Analysis of spreads in the Dollar/Euro and Deutsche Mark/Dollar foreign exchange markets

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ABSTRACT

This paper tries to provide a simple explanation for the empirical finding, documented here and also by Hau, Killeen and Moore (2002), that spreads in the spot USD/EUR market are substantially higher than those in the preceding DEM/USD foreign exchange market. The paper argues that it is primarily the re-factoring of the exchange rate, 1.75 DEM per USD compared to 1 USD per EUR together with the fact that dealers are faced with a minimum tick size, that has caused spreads to increase (as a percentage of mid-quote).

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1. Introduction

At the creation of the euro on 1st January 1999, it was suggested that the new European currency might challenge the dollar in its position as the world/vehicle currency. The dominance of the dollar is shown by the huge share that it takes in global daily foreign exchange (FX) turnover. In April 2001 the US dollar was on one side of 90.4% of all currency trades.[1] In an international setting, market participants will, more often than not, choose the transactions medium with the lowest costs. The subsequent accumulation of trades will cause these costs to fall still further by economies of scale: the fixed order processing costs of market makers will be spread across larger volume. This virtuous cycle implies the existence of multiple equilibria (the dominance of any of a number of currencies in financial markets) and can result in inertia of the current equilibrium, i.e. the currency with hegemonic status will be maintained as the international/vehicle currency. For a greater discussion of these issues see Hartmann (1998a). It has been argued that the world's financial markets could shift from one equilibrium to another only if a large enough shock occurs (Portes and Rey 1998) and the arrival of the euro has thus been suggested to be the required impetus that might break the dollar's hegemonic status. But how has the euro performed since its birth in its role as a possible international transaction medium? One approach to answering this is to consider the costs that FX market participants face when trading euros. If the costs of trading in the euro markets have fallen compared to those seen for the euro's 'predecessor', the deutsche mark, then one can argue that the euro is more liquid than the DM and stands a better chance of breaking the hegemony of the dollar.

It is for this reason that we consider the costs of trading euros in the foreign exchange markets. More specifically we consider the spread, the difference between the price at which one buys and sells the currency.[2] We compare the spread between the euro and

[1] BIS press release 9th October 2001. This is a slight increase from the corresponding figure for April 1998, which was 87.3%.

[2] However we accept that in order to make a more complete assessment of the euro's role, we should consider other financial markets such as debt instruments and other securities.

the dollar to the spread between the deutsche mark (the previous dominant European currency) and the dollar. However, our paper goes beyond simply analysing the cost of trading euros and looks more closely at the structural/institutional factors that underlie spread determination; namely, price grids and the granularity of markets.

Hau, Killeen, and Moore (2002), from here on referred to as HKM, examine spreads for a number of currencies from January 1998 to August 1999, i.e. twelve months prior to the euro's introduction and eight months post euro introduction, finding that the DM/$ to $/euro spreads increased from 3.76 basis points to 5.26 basis points, an increase of 40%. They also find that Yen/DM-euro and £/DM-euro spreads increased over the same period and offer a microstructure approach explanation; namely the market transparency hypothesis. This suggests that after the currency unification, imbalances and desired trading positions of market makers became more easily identifiable by other market participants. Therefore larger spreads are quoted by FX dealers to compensate for this increased risk.

In this paper we offer evidence on how bid-ask spreads, as well as other relevant statistics (number of trades, volatility, etc.), have changed since the introduction of the euro. We find that spreads on Reuters D2000-2 (an electronic broking system), when defined as a percentage of mid-quote, have increased significantly from the DM/$ to the $/euro era, consistent with HKM. However we also offer a different explanation for this increase, which is somewhat simpler than the market transparency hypothesis. We suggest that the spreads in both the DM/$ and $/euro periods are set by market makers as a number of pips, the absolute difference between the bid and ask prices, and not as a percentage of mid-quote. For example a market maker may buy euros at an exchange rate, bid price, of 0.8900 dollars per euro and sell euros at an ask price of 0.8902 dollars per euro. This implies a spread of 2 pips. We find that this pip spread has not changed significantly between the two exchange rate periods and it is purely the definition of the exchange rate that has caused the spread (as a percentage of mid-quote) to increase for the $/euro. 1 pip as a percentage of 0.8901 ($/euro mid-quote) is obviously greater than 1 pip as a percentage of 1.7530 (DM/$

mid-quote). Note that the pip defines the minimum bid-ask spread.

Thus, if we were to assume a degree of dealer competition in the DM/$ market that led to a fair number of observations of spreads at their minimum level, one would quite naturally expect observed percentage spreads in the subsequent $/euro market to be higher. Dealers would be prevented from competing spreads down to their prior magnitudes (in percentage terms) simply due to the granularity of the pricing system.

There is an existing literature that studies changes in effective pip/tick sizes, focussing mainly on regulatory changes to the nominal minimum price variation in North American equity markets. In June 1997, both the NYSE and the NASDAQ stock market lowered the nominal minimum price variation from one eighth to one sixteenth of a dollar. By the end of January 2001, the minimum price variation had been further lowered for all NYSE issues to one cent. Thus the US experience is one of reductions in the (percentage) tick size. The evidence from these reductions is fairly consistent. Subsequent to the changes, quoted (and effective) spreads declined, as did quoted depths. See, for examples, Goldstein and Kavajecz (2000) and Jones and Lipson (2001) for evidence on the 1997 reforms and Bacidore, Battalio, Jennings, and Farkas (2001) for evidence on the effects of the NYSE decimalization. Harris (1999) provides a survey of the debate surrounding the implementation of decimalization.

Thus the US evidence suggests that larger tick sizes maintain larger costs of trade, at least for those individuals for whom bid-ask spreads are the relevant measure of transactions costs. In the situation under study in the current paper, we see effective tick sizes increasing in the transition from DM/$ to $/euro. Reference to the US equity markets literature then raises the possibility of a resultant increase in percentage spreads/costs of trade.

The increase in percentage spreads is discomforting not only because of the higher transactions costs but also because of something which is not as easy to observe; liquidity.[3] The higher spreads may be an equilibrium response to increased difficulties

[3]As reported in the BIS 71st annual report, evidence on how liquidity has changed, when proxied

in inventory control due to lower liquidity, making risk management more difficult. However, it could well be the case that spreads are relatively tighter in the $/euro market than in the DM/$ market for larger trade sizes. These large volumes have tended to move from direct inter-dealer to electronically brokered trading, such as Reuters D2000-2 and EBS, since it is possible to hide your true position and trade size on these systems.[4]

Our analysis makes use of a unique dataset that allows us to analyse real time firm/tradable spreads. The data, taken from the Reuters D2000-2 broking system, shows the quoted prices and spreads at which trades actually occur, rather than indicative spreads which have often been used in previous analysis, including Hartmann (1999) and Hartmann (1998b) and also that of HKM. Indicative quotes are just that; they give an indication of the prices in the market and hence are less accurate, with the spreads tending to be larger than actual spreads. Tradable spreads show more precisely the cost of transactions for the agents participating in the market and the cost of providing liquidity for the specialist dealers. Using this dataset, we should be able to give a much more accurate impression of how the cost of trading/spreads have changed.

The remainder of the paper is organised as follows. Section 2 discusses the data and presents summary statistics for the two periods. Section 3 explains our spread determination exercise, presents our regression results and includes a more detailed comparison of the spreads after taking into consideration the different market conditions in the two samples. A discussion of our findings is given in section 4 along with policy implications and section 5 concludes.

by volumes, spreads and volatility, is inconclusive. Bid-ask spreads and short-term volatilities in the $/euro market in 2000 were broadly similar to those present in 1998. However the BIS also report that foreign exchange market activity declined substantially between 1998 and 2001. Daily average spot transactions for April fell from US$568 billion in 1998 to US$387 billion in 2001. This is also consistent with Goldman-Sachs (2000), which shows that monthly spot foreign exchange turnover through EBS (Electronic Broking Services) between the dollar and the dominant European currency was lower in 1999 than 1998, i.e. lower for the $/euro than the DM/$. BIS suggests that the decrease in volume is due to the loss of trading in former EMS currencies and the widespread adoption of electronic brokers.

[4]From the BIS 71st annual report, between 85% and 95% of inter-bank trading took place using electronic broking in 2000 compared to only 50% in 1998.

2. Data and analysis

The data used were for the dollar/euro (\$ per euro) exchange rate from 28th September 1999 to 8th March 2000, obtained from Reuters D2000-2 via the Bank of England, and the deutsche-mark/dollar (DM per \$) exchange rate for the five days from 6th to 10th October 1997, obtained directly from Reuters. For this analysis, two datasets were used for both DM/\$ and \$/euro periods. The first contained data including the date, time (hour and minute) together with the best bid and ask prices. The second contained data on trade flows, also including the date, time (hour and minute), the direction of the trade (buyer initiated or seller initiated) and the price at which the transaction occurred. From the first dataset the mid-quote (mq) of the bid and ask prices was calculated as:

$$mq = \frac{bid + ask}{2} \tag{1}$$

and the spread (s) was calculated as a percentage of this mid-quote.

$$s = \frac{100 * (ask - bid)}{mq} \tag{2}$$

The spread as a number of pips (pip) was calculated as:

$$pip = 10000 * (ask - bid) \tag{3}$$

This was done for every datum observation over the entire period and, since a zero bid or ask suggests erroneous data, all observations with these characteristics were removed. Non-positive spreads were also removed, primarily because they represent the matching of market orders on the Reuters D2000-2 system.

The aim of the exercise was to calculate the average spread over each day and over each hour. However since any analysis would be distorted if data over the entire period were used, due to the large spreads late at night and early in the morning when trading activity is thin, it was decided that only data during periods of significant trading would be considered. To determine which hours of the day should be used, the average numbers of trades per hour were calculated for both datasets. For the $/euro, 97.5% of all trades took place in the ten hours between 0700 and 1700 London time and for the DM/$, 95.3% of all trades took place between 0600 and 1600 GMT. The apparent one hour delay for the $/euro data comes from the fact that these data were already adjusted for daylight saving time pre 31st October 1999, whilst the DM/$ data were not. It was then decided that only these ten-hour periods of each day would be considered when analysing the spreads.

When calculating the spreads over each hour and each day for both the percentage of mid-quote and in pips, two definitions were used. The first was the arithmetic mean of the spreads and the second weighted each spread by how long it lasted in the market. As well as these spread measures, total trades, absolute imbalance, return volatility and the standard deviation of spreads, were also calculated for each hour (day). To calculate return volatility each hour (day) was split into five-minute intervals. The percentage change between the first calculated mid-quotes in each interval was defined as the return (r) from one interval to the next and return volatility (VOLAT) was defined as the sum of the square of the returns:

$$VOLAT = \sum_{t=1}^{T} (r_t)^2 \tag{4}$$

Where T =12 for hourly volatility and 120 for daily volatility.[5] Total trades is defined as the number of times a transaction (buy or sell) occurred in the hour (day). Unfortunately we were not given the information on the size of the trades or market depth but only the number of trades. Absolute imbalance is simply defined as the absolute difference between the number of market buys (buyer initiated trades) and the number of market sells (seller initiated trades) in each time period.

[5] For this definition of volatility see Andersen, Bollerslev, Diebold, and Labys (2001).

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1. Summary statistics

The summary statistics for average spread (AS), time weighted average spread (TWAS) average pip spread (ASPIP), time weighted average pip spread (TWASPIP), trades (TRAD), absolute imbalance (ABIM), volatility (VOLAT), standard deviation of spreads (STDSP) and standard deviation of pip spread (STDSPPIP) are given in table 1 for the $/euro and DM/$ together with the indicative spread results of HKM.

2. Spread results

The results show that the average hourly spread, as a percentage of mid-quote, for the $/euro market was 2.77 basis points, an increase of 71% from the 1.62 basis point average spread seen for the DM/$. This is consistent with the results of HKM, who found an increase of 40%, although our findings are more extreme. Unsurprisingly, the time weighted average spread also increased, this time by 84% from 1.45 to 2.67 basis points.[6] Only rarely did the daily $/euro spreads fall below 2 basis points whereas the DM/$ spread was consistently below this level. However the spread when measured as a number of pips only increased by 7% for the time weighted average and actually fell by 1% for the average spread. The DM/$ spread fluctuated roughly between 2 and 3.5 pips, see figure 2, and this is the same as the $/euro spread fluctuations, figure 1. As can be seen, the average daily spread for the $/euro over the sample period to1%aaiurlytable1%uenile1%mi(d)-305Deceimber anM, although theto1%pberiod been ecludted bcauase of the pssiable deationary (eclts)-134iltsyavy in
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As for the DM/$ data, the spread appeared to increase on the 9th and 10th October 1997 for both the average and time weighted definitions, as seen in figure 2. This is almost certainly due to the change in interest rates in Germany, announced at 1130 GMT on 9th October, the fourth day of our series. As reported in the Financial Times,[7] the Bundesbank, to the surprise of many analysts, increased its securities repurchase (repo) rate from 3% to 3.3%. This caused volatility in the DM/$ rate to rise dramatically. Whereas hourly volatility never increased above 0.05 pre interest rate announcement, between 1100 and 1200 volatility was 0.45, a nine-fold increase on the previous observed maximum. In table 1, the average hourly return volatility for the $/euro and DM/$ are 0.0387 and 0.0318 respectively. However if we exclude the observation for 1100 on 9th October for the DM/$, the DM/$ return volatility measure falls to 0.0237, which is substantially below the figure for the $/euro.

Although the dataset for the DM/$ was much smaller than that for the $/euro and it may have been the case that the week observed for the former was in some way out of the ordinary, there is considerable evidence to suggest that spreads against the dollar (when defined as a percentage of mid-quote) have risen post introduction of the euro.[8] This is consistent with the results of HKM. However, there is also considerable evidence to suggest that the spread, when given in pips, has not changed. When testing the null hypothesis of equal population pip spreads, the test statistic for the time weighted average is 1.29 and that for the average spread is only 0.16. The null hypothesis of equal spreads can therefore not be rejected at any reasonable level. If we examine the breakdown of the pip spreads for both DM/$ and $/euro datasets, we can see that the distribution of spreads is broadly similar. This is shown in figure 3.

From this analysis, we therefore claim that firstly, the spreads in the DM/$ and $/euro markets are set as a number of pips, and secondly that these pip spreads have

[7]Financial Times, 10th October 1997.

[8]Testing the null hypothesis that the two population basis point spreads (hourly data) are equal results in test statistics of 14.37 for average spreads and 13.74 for time weighted average spreads. The 1% critical value for the standard normal distribution is 2.57 for a two-tailed test. Therefore the null of equal spreads can be rejected at any reasonable level.

not significantly changed post introduction of the euro. It seems sensible that FX dealers decide their spread as a number of pips since what they actually set are the bid and ask prices. From this the percentage of mid-quote spread can be calculated but is not directly chosen by the dealers. If our hypothesis is true then it can help explain the findings of HKM, in that the same number of pips as a percentage of a lower mid-quote will naturally lead to a higher spread when given as a percentage of this mid-quote. Our hypothesis is also consistent with some of the other findings of HKM, namely the increased spreads in the £/DM-euro foreign exchange markets where again the mid-quote has changed, and the much smaller changes in the Yen/$ and $/£markets where no re-factoring of the mid-quote has occurred.

3. Trade results

Moving onto the trades data, it is quite clear that the number of trades in our $/euro data is significantly reduced compared with that for the DM/$ data. The average number of trades for the euro was 2864 per day (one trade every 12.5 seconds). As is the case for spreads, there is a Christmas effect where trading volume fell off leading towards Christmas. For the deutsche mark, the average daily number of trades was 6027 (one trade every 6 seconds), more than double the euro figure. In fact the highest number of daily trades in the $/euro market was 4417, 17th February 2000 and this is still below the minimum number of trades seen in the DM/$ market, 5375, 10th October 1997. When considering the same week in October for the $/euro market, 4th - 8th October, so avoiding criticism of ignoring calendar effects, the daily average number of trades was 3045.8, 50.5% of the DM/$ figure.

3. Determination of the dollar/euro and deutsche-mark/dollar spreads

We now turn to the factors that determine the pip spreads for the two currency pairs. Standard microstructure theories suggest that the greater the number of trades, the lower should be the spread; the fixed order processing costs being spread among the larger number of trades. More precisely, expected trades should have a negative effect on spreads whilst unexpected trades should have a positive effect.[9] Due to asymmetric information and inventory control explanations, greater volatility and absolute imbalance should have a positive effect on spreads. A more volatile market or one way buying or selling pressure suggests new information being incorporated into prices, and makes inventory control more difficult. Building on work by Hartmann (1998b) and Hartmann (1999), average and time weighted pip spreads were regressed on a number of variables, return volatility, the standard deviation of spreads, trades and absolute imbalance. The reason why we include the standard deviation of spread in the regression is not as another proxy for market volatility but as a factor that captures Reuters D2000-2 going off market. If the spread increased from 1 pip to 6 pips this will naturally cause average spread and spread standard deviation to increase. However this is likely to be due to D2000-2 becoming uncompetitive with trading activity moving to the competing EBS system.[10] Due to the presence of obvious seasonal patterns in the data ('U' shaped spreads and 'M' shaped trades within the day for example) all data were appropriately deseasonalised. This was done by first estimating the intra-day pattern for each variable, x, $\bar{x}_i$, for $i = 7, \ldots, 16$ where $i = 7$ corresponds to the data from 0700 to 0800, etc.[11]

[9] Following Hartmann (1999), attempts were made to breakdown trades into expected and unexpected components by fitting trades to an ARMA process and taking the residual from this regression as unexpected trades. However this proved unsuccessful.

[10] Regressions were also performed without standard deviation of spreads but this did not change our results or conclusions.

[11] $i = 6, \ldots, 15$ for the DM/$ data.

$$\bar{x}_i = \frac{1}{N} \cdot \sum_{n=1}^{N} x_{n,i} \tag{5}$$

$n = 1; \ldots; N$, where N is the number of days. Deseasonalised data, x^{DS}, were then calculated as:

$$x^{DS} = \frac{x_{n,i}}{\bar{x}_i} \tag{6}$$

$i = 7; \ldots; 16$, $n = 1; \ldots; N$. Before any regressions were performed, each series was tested for stationarity. We would expect every series to be stationary and for the $/euro data standard Augmented Dickey Fuller tests confirmed these hypotheses. However for the DM/$ data average spread, time weighted spread and the standard deviation of spreads were all found to be I(1). This appears implausible. As was reported earlier, there was an interest rate change made by the German Bundesbank at 1130 GMT on 9th October 1997, which suggested the possibility of a structural break around the time of the announcement.[12] Indeed, when eyeballing the deseasonalised spread series for the DM/$, after removing the observation for 1100 on 9th October, it is quite clear that average spreads are higher post interest rate announcement than pre announcement. For the DM/$ data, the deseasonalised spread was therefore modelled with a structural break around the time of the interest rate announcement. The regression results are given in table 2, along with those for the $/euro spread.

1. Deutsche-mark/dollar and dollar/euro spread regressions

Microstructure theory suggests that volatility and trades will affect the spread but it is indeed correct that the spread will also have an influence on the number of trades. If the spread was very high for example, then this will deter market participants from trading. For this exercise however, we use simple single equation regression techniques

[12]It has been shown that ADF tests tend to accept the null hypothesis of unit root processes far too often when the series is in fact stationary but with a structural break. See for example Perron (1990).

rather than estimating a system of simultaneous equations. At this point there is another econometric issue to be raised: the fact that pip spreads are integers. If we were running regressions on tick-by-tick data, the simple techniques below would not be appropriate. Another approach by Huang and Stoll (1997) is to estimate by GMM and let the error term capture the discreteness. This is possible since GMM puts very few distributional constraints on the error. However we are looking at averages over each hour and also deseasonalising the data. For this exercise, discreteness of the original data does not impose any serious econometric problems. The following dummied regression was therefore performed for deseasonalised DM/$ pip spreads (average and time weighted) and the results are shown in table 2.

$$TWASPIP_t^{DS} = X_t^{DS}\gamma_1 + X_t^{DS}D\gamma_2 + \epsilon_t \qquad (7)$$

Where $X_t^{DS} = [1; VOLAT_t^{DS}; STDSPPIP_t^{DS}; TRAD_t^{DS}; ABIM_t^{DS}]$ and γ_1 and γ_2 are 5×1 vectors of coefficients, i.e. we regress the pip spreads on trades, volatility, etc. but allow for a structural change at the time of the interest rate announcement by introducing the dummy variable D. D takes the value of '1' for observations from 1200 GMT on 9th October onwards and zero otherwise. If there were a jump change in the spread, then the first element of γ_2, corresponding to the constant in the regression, would be statistically significant. However, if the responsiveness of the spread to the explanatory variables changed following the Bundesbank announcement, then the other γ_2 coefficients would be shown to be significant. Insignificant explanatory variables were sequentially removed in a general to specific approach and upon further investigation, an AR(1) process was suggested for time-weighted spreads. However for average spreads, no evidence was found to suggest using lagged dependant variables.

For the $/euro data, the following model was fitted:

$$TWASPIP_t^{DS} = X_t^{DS}\gamma + \epsilon_t \qquad (8)$$

Where X_t^{DS} is as above and ° is a 5×1 vector of coefficients to be estimated. On more detailed inspection of the residuals, an AR(3) process was suggested. The model presented in table 2 was therefore estimated and found to work well; further AR terms failed to significantly improve the fit of the model. For average spreads the same procedure resulted in the same model specification and the results are again given in the accompanying table.

When modelling the pip spreads, those for the \$/euro are affected by return volatility and the number of trades as well as spread standard deviation, capturing the fact that when Reuters D2000-2 goes off market, the spread will naturally increase. There also appear to be lags in the \$/euro market as shown by the AR(3) process in the regressions. Determination of the DM/\$ spread has proved itself to be more awkward, largely due to the shorter dataset and the fact there was a large shock in the market in the form of an unexpected interest rate increase by the Bundesbank on the fourth day of the data series. For the purpose of the spread determination exercise a structural break was tested and indeed found around the time of the interest rate change and this has been incorporated into our spread model. There appeared to be a jump in the spread following the interest rate change (which was sure to die out in subsequent days) and it was found that the responsiveness of the spread to changes in the exogenous variables remained the same post interest rate announcement. However, despite the higher R^2 for the DM/\$ spread model, fewer variables were found to affect the spread. Trades were only significant at barely the 10% level for average spread and, along with return volatility, were found to be insignificant when looking at the time weighted average.

2. Taking account of the different market conditions

We have shown that the \$/euro pip spreads are approximately the same as those seen in the DM/\$ period. Although in order for us to see whether the spreads set by the market makers have fundamentally altered we must abstract from the factors which we have found to affect these spreads, since the increased volatility and smaller number of trades should naturally cause the \$/euro spreads to rise. This is done by fitting the DM/\$ data into the model for \$/euro spreads as presented in table 2. If the spreads predicted by the \$/euro model, i.e. the spreads that would be seen in the \$/euro market if there were the same number of trades, etc. as in the DM/\$ period, are higher than the spreads actually seen for the DM/\$, then one can argue that DM/\$ spreads are intrinsically lower than \$/euro spreads, i.e. after taking into consideration the differing levels of trades and volatility measures, spreads have increased post introduction of the euro. However this conclusion rests on the assumption that the linear model fitted for the \$/euro can be extrapolated to the DM/\$ data. This appears optimistic since the number of trades for the DM/\$ were more than double that for the \$/euro. There were also two other major structural changes between the DM and the euro data periods which we accept are likely to have impacts on market liquidity but about which we are able to do very little. These are the rapid expansion of electronic broking used in inter-bank trading as described in the introduction; see footnote 4, and greater concentration in the banking industry. The greater concentration (possible reduction in competition) in the banking sector is shown by the fact that in 2001 there were 2772 banks in 48 countries reporting to the BIS as opposed to 3087 in 43 countries in 1998. Both these phenomena are likely to result in reduced numbers of trades while the effect on liquidity could possibly be unchanged. Another possible problem is that the data made available for the DM/\$ period was small, only covering five days, and so may not have been representative of the foreign exchange market at the time, even more of a problem when we acknowledge the existence of a structural break midway through the series. However, corroborating evidence comes from Lyons (1995) who found a median bid-ask spread of 3 pips when using five days of data from August 1992 and Bjønnes and Rime (2001) who examined data from one dealer operating on Reuters D2000-1 in March 1998, finding an average spread of 1.985 pips.[13] At this stage it should also be noted that anecdotal evidence suggests that D2000-2's share of the foreign exchange

[13] Although Evans (1997) found a larger average DM/\$ spread of 6 pips when using data from May to August 1996. However his data were from the bilateral D2000-1 system, which included all large trades where spreads are naturally higher.

market has declined between our two data periods, at least for the $/DM-euro. This itself could cause spreads (as a percentage of mid-quote) to rise. These are important caveats to our results but in the analysis set out below we are forced to make the assumption that pre and post euro, the foreign exchange markets worked in not too dissimilar fashions. The actual DM/$ spreads and those predicted by the $/euro model are given in figure 4.

As can be seen, the spread predicted by the $/euro model matches the actual DM/$ spread reasonably well. Towards the end of the sample, the $/euro model under predicts the DM/$ spreads and this is largely due to the structural break at the time of the interest rate announcement, after which DM/$ spreads experienced a jump shift. In the graph, a value of 1 refers to the $/euro average, 2.71 pips for the time weighted average spread. Since trades were higher for the DM/$ and both volatility measures lower, one would naturally expect the predicted $/euro spreads to be lower than those seen in the actual $/euro market. This is indeed the case since the predicted pip spreads are nearly always below unity. Since the actual DM/$ and predicted $/euro spreads follow each other quite well, then we conclude that after taking into consideration the differing levels of volatility and trades, the spreads set in the $/euro market are no different to those seen in the DM/$ period. This may come as a surprise considering that the number of trades in the DM/$ period were more than twice that for the $/euro and return volatility was much lower. However, the coefficients on these variables in the spread model, although statistically significant, are very small and so the great variety in the explanatory variables makes little difference.

4. Discussion and policy implications

In summary, the $/euro market on D2000-2 has been shown to be characterised by a smaller number of trades and higher volatility compared with the previous D2000-2 DM/$ market. We have found that the $/euro spreads, when defined as a percentage

of mid-quote, are considerably higher than those observed in the preceding DM/$ market, consistent with the findings of HKM. However we argue that this is due to the re-factoring of the European currency, approximately 1.75 DM per $ and 1 $ per euro in the periods under review. The pip spread, which we find to be unchanged, as a percentage of the lower mid-quote will by definition result in a larger (percentage of mid-quote) spread. This implies that the costs of making transactions in the euro foreign exchange markets have indeed increased (the cost should always (unc)26(hmar0((unc)1as)-340((u
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malecterldv8(-34179h)-29179hfall-43119(But29179hn-29180rrk)26(7ts)34179hrk26(etsr3J0-21.66TD[(mall)

1999. Given that the euro was the most expensive currency in January 1999, it was natural to give quotes in dollars rather than in per dollar terms as was the case in the preceding market. One pip was less as a percentage of a $/euro mid-quote than a euro/$ mid-quote. Prior to January 1999 both the ECU and deutsche mark had appreciated against the dollar. If one expected the euro to continue on this path, which some expected because they believed that the demand for euros would increase as it became a reserve currency, then $/euro pips would have been even less as a percentage of the mid-quote during the spring. However, history proved this to be wrong, but in January 1999 (or fall 1998) one could not know.

At this stage it is worth asking whether a move to using five decimals when quoting prices would have helped. This is a possible policy question arising from this analysis, but the issue is not as simple as it first appears. From the data in table 1, one can calculate the pip spread in the $/euro market that would result in the same percentage spread as in the DM/$ market. This turns out to be 1.65 pips, which suggests that a move to five decimal places would indeed help to reduce the costs of trade. Five decimals would facilitate a 1.6 'pips' spread, although technically now a pip would be one movement of the fifth decimal, not the fourth. However, when one considers what happened in the North American equity markets after the move from eighths to sixteenths and then to cent spreads, depths also decreased, see Jones and Lipson (2001) and Goldstein and Kavajecz (2000). If you wanted to trade at the smaller spreads, you could only trade smaller volumes. It may well be the case, although this is purely a conjecture, that a move to five decimals may indeed improve the tightness of the market, the spread at the smallest trade size, but will also be associated with a reduction in depths. Once one conditions on trade size, the costs of trading may not necessarily fall. Indeed, anecdotal evidence from traders suggests that despite the increase in spreads that we report, trades are moving to larger sizes where spreads are relatively lower compared to those for comparative sizes in the DM/$ market. So when conditioning on trade size, total costs of trade may not have increased when moving to the $/euro period. Again, this is a conjecture and cannot be verified using our data.

One may also ask why a fifth decimal was not introduced in practice. After conversations with dealers, it became clear that the network suppliers, EBS and Reuters, had no incentive to do this as long as the dealers did not demand it. And why should the dealers not demand it? First they may have believed that five decimals would be confusing and increase the risk of keying in mistakes. Second, as providers of liquidity they enjoyed making the extra money from the higher percentage spread. Also, the dealers claim that the spreads to customers have decreased sufficiently over the last couple of years so customers are not hurt by the four-decimal constraint.

The argument whether bid and ask prices should be given to five decimal places is reminiscent of the odd eighth debacle following the Christie and Schultz paper in 1994. Their results showed that market makers in NASDAQ avoided odd eighth quotes through collusion, earning excess rents. If market makers are earning extra rents in the foreign exchange market through increased percentage spreads, via pip persistence, could this also be a case of market maker collusion? In the opinion of the authors, the answer is no! Whereas dealers in NASDAQ were colluding to offer the same even eighth spread, each FX dealer offers spreads of multiple pips and it is the market that brings spreads down to one or two pips.[14] However, even though dealers may not be colluding to prevent spreads from falling, the current system still supports a maximum lower bound on the minimum spread, that being one unit of the fourth decimal, 0.0001. The introduction of fifth decimal quoting would see the lower bound on spreads fall to 0.00001 and should see rents made by dealers on small trades fall to those seen pre introduction of the euro. However, as noted above, once one conditions on trade size, the total cost of trading after a move to five decimals may not fall.

[14]It is usually the case that the best bid and ask prices, which form the spread that we observe, are quoted by different dealers/banks.

5. Conclusion

From the above analysis we can conclude that the \$/euro spreads did increase significantly from those seen in the DM/\$ period but only when defining spreads as a percentage of mid-quote. This, we argue, is due to the re-factoring of the mid-quote along with the fact that pip spreads have remained unchanged. We model the spread (successfully) as a function of trades and return volatility and when we allow for the

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Table 1
Summary Statistics[a]

	Hourly[b]			Daily[c]		
	DM/$[d]	$/euro[e]	% change	DM/$[d]	$/euro[e]	% change
AS[f]	1.62	2.77	71%	1.63	2.77	70%
	(0.4783)	(1.2823)		(0.2917)	(0.6592)	
TWAS[f]	1.45	2.67	84%	1.44	2.69	87%
	(0.5310)	(1.4189)		(0.2474)	(0.6654)	
ASPIP	2.84	2.82	-1%	2.86	2.82	-1%
	(0.8339)	(1.2843)		(0.4997)	(0.6264)	
TWASPIP	2.53	2.71	7%	2.53	2.74	8%
	(0.9274)	(1.4305)		(0.4246)	(0.6379)	
TRAD	602.74	289.55	-52%	6027.4	2864.13	-52%
	(313.28)	(146.13)		(914.32)	(735.04)	
ABIM	51.3	30.22	-44%	86.6	104.16	20%
	(47.473)	(26.566)		(129.009)	(88.400)	
VOLAT	0.0318	0.0387	22%	0.3178	0.3888	22%
	(0.05996)	(0.05800)		(0.2181)	(0.2930)	
STDSP	1.11	2.00	80%	1.25	2.58	106%
	(0.5660)	(1.7955)		(0.4110)	(1.2311)	
STDSPPIP	1.93	2.03	5%	2.19	2.63	20%
	(0.9888)	(1.8531)		(0.7133)	(1.2682)	
HKM Spread[g]	3.76	5.26	40%			

[a] Standard deviations in parentheses.
[b] For hourly data, statistics were only calculated if there were full data over the hour. Hours during which the Reuters computer feed crashed have been omitted.
[c] Daily statistics were only computed if there were ten complete hours of data and this explains the slight variations between the daily and hourly results.
[d] DM/$ data used 0600 to 1600 observations from 6th to 10th October 1997.
[e] $/euro data were calculated using 0700 to 1700 observations from 28th September 1999 to 8th March 2000. All statistics were calculated excluding the Christmas period from 24th December 1999 to 3rd January 2000.
[f] Basis points.
[g] HKM data from Hau et al 'How has the euro changed the foreign exchange market?' Economic Policy, volume 34, April 2002.

Table 2
Deseasonalised spread regressions[a]

	DM/$[b]		$/euro	
	TWASPIP	ASPIP	TWASPIP	ASPIP
C	0.5307	0.6143	0.7823	0.8082
	(12.08)	(11.59)	(17.57)	(13.39)
VOLAT		0.0487	0.0311	0.0421
		(2.04)	(3.93)	(3.70)
STDSPPIP	0.4352	0.3887	0.2643	0.2422
	(9.28)	(11.37)	(6.41)	(3.91)
TRAD		-0.0700	-0.0773	-0.0920
		(-1.73)	(-3.70)	(-4.58)
AR(1)	0.3211		0.2952	0.4068
	(2.22)		(5.60)	(7.61)
AR(2)			0.1578	0.1105
			(3.46)	(2.14)
AR(3)			0.1938	0.1794
			(4.91)	(3.78)
DUMMY	0.1045	0.0642		
	(2.70)	(3.27)		
R^2	0.86	0.91	0.73	0.78

[a] Test statistics in parentheses. Newey West consistent standard errors were used throughout. All variables are deseasonalised as described in the text. However, for the DM/$ data, due to the distortionary effects the 1100 GMT 4th day may have, it was excluded in the deseasonalisation procedure, i.e. the intra-day pattern for 1100 GMT was found by averaging only the 1st, 2nd, 3rd and 5th days' data.
[b] The dummy variable 'D' takes the value '1' for observations from 1200 GMT on 9th October 1997 onwards and zero otherwise. The observation for 1100 GMT has been removed. Pre and post interest rate announcement, it was found that the responsiveness of the spread to changes in the explanatory variables remained unchanged.

Figure 1. Time weighted and average pip spreads (daily $/euro)

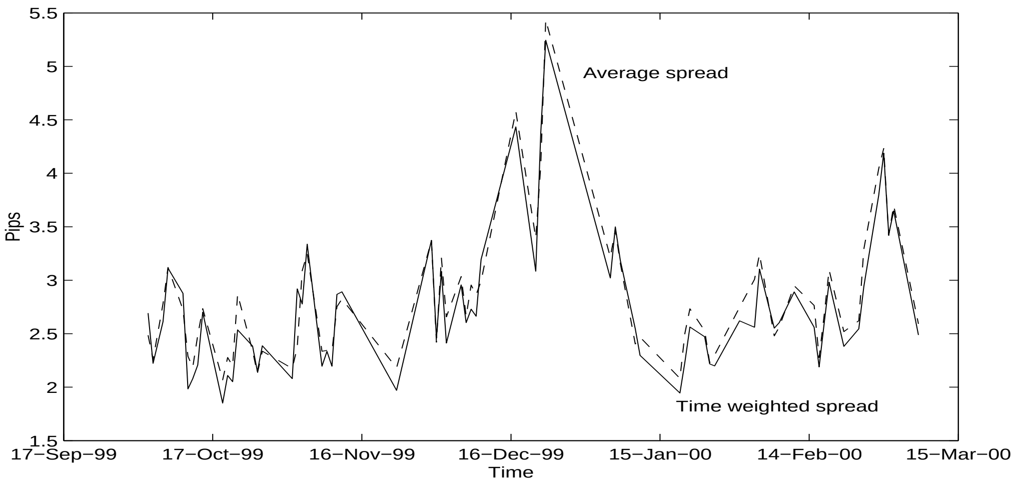

Figure 2. Time weighted and average pip spreads (daily DM/$)

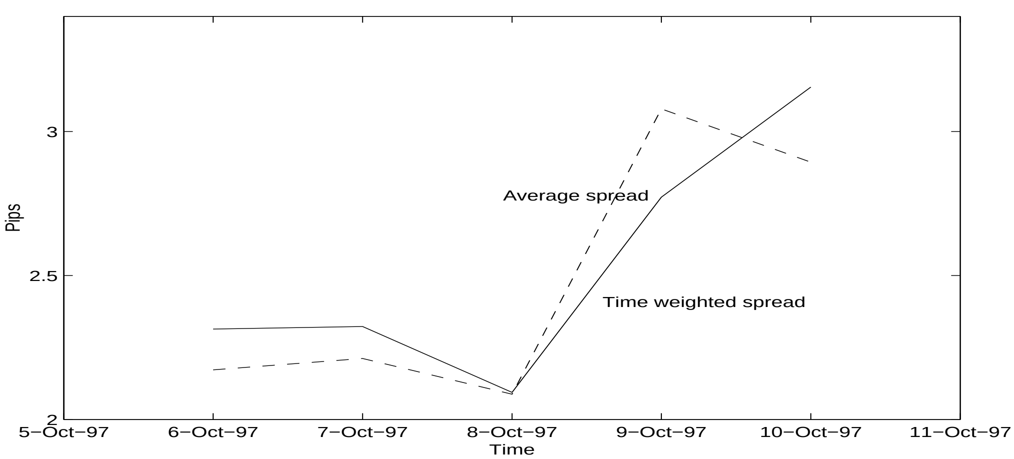

Figure 3. Breakdown of spreads for the DM/$ and $/euro markets

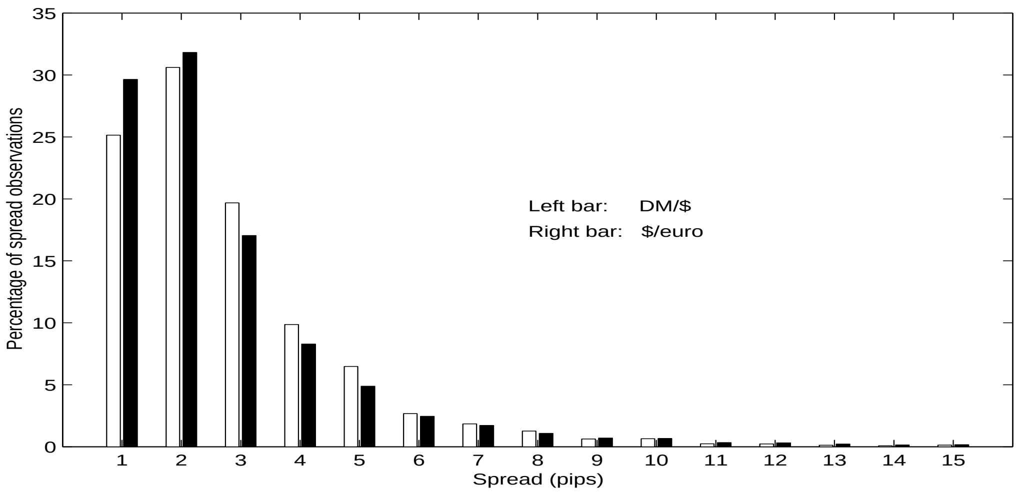

Figure 4. Actual DM/$ and predicted $/euro time weighted pip spreads