ASYMMETRIC INFORMATION AND BID-ASK

SPREADS IN THE EUROCURRENCY MARKETS

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ABSTRACT

The paper develops a model of the determination of bid-ask spreads for a security dealer. The size of the equilibrium bid-ask spread is shown to depend on parameters describing the information structure of the model. Other things being equal, the spread is an increasing function of the dealer's uncertainty about what his customers know, and is a decreasing function of the variance of noise in the market. Empirically, this stylised result suggests that bid-ask spreads may be significant predictors of the distribution of future asset prices; this is supported using data for the Eurocurrency markets.

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by Malcolm Edey

1. Introduction

It is sometimes suggested that when market participants have unequal access to information, asset prices may not be fully efficient in the sense of reflecting the combined information of all agents. A strong theoretical basis for this view is provided in an influential paper by Grossman and Stiglitz (1980). They argue that when information is costly, it will not in general be optimal for all participants in the market to acquire it; in equilibrium, some proportion of agents will invest in information, and the pricing system will be sufficiently noisy so as to allow those investors to earn an additional return which compensates them for information costs.

Whether or not asymmetric information effects are quantitatively important is of course an empirical question. One way of approaching this question is to specify a joint hypothesis concerning informational efficiency and the determination of equilibrium asset prices, and to test such a hypothesis. This is the standard method used in the empirical literature on market efficiency. Whilst not denying the value of this approach for other purposes, it seems unlikely that these tests will tell us very much about the specific issue of asymmetric information. Rejections of the joint hypothesis, when they occur, are always ambiguous in their interpretation, and the possibility that asymmetric information effects are important is only one of the competing explanations for a rejection. The aim of this paper is to develop a method for detecting asymmetric information effects directly. The method will be to analyse the influence of the information structure on the determination of the equilibrium bid-ask spread of a security dealer. Data on bid-ask spreads in the foreign exchange markets will then be used to test for significant informational effects in these markets.

The optimal bid and ask prices of a security dealer have been studied by a number of writers. Several have considered this problem as one of optimal inventory management, for example Garman (1976), Amihud and Mendelson (1980) and Ho and Stoll (1981). In contrast to these earlier papers, Copeland and Galai (1983) and Glosten and Milgrom (1985) consider the bid-ask spread as a purely informational phenomenon, and it is on that approach that the present paper builds. In the Glosten-Milgrom model, the dealer is assumed to be risk neutral and competitive (i.e. he expects to make a zero profit on every transaction). The dealer's customers are either "informed" or "uninformed";

in other words they are motivated to trade either by liquidity considerations or by the possession of superior information to the dealer. Glosten and Milgrom are able to show that when an equilibrium exists, the dealer will in general need to set a non-zero spread between bid and ask prices in order to break even. Intuitively, the purpose of the spread is twofold. First, a large spread acts as a disincentive to the informationally motivated traders; secondly, it secures an expected profit from the liquidity traders, which can offset the expected losses to those informational traders who remain willing to transact.

The Glosten-Milgrom idea is important because it suggests a way in which the effects of asymmetric information in financial markets might be detected empirically. Their work suggests that the size of the bid-ask spread is related to the accuracy of the dealer's information, and to the number of liquidity traders relative to informational traders. If we suspect that informational asymmetries may have an influence on the mean and variance of asset prices, then the use of data on bid-ask spreads provides an obvious way of testing for such effects.

The theoretical part of this paper aims to develop in more detail the empirical implications of asymmetric information in a dealership market. To do this it takes a somewhat simpler theoretical framework than Glosten and Milgrom, by assuming that asset returns are normally distributed, and that asset demand functions are linear. This ensures that the dealer's expected profit function is continuous, and allows us to find necessary and sufficient conditions for equilibrium to exist, which Glosten and Milgrom were unable to do. The approach also does away with the somewhat artificial distinction between informed and uninformed traders, and leads to some fairly straightforward empirical implications.

The basic model and its equilibrium are described in sections 2 and 3. Section 4 focusses on how the empirical implications can be tested, and contains results using bid-ask spreads in the Eurocurrency markets. Conclusions are summarised in section 5.

2. The Model

We consider a market for a single risky security in which all trade is transacted through a single professional intermediary (the "dealer"). The dealer is assumed to be risk neutral and competitive, so that he always sets prices at break even point. In addition to the dealer the market is made up of potential customers ("traders"). The dealer transacts with traders one at a time, and the order in which they are selected for trade is, from the dealer's point of view, random (or at least uncorrelated with other information of relevance to the dealer). On the arrival of each trader the dealer announces the prices at which he is willing to buy or sell the security and the trader is then permitted to buy or sell a fixed quantity or not to transact.

The asset pays a random return of v, where

$$v = 1 + \eta + \varepsilon + u$$

at a fixed date (time T) in the future. Thus v is the sum of three random components, and we asume that the first two of these are observed privately, before the market opens, by the dealer and the traders respectively. The third component u represents pure uncertainty and is not known until time T when the asset return is realised. In the absence of all uncertainty the asset would have unit value. The distributions of the random variables are assumed to be normal, each with zero mean, and variances σ_η^2, σ_ε^2 and σ_u^2 respectively; the three components are independent. Asymmetric information thus enters the model in the form of uncertainty about the location of the mean, while variances are common knowledge. This structure ensures that the conditional distributions of v given a subset of the full information set, remain normal.

The model assumes that traders have exponential utility functions, that is, utility functions of the form

$$u(w_i) = e^{-a_i w_i}$$

where a_i is trader i's coefficient of absolute risk aversion and w_i is his end of period wealth. With normally distributed asset returns, this implies that the traders have linear asset demand functions of the form

$$z_i = \frac{\mu_i - P}{a_i \sigma_i^2} - x_i \tag{1}$$

where μ_i, σ_i^2 are trader i's estimates of the mean and variance of the asset return, x_i is his initial endowment and P is the relative price of the asset in terms of a risk-free numeraire.

To reduce the number of unknown parameters in the demand function to just two, I assume that traders have equal coefficients of risk aversion. Endowments vary however, and the endowment of each trader is assumed to be drawn independently from a normal distribution with parameters $(0, \sigma_x^2)$. (The possibility of negative holdings is perfectly reasonable in a currency market where a posiive holding represents a deposit and a negative holding an overdraft.) These endowments might be thought of as being determined in the real sector (perhaps, in the context of a foreign exchange market, by real trade).

We now consider the pricing policy of the dealer. To illustrate the necessity of setting a spread between bid and ask prices, suppose the dealer were to set a single price P for buying and selling. Clearly the best he could do in this case would be to set P equal to the expected value of the asset given the information available to him, i.e. $P = 1 + \eta$. The first trader to arrive has a demand function

$$z_i = \frac{E(v|P,\varepsilon) - P}{a \text{ var } (v|P,\varepsilon)} - x_i$$

$$= \frac{(1+\eta+\varepsilon) - (1+\eta)}{a \ \sigma_u^2} - x_i$$

since the trader can infer η from P. This simplifies to

$$z_i = \frac{\varepsilon}{a \ \sigma_u^2} - x_i$$

The trader will buy ($z_i > 0$) if $\dfrac{\varepsilon}{a\,\sigma_u^2} > x_i$, that is, if $\varepsilon > a\sigma_u^2 x_i$. What is the dealer's expected gain on the first transaction if the first trader is a buyer? This is given by

$$\pi = E(P-v \mid \varepsilon > a\sigma_u^2 x_i)$$

$$= -\,E(\varepsilon \mid \varepsilon > a\sigma_u^2 x_i)$$

which is negative, since the unconditional expectation of ε is zero. Thus the dealer expects to make a loss on the first transaction if the first trader buys. For similar reasons, he also makes a loss if the first trader sells. He cannot break even with a single buying and selling price because traders will use the information contained in price combined with their own private information to extract a positive expected return.

Suppose instead that the dealer sets separate bid and ask prices (B and A respectively). The zero profit conditions on the two prices can be written as

$$A = E(v \mid \eta, b)$$

$$B = E(v \mid \eta, s) \qquad (2)$$

where b is the information that the next trader chooses to buy and s is the information that he sells. This condition requires that every transaction is fair in expected value terms relative to the dealer's ex-post information (the information as to whether the trader buys or sells). It rules out a strategy of (for instance) making expected losses on purchases matched by gains on sales, while breaking even overall, and ensures that the equilibrium bid and ask prices are symmetric about the dealer's conditional mean.

The following section examines equation (2) to show the nature of equilibrium in this model.

3. Equilibrium

It is necessary here to deal only with the ask price A, since the bid price is determined by an exactly similar argument. We can simplify expression (2) as follows.

$$A = E(v|\eta,b)$$

$$= E(1 + \eta + \varepsilon|\eta,b)$$

$$= 1 + \eta + E(\varepsilon|\eta,b) \equiv 1 + \eta + k \qquad (3)$$

Here b represents the fact that

$$\frac{E(v|\eta,\varepsilon)-A}{a\,\sigma_u^2} - x > 0$$

$$\text{i.e.} \quad \varepsilon > a\,\sigma_u^2 x + k$$

where $\quad k = E(\varepsilon|\varepsilon - a\sigma_u^2 x > k).$ (4)

Thus we can rewrite (3) as

$$A = 1 + \eta + k.$$

This defines the break-even point for the ask price. It is not immediately obvious that there exists a k which satisfies (4). In order to show this we need to examine the properties of the function defined in this expression. First we define $y \equiv \varepsilon - a\sigma_u^2 x$, and note that ε and y have a bivariate normal distribution. We can use the formula for conditional expectation of a bivariate normal (Mood, Graybill and Boes (1974), p.167)) to write

$$E(\varepsilon|y = k) = E(\varepsilon) + \frac{cov(\varepsilon,y)}{var(y)}(k-E(y))$$

$$\frac{\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + a^2 \sigma_u^4 \sigma_x^2} k \equiv Rk \tag{5}$$

where we define R to be the ratio of the variance of the traders' signal (σ_ε^2) to the variance of the traders' criterion function ($\text{var}(\varepsilon - a\sigma_u^2 x) = \sigma_\varepsilon^2 + a^2\sigma_u^4\sigma_x^2$).

We can now simplify expression (4) as follows:

$$E(\varepsilon | y > k) = \int_k^\infty E(\varepsilon | y = t) f(t) dt$$

$$= \int_k^\infty Rt\ f(t)\ dt \tag{6}$$

where f(t) is the conditional density function for $t(= \varepsilon - a\sigma_u^2 x)$ given that $t \geq k$. Equation (6) can be written as

$$E(\varepsilon | \varepsilon - a\ \sigma_u^2 x > k) = R\ E(t | t \geq k). \tag{7}$$

The unconditional distribution of t is normal with parameters

$(0, \sigma^2)$, where $\sigma^2 = \sigma_\varepsilon^2 + a^2\ \sigma_u^4\sigma_x^2$.

Next we standardise (7) by noting that

$$E(t | t \geq k) = \sigma E(t/\sigma | t/\sigma \geq k/\sigma)$$

$$= \sigma E(r | r \geq h) \tag{8}$$

where $h = k/\sigma$ and r has a standard normal distribution. Finally, using (7) and (8) we can rewrite the basic equilibrium condition that was given by equation (4).

$$A = (1+\eta) + h\sigma$$

where h satisfies $h = RE(r|r \geq h)$

$$\equiv R\, g(h). \tag{9}$$

Equation (9) defines the break-even ask price for the dealer. By exactly similar reasoning it can be shown also that

$$B = (1+\eta) - h\sigma$$

so that bid and ask prices are set symmetrically about the dealer's conditional mean.

It still remains to find the function g(h). For reasons described in the appendix, an analytical expression for this function cannot be obtained, and hence we cannot solve explicitly for the equilibrium value of h. We can however obtain the following properties of the function which will be useful in describing the nature of equilibrium. Moreover the values of the function can be accurately tabulated using the standard normal distribution tables. Here we note three properties of g(h) for h>0. These are proved in the appendix.

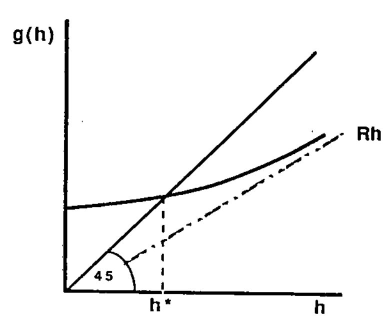
1. g(h) is continuous.

2. The function is bounded by $h < g(h) < h + 1/h$

3. The slope is bounded by $0 < g'(h) < 1$.

Figure 1 below illustrates the nature of equilibrium

Figure 1: Determination of the break-even Ask Price.



Intuitively Rg(h) represents what the dealer estimates to be the expected value of the trader's information advantage, for a given h. This increases with h (the standardised spread size) because the higher is h, the higher ε must be (other things being equal) to induce a trader to buy; however it increases more slowly than h because the dealer will rationally attribute some proportion of the demand at any price as arising from a liquidity motive. Equilibrium is at the break even point h*, where the expected value of the traders' informational advantage is just equal to the premium charged by the dealer.

The diagram suggests that a unique equilibrium exists. This is formalised by the following proposition.

<u>Proposition 1</u>: There exists a unique break-even point h* if and only if

$a^2\sigma_u^4\sigma_x^2>0$.

Proof: (i) Existence follows directly from properties 1 and 2. It is readily seen that $g(0)>0$. Also, from property 2, if $R<1$ there exists an h such that Rg(h) is arbitrarily close to Rh($<$h) and, by continuity, there exists an h* such that $Rg(h^*)=h^*$. If $R=1$ (which is true if and only if $a^2\sigma_u^4\sigma_x^2=0$) then $Rg(h)>h$ for all positive h, so no equilibrium exists.

(ii) Uniqueness is proved by noting that Rg(h)/h is a strictly decreasing function of h:

$$\frac{d}{dh}\;\frac{Rg(h)}{h} = \frac{R}{h^2}\;[h\,g'(h) - g(h)] < 0.$$

Therefore the equation $Rg(h)/h = 1$ can have at most one solution.

The condition that $a^2\sigma_u^4\sigma_x^2>0$, simply requires that there be some variation in endowments and some underlying uncertainty that matters, so as to ensure the presence of a non-zero expected volume of liquidity trading. In other words, for any price there must be a non-zero probability that the next trader will take an expected loss in order to cover an initial risky position. Provided this is so, raising the ask price of the asset will cause its expected value (conditional on the dealer's ex-post information) to increase less quickly, because the dealer will be unsure whether to interpret the trader's willingness to buy as an indication of a favourable value signal (high ε) or of a low endowment (low x).

It is clear from the equilibrium condition (9) that the size of the spread is a function of the parameters which determine R, that is, the variance terms σ_ε^2, σ_u^2 and σ_x^2, and the coefficient of risk aversion.
Obviously an increase in the ratio R increases the standardised spread h, but the influence of each parameter on the total spread $k(=h\sigma)$ is not immediately obvious. The directions of these effects are given in the following proposition (which is proved in the appendix).

<u>Proposition 2</u>: The equilibrium spread k^* is an increasing function of the variance of the traders' signal (σ_ε^2) and a decreasing function of

(i) the variance of endowments (σ_x^2)
(ii) the variance of the noise component (σ_u^2)
(iii) the coefficient of risk aversion (a).

This can be summed up by saying that the spread decreases with those factors which tend to increase the relative importance of liquidity trading as against speculative trading. A high coefficient of risk aversion for example indicates a willingness of traders to accept relatively unfavourable trades in expected value terms in order to reduce the risk to which they are exposed by their initial allocation. The spread required to break even against such traders would be smaller than for those who were less risk averse. In the limit, if traders are risk neutral, no spread would be large enough to allow the dealer to break even since the traders' criterion functions would ensure that they only ever transacted at an expected profit to themselves. Perhaps slightly counterintuitively, an increase in pure uncertainty (σ_u^2) has a similar effect in reducing the spread since it tends to discourage informational trading by risk-averse traders.

4. A Numerical Example

To give an idea of the orders of magnitude involved consider the following simple numerical example. Recall that the equilibrium prices are given by

$$A = 1 + \eta + k$$

$$B = 1 + \eta - k$$

where $k = h\sigma$

h satisfies $h = RE(t|t \geq h)$

the unconditional distribution of t is a standard normal

$$\sigma^2 = \sigma_\varepsilon^2 + a^2\sigma_u^4\sigma_x^2$$

and $R = \sigma_\varepsilon^2/\sigma^2$.

The variances σ_ε^2 and σ_u^2 are, roughly speaking, variances in proportionate rates of return, since the unconditional expected value of the asset is standardised to one. Thus k is interpreted as the spread size for an asset of unit value. A reasonable representative value of the coefficient of risk aversion may be obtained roughly as follows. For any individual, $a_i = \gamma_i/w_i$ where γ_i is his coefficient of relative risk aversion, w_i is his wealth. Supposing $\gamma_i=2$, and $w_i=\$100{,}000$, this gives us a value of $a=2\times10^{-5}$. Assume also that $\sigma_\varepsilon=.01$ and $\sigma_u=.02$, and σ_x (the representative desired transaction size) equal to \$5m, which seems a reasonable value for a wholesale market. From this we can calculate that $\sigma=.04$, $R=.06$.

The value of h is calculated using $h=Rg(h)$. This can be solved numerically to give $h=.05$ when $R=.06$. Thus we obtain for this example that $k=h\sigma=.002$, i.e. a spread of about 0.2 per cent of value. This is quite close to standard spreads in the foreign exchange market. Of course this constitutes no evidence for the model, but simply illustrates that it yields plausible orders of magnitude. It also illustrates the point that quite small, even apparently negligible, spreads can be indicative of a much larger degree of uncertainty or of difference of beliefs (as measured by σ_u and σ_ε respectively). In this case the standard error of prices due to these two sources is about ten times the order of magnitude of the spread.

5. Empirical Implications and Results

In this section we focus on how the qualitative predictions of the model might be tested. The model is highly stylised and contains several unobservable variables, so it is not possible to subject the model as it stands to rigorous empirical testing. There are however two implications which can be tested at a more general level. The first is that the spread is a function of the variance of the asset price; this was established in proposition 2. Econometrically, this implies that the spread would be a predictor of the squared change in he actual asset price. Moreover, the direction of this correlation has a straightforward intuitive interpretation. The relationship between spread and variance is positive for the asymmetric information component of variance (σ_ε^2) and negative for the pure uncertainty component (σ_u^2). Thus a positive relationship between spreads and variances may be taken as evidence that the asymmetric information component predominates.

A second implication is as follows. Suppose the dealer is risk averse.[1] Assuming the dealer holds positive stocks, this would imply that his average price (average of bid and ask) would be at a discount from the risk neutral case; the dealer would require a higher expected return as compensation for risk. The expected excess return will be positively related to the conditional variance, and hence will be positively related to the spread if the asymmetric information component of uncertainty predominates.

In order to test these two qualitative predictions using data on the foreign exchange markets, a simple model of the relationship between forward and spot exchange rates is used. This is taken from Fama (1984). The model is written as

$$S_{t+j} - S_t = \alpha + \beta f_{t+j} + \varepsilon_{t+j} \tag{10}$$

where S_t is the log of the spot exchange rate at t (in U.S. dollrs), $f_{t,j}$ is the j-period forward premium, and ε_{t+j} is an expectational error uncorrelated with information available at t. Under the joint null hypothesis of risk neutrality and market efficiency, $\alpha=0$ and $\beta=1$. An alternative

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1. No attempt is made here to formalise the equilibrium for the risk averse case. This would require a separate and much more complicated analysis. Here only an informal argument is presented to provide motivation for the second set of empirical tests that are reported.

expression is to use

$$S_{t+j} - S_t = \alpha + \beta_1 r_{t,j} - \beta_2 r^*_{t,j} + \varepsilon_{t+j} \tag{11}$$

which makes use of the fact that the interest differential must be equal to the forward premium by covered interest parity. Here $r_{t,j}$ and $r^*_{t,j}$ are the j-period nominal interest rates for foreign and U.S. currency deposits respectively. Under the null hypothesis $\beta_1=\beta_2=1$.

Our interest in this paper is not primarily in estimating equations (10) and (11). There is already a large literature which thoroughly examines such equations (see for example Hansen and Hodrick (1980,1983) and Fama (1984)). Rather, the purpose is to test whether in the context of these simple models, variables which measure bid-ask spreads enter significantly as positive predictors of the mean and variance of S_{t+j}. Two sets of tests are therefore carried out: first, we test whether bid-ask spreads enter as significant additional regressors in equations (10) and (11); secondly, spreads are tested as predictors of the squared residuals $\hat{\varepsilon}^2_{t+j}$ generated by those equations. The tests are applied to three exchange rates against the U.S. dollar: the Pound Sterling, Deutschemark, and Swiss Franc, and for contract maturities of one and three months in each case (i.e. j=1 or 3 in equations (10) and (11)). Monthly data are used for the period 1973:7 to 1984:12. Nominal interest rates are Eurocurrency deposit rates, which ensures consistency between forward premia and measured interest differentials. For each equation, three bid-ask spreads are tested: these are the spreads on the forward exchange rate, and on the U.S. and the relevant foreign deposit rates, for the appropriate maturities. All data are obtained from the Financial Times.

The regression results appear in Tables 1 and 2. Table 1 shows the estimated coefficients in the variance prediction equations. These results provide no clear support for the theory, with the spread variables being significant predictors of variances in only two of the six equations. Much more striking however are the estimated coefficients in the equations for expected returns. Table 2 shows estimates of equations (10) and (11), augmented by the inclusion of the relevant spread variables as additional regressors. The results show

Table 1: Predictors of Variances

Currency & Maturity	U.S. interest rate spread	Foreign interest rate spread	Forward premium spread	U.S. interest rate	Foreign interest rate
£ (1)	-0.07 (1.76)	-0.0003 (0.11)	0.04 (0.54)	-0.11 (2.50)	0.05 (1.27)
£ (3)	-0.22 (1.35)	-0.23 (2.25)	0.03 (0.07)	-0.08 (1.36)	-0.18 (3.22)
DM (1)	0.02 (0.39)	-0.03 (0.39)	-0.04 (0.31)	-0.207 (2.74)	0.02 (0.25)
DM (3)	-0.08 (0.49)	-0.11 (0.86)	-0.21 (0.56)	-0.09 (1.07)	-0.04 (0.36)
SF (1)	0.02 (0.35)	-0.04 (0.63)	0.30 (2.96)	-0.12 (1.17)	-0.06 (0.55)
SF (3)	0.10 (0.42)	-0.09 (0.38)	0.28 (0.78)	-0.19 (1.38)	0.08 (0.54)

Notes: (a) Figures in parentheses in this table are t-statistics.

(b) Table shows coefficients from a regression of $\hat{\varepsilon}^2_{t+j}$ on the vector of "spread" variables shown, where $\hat{\varepsilon}_{t+j}$ is the OLS residual from the equation referred to in the first column.

Table 2: Bid-ask spreads in the Exchange Rate Equations

Currency	Maturity (months)	Constant	Forward Premium	U.S. Interest Rate	Own Interest Rate	Spread on U.S. Interest Rate $\times 10^{-4}$	Spread on Own Interest Rate $\times 10^{-4}$	Spread on Premium $\times 10^{-2}$
U.K. £	1	-0.015 (0.011)		-1.24 (0.83)	1.71 (0.89)	-4.76 (2.09)	1.84 (1.07)	12.25 (9.82)
	3	-0.037 (0.025)		-1.45 (0.68)	1.76 (0.72)	-16.68 (4.53)	4.36 (3.87)	40.51 (24.91)
U.K. £	1	-0.012 (0.009)	-1.56 (0.71)			-4.76 (2.08)	1.62 (1.01)	13.77 (9.14)
	3	-0.026 (0.21)	-1.75 (0.61)			-16.38 (4.49)	3.18 (3.45)	47.70 (23.12)
D-Mark	1	-0.009 (0.016)		-1.49 (1.49)	1.31 (1.84)	-3.77 (3.11)	-1.04 (3.90)	1.36 (0.73)
	3	-0.035 (0.030)		-1.09 (0.94)	0.94 (1.22)	-14.57 (5.35)	-11.98 (7.35)	6.32 (1.27)
D-mark	1	-0.013 (0.013)	-1.12 (1.40)			-3.64 (3.03)	-1.07 (3.88)	1.41 (0.66)
	3	-0.038 (0.025)	-1.13 (0.94)			15.25 (5.50)	-12.95 (9.55)	6.71 (1.4)
S-Franc	1	-0.008 (0.018)		-2.91 (1.33)	3.38 (1.54)	1.41 (3.92)	-11.54 (7.39)	2.39 (0.59)
	3	-0.034 (0.036)		-2.19 (0.87)	2.16 (1.01)	-16.60 (6.91)	-1.70 (9.43)	4.95 (1.33)
S-Franc	1	0.007 (0.017)	-2.66 (1.19)			1.64 (3.88)	-10.70 (7.15)	0.38 (0.59)
	3	-0.041 (0.034)	-1.96 (0.84)			-17.00 (6.93)	-1.21 (9.36)	4.85 (1.33)

Note: (a) Figures in parentheses are standard errors.
(b) Bid-ask spreads are expressed as a ratio to the underlying contract price.
(c) The table reports regression coefficients for equations (10) and (11), augmented by the inclusion of the relevant "spread" variables shown.

that almost all the equations have significant coefficients on at least one of the spread variables, a fact that is interesting in its own right in view of the generally recognised difficulty in finding significant predictors for exchange rate movements. The forward rate spreads, when they are significant, tend to predict positive future movements in the value of the associated currency against the U.S. dollar. This is consistent with the interpretation that significant asymmetric information effects are present and make a relatively large contribution to the degree of uncertainty in these markets. The other interesting feature is that speads on U.S. dollar deposit rates are negatively correlated in most cases, with future changes in the value of the other currencies against the dollar (and hence positively correlated with future changes in the dollar's value against the other currencies). Thus a large spread on the U.S. dollar deposit rate is associated with a discount from the current value of the dollar, which again is in line with the asymmetric information interpretation.

It will be noted that the estimates of the coefficients β, β_1 and β_2 are in general significantly different from their values under the null hypothesis. Similar results for the spot-forward parity equations are reported by Fama (1984). Re-estimation with the spread variables excluded shows that the estimated coefficients are not very sensitive to this change of specification. Thus although the informational effects captured by the spread variables are statistically significant, they make no substantial contribution to explaining the violations of the parity conditions that have been documented in earlier studies.

6. Conclusions

Our analysis has suggested a simple and intuitively plausible relationship between the information structure of a market, and the bid-ask spread of a competitive security dealer. This relationship can be summarised as follows: the size of the spread is positively related to the degree of asymmetry in the information structure, and is inversely related to the degree of pure uncertainty. In Section 5 it was argued that this result can be used as a basis for testing for the presence of asymmetric information effects in the foreign exchange market. The method was to test the significance of variables measuring bid-ask spreads as predictors of the mean and variance of future exchange rates. These data have not previously been used in empirical studies of exchange rate movements.

The results were in broad agreement with the qualitative predictions of the model. Informational effects captured by the spreads were significant in almost all the exchange rate equations, and were consistent in sign with the interpretation that asymmetric information effects make a relatively large contribution to total uncertainty. These effects were not however large enough to explain the failure of the uncovered interest parity condition, which remains a puzzle in empirical finance. The results obtained in this study deserve to be emphasised because they represent the first attempt to find direct evidence concerning asymmetric information effects in the foreign exchange market. This is in contrast to standard studies of informational efficiency which are of a joint nature and therefore offer no obvious interpretation as to the reason for any failure of the joint hypothesis.

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Appendix 1 Properties of the Function g(h)

Here we derive the properties of g(h) given in section 3. The function is defined by

$g(h) = E(t|t > h)$ where the unconditional distribution of t is a standard normal.

This can be written as

$$g(h) = \frac{\int_h^\infty t\, e^{-\frac{t^2}{2}}\, dt}{\int_h^\infty e^{-\frac{t^2}{2}}\, dt} = \frac{e^{-\frac{h^2}{2}}}{\int_h^\infty e^{-\frac{t^2}{2}}\, dt} \equiv \frac{n(h)}{d(h)}$$

The primitive function of $e^{-\frac{t^2}{2}}$ is not known.

Bounds for g(h) are obtained as follows.

$$1.\ g(h) = \frac{h\, e^{-\frac{h^2}{2}}}{\int_h^\infty h\, e^{-\frac{t^2}{2}}\, dt} > \frac{h\, e^{-\frac{h^2}{2}}}{\int_h^\infty t\, e^{-\frac{t^2}{2}}\, dt} = \frac{h\, e^{-\frac{h^2}{2}}}{e^{-\frac{h^2}{2}}} = h$$

2. $$g(h) = \frac{e^{-\frac{h^2}{2}}\left[1+\frac{1}{h^2}\right]}{\int_h^\infty \left[1+\frac{1}{h^2}\right] e^{-\frac{t^2}{2}}\,dt} < \frac{e^{-\frac{h^2}{2}}\left[1+\frac{1}{h^2}\right]}{\int_h^\infty \left[1+\frac{1}{t^2}\right] e^{-\frac{t^2}{2}}\,dt}$$

It is easily verified that the primitive function of

$$\left[1+\frac{1}{t^2}\right] e^{-\frac{t^2}{2}} \quad \text{is} \quad -\frac{e^{-\frac{t^2}{2}}}{t}$$

Thus $$g(h) < \frac{e^{-\frac{h^2}{2}}\left[1+\frac{1}{h^2}\right]}{\left[\dfrac{-e^{-\frac{t^2}{2}}}{t}\right]_h^\infty} = \frac{e^{-\frac{h^2}{2}}\left[1+\frac{1}{h^2}\right]}{\left[\dfrac{e^{-\frac{h^2}{2}}}{h}\right]} = h + \frac{1}{h}.$$

Thus we have $h < g(h) < h + \frac{1}{h}$ (A1)

<u>Continuity</u>

First note that $n'(h) = -h\, e^{-\frac{h^2}{2}}$

$$d'(h) = -e^{-\frac{h^2}{2}}$$

$$\text{Thus } g'(h) = \left[\frac{1}{d(h)}\right]^2 \left\{dn' - nd'\right\} \tag{A2}$$

$$= g(h)\ (g(h) - h)$$

Since $g'(h)$ is defined for all $h > 0$, $g(h)$ is a continuous function for $h > 0$.

Bounds for $g'(h)$

Differentiating $g'(h)$ we obtain

$$g''(h) = (g(h)-h)g'(h) + g(h)(g'(h)-1). \tag{A3}$$

Suppose for some $h > 0$ (say $h = t$), that $g'(t) > 1$.

Then from (A3), $g''(h) > 0$, i.e. the slope is increasing with h. Therefore $g'(h) > 1$ for all $h > t$. But this is impossible since the upper bound of $g(h)$ has a maximum slope of one. Therefore $g'(h) < 1$ for all $h > 0$.

Appendix 2 Proof of Proposition 2

Equilibrium is defined by $h = Rg(h)$

$$k = h\sigma.$$

Let $R = \dfrac{\sigma_\epsilon^2}{\sigma_\epsilon^2+c}$ where $c \equiv a^2\ \sigma_u^4\ \sigma_x^2$

We wish to sign the derivatives of k with respect to σ_ϵ^2 and c.

1. $\dfrac{dk}{d\sigma_\epsilon^2} = \dfrac{dh}{d\sigma_\epsilon^2}.\sigma + \dfrac{d\sigma}{d\sigma_\epsilon^2}.h$

(i) $$\frac{dh}{d\sigma_\epsilon^2} = \frac{dR}{d\sigma_\epsilon^2}.g(h) + \frac{dg(h)}{d\sigma_\epsilon^2}.R$$

$$= \frac{c}{(\sigma_\epsilon^2+c)^2} \cdot g(h) + g'(h)\ \frac{dh}{d\sigma_\epsilon^2}.R$$

$$= \frac{cg(h)}{\sigma^4} + Rg'(h)\ \frac{dh}{d\sigma_\epsilon^2}$$

(ii) $$\frac{d\sigma}{d\sigma_\epsilon^2} = \frac{1}{2}\left[\sigma_\epsilon^2 + c\right]^{-\frac{1}{2}} = \frac{1}{2\sigma}$$

Thus $$\frac{dk}{d\sigma_\epsilon^2} = \frac{cg(h)}{\sigma^3}\left[\frac{1}{1-Rg'(h)}\right] + \frac{h}{2\sigma} > 0$$

since $R < 1$

$g'(h) < 1$.

2. $\dfrac{dk}{dc} = \dfrac{dh}{dc}.\sigma + \dfrac{d\sigma}{dc}.h$

(i) $\frac{dh}{dc} = \frac{dR}{dc} g(h) + Rg'(h) \frac{dh}{dc}$

$$\frac{dh}{dc} = \left[\frac{1}{1-Rg'(h)}\right]\left[\frac{g(h)(-\sigma_{\epsilon}^{2})}{\sigma^{4}}\right] = \left[\frac{1}{1-Rg'(h)}\right]\left[\frac{-h}{\sigma^{2}}\right]$$

(ii) $\frac{d\sigma}{dc} = \frac{1}{2\sigma}$

Therefore $\frac{dk}{dc} = \frac{h}{\sigma}\left[\frac{1}{2} - \frac{1}{1-Rg'(h)}\right] < 0$.

Then $\frac{dk}{da}$, $\frac{dk}{d\sigma_x^2}$, $\frac{dk}{d\sigma_u^2}$ are also negative from the definition of c.

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