies an expected loss (due to asymmetric information) of $-1/2\gamma_{AB}f(s)$ from his residual position, while receiving the hedging demand from traders *AC* and *BC* implies an additional loss of $-1/4\gamma_{AC}f(s)$ and $-1/4\gamma_{BC}f(s)$, respectively. We recall that the respective cross rate changes only with probability 1/2. The total expected loss for trader *AB* due to asymmetric information is therefore proportional to

$$-\frac{1}{2}\gamma_{AB}-\frac{1}{4}\gamma_{AC}-\frac{1}{4}\gamma_{BC} = \tilde{\gamma}_{AB}.$$

In a triangular system the currency rates with less informative trading exercises a positive externality on the rates with more informative trading. With the elimination of the cross rates this positive externality is eliminated. The composition of informed and uninformed demand therefore changes for the currency union. If the remaining rate is γ_{AB}, then the spread increase should be higher than implied by forgone risk sharing benefits of the triangular system. The following proposition summarizes this intuition:

Proposition 4 *A competitive triangular currency system with unevenly informative demand across the rates (γ_{AB}=γ_{BC}>γ_{AC}) has equilibrium spread for the cross rates i=AB, AC, BC characterized by*

$$s_i^T = \tilde{\gamma}_i + \frac{1}{2}\rho\sigma_\varepsilon^2 f(s_i^T), \tag{5}$$

where

$$\tilde{\gamma}_i = \frac{3}{4}\bar{\gamma} + \frac{1}{4}\gamma_i.$$

The term γ denotes the average covariance of informed demand with consecutive currency rate changes. The external spread under the currency union is given (as before) by

$$s_i^U = \gamma_i + \rho\sigma_\varepsilon^2 f(s_i^U). \tag{6}$$

Proof. Similar to proposition 3. We assume that the condition for the hedging conjecture of proposition 2 is fulfilled for trader AC, who faces the highest spreads for implementing the hedging strategy. ■

Any spread increase following a move from a triangular system to a currency union of currencies *A* and *C* may now have two causes. The first cause is the loss in risk sharing efficiency in the dealership market due to the loss of the cross hedging option. This aspect is captured by the lower risk component of the spread, $\rho\sigma_\varepsilon^2 f(s_i^U) > 1/2\rho\sigma_\varepsilon^2 f(s_s^T)$. The second cause is that the traders in the remaining unilateral rate may face a more severe adverse selection problem since the uninformative demand from the currency imbalances in the rate *AC* is now missing. This is captured by $\gamma_{AB} > \tilde{\gamma}_{AB}$.

Our model set-up provides a straightforward representation of the inventory cost and the information cost components of spreads in a multicurrency system. A currency union may increase the inventory cost component if the increased market transparency decreases the risk sharing efficiency of the dealership market. The information cost component is only affected if the legacy currencies were characterized by different degrees of information asymmetry between dealers and customers. In the latter case, the multicurrency system provides a cross rate subsidization of spreads in which the cross rate with the less informative excess demand can reduce the spread in the two other cross rates.

4. Conclusions

The advent of the euro raised the expectation that this new currency would establish itself as a currency of greater global importance than its predecessor, the DM. Such expectations were grounded in the belief that a currency union is primarily a consolidation of the financial liquidity of the union members and that this liquidity consolidation would be large enough to set in motion substantial network externalities.

Our evidence suggests that the contrary took place at the start of EMU, namely euro volumes decreased and euro spreads increased. This suggests that an important theory element was absent in the previous analysis. The scale economy hypothesis underlying the evidence for existing currency pairs and the vehicle currency theory itself may not be in question. But we argue that a currency union changes the information environment in which the new external currency rates of the union are determined. Parallel to the consolidation of liqudity occurs an increase of market transparency as many opaque cross hedging opportunities disappear. This can have important microstructure consequences for the risk sharing efficiency of the dealership market. Under accelerated information revelation, inventory risk increases and pushes up the competitive equilibrium spreads relative to the corresponding rates in the legacy currencies. The market transparency effect can explain why we find that euro transactions are more expensive than former DM transactions. The increase in the spread is associated with a decrease in volume according to the conventional spread-volume linkage which can more than offset the volume enhancing liquidity consolidation. This can explain the low euro rate transaction volumes relative to the DM volumes.

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Appendix A

A.1. Generalization of proposition 2

Assume that trader AB hedges a positive fraction μ of his excess balances X^E in period 2. The components of his utility are

$$E(\Pi^s) = \frac{s}{2}E[(1-\mu)\{|X^I| + |X^U|\}] = (1-\mu)sf(s),$$

$$E(\Pi^D) = E[(1-\mu)X^E\varepsilon] = -(1-\mu)\gamma f(s),$$

$$\mathrm{Var}(\Pi^D) = 2(1-\mu)^2f(s)^2\sigma_\varepsilon{}^2.$$

Expected utility for the trader hedging the fraction μ is therefore given by

$$(1-\mu)sf(s)-(1-\mu)\gamma f(s)-\rho(1-\mu)^2f(s)^2\sigma_\varepsilon^2.$$

Subtracting expected utility for the case of no hedging, we obtain the inequality condition which characterizes the hedging state, that is

$$s^T < \gamma + \rho f(s)\sigma_\varepsilon^2\frac{1-(1-\mu)^2}{\mu}$$

or equivalently

$$s^T < \gamma + \rho f(s)\sigma_\varepsilon^2(2-\mu).$$

Note that for $\mu = 1/2$, we obtain the inequality in proposition 2.

A.2. Generalization of proposition 3

Trader AB hedges through acquisition of short positions $-\mu X^E$ in both currency pairs AC and BC. The expected utilities of traders AC and BC are identical. For trader AC, it is calculated as

$$E(\Pi^s) = \frac{s}{2}E[\mu|X^E|] = \frac{s\mu}{2}sf(s),$$

$$E(\Pi^D) = -\frac{\mu\gamma}{2}f(s),$$

$$\mathrm{Var}(\Pi^D) = \mu^2f(s)^2\sigma_\varepsilon{}^2.$$

Therefore,

$$U(\Pi_{AC}) = U(\Pi_{BC}) = \frac{\mu s}{2}f(s)-\frac{\mu\gamma}{2}f(s)-\frac{\rho\mu^2}{2}f(s)^2\sigma_\varepsilon^2.$$

The utility of trader AB is given by (see the generalization of proposition 2)

$$U(\Pi_{AB}) = (1-\mu)sf(s)-(1-\mu)\gamma f(s)-\rho(1-\mu)^2f(s)^2\sigma_\varepsilon^2.$$

The ex-ante expected utility for any trader is

$$\frac{1}{3}U(\Pi_{AB}) + \frac{1}{3}U(\Pi_{AC}) + \frac{1}{3}U(\Pi_{BC}) = \frac{s}{3}f(s) - \frac{\gamma}{3}f(s) - \frac{\rho(\mu^2 + (1-\mu)^2)}{3}f(s)^2\sigma_\varepsilon^2,$$

which implies the equilibrium spread in the triangular system given by

$$s^T = \gamma + \rho f(s)\sigma_\varepsilon^2[\mu^2 + (1-\mu)^2].$$

Setting $\mu = \frac{1}{2}$ yields the expression for s^T in proposition 3.

Corollary 5 *The inequality in proposition 2 holds irrespective of the hedge ratio.*
To show this, it is sufficient to demonstrate that

$$1-2\mu + 2\mu^2 < 2-\mu \leftrightarrow (1 + 2\mu)(1-\mu) > 0.$$

The last inequality is trivial since $0<\mu<1$.

Corollary 6 *Spreads in the triangular system are less than under the currency union irrespective of the hedge ratio.*

This requires that

$$1-2\mu + 2\mu^2 < 1.$$

This holds because $0<\mu<1$.

Corollary 7 *The optimal hedge ratio (in terms of ex-ante trader utility) is* $\mu = 1/2$.

We choose the value of μ which maximizes ex-ante expected utility. This requires us to maximize $\mu^2 + (1-\mu)^2$ which yields $\mu = 1/2$.

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