Y2K fears and safe haven trading of the U.S. dollar

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Abstract

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1. Introduction

> "The United States is likely to emerge as a perceived safe haven for investors fleeing Year 2000 technology problems." [Comments by the U.S. intelligence community and its sister organizations around the world as reported by Reuters, October 13, 1999.]

The notion of a *safe haven currency* has been around for years. Cumby (1988) and Froot and Thaler (1990), for example, suggest that the excess returns to the U.S. dollar beginning in the early 1980s were driven by purchases on the part of foreign investors who viewed the dollar as a safe haven. The more general belief is that currencies such as the U.S. dollar and the Swiss Franc are ideal venues for investors to park their money during periods of uncertainty. Consequently, investors all over the world purchase assets denominated in these currencies when uncertainty increases. This paper empirically examines the extent to which safe haven flows affect the foreign exchange markets in the context of a specific event—the Y2K (Year 2000) problem.[1]

We examine the effects of safe haven flows using Y2K, rather than other recent events associated with global uncertainty, for several reasons.[2] First, even though Y2K did not turn out to be a serious problem *ex post*, there is substantial evidence that it was perceived as a major problem *ex ante*.[3] Second, and more important, the event was clearly delineated—investors knew exactly when the problem would manifest itself (midnight on December 31, 1999), and when the uncertainty would be resolved (early

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[1] The Y2K problem arose because dates were stored in computers using a DD/MM/YY format. It was believed that this format would lead computer systems to mistake January 1, 2000 for the year 1900, and thereby wreak havoc with date calculations. The only solution was to check and correct every date-relevant piece of computer code.

[2] The Mexican 'tequila' crisis in December 1994, the Asian 'flu' following the devaluation of the Thai baht in 1997, the Russian debt crisis in 1998, and the Brazilian crisis in 1999 are other recent examples of times when it was conjectured that the U.S. dollar was subject to safe haven flows.

[3] For example, the Central Intelligence Agency (CIA) and other intelligence agencies around the world warned that Y2K-related malfunctions had the potential "to cause or exacerbate humanitarian crises" worldwide (CIA Report, October 1999). Moreover, academic work discusses the possible impact of such events on countries' economies (see, for example, the general equilibrium model in Schmitt-Grohe and Uribe, 1999).

January, 2000). By contrast, none of the other candidate events was entirely predictable, so it is difficult to tell when the safe haven flows associated with these events, if any, began and when they ended. Third, analysis of financial market effects related to Y2K concerns is interesting in its own right, since fears of a meltdown in global financial markets were at the core of the problem. Finally, we can concentrate on the U.S. because it was viewed as the best prepared to handle potential Y2K problems. As a result, the U.S. dollar became the principal safe haven as Y2K concerns grew. Using the U.S. dollar to study safe haven flows around Y2K therefore represents our best chance of uncovering safe haven effects.

Unfortunately, we cannot directly observe flows into the U.S. dollar because order flow data from the foreign exchange market are proprietary. However, we *can* examine the effects of these flows on such variables as the bid-ask spread[4]. Microstructure models of dealer behavior suggest that dealers increase their spreads as the cost of holding inventory increases, and the cost of holding inventory increases as either the imbalance between supply and demand or uncertainty regarding the value of the asset increases. Quoted spreads have been used extensively to draw inferences about liquidity and order flow in the foreign exchange market (see, for instance, Huang and Masulis, 1999, and for a survey, Dacrogna, Gencay, Mueller, Olsen and Pictet, 2001). In the spirit of these studies, we investigate safe haven flow effects around Y2K by assuming that time-variations in the bid-ask spread are the result of changes in market conditions: dealers manipulate their spreads to optimally manage their inventory positions, given the level of customer order flow and other information.

To determine the effects of safe haven flows, we compare spreads as December 1999 came to an end and after the resolution of Y2K-related uncertainty in January 2000 with spreads at other times. Any flows associated with Y2K fears should have given rise to excess demand for the U.S. dollar before January 1, 2000, as investors moved into U.S. dollar denominated assets, and to excess supply of the U.S.

[4] Our study also adds to the growing literature suggesting that order flow has greater explanatory power for movements in exchange rates than do many standard economic variables (e.g. Evans and Lyons, 2002). Although we do not have actual order flow information, we are investigating the impact of a specific type of order flow—safe haven order flows—on exchange rates.

dollar after January 1, when funds began to be repatriated. To the extent that actual or potential flows of this nature, coupled with uncertainty about future currency values (especially before January 1), imposed inventory risk on foreign exchange dealers, we would expect to see wider spreads in December 1999 and January 2000 than at other times.

Our tests are based on intraday data from the spot and forward markets for the Euro-U.S. dollar currency pair over the 13-month period, December 1, 1999 through December 31, 2000. For at least two reasons, the Euro-U.S. dollar currency pair is ideal for the purposes of investigating possible effects of safe haven flows. The Euro-U.S. dollar is the most active, liquid currency pair in 2000 (BIS, 2002), which means that effects driven by thin trading and stale quotes are unlikely to be important in our analysis. Also, Hau, Killeen and Moore (2002) suggest that changes in the way dealers offset their foreign exchange inventory positions following the introduction of the Euro likely made spreads in the Euro exchange rates especially sensitive to inventory risk and order flow imbalances. By considering both the spot and the forward foreign exchange markets, we are able to judge the effects of Y2K fears on short-term traders (who are more likely to deal in the spot market) and on traders with longer horizons (who are more likely to deal in the forward market). In addition, forwards are a rarely studied but very important part of the foreign exchange market (Flood, 1991; BIS, 2002).

To isolate the impact of Y2K, we estimate a simple model for the bid-ask spread in which we control for well-documented seasonalities in high frequency foreign exchange data (see, for instance, Dacrogna et al., 2001) as well as for factors known to influence the bid-ask spread in these data, including quoting frequency and exchange rate volatility. After controlling for these, we find clear evidence of wider spreads in both the spot and forward markets in December 1999 and January 2000. Specifically, spreads in both markets widen as we approach the end of 1999. The spot spread continues to rise after January 1, 2000 whereas the forward spread starts to decline. Spreads in both markets fall through the latter part of January, and are relatively constant between February and the end of the year. The fact that

the spread does not widen in December 2000 rules out a calendar explanation for the wider spread in December 1999.

These results suggest the following picture of order flow around Y2K. Safe haven flows into the U.S. dollar created excess demand for the dollar before January 1, 2000, imposing inventory risk on foreign exchange dealers and causing them to widen their spreads. The additional widening of the spot spread in January 2000 is consistent with inventory risk imposed by the excess supply of U.S dollars as investors repatriated funds following the resolution of Y2K-related uncertainty. For forwards, the spread peaks in late December 1999 which is consistent with heightened hedging activity before Y2K. This story of supply and demand imbalances in the spot and forward markets is supported by macroeconomic evidence on the supply of currencies in the U.S. and Euro region around Y2K.

We supplement our intraday results with an informal analysis of daily foreign exchange and bond market data over a longer time period, July 1, 1999 through December 31, 2001. Even in this longer sample, our regression results indicate that spreads for the spot and forward Euro-U.S. dollar exchange rate are abnormally wide in December 1999 and January 2000. The spreads in the spot market start to widen in December 1999 whereas those for the one month, three month and six month forwards start to widen in December, September and August respectively, approximately when the traded contract expires in January 2000. Similarly, we find abnormal changes in the yields of benchmark bonds maturing in January 2000, i.e. for the three-month bond in October 1999 and for the one-month bond in December 1999.[5] The results of this supplementary analysis reinforce the spread results, and provide further evidence of unusual trading patterns and reduced liquidity in response to Y2K.

To summarize, we provide evidence that safe haven trading affects the spot and forward foreign exchange markets. In addition, consistent with covered interest parity, we uncover evidence of safe haven

[5] These yield results are consistent with the higher overnight yields in the last week of December 1999 documented by Hartmann, Manna and Manzanares (2001).

trading effects in the fixed income markets. Overall, our results suggest that safe haven trading has an appreciable influence on global financial markets.

The rest of the paper is organized as follows. The next section describes our data. Section 3 presents our results and the final section concludes.

2. Data

We focus on intraday data from the Euro-U.S. dollar spot and forward markets. The intraday data consist of spot and three-month forward indicative quotes covering the 13-month period, December 1, 1999 through December 31, 2000, and are provided by Olsen and Associates. The principal advantage in using intraday data is that such data permit a detailed examination of trading activity, including an investigation of changes over the 24-hour trading day.

This time period is selected because it allows us to study quoting behavior during December 1999, which should be related directly to Y2K effects, and compare this to a complete year of data to correct for seasonalities and other factors which may influence quotes. We choose the Euro because it is the most liquid non-U.S. dollar currency, with approximately 20% of all foreign exchange transactions in April 2001 involving the Euro (BIS, 2002)[6]. We also consider the forward market because outright forwards have become an important part of the foreign exchange market—the volume of traded forward contracts is about one-third that of spot contracts and growing rapidly (BIS, 2002). Using data from both the spot market and the forward market allows us to investigate differences in trading behavior based on investors' current needs (the spot market) versus future needs or beliefs (the forward market). We focus on the three-month forward contract because it is the most active and liquid forward contract.

[6] This 20% market share for the Euro compares to market shares of 45% for the U.S. dollar, 12% for the Japanese Yen and 7% for the Pound Sterling. The shares of other currencies are less than 5%. Trade in the constituent currencies of the Euro (including the German mark and the French Franc) effectively ceased after the introduction of the Euro on January 1, 1999.

We use quoted spreads because these are the best publicly available summary measure of market conditions and, in particular, of order flow and dealers' desired inventory positions. Although the data consist of indicative quotes, there is evidence that these data can provide significant insights into the actual transaction (or "firm") data that we would ideally use. Goodhart, Ito and Payne (1996) and Danielsson and Payne (2002) have considered the quality of indicative quotes as a proxy for transaction data. They find that at coarser frequencies (i.e. when the measurement interval is greater than 10 minutes in length) the indicative quote and transaction data yield very similar results. In view of this correspondence, we use 15-minute and 60-minute intervals in our analysis. We concentrate on the 15-minute results for consistency with the extant literature, but also consider 60-minute intervals to confirm the robustness of our results.

Many previous studies have used indicative quotes as proxies for transaction prices (e.g. Baillie and Bollerslev, 1991; Dacrogna et al., 1993; Andersen and Bollerslev, 1997; and for a survey see Dacrogna et al., 2001). Indicative spreads have also been used as a proxy for market liquidity in studies such as Bollerslev and Melvin (1994), Hartmann (1999) and Huang and Masulis (1999), and indicative quoting frequency as a proxy for trading volume, e.g. Bollerslev and Domowitz (1993) and Melvin and Yin (2000). For our purposes, it is important to note that Danielsson and Payne (2002) find that indicative spreads are stable in comparison to firm transaction data across the trading day, so our use of indicative spreads should, if anything, lead to a bias against finding safe haven trading effects.[7]

Our time series tests require equally spaced observations and, since the quotes appear at irregularly spaced intervals, we use the median spread in each 15-minute or 60-minute interval. Using the median allows us to capture the characteristics of all the quoted spreads during the interval, while

[7] Other relevant findings are that quoted indicative spreads are wider than traded spreads (they include a safety margin so traders can make fine changes in the bid and ask prices based on market conditions); dealers often choose one of the prices to attract investors and make the other price unattractive (quote shading); dealers quote "even" quotes (e.g. 5 or 10 bps, frequently referred to as pips, representing multiples of the last quoted decimal digit); indicative quote spreads are large when trading and quoting activity are low (e.g. weekends); and more actively traded currencies have tighter spreads. See, for instance, Bollerslev and Domowitz (1993), Bollerslev and Melvin (1994), Bessembinder (1994), Huang and Masulis (1999) and Dacrogna et al. (2001).

mitigating the possible influence of some outliers. Outliers are usually the result of quote shading by a few dealers or other short-term forces impacting only a few dealers' spreads.

As in other studies (e.g. Bollerslev and Domowitz, 1992; Andersen and Bollerslev, 1997, 1998), we exclude data corresponding to the weekend, which is defined as extending from 20:00 GMT Friday evening (the close of the North American markets) until 24:00 GMT Sunday evening (when trading commences in the Far East). The rationale is that quoted spreads in the foreign exchange market demonstrate a strong weekend effect with values that are much higher than at other times (for a detailed discussion, see Dacrogna et al., 2001).

To supplement this analysis, we also examine daily data from a longer time period. Daily bid-ask spreads for the Euro-U.S. dollar spot exchange rate and one-month, three-month and six-month forward contracts from July 1, 1999 through the end of 2001 are obtained from DataStream and represent the closing values in London from WM/Reuters.[8] Because spot and forward rates are connected through the interest rate differential, we also consider daily yields on one-month, three-month and six-month Euro and Eurodollar bonds over the same period. These are quoted by Goldman Sachs and provided by DataStream.

3. Empirical Analysis

To determine the significance of changes in the quoting behavior of dealers in the spot and forward markets around Y2K, we estimate several simple models of the intraday bid-ask spread that allow us to capture abnormal activity in these markets over our thirteen month sample period. The most general of these models uses dummy variables to capture seasonal components in our data and adds controls for other effects:

[8] We start on July 1, 1999 rather than January 1, 1999 (the day the Euro officially started trading) in order to avoid possible new currency trading effects associated with the Euro.

$$y_t = \alpha_0 + \alpha_1 ddec_{1999,1} + \alpha_2 djan_{2000,1} + \alpha_3 djan_{2000,2} + \alpha_4 ddec_{2000,1} + \alpha_5 ddec_{2000,2} + \sum_{i=2}^{11} \beta_i dmth_{i,2000} + \sum_{j=1}^{4} \delta_j dgeog_j + X_t'\phi + \varepsilon_t \quad (1).$$

In specification (1):

- y_t is the median spread (from the spot or forward market) in 15-minute or 60-minute interval *t*. We focus on the spread because it is a good proxy for the transaction costs of foreign exchange dealers as influenced by their information and inventory considerations. We concentrate on 15-minute intervals to be consistent with studies such as Huang and Masulis (1999) who use 15-minute intervals in their empirical investigation of foreign exchange spreads. [9]
- $ddec_{1999,1}$, $djan_{2000,1}$, $djan_{2000,2}$, $ddec_{2000,1}$ and $ddec_{2000,2}$ are dummy variables corresponding to the first half of December 1999 (December 1 through 15, inclusive), and the first and second halves of January 2000 and December 2000.
- $dmth_{2000,i}$ are month dummies corresponding to the rest of the year 2000 (*i* = 2 for February, 3 for March, … and 11 for November).
- $dgeog_j$ are, following past research (e.g. Bollerslev and Domowitz, 1993; Andersen and Bollerslev, 1997; Huang and Masulis, 1999; and Dacrogna et al., 1993, 2001), dummies to account for the well-documented differences as trading moves from Asian markets to European and then North American markets over the 24-hour trading day. Specifically, $dgeog_1$ corresponds to Asian trading (00:00-08:00 GMT), $dgeog_2$ to European trading (08:00-12:00),

[9] For the sake of completeness we also considered the mean quote rather than the median quote in each interval and the end of period spread instead of the median spread. In each case, our conclusions were identical. For brevity, we only present the results for the median spread. For consistency with previous work we only analyze the raw spread rather than the relative spread. The advantage with using the raw spread is that it tends to assume a few values, so that changes are easier to interpret and attribute to altered market conditions. By contrast, a change in the relative spread could be driven by a change in the raw spread or by a change in the quote midpoint (used to deflate the raw spread).

$dgeog_3$ to the overlap in European and U.S. trading (12:00-16:00) and $dgeog_4$ to post-U.S. trading (20:00-24:00).[10]

- X_t consists of our set of control variables: quoting frequency, volatility and a trend. Studies such as Bollerslev and Domowitz (1993), Bessembinder (1994), Bollerslev and Melvin (1994), and Huang and Masulis (1999) show that the bid-ask spread is related to both quoting frequency (a proxy for trading volume and competitive pressures) and volatility (which captures inventory effects and market uncertainty)[11]. Following these studies, our measure of quoting frequency is the number of quotes in the interval, and our measure of volatility is the average value of the absolute quote to quote (midpoint to midpoint) return for all quotes issued during the previous interval. Finally, the trend variable is added to capture any spread effects associated with the persistent depreciation of the Euro versus the U.S. dollar over our sample period[12].

We use a simple dummy variable-based technique to deseasonalize our data because it allows us to easily interpret the effects of seasonalities on our results. The dummies correct for monthly differences in quoting behavior and geographic intraday seasonalities in the foreign exchange market. It should, however, be noted that little work has been done to characterize the forward market, so we assume that the seasonalities in the three-month forward market are similar to those in the spot market.

In this specification, we are especially interested in α_0 to α_3, which represent Y2K effects. Given our definitions of the other dummy variables, the intercept, α_0, represents the mean 15-minute or 60-minute spread during U.S. trading (16:00-20:00 GMT) in the second half of December 1999. This

[10] We also estimated a version of this model adding dummies for the different days of the week. This model is not presented, as there was little statistical variation across the different days. Our approach is consistent with existing research, which ignores variations across working days (e.g. Dacrogna et al., 2001).

[11] Nice surveys of these results in the foreign exchange market microstructure literature can be found in Dacrogna et al. (2001), Lyons (2002) and Sarno and Taylor (2002).

[12] After being introduced at a level of 1.18 $/Euro in December 1998, the Euro depreciated steadily through the time periods of both our intraday and daily analysis. For instance, over the period from December 1, 1999 to December 31, 2000 the Euro declined from 1.0091 $/Euro to 0.9420 $/Euro.

becomes our benchmark period.[13] The coefficient on a particular dummy variable reflects the difference between the mean effect during the period to which the dummy corresponds and the mean during U.S. trading in the latter half of December 1999, holding all else (e.g. volatility and quoting frequency) constant. For instance, α_1 is the difference between mean spreads during U.S. trading in the first half of December 1999 and our benchmark period, *ceteris paribus*. Similarly, α_2 and α_3 are the differences corresponding to U.S. trading in the first and second halves of January 2000. As a final illustration, the difference between mean spreads during Asian trading in the second half of December 1999 and U.S. trading over the same period is δ_1, and the difference between European-only trading in October 2000 and U.S. trading in the second half of December 1999 is $\beta_{10} + \delta_2$.

3.1. Qualitative Results

Before estimating our model, we present visual characteristics of the spread data in Figures 1 and 2. Figure 1 provides the median Euro-U.S. dollar spot spread for each 60-minute interval over the 13-month sample period, December 1999 through December 2000[14]. The solid line is a weekly moving average, which facilitates interpretation by compensating for many of the seasonalities. It is seen that the median spread averages about 5 pips (in this context, a *pip* is \$0.0001 or 0.01 cents) in early December 1999, and it increases in the third week of December to 6 pips, where it remains until mid-January 2000. The spread declines during the latter part of January 2000, and by the end of February levels off at approximately 3 pips for the rest of the year. The fact that there is no visible increase in the spread around Christmas 2000 provides preliminary evidence that the higher spread in December 1999 is unusual.

[13] The correct way to interpret our results is in terms of the mean 15-minute or 60-minute median spread. However, for the sake of brevity, we talk in terms of the mean spread.

[14] The results for the 15-minute spread are identical, but more difficult to visualize due to the larger number of observations.

Figure 2 provides the median 60-minute spread in the 3-month forward market. Similar to figure 1, this figure suggests a change in quoting behavior around January 2000. The quoted spread is less than 6 pips in early December 1999, but increases rapidly to over 7 pips by the end of December. It starts to decrease immediately after January 1, 2000 and, by the end of January 2000, settles at a level of approximately 5 pips, where it remains for the rest of the year.

Although these graphical results are informal, figures 1 and 2 show that spreads in both the spot and forward foreign exchange markets widen preceding January 1 and narrow by mid-January. The pre-January widening of the spread is consistent with excess demand for the U.S. dollar, the continued elevation in early January 2000 is consistent with excess supply of the U.S. dollar, and the subsequent narrowing of the spread with the return of net demand to normal levels. Thus, the patterns in the spread are consistent with the effects of safe haven inflows and outflows associated with Y2K, but we must control for other factors that affect spreads before we can reach definite conclusions.

Since we hypothesize that net flows into or out of U.S. dollar denominated assets are driving the spread results, we investigate the asymmetry of demand for U.S. dollars and U.S. dollar denominated assets around Y2K. Figure 3 shows changes in M1 (which includes currency held by the public, travelers checks, demand deposits and other checkable deposits) for both the U.S. (the data are from the Federal Reserve) and the Euro-zone (these data are from the European Central Bank). It clearly shows a dramatic increase in U.S. M1 preceding January 2000 and a decrease following January 2000, and the reverse for the Euro-zone. These patterns are consistent with an increase in U.S. dollar demand deposits and a reduction in Euro deposits just before Y2K, and a reversal of these positions following Y2K. Because the M1 data are measured monthly, the precise timing of these effects is difficult to determine. Nevertheless they suggest that there were increased flows into U.S. dollars preceding Y2K and outflows immediately after Y2K, consistent with investor fears about the event.

3.2 Regression estimates: 15-minute intervals

We first estimate model (1) for the median spread in 15-minute intervals during the 24-hour trading day. Table 1 contains the results for four different specifications, differing in the control variables that have been included in the model. Table 2 presents the corresponding results for the forward market. In interpreting these results it is important to remember that the base case (the intercept) corresponds to U.S. trading in the second half of December 1999.

We start with the results for the median spread in the spot market. The first column reports the results of the specification where the only control variable is the trend. With the exception of the coefficients on the dummies for January 2000, the coefficients on the calendar dummy variables are significantly negative (t-statistics less than -4.50). The coefficients on the dummies for the first and second halves of January 2000 have t-statistics of 9.5 and -0.5 respectively. Hence, the mean spread in the first half of January is even larger than the mean spread at the end of December and the mean spread by the end of January has declined to the level it was at during the latter part of December. The mean spread during the second part of December 1999 is significantly larger than that during all other periods.

Since t-statistics are not necessarily informative about economic significance, we also consider the estimated coefficients. The coefficients suggest that, *ceteris paribus*, the mean spread at the end of December 1999 is wider by almost 1 pip than the mean spread during the first half of December 1999, and the spread during the first half of January 2000 approximately half a pip wider than at the end of December 1999. The spreads are tightest from February to September 2000, approximately 1 pip below the spread at the end of December 1999, and widen gradually over the rest of the year.[15] Despite this increase, spreads during December 2000 are approximately half a pip tighter than during the corresponding periods in December 1999. Since the mean spread at the end of December 1999 (the intercept) is 5 pips, the spread increases by 20% or more in late December and January 2000 relative to

[15] It should be noted that, starting in September 2000, central banks in Europe, Japan and the U.S. intervened to support the Euro. This intervention activity continued until early November 2000. As a result, the widening of quoted spreads towards the end of our sample is not surprising. By using monthly dummies, we are able to capture the effects on the spread of the intervention as well as the changes around Y2K.

every other month except December 2000 (relative to which it increases by 10%). Note that these results do *not* imply that spread is wider during every period in December 1999 than during every other period in 2000. For instance, the spread during U.S. trading in December 1999 is tighter than the spread during Asian trading in November 2000. However, controlling for region, the results do imply that spread is widest in December 1999 and early January 2000. This suggests that quoting behavior immediately around Y2K is different than at other times.

Using insights from market microstructure models that focus on inventory holding costs, we interpret these results as being consistent with safe haven trading effects around January 1, 2000. Models of dealer behavior such as Amihud and Mendelson (1980), Ho and Stoll (1983) and Biais (1993) suggest that the cost to a dealer of holding inventory is based on the liquidity of the asset as well as uncertainty regarding the value of the asset (for a comprehensive discussion see O'Hara, 1995). Lyons (1995) and Yao (1996) test these models by investigating the quoting behavior of individual dealers and find that inventory considerations play a large role in the determination of quoted spreads. Since there was significant uncertainty regarding the impact of Y2K on global financial markets and the value of currencies, our evidence of increased spreads as January 1, 2000 drew near is consistent with dealers widening their spreads to reduce the probability of unwanted inventory accumulation and as compensation for bearing inventory risk. Although this uncertainty was resolved on January 1, 2000, we would expect spreads to remain wide since dealers faced a potentially large number of investors wishing to unwind their U.S. dollar positions. This potential outflow from the U.S. dollar, once again, imposed inventory risk on dealers who continued to quote large spreads to manage the size of their inventory positions until the flows reached normal levels. In the absence of actual order flow data, we cannot establish the occurrence of these flows. However, this pattern in the flows is supported by the M1 evidence in figure 3.

The geographic region dummies provide evidence of significant differences in the width of the spread across the trading day. The coefficient on the dummy corresponding to Asian trading hours shows

that the mean spread during Asian trading is wider by almost 1 pip than the spread during North American trading. The spread tightens by over half a pip as European markets open, and is tightest (by 0.2 pips) when both the European and the North American markets are open, increasing again by half a pip after North American trading is complete.[16] Our findings are consistent with prior research documenting a geographic component to quoted spreads.

The second column presents the results when we add quoting intensity, measured by the number of quotes in the 15-minute interval. This is an important control given the possibility of differences in dealers' quoting behavior and trading patterns around Y2K. As discussed briefly above, there are two justifications for including quoting frequency. First, quoting intensity is a proxy for trading volume. The literature does not provide a clear hypothesis regarding the effect of increased trading volume on the bid-ask spread. A positive relation between volume and the spread occurs either because higher volume increases inventory risk (e.g. Demsetz, 1968; Ho and Stoll, 1981; Cohen, Maier, Schwartz and Whitcomb, 1981) or because higher volume makes it more likely that an information event has occurred (e.g. Easley and O'Hara, 1992). On the other hand, a negative relation between volume and the spread is predicted either by the existence of fixed inventory costs (e.g. order processing costs) or by asymmetric information models such as Admati and Pfleiderer (1988). Second, quoting frequency is a direct measure of dealer competition, and an increase in quoting intensity should lead to a decrease in the quoted spread (e.g. Huang and Masulis, 1999). Consequently, the impact of quoting intensity on the quoted spread is an empirical issue.

The estimated coefficient on the number of quotes is significantly negative (t-statistic = -28.5), implying that the spread tightens as quoting activity increases. This is consistent with the spread declining in the face of increased competition and/or declining order processing costs. After controlling for quoting frequency, our conclusions regarding time-variation in the spread are unaltered. The estimated values of the coefficients on the monthly dummies as well as their statistical significance are

[16] All of these differences, as well as any others that we highlight below, are statistically significant.

little affected by the addition of this variable. Most importantly, spreads at the end of December 1999 continue to be significantly wider than during other months excepting January 2000. The similarity of these results in relation to those in column one allows us to rule out the possibility that the wider spreads in December 1999 and January 2000 are driven by changes in quoting activity around the end of the year.[17]

The only noteworthy change is in the geographic dummy coefficients. Controlling for quoting intensity, the spreads in every market are wider than spreads during the period when only the North American markets are open. Spreads are still largest in Asia and decrease after the European markets open and especially after the North American markets open. Once the European markets close, however, there is a drop in quoting intensity and, controlling for the reduced number of quotes, spreads decrease further. Even though this result indicates that geographic variations in the spread could be heavily influenced by differences in quoting frequency (measuring competition or trading activity) in the different markets, it does not affect the Y2K-related results.

The third column adds a control variable to capture market volatility, measured by the average value of the absolute quote to quote return in the preceding 15-minute period. Several studies suggest that increased volatility in prices reflects uncertainty on the part of market participants regarding the value of the underlying asset, and imply that the size of the bid-ask spread should increase with volatility.[18] We find that, consistent with previous research, the spread increases significantly following a period of increased market volatility (the t-statistic on the coefficient is 21.0). Once again, however, the coefficients on the variables in the initial regression are little changed. We continue to find that the bid-ask spread is widest around Y2K, and that the coefficient values on the geographic dummies are similar to those in the basic model. The fact that the spread is wider in late December and in January even after

[17] In results not presented, we find that quoting frequency in both the spot and the forward markets decreases going into January 2000 and then increases gradually until the end of January. Quoting frequency is stable for the rest of the year.

[18] For example Bollerslev and Melvin (1994) and Bessembinder (1994) provide evidence that bid-ask spreads are positively related to exchange rate uncertainty.

controlling for volatility suggests that uncertainties beyond those associated with short-term volatility affected the spread around Y2K.

The final model includes both the number of quotes and the previous period's volatility. The results from this model are similar to those from the models in which we include only one of the control variables. We find that the spread decreases as the number of observations increases and increases as volatility in the previous period increases. The geographic results are also similar to those documented earlier. Most importantly, the coefficients on the month dummy variables retain their signs and significance, implying the continued presence of a Y2K effect in spreads in both December 1999 and January 2000.

Table 2 presents the results for the median spread from the forward market for 15-minute intervals. The specifications are identical to those estimated for the spot spread. The first column shows that spreads widen through December 1999 and gradually become narrower in January. They are widest in the latter part of December 1999, and narrower (although still wider than for the rest of the sample period) both in early December 1999 (by half a pip) and in the first half of January 2000 (by 0.3 pips). The wider spread for contracts that settle in three months' time suggests that the Y2K episode was viewed as potentially causing longer-term disruptions. Unlike spot spreads, however, forward spreads are slightly tighter in early January 2000 than at the end of December 1999. A plausible explanation for this difference is that there is a more gradual unwinding of positions in the forward market, since some traders will hold the forward contract until maturity. The forward spread shrinks through to March and, for the rest of the calendar year, is approximately 1.5 pips lower than at the end of December 1999. Thus, unlike spot market spreads, there is no increase in forward spreads in December 2000 and there is an appreciably weaker monthly seasonal. As a result, the behavior of the spread in the period around Y2K is even more striking in the forward market than in the spot market.

The general pattern in the coefficients on the geographic dummies is similar to that in the spot market. In relation to spreads during North American trading, spreads in Asia are wider by 1 pip, and

spreads during the overlap in European and North American trading are narrower by 0.3 pips. The only difference is that forward spreads during the period when only the European markets are open are statistically indistinguishable from those during North American trading.

The second column presents the results when the number of quotes is added to the model. Since there are fewer quotes in the forward market than in the spot market, it is especially important to ascertain that our results are not being driven by the lower quoting frequency in this market. As in the spot market, we find that the spread decreases as the number of quotes increases (t-statistic = -15.0). After controlling for quoting frequency, we continue to find that spreads in the forward market are higher around Y2K than at other times. There are only minor changes in the coefficients on the geographic dummies. The fact that spreads are similar from February 2000 until December 2000, but elevated especially in December 1999 and to a lesser extent in early January 2000, supports safe haven trading effects in the forward market around Y2K even after correcting for quoting intensity.

The third column presents the results when we add the previous period's volatility to the model. Contrary to the spot market, an increase in the volatility is followed by a decrease in the spread in the forward market (t-statistic = -3.4). This result is counter-intuitive though, as we show in the next sub-section, it is not robust to the length of the measurement interval. Despite this result, the remaining coefficients are similar to those in the original regression.

The final column presents the results from the model that includes both the number of quotes and volatility. The results are similar to those in the previous columns. Forward spreads decrease as either quoting frequency or volatility increases. The monthly dummies indicate that spreads are widest at the end of December 1999, are slightly narrower in early January 2000 and early December 1999, but narrow substantially by the end of January 2000 and remain at that level for the rest of the year (approximately 1 pip below spreads around Y2K). The contrast between the spread around January 1, 2000 and during the rest of the year, as well as the constancy of the spread after the end of January 2000, suggests that quoting behavior in the forward market was different around Y2K, even after controlling for other factors known to influence the spread.

To summarize, our investigation of 15-minute spot and forward market spreads reveals that spreads in both markets were wider preceding and immediately following January 1, 2000. This result continues to hold after we control for other factors known to influence the spread, suggesting that dealer behavior was different around the Y2K changeover. A logical source of the wider spreads before the end of the year is increased demand for the U.S. dollar as a safe haven currency around Y2K. The wider spreads in the forward market, and not just the spot market, suggest that investors perceived the Y2K problem to be both important and enduring. An explanation for the larger spreads after January 1 is inventory costs associated with dollar selling after the resolution of Y2K-related uncertainty. The fact that post-January 1 spreads were especially wide in the spot market lends credence to this view, since holders of 3-month forward contracts were less likely to unwind their positions immediately.

3.3. Regression estimates: 60-minute intervals

In order to confirm that our findings are not merely the result of characteristics of 15-minute data intervals, we repeat our analysis using 60-minute intervals. The specifications are identical to those presented in Section 3.2.

The results for the median 60-minute spot market spread are presented in table 3. Comparing the coefficients in column one of table 3 with those in column one of table 1, it is apparent that the results are very similar. Importantly, we continue to find that the spread is widest at the end of December 1999 and in early January 2000. The spread is slightly narrower in early December 1999, starts to narrow from its highs around Y2K by late January 2000, and is similar from February 2000 to September 2000. While it widens thereafter, the spread in December 2000 is significantly smaller than in December 1999 and is similar to that in October and November. Thus, the major difference in quoting behavior occurs, once again, around Y2K.[19]

[19] The pattern in the coefficients on the geographic dummies is similar to that in Table 1, with spreads being wide during Asian trading, tightening as the European markets open and especially as the North American markets open and then widening after the European markets close. The coefficients on the geographic dummies are always

Our main result is robust to the addition of the other control variables. As with the 15-minute spread, the 60-minute spread is decreasing in quoting frequency (columns 2 and 4) and increasing in recent volatility (columns 3 and 4). Also as before, the widening of the spread in late December 1999 and early January 2000 is pronounced, even after controlling for quoting frequency and/or volatility. Inferences regarding the monthly seasonals are largely unaltered. The widening of the spread in December 1999 and January 2000 is consistent with the existence of a Y2K effect.

Turning to the forward spread, the only major difference between the results in tables 2 and 4 is that the coefficient on the previous period's volatility is no longer statistically significant at conventional levels. This lack of significance is perhaps not surprising bearing in mind that investors trading forwards are likely to have a longer horizon than do traders active in the spot market. As a result the spread is expected to be less sensitive to short-term volatility in the forward foreign exchange market.

The similarity between the 15-minute and 60-minute results is important because it shows that our results are robust to the interval over which the data are aggregated. The 60-minute results confirm the unusual increase in spreads around Y2K.

3.4. Analysis of daily data

The results in the previous sub-sections show that spot and forward foreign exchange dealer quoting behavior around Y2K was unusual. In this section we briefly examine the robustness of these conclusions by considering daily data over a longer 30-month period, July 1, 1999 through December 31, 2001. First, we visually examine the data in figure 4, which presents the daily bid-ask spread from the spot market, as well as from the 1-month, 3-month and 6-month forward markets over the full 30-month period, together with a 30-day moving average to identify patterns in each spread series.

Figure 4a presents the daily spread for the spot market, and shows that the spread starts to widen at the end of November 1999 and remains high until early February 2000. Thereafter, the spread shrinks

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similar to those from the corresponding specification in table 1, and likewise for the forward spreads in tables 2 and

and remains at this lower level for the rest of 2000 and almost all of 2001. Even though it increases slightly at the end of 2001, this increase is less appreciable than the increase at the end of 1999. Consequently, this figure shows that the increases in the spread found in the intraday data at the end of 1999 are also evident, though somewhat less pronounced, in a longer sample. The forward spread at each maturity, shown in Figures 4b to 4d, is relatively wide and increases for a longer period than does the spot spread—in fact, the forward spread (especially for the 6 month contract) appears to start widening as much as five months before Y2K. However, in each series, there is additional widening immediately preceding January 1, 2000, followed by a tightening early in the new year. While there are, perhaps not surprisingly, other periods when individual forward spreads increase, neither the increases nor the subsequent decreases are present as consistently in every series as around Y2K. The distinctive increase preceding January 2000 and equally distinctive decrease following January 2000 in each of the spread series provide additional evidence of Y2K effects.

For completeness, we perform a similar analysis to that for our intraday data. Table 5 presents coefficient estimates from regression model (1) modified for daily spreads from the spot and three month forward markets. The specifications differ slightly from those estimated with intraday data because we are not able to construct corresponding measures for volatility, quoting frequency or the geographic dummies. When interpreting these results it is important to remember that tests based on daily data have low power to uncover time variation in the spread because of the substantially reduced sample sizes relative to intraday data. (When using daily data, we have approximately 22 observations per month and 10 per two-week period during December and January.) Hence, we focus on the signs of the coefficients and less on their statistical significance. The intercept in table 5 corresponds to the mean spread at the end of December 1999, while the coefficient estimates represent the deviations from the mean spread at that time.

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4. To save space, therefore, we do not discuss the geographic dummies again.

Overall, the daily results provide evidence consistent with safe haven trading effects. For the spot spread, with the exception of the coefficients on the dummies for the first halves of January 2000 and December 1999, the coefficient estimates are uniformly negative, many of them significantly so. Thus, the spot spread increases in December 1999 and especially in the first part of January 2000. The spread in the remaining months is narrower, and there is no increase in December 2000 or in December 2001[20]. These results suggest that the daily spot market spread around Y2K was unusually large. Looking at the spread for the three month forward contract, we find similar coefficient patterns to those in the spot market. In order to check for anticipatory trading in the forward market, we also examine the mean spread in months before December 1999. There is some (albeit weak) evidence of wider spreads starting in September 1999, but no earlier. In results not presented, we estimate specification (1) for the one and six month forward spreads and find these start to widen in December and August respectively. It is striking that the spread for each forward contract starts to widen during or soon after the first month in which that contract matures after Y2K. The patterns in the forward market are, therefore, consistent with trading activity in anticipation of Y2K.

Covered interest parity demonstrates that the forward and spot rates are related through the interest rate differential. Therefore, we also look at daily observations for Eurodollar and EuroECU bond yields as measures of U.S. dollar and Euro interest rates. To minimize the effects of changes in monetary policy, we deal with term spreads (the difference between the 6-month or 3-month Eurocurrency yield and the 1-month Eurocurrency yield). Figure 5a presents the Eurodollar and EuroECU term spread for 3-month bonds.[21] The figure clearly demonstrates a rise in the premium on both of the 3-month bonds

[20] In this specification, the dummy for December represents the effects for December 2001, since dummy variables for December 1999 and December 2000 are included separately.

[21] Under the expectations hypothesis of the term structure, the term spread measures how future interest rates are expected to differ from current interest rates. The most common use of this spread is as an indicator of economic sentiment. Many studies have suggested that a positive term spread indicates an improvement in future economic performance since it reflects the market's view that interest rates will rise in the future as conditions improve. In this analysis, we explore the possibility that interest rates could rise in anticipation of problems related to the Y2K changeover.

around October 1999[22]. This result is interesting because October is the first month in which the traded bond matures in January 2000, and is similar to Hartmann et al. (2001), who document substantial increases in overnight yields during the latter part of the final week of 1999. Since these bonds mature around January 1, 2000, the Hartmann et al. evidence suggests that Y2K concerns influenced yields in the overnight fixed income markets before January 1, 2000. To examine this effect further, we present the yields on the 1-month Eurodollar and EuroECU bonds in figure 5b. The jump of almost one percent in the yield on the 1-month Eurodollar bond maturing in January 2000 and of over half a percent in the yield on the corresponding 1-month EuroECU bond is striking, as is the decline in the yields on these bonds immediately after January 1, 2000.

It is unlikely that changes in monetary policy could induce opposite swings in the yield over this short period. On the contrary, these patterns in the yield are consistent with the presence of a risk premium for bonds maturing after Y2K. These results suggest that Y2K fears were reflected in the values of several financial assets, even low risk assets such as Eurobonds.[23]

We caution that the low power of this daily analysis makes it difficult to regard these results as more than suggestive. However, the daily results from the forward, spot and bond markets appear to be consistent with each other and with our previous findings. Specifically, the evidence of widening spreads or increasing yields is consistent with declining liquidity for instruments maturing in January 2000. Taken together, therefore, this evidence suggests the existence of material Y2K effects.

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[22] In results not presented, we find a similar increase in the term spread for the 6-month bonds. However, this increase starts in late June 1999 (about 6 months before Y2K) and is more gradual, whereas the increase in Figure 5a occurs abruptly at the beginning of October 1999.

[23] Although we take the position that the increase in yields for bonds maturing after January 1, 2000 is necessary compensation for the risk of Y2K related failures, it is also possible that the increased demand for U.S. dollar denominated assets at the end of 1999 would result in lower U.S. bond yields at this time. We believe that the concerns regarding Y2K failures would lead to a risk-premium to induce investors to purchase bonds as opposed to simply holding cash. Ultimately, however, this becomes an empirical issue and our evidence suggests that, consistent with the risk premium argument, yields actually rise. More fundamentally, our goal in this analysis is simply to point out the unusual changes in yields that coincided almost exactly with Y2K.

4. Conclusion

Academics and practitioners have discussed safe haven trading for years. Yet, we have little evidence on the importance of safe haven trading. The goal of this paper is to assess the effects of safe haven flows by examining the U.S. dollar-Euro spot and forward markets around the Y2K changeover. The Y2K problem was a clearly defined episode of global uncertainty, and was widely believed to have resulted in safe haven trading. Using this event therefore allows a clean analysis of the impact of both inflows and outflows related to safe haven trading on several financial markets.

In the absence of actual transaction data, we use intraday indicative quotes from the spot and forward foreign exchange markets from December 1, 1999 to December 31, 2000. We find statistically and economically significant increases in the bid-ask spread from mid-December 1999 until mid-January 2000 in both the spot market and the forward market. These increases remain highly significant after we control for seasonalities and other determinants of spreads found to be important in previous studies. The increase in the bid-ask spread is consistent with increased inventory risk faced by currency dealers around Y2K, due to increased order flow, or the potential for increased order flow, associated with safe haven trading. This order flow takes the form of U.S. dollar inflows before January 1, 2000 and dollar outflows in early January 2000, after uncertainty regarding the Y2K problem had been resolved. The fact that these effects are present, not only in the spot market, but also in the forward market, where currencies were delivered well after January 1, 2000, suggests that the Y2K problem was viewed by investors as having serious long-term repercussions.

The robustness of these results is confirmed by considering the behavior of daily spreads over a longer time period, July 1, 1999 through December 31, 2000. This longer sample establishes that the widening of the spread documented in the intraday data is not the result of higher spreads going into December 1999, but rather is the result of a jump in the spread as the end of 1999 drew near. Examining daily bond yields, we find that the yields on 3-month Eurodollar and EuroECU bonds (in excess of the yields on 1-month bonds), as well as the yields on the 1-month bonds, increased in the month during

which the bond being traded matured in January 2000. A risk premium related to Y2K is thus evident in the prices of bonds maturing around Y2K.

We conclude that Y2K fears had important effects in the foreign exchange and bond markets. The more general implication of our analysis is that safe haven flows have an appreciable influence on financial markets.

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Figure 1:

The dotted line is the graph of the intraday quoted bid-ask spread for the Euro-U.S. dollar spot contract over the period December 1, 1999 to December 31, 2000. The spread series consists of the median quote for 60-minute intervals. The solid line is a weekly moving average of spreads to smooth weekly and daily seasonalities.

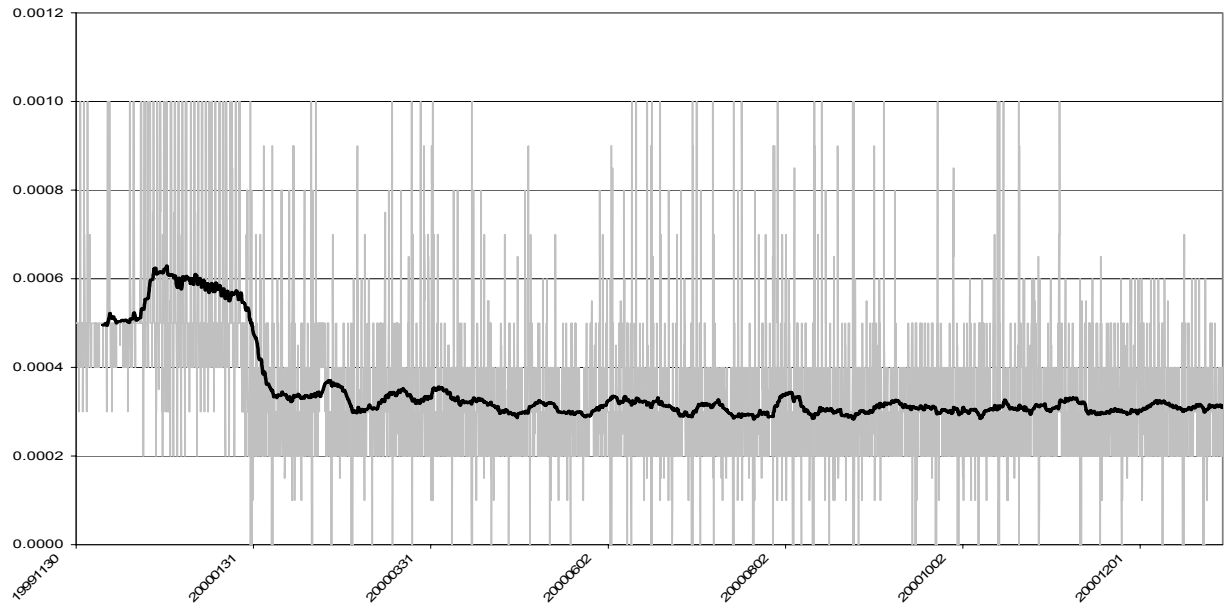


Figure 2:

The dotted line is the graph of the intraday quoted bid-ask spread for the Euro-U.S. dollar forward contract over the period December 1, 1999 to December 31, 2000. The spread series consists of the median quote for 60-minute intervals. The solid line is a weekly moving average of spreads to smooth weekly and daily seasonalities.

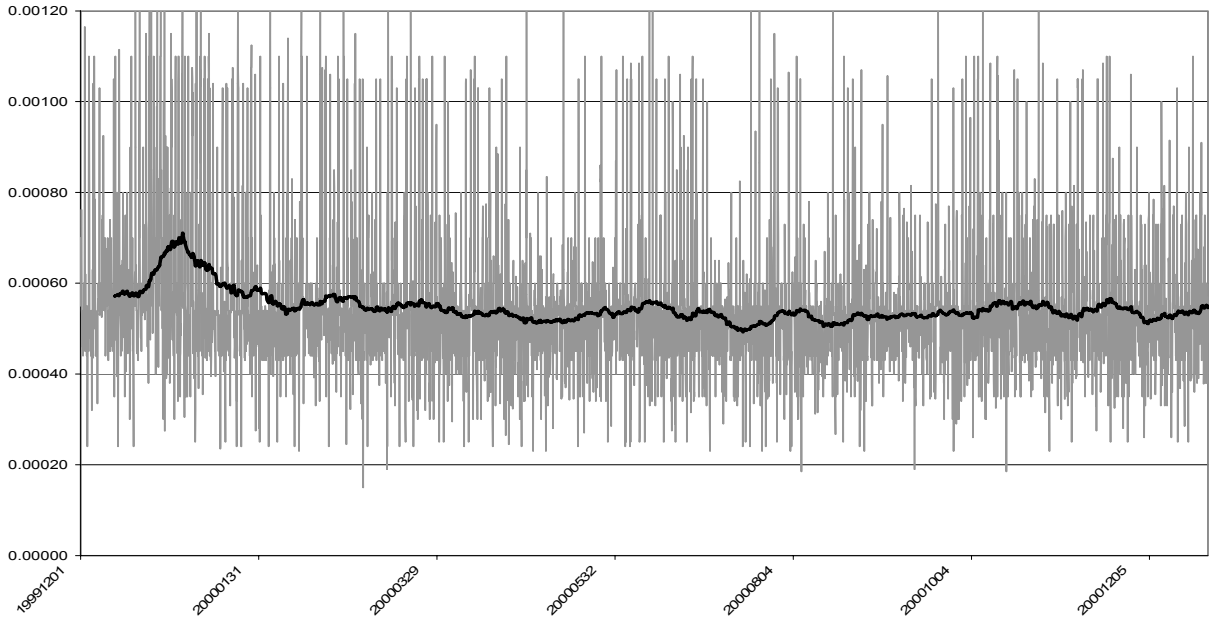


Figure 3:
Percent changes in the M1 measure of money supply for the U.S. dollar and for the Euro over the period January 1999 through January 2001. The data are from the Federal Reserve Board of Governors and the European Central Bank respectively.

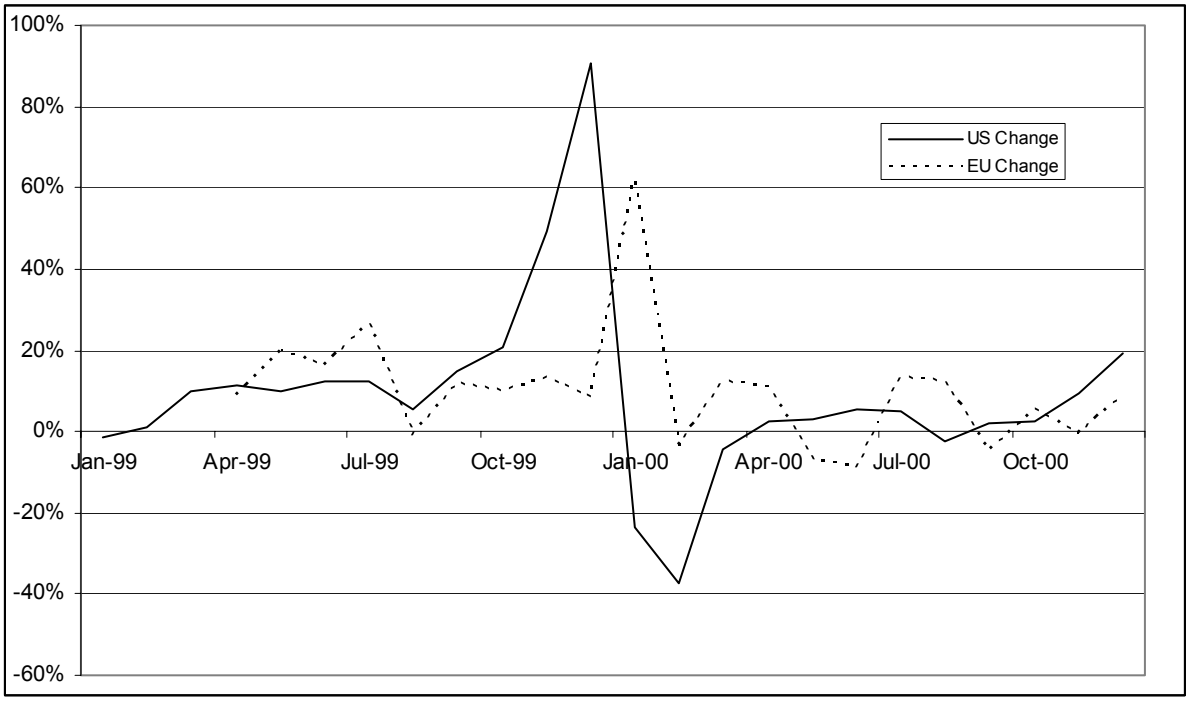
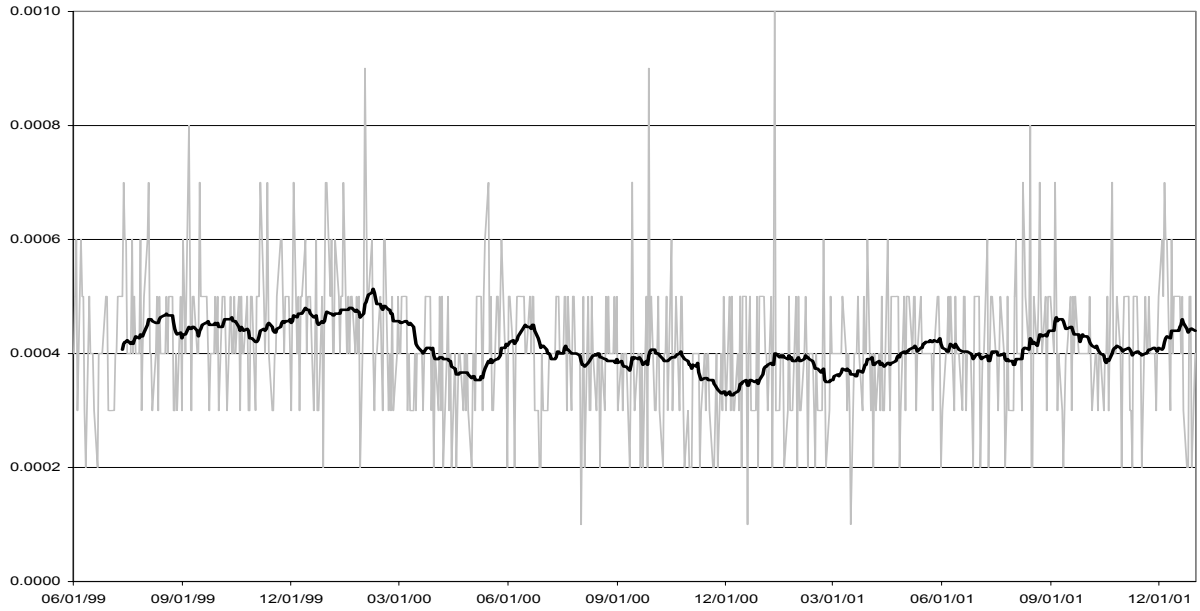


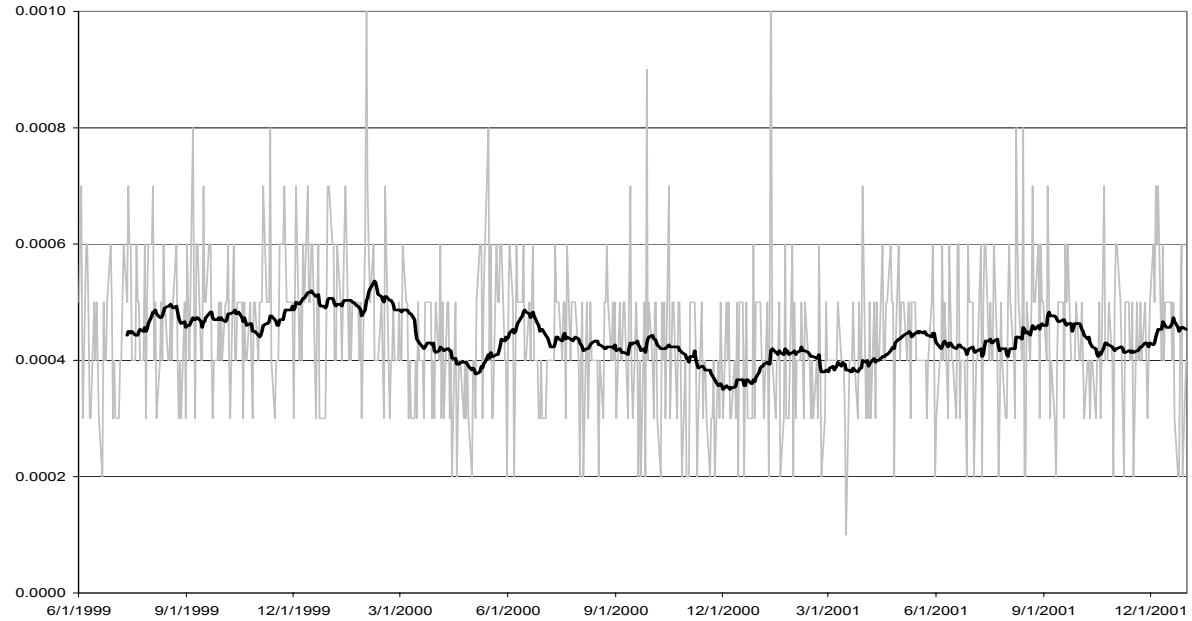
Figure 4:

The dotted line is the quoted daily bid-ask spread over the period July 1, 1999 through December 31, 2001. The quotes are recorded just before the London close by WMB. The solid line is a monthly moving average of spreads to smooth weekly and daily seasonalities.

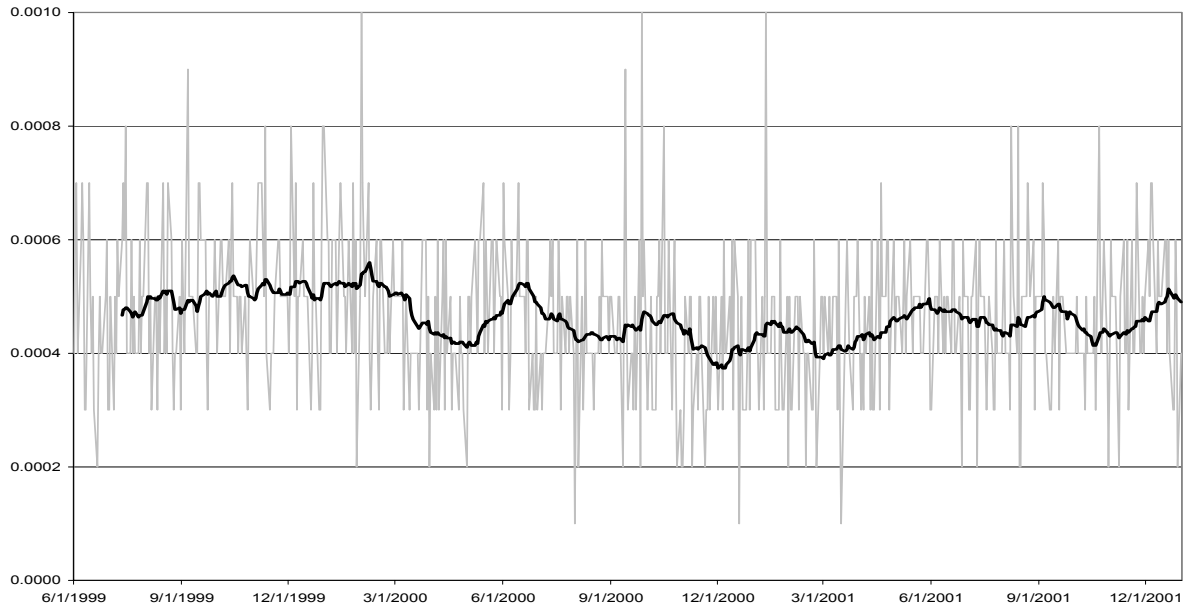
a) Spot spread:



b) Forward spread (1 Month):



c) Forward spread (3 Month)



d) Forward spread (6 Month)

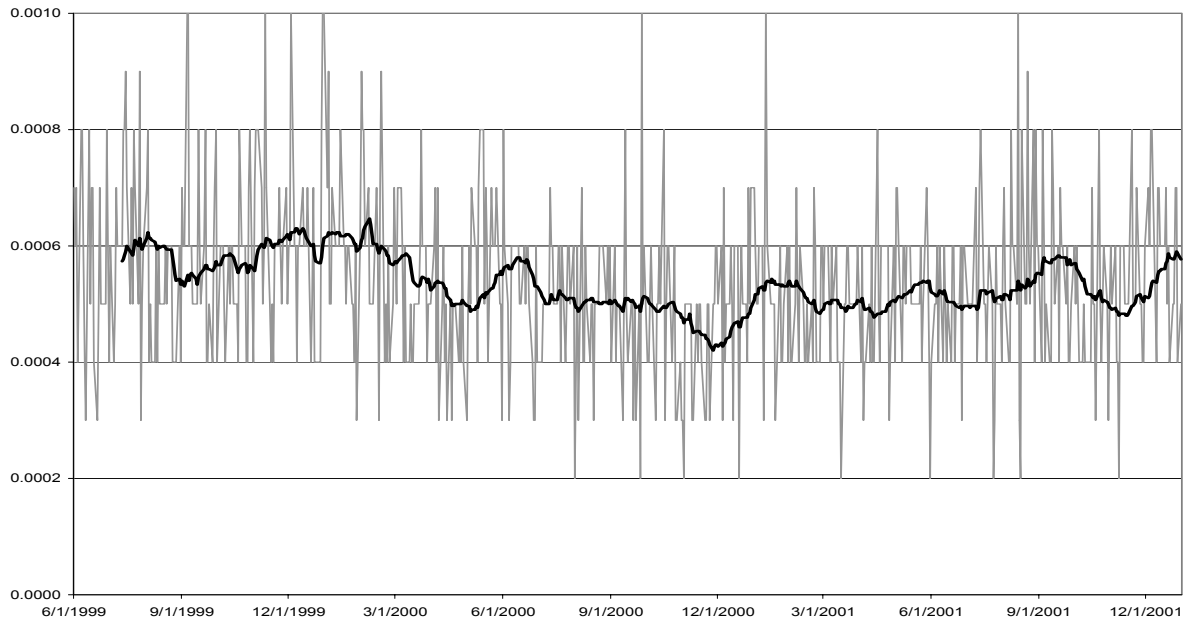
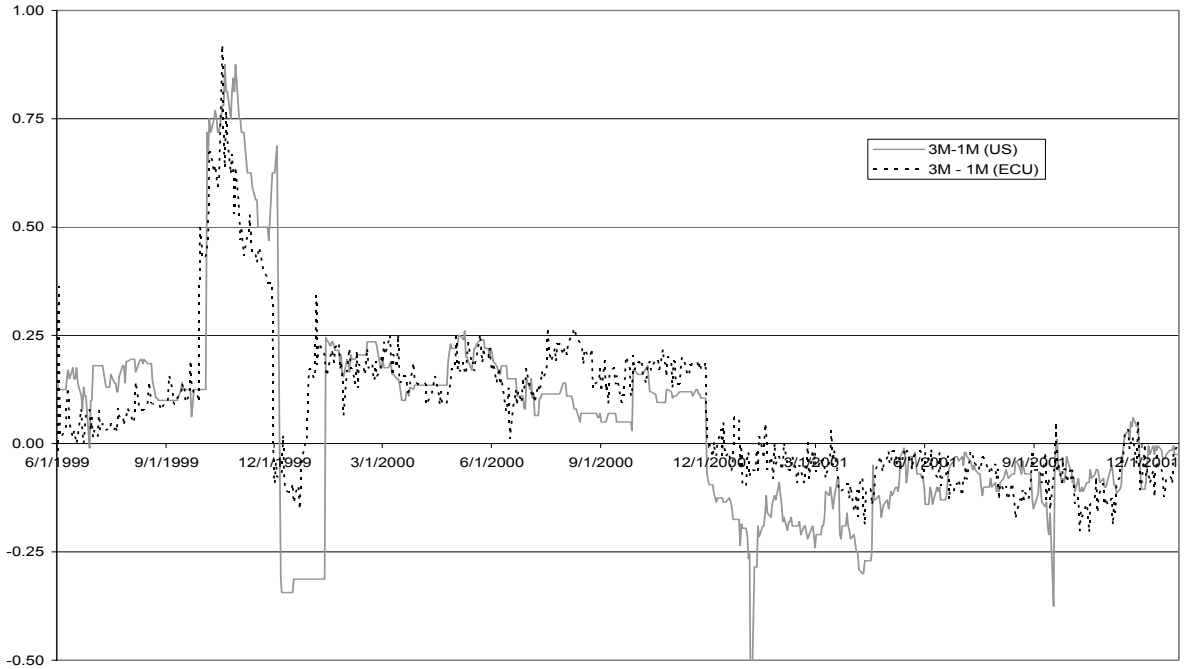


Figure 5:

Daily Eurocurrency bond yields and yield spreads. The yields are quoted by Goldman Sachs at the end of trading in London, and are the Eurocurrency rates from January 4, 1999 through December 31, 2000.

a) 3-month yield less 1-month yield for Eurodollar and EuroECU bonds:



b) 1-month Eurocurrency yields

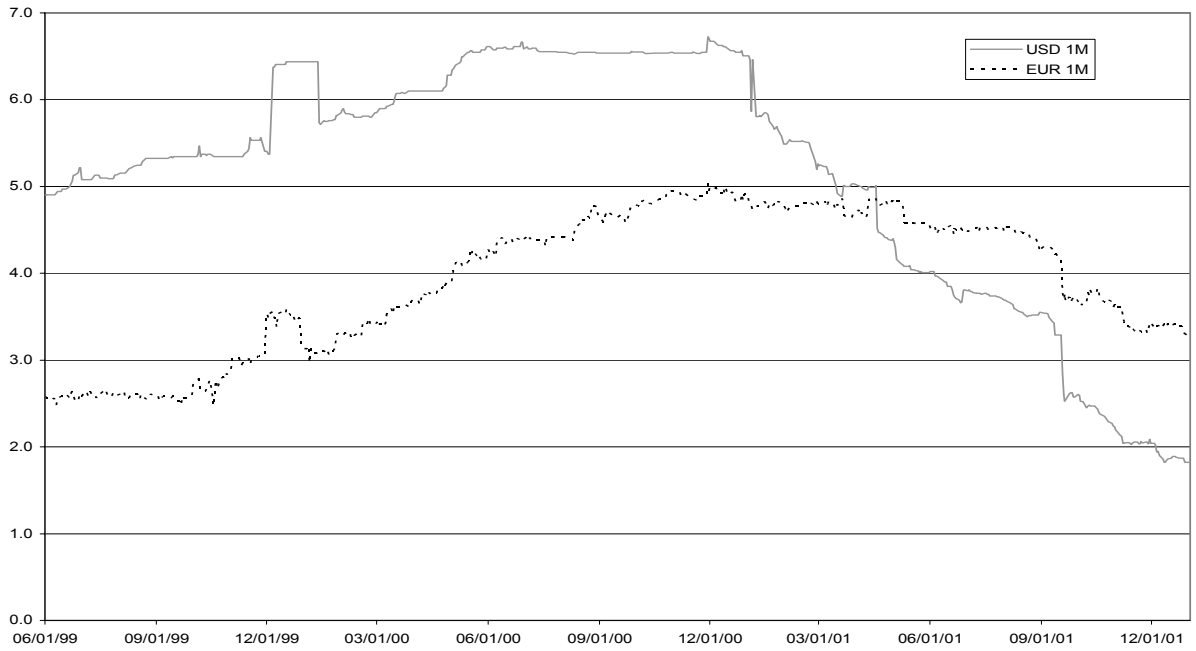


Table 1:

Results for the regression based on equation (1) for the bid-ask spread in the spot U.S. dollar-Euro market. The sample period is December 1, 1999 through December 31, 2000. The dependent variable is the median spread during a 15-minute interval. The independent variables are number of observations in the interval (nobs), average volatility in the previous interval (av_aret1), dummy variables for each month as well as for the first and second halves of December and January (e.g. ddec99f and ddec00f), and dummies for the geographic trading regions (Asia, Europe, Europe and North America together, and no major markets open). The first column presents the estimated coefficients and the second column the corresponding t-statistics. All coefficients are multiplied by 10,000 so they can be interpreted in terms of pips.

	Parameter		Parameter		Parameter		Parameter	
Variable	Estimate	t Value	Estimate	t Value	Estimate	t Value	Estimate	t Value
Intercept	5.080	38.82	5.220	40.53	4.690	36.00	4.820	37.61
nobs			-0.002	-28.51			-0.002	-29.89
av_aret1					2640.0	21.01	2780.0	22.56
ddec99f	-0.512	-6.82	-0.503	-6.80	-0.442	-5.97	-0.430	-5.91
djan00f	0.538	9.54	0.577	10.39	0.548	9.76	0.585	10.61
djan00s	-0.031	-0.50	0.019	0.31	-0.034	-0.55	0.015	0.25
dfeb	-0.755	-11.38	-0.714	-10.94	-0.715	-10.88	-0.675	-10.44
dmar	-0.772	-10.05	-0.748	-9.90	-0.754	-9.90	-0.731	-9.78
dapr	-1.040	-12.09	-1.030	-12.17	-1.030	-12.09	-1.020	-12.23
dmay	-0.919	-9.96	-0.812	-8.93	-0.887	-9.70	-0.778	-8.66
djun	-0.816	-8.27	-0.581	-5.96	-0.788	-8.06	-0.547	-5.67
djul	-0.978	-9.41	-0.798	-7.79	-0.925	-8.99	-0.739	-7.30
daug	-0.995	-9.19	-0.808	-7.57	-0.945	-8.82	-0.753	-7.14
dsep	-0.785	-6.96	-0.511	-4.59	-0.815	-7.29	-0.539	-4.89
doct	-0.765	-6.58	-0.557	-4.86	-0.755	-6.56	-0.543	-4.79
dnov	-0.664	-5.54	-0.450	-3.81	-0.647	-5.46	-0.430	-3.69
ddec00f	-0.650	-5.20	-0.415	-3.36	-0.646	-5.22	-0.407	-3.34
ddec00s	-0.613	-4.81	-0.377	-3.00	-0.620	-4.92	-0.382	-3.08
d_asia	0.850	38.65	0.819	37.81	0.829	38.23	0.797	37.38
d_eur	0.148	5.93	0.691	22.27	0.115	4.68	0.674	22.09
d_eurus	-0.245	-9.86	0.224	7.60	-0.287	-11.70	0.194	6.70
d_none	0.497	18.82	0.316	11.79	0.434	16.52	0.244	9.18
ltrend	0.015	0.36	0.001	0.02	0.022	0.54	0.009	0.22
Adj R-Square		0.1933		0.2190		0.2063		0.2342

Table 2:

Results for the regression based on equation (1) for the bid-ask spread in the three month forward U.S. dollar-Euro market. The sample period is December 1, 1999 through December 31, 2000. The dependent variable is the median spread during a 15-minute interval. The independent variables are number of observations in the interval (nobs), average volatility in the previous interval (av_aret1), dummy variables for each month as well as for the first and second halves of December and January (e.g. ddec99f and ddec00f), and dummies for the geographic trading regions (Asia, Europe, Europe and North America together, and no major markets open). The first column presents the estimated coefficients and the second column the corresponding t-statistics. All coefficients are multiplied by 10,000 so they can be interpreted in terms of pips.

	Parameter		Parameter		Parameter		Parameter	
Variable	Estimate	t Value	Estimate	t Value	Estimate	t Value	Estimate	t Value
Intercept	5.580	22.56	5.640	22.99	5.600	21.20	5.650	21.52
Nobs			-0.041	-15.00			-0.030	-11.24
av_aret1					-219.0	-3.41	-177.0	-2.76
ddec99f	-0.423	-2.99	-0.399	-2.85	-0.387	-2.57	-0.373	-2.50
djan00f	-0.251	-2.31	-0.221	-2.05	-0.259	-2.25	-0.239	-2.08
djan00s	-0.793	-6.98	-0.677	-5.99	-0.688	-5.70	-0.600	-4.98
Dfeb	-1.060	-8.40	-0.952	-7.59	-0.872	-6.43	-0.782	-5.79
Dmar	-1.110	-7.63	-1.030	-7.08	-0.974	-6.19	-0.898	-5.74
Dapr	-1.380	-8.43	-1.310	-8.07	-1.130	-6.38	-1.070	-6.11
Dmay	-1.380	-7.86	-1.280	-7.34	-1.130	-5.98	-1.050	-5.56
Djun	-1.430	-7.62	-1.350	-7.25	-1.340	-6.63	-1.270	-6.31
Djul	-1.580	-8.03	-1.540	-7.88	-1.350	-6.34	-1.310	-6.19
Daug	-1.620	-7.86	-1.510	-7.38	-1.380	-6.25	-1.280	-5.83
Dsep	-1.560	-7.32	-1.410	-6.66	-1.320	-5.76	-1.190	-5.23
Doct	-1.560	-7.07	-1.450	-6.62	-1.420	-5.98	-1.320	-5.60
Dnov	-1.650	-7.28	-1.580	-7.00	-1.520	-6.22	-1.440	-5.95
ddec00f	-1.630	-6.90	-1.540	-6.58	-1.490	-5.87	-1.400	-5.57
ddec00s	-1.460	-6.04	-1.390	-5.82	-1.330	-5.15	-1.280	-4.95
d_asia	0.962	17.55	1.070	19.50	0.670	10.62	0.795	12.48
d_eur	-0.062	-1.12	0.091	1.64	-0.027	-0.43	0.085	1.38
d_eurus	-0.314	-5.67	-0.157	-2.81	-0.272	-4.41	-0.157	-2.53
d_none	0.696	9.91	0.664	9.53	0.528	5.43	0.507	5.25
Ltrend	0.147	1.94	0.135	1.80	0.114	1.41	0.101	1.26
Adj R-Square		0.1359		0.1492		0.1035		0.1141

Table 3:

Results for the regression based on equation (1) for the bid-ask spread in the spot U.S. dollar-Euro market. The sample period is December 1, 1999 through December 31, 2000. The dependent variable is the median spread during a 60-minute interval. The independent variables are number of observations in the interval (nobs), average volatility in the previous interval (av_aret1), dummy variables for each month as well as for the first and second halves of December and January (e.g. ddec99f and ddec00f), and dummies for the geographic trading regions (Asia, Europe, Europe and North America together, and no major markets open). The first column presents the estimated coefficients and the second column the corresponding t-statistics. All coefficients are multiplied by 10,000 so they can be interpreted in terms of pips.

	Parameter		Parameter		Parameter		Parameter	
Variable	Estimate	t Value	Estimate	t Value	Estimate	t Value	Estimate	t Value
Intercept	5.190	20.91	5.330	21.78	4.620	18.40	4.790	19.31
Nobs			-0.0004	-13.96			-0.0004	-13.43
av_aret1					3790.0	12.60	3570.0	12.00
ddec99f	-0.618	-4.35	-0.610	-4.36	-0.555	-3.94	-0.551	-3.97
djan00f	0.333	3.18	0.371	3.59	0.272	2.61	0.312	3.03
djan00s	-0.206	-1.79	-0.158	-1.39	-0.259	-2.26	-0.210	-1.86
Dfeb	-0.962	-7.77	-0.923	-7.56	-0.982	-7.96	-0.943	-7.75
Dmar	-1.060	-7.37	-1.040	-7.32	-1.120	-7.82	-1.090	-7.74
Dapr	-1.330	-8.27	-1.320	-8.34	-1.400	-8.74	-1.390	-8.77
Dmay	-1.170	-6.74	-1.060	-6.23	-1.220	-7.06	-1.120	-6.55
Djun	-1.070	-5.80	-0.849	-4.64	-1.130	-6.12	-0.910	-4.98
Djul	-1.300	-6.65	-1.130	-5.84	-1.310	-6.76	-1.150	-5.98
Daug	-1.310	-6.43	-1.130	-5.62	-1.340	-6.59	-1.160	-5.80
Dsep	-1.050	-4.97	-0.793	-3.78	-1.200	-5.67	-0.942	-4.50
Doct	-1.040	-4.77	-0.843	-3.91	-1.140	-5.21	-0.938	-4.36
Dnov	-0.958	-4.25	-0.756	-3.40	-1.030	-4.60	-0.834	-3.76
ddec00f	-0.964	-4.10	-0.737	-3.17	-1.060	-4.51	-0.836	-3.60
ddec00s	-0.936	-3.91	-0.708	-2.99	-1.050	-4.40	-0.827	-3.50
d_asia	0.807	19.34	0.776	18.85	0.791	19.20	0.763	18.75
d_eur	0.119	2.51	0.640	10.73	0.089	1.91	0.587	9.93
d_eurus	-0.274	-5.80	0.177	3.13	-0.301	-6.45	0.130	2.32
d_none	0.446	8.97	0.272	5.38	0.373	7.53	0.211	4.20
Ltrend	0.051	0.66	0.037	0.49	0.077	1.01	0.062	0.82
Adj R-Square		0.2160		0.2398		0.2352		0.2567

Table 4:

Results for the regression based on equation (1) for the bid-ask spread in the three month forward U.S. dollar-Euro market. The sample period is December 1, 1999 through December 31, 2000. The dependent variable is the median spread during a 60-minute interval. The independent variables are number of observations in the interval (nobs), average volatility in the previous interval (av_aret1), dummy variables for each month as well as for the first and second halves of December and January (e.g. ddec99f and ddec00f), and dummies for the geographic trading regions (Asia, Europe, Europe and North America together, and no major markets open). The first column presents the estimated coefficients and the second column the corresponding t-statistics. All coefficients are multiplied by 10,000 so they can be interpreted in terms of pips.

	Parameter		Parameter		Parameter		Parameter	
Variable	Estimate	t Value	Estimate	t Value	Estimate	t Value	Estimate	t Value
Intercept	5.260	14.64	5.280	14.89	5.420	14.00	5.470	14.39
nobs			-0.016	-11.45			-0.018	-12.68
av_aret1					-151.0	-1.72	-166.0	-1.92
ddec99f	-0.366	-1.78	-0.325	-1.60	-0.363	-1.67	-0.325	-1.52
djan00f	-0.152	-0.98	-0.106	-0.69	-0.016	-0.09	0.048	0.29
djan00s	-0.981	-5.90	-0.805	-4.89	-0.839	-4.71	-0.629	-3.59
dfeb	-1.340	-7.36	-1.190	-6.61	-1.070	-5.41	-0.874	-4.50
dmar	-1.470	-6.99	-1.340	-6.44	-1.190	-5.17	-1.020	-4.51
dapr	-1.790	-7.61	-1.700	-7.31	-1.440	-5.60	-1.320	-5.25
dmay	-1.890	-7.46	-1.750	-7.00	-1.510	-5.44	-1.320	-4.86
djun	-1.710	-6.32	-1.600	-5.96	-1.350	-4.56	-1.190	-4.09
djul	-2.030	-7.13	-1.960	-6.95	-1.610	-5.18	-1.510	-4.93
daug	-2.040	-6.87	-1.900	-6.48	-1.660	-5.12	-1.460	-4.60
dsep	-1.950	-6.30	-1.740	-5.68	-1.530	-4.56	-1.250	-3.79
doct	-1.870	-5.86	-1.710	-5.44	-1.520	-4.37	-1.300	-3.82
dnov	-1.960	-5.98	-1.850	-5.70	-1.570	-4.40	-1.410	-4.02
ddec00f	-2.060	-6.03	-1.930	-5.70	-1.720	-4.63	-1.530	-4.19
ddec00s	-1.820	-5.21	-1.730	-5.00	-1.420	-3.73	-1.280	-3.42
d_asia	0.960	14.31	1.100	16.32	1.070	14.40	1.260	17.03
d_eur	-0.079	-1.11	0.211	2.82	-0.036	-0.48	0.283	3.62
d_eurus	-0.361	-5.06	-0.082	-1.10	-0.311	-4.16	-0.006	-0.08
d_none	0.628	7.80	0.601	7.56	0.697	7.39	0.663	7.15
ltrend	0.297	2.69	0.281	2.58	0.200	1.68	0.174	1.49
Adj R-Square		0.1753		0.1961		0.1844		0.2142

Table 5:

Results for the regression based on equation (1) for the daily bid-ask spread for the spot and three-month forward U.S. dollar-Euro market over the period July 1, 1999 through December 31, 2001. Monthly dummy variables are used for each month and for the first and second halves of December and January (e.g. ddec99f and ddec00f). The first column presents the estimated coefficients and the second column the corresponding t-statistics. All coefficients are multiplied by 10,000 so they can be interpreted in terms of pips.

Variable	Spot Estimate	t-value	3M Forward Estimate	t-value	3M Forward Estimate	t-value	3M Forward Estimate	t-value	3M Forward Estimate	t-value	3M Forward Estimate	t-value
Intercept	4.600	13.41	5.200	13.77	5.200	19.39	5.200	19.32	5.200	19.32	5.200	19.25
d_dec99f	0.140	0.29	0.110	0.20								
d_nov99					0.010	0.03						
d_oct99							-0.220	-0.56				
d_sep99									0.100	0.26		
d_aug99											-0.490	-1.26
d_jan00f	0.520	1.02	0.230	0.42	0.180	0.37	0.180	0.37	0.180	0.37	0.180	0.37
d_jan00s	-0.220	-0.44	-0.350	-0.64	-0.400	-0.84	-0.400	-0.84	-0.400	-0.84	-0.400	-0.84
d_dec00f	-0.860	-1.73	-0.550	-1.13	-0.760	-1.61	-0.760	-1.61	-0.760	-1.61	-0.760	-1.60
d_dec00s	-0.980	-1.94	-1.000	-2.00	-1.200	-2.49	-1.200	-2.48	-1.200	-2.48	-1.200	-2.47
d_jan	-0.580	-1.38	-0.690	-1.49	-0.740	-1.94	-0.740	-1.94	-0.740	-1.94	-0.740	-1.93
d_feb	-0.460	-1.19	-0.610	-1.42	-0.660	-1.95	-0.660	-1.95	-0.660	-1.95	-0.660	-1.94
d_mar	-0.650	-1.69	-0.810	-1.92	-0.860	-2.61	-0.860	-2.60	-0.860	-2.60	-0.860	-2.59
d_apr	-0.880	-2.25	-0.830	-1.93	-0.880	-2.61	-0.880	-2.60	-0.880	-2.60	-0.880	-2.59
d_may	-0.370	-0.95	-0.300	-0.71	-0.350	-1.06	-0.350	-1.05	-0.350	-1.05	-0.350	-1.05
d_jun	-0.560	-1.45	-0.450	-1.05	-0.500	-1.49	-0.500	-1.48	-0.500	-1.48	-0.500	-1.48
d_jul	-0.410	-1.11	-0.580	-1.43	-0.630	-2.02	-0.630	-2.01	-0.630	-2.01	-0.630	-2.01
d_aug	-0.330	-0.90	-0.530	-1.31	-0.590	-1.88	-0.590	-1.87	-0.590	-1.87	-0.630	-1.90
d_sept	-0.310	-0.84	-0.330	-0.79	-0.380	-1.20	-0.380	-1.19	-0.630	-1.87	-0.380	-1.19
d_oct	-0.610	-1.65	-0.670	-1.63	-0.720	-2.30	-0.950	-2.86	-0.720	-2.29	-0.720	-2.28
d_nov	-0.570	-1.53	-0.620	-1.52	-1.000	-3.05	-0.670	-2.14	-0.670	-2.14	-0.670	-2.14
d_dec	-0.060	-0.14	-0.170	-0.35	-0.220	-0.56	-0.220	-0.56	-0.220	-0.56	-0.220	-0.55
Adj R-Sq		0.043		0.035		0.048		0.041		0.041		0.035