"MARKET MICROSTRUCTURE EFFECTS OF GOVERNMENT INTERVENTION IN THE FOREIGN EXCHANGE MARKET"

by

Peter BOSSAERTS*
and
Pierre HILLION**

N° 89 / 67 (FIN)

* Assistant Professor of Finance, Graduate School of Industrial Administration, Carnegie Mellon University, Pittsburgh, U.S.A.

** Assistant Professor of Finance, INSEAD, Boulevard de Constance, 77305 Fontainebleau, France

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Peter Bossaerts
Graduate School of Industrial Administration
Carnegie Mellon University

Pierre Hillion
INSEAD
Fontainebleau France

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Market Microstructure Effects Of Government Intervention In The Foreign Exchange Market

Abstract

An asymmetric information model of the bid–ask spread is developed for a foreign exchange market subject to occasional government intervention. Traditional tests of the unbiasedness of the forward rate as a predictor of the future spot rate are shown to be inconsistent when the rates are measured as the average of their respective bid and ask quotes. Three important results emerge from the empirical analysis. First, bid–ask spreads are larger on Fridays. Second, the volatility of the risk premium seems to depend on the uncertainty about government intervention. Third, the forward bid–ask spread is asymmetric, namely the expected future spot rate is closer to the forward ask or the forward bid depending on whether a devaluation or a revaluation is expected.

1 Introduction

The unbiasedness of forward rates as predictors of future spot rates, referred to henceforth as the unbiasedness hypothesis, has received considerable attention in the finance and economic literature.[1] Conditional on market efficiency and rational expectations, Fama (1984) decomposes the forward exchange rate into a future spot rate and a risk premium. The risk premium is potentially traceable to the risk aversion of individual investors but may also exist in a risk neutral economy. This decomposition suggests testing the unbiasedness hypothesis by regressing the percentage change in the spot rate onto the forward premium, defined as the difference between the forward and spot rates over the spot rate. Under the null hypothesis, the intercept and slope coefficients of the regression should be equal to zero and one, respectively.

The empirical evidence does not support the unbiasedness hypothesis. Using one month forward rates for different currencies relative to the U.S. dollar, the slope coefficients systematically differ from one, and even more puzzling, are significantly negative.[2] A time–varying risk premium might explain these results. Fama (1984) suggests that the negative slope coefficients arise from the higher volatility of the risk premium relative to the the volatility of the expected change in the spot rate, and that the two covary negatively. The volatility of the risk premium is hard to explain, however. Attempts to model the time–varying risk premium and fit specific asset pricing models to the data have met little success.[3]

The results obtained from the futures market contrast singularly with their forward market counterparts.[4] The findings on the unbiasedness hypothesis carry over to futures prices, *i.e.*, the hypothesis is rejected. However, the slope coefficients of the regressions are positive and close to one. The risk premium is, therefore, less volatile than the expected change in the

[1]See Hodrick (1987) for a comprehensive survey of the theoretical and empirical literature.

[2]See Fama (1984) and Hodrick and Srivastava (1986).

[3]See Frankel (1982), Frankel and Engel (1984), Rogoff (1984), Danker and *al.* (1985), Boothe and *al.* (1985), Mark (1985), Lewis (1986), and Korajczyk and Viallet (1989).

[4]See Hodrick and Srivastava (1988). McCurdy and Morgan (1989) model the time variation of the risk premium in the foreign exchange futures market.

spot rate. To reconcile the findings from the forward and futures markets, Hodrick and Srivastava (1985) propose an explanation based on the positive serial correlation of daily risk premiums. Their argument is challenged by McCurdy and Morgan (1986), however.

The unbiasedness hypothesis is examined here from a market microstructure perspective. The purpose of this paper is to investigate whether an explicit modelling of the bid–ask spread explains the strong rejection of the unbiasedness hypothesis. A competitive dealer market for both the spot and forward foreign exchange markets with asymmetrically informed agents is assumed. Drawing upon arguments developed by Admati and Pfleiderer (1988b), the effects of government intervention on the bid–ask spread are examined. The model is used to derive the conditions under which the expected spot rate is halfway between the spot and forward bid and ask quotes. These conditions are violated under pending government intervention.[5]

More specifically, pending government intervention introduces skewness in the expectation of future spot rates. Consequently, the expected future spot rate, equal to the forward rate under the null hypothesis, is not located halfway between the bid and the ask forward quotes, *i.e.*, the forward bid–ask spread is asymmetric. The asymmetry is shown to be accompanied by an increase in the bid–ask spread. Since the decision to intervene is usually taken and revealed during week–ends when the foreign exchange markets are closed, the increase in the bid–ask spreads is most likely to be observed on Fridays.

The positions of the forward and spot rates within the forward and the spot bid–ask spreads, respectively, have serious implications for the empirical tests of the unbiasedness hypothesis. These tests usually employ the *average* bid and ask quotes of both the forward and spot rates. A different location is shown to yield inconsistent estimates of the slope coefficient of the regression relating the change in the spot rate to the forward premium. The inconsistency of the regression parameter estimates invalidates

[5]Government intervention in the spot exchange market is suggested by Fama (1984) as a possible explanation to the rejection of the unbiasedness hypothesis. Government intervention is viewed as a form of market inefficiency where "government logic and obstinacy may be inversely related to natural market forces." The market microstructure effects of government intervention are not evoked, however.

inferences on the unbiasedness hypothesis. A regression equation which explicitly models the bid–ask spread is proposed as an alternative. This regression can be used to test the unbiasedness hypothesis *and* test whether the expected future spot rate is halfway between the forward bid and ask quotes.

The preliminary empirical evidence reported below is consistent with the implications of the model. First, bid–ask spreads are found to be larger on Fridays. Second, the volatility of the risk premium is shown to depend on the base currency. More specifically, a relation between the volatility of the risk premium and the uncertainty about government intervention is observed. Third, the location of the forward rate is not halfway between the forward bid and ask quotes. The forward rate is closer to the ask or to the bid depending on the type of government intervention, *i.e.*, a devaluation or a revaluation. The asymmetry of the forward bid–ask spread implies that inferences about the unbiasedness hypothesis are incorrect when the forward and spot rates are estimated as the average of their respective bid and ask quotes.

This paper does not aim at "explaining away" the existence of a risk premium. From a theoretical perspective, the presence of a risk premium is consistent with either a risk–averse or a risk–neutral economy. Rather, it aims at understanding the high volatility displayed by the risk premium in the forward market especially relative to its low volatility in the futures market. Characteristics pertaining to the organization of the two markets, particularly the open outcry as opposed to the double auction feature, might explain the difference.

The paper is organized as follows. A model of the bid–ask spread in the foreign exchange market is developed in section 2. The empirical implications of the model are derived in section 3. The sample and the empirical evidence are presented in section 4. Section 5 concludes the paper.

2 A Model of the Bid-Ask Spread in the Foreign Exchange Market

A model is developed in this section to determine the position of the expected spot rate within the forward and spot bid and ask quotes. The conditions under which the expected spot rate is exactly in the middle of these quotes are also derived.

2.1 Notation and assumptions

Let $r_{1,t}^T$ and $r_{2,t}^T$ be the yield at time t on a domestic and foreign pure discount bond maturing at time T, respectively. Let s_t be the spot value in domestic currency of one unit of foreign currency at time t. The spot contract is assumed to pay a liquidating payoff equal to $s_{T'}$ at time T' with $T' \geq T$ and,

$$s_{T'} = s_t + \sum_{\tau=t+1}^{T'} \eta_\tau, \tag{1}$$

where the η_τ's are independently but not necessarily identically distributed random variables. The shocks, or equivalently the changes in the spot currency, the η_τ's, might have a nonzero drift, *i.e.*, $E[\eta_\tau|\phi_t]$, the expected shock conditional on the public information at time t (ϕ_t), may be different from zero.

The foreign exchange rate s_t is not an asset *per se* but the relative price of two currencies. Rather than simply buying or selling the currency, the market participants are assumed to borrow at the yield prevailing in the domestic (foreign) country, convert it into foreign (domestic) currency, and invest the proceeds in the foreign (domestic) bond. Let $v_t^{T'}$ be the expected spot price at T', conditional on the information publicly available at t, times the return on a foreign bond, discounted to the present using the yield on a domestic bond,

$$\begin{aligned} v_t^{T'} &= E[s_{T'}|\phi_t] \left(\frac{1 + r_{2,t}^{T'}}{1 + r_{1,t}^{T'}} \right), \\ &= E[s_{T'}|\phi_t]\, \rho_t^{T'}, \end{aligned} \tag{2}$$

with $\rho_t^{T'} = (1 + r_{2,t}^{T'})/(1 + r_{1,t}^{T'})$. Using equation (1), $v_t^{T'}$ can be rewritten,

$$v_t^{T'} = \left(s_t + \sum_{\tau=t+1}^{T'} E[\eta_\tau|\phi_t] \right) \rho_t^{T'}. \tag{3}$$

Equation (3) indicates that $v_t^{T'}$, referred to henceforth as the "adjusted expected spot currency", is not necessarily equal to s_t, except at time T' by construction.

Let f_t^T be the forward price at time t for delivery at time T of one unit of foreign currency. To avoid arbitrage, the forward contract must pay an amount equal to s_T on the maturity date of the contract T,

$$f_T^T = s_T. \tag{4}$$

The relationship between the forward and spot rates is given by the interest rate parity theorem,

$$\begin{aligned} f_t^T &= s_t \frac{1 + r_{1,t}^T}{1 + r_{2,t}^T}, \\ &= \frac{s_t}{\rho_t^T}. \end{aligned} \tag{5}$$

Equation (5) indicates that under stochastic interest rates, changes in the forward price are not perfectly correlated with changes in the spot price. Finally, the relationship between the value of the forward contract today and on its maturity date, i.e., f_t^T and f_T^T, respectively, is assumed to be given by,

$$f_T^T = f_t^T + \sum_{\tau=t+1}^{T} \delta_\tau, \tag{6}$$

where the δ_τ's are independently but not necessarily identically distributed random variables. Since the forward contract requires no investment, the condition,

$$E[\delta_\tau|\phi_t] = 0, \tag{7}$$

can be imposed in a risk–neutral world. The drift in the price of the forward contract, conditional on public information at t (ϕ_t), is equal to zero. Consequently, the price of the forward contract at time t, f_t^T, is the expected final forward price, conditional on the information publicly available at t,

$$f_t^T = E[f_T^T|\phi_t] = E[s_T|\phi_t], \tag{8}$$

where the latter equality holds from equation (4).

2.2 The structure of the spot and forward exchange markets

Drawing upon Admati and Pfleiderer's (1988b) model, the spot and forward foreign exchange markets are assumed to be competitive dealer systems where a large number of risk–neutral market makers commit to take either side of the market. Each one sets bid and ask quotes on the spot and/or the forward foreign exchange markets. For sake of simplicity, the bid–ask spread on the bond market is ignored.[6] Every market maker is prepared to satisfy all the orders that arrive. They do not supply quotes conditional on the number of orders unlike Kyle's (1985), Admati and Pfleiderer's (1988a), or Hughson's (1988) model.

The bid and ask quotes in the forward and spot foreign exchange markets are denoted and defined as follows. The lowest ask commission in the forward market at time t, denoted by a_t^f, is defined as the difference between the lowest ask price, A_t^f, and the price of the forward contract, f_t^T,

$$a_t^f = A_t^f - f_t^T. \tag{9}$$

Similarly, the lowest bid commission in the forward market at time t, denoted by b_t^f, is defined as the difference between the price of the forward contract, f_t^T, and the highest bid price, B_t^f,

$$b_t^f = f_t^T - B_t^f. \tag{10}$$

In the spot market, the market participants are assumed to trade at time t the "adjusted expected spot currency", $v_t^{T'}$, rather than the spot currency, s_t. Accordingly, the lowest ask commission in the spot market at time t, denoted by a_t^s, is defined as the difference between the lowest spot ask price A_t^s and the "adjusted expected spot currency", $v_t^{T'}$,

$$a_t^s = A_t^s - v_t^{T'}. \tag{11}$$

[6]This might seem unrealistic, but is not inconsistent with the data. See table 2, which will be discussed below.

Similarly, the lowest bid commission in the spot market at time t, denoted by b_t^s, is defined as the difference between the "adjusted expected spot currency", $v_t^{T'}$, and the highest spot bid price, B_t^s,

$$b_t^s = v_t^{T'} - B_t^s. \tag{12}$$

Other commissions are ignored, since no market participant will trade at those commissions.

The market makers are assumed to face two different types of traders in both the spot and forward markets, namely informed and liquidity traders. Let I^s and I^f denote the number of informed traders in the spot and forward market, respectively. Similarly, let L^s and L^f denote the number of liquidity traders in the spot and forward market, respectively. The informed and liquidity traders are allowed to trade exactly one unit of the spot or forward foreign currency. The informed traders observe at time t the shock δ_{t+1} in the forward market or η_{t+1} in the spot market. Their superior information has a limited life of one period, since the shock δ_{t+1}, or η_{t+1}, becomes public information at time $t+1$. Each liquidity trader receives at time t an independent and identically distributed signal $z_{t,i}^s$, with $i = 1, \ldots, L^s$ for the liquidity traders in the spot market, or $z_{t,i}^f$ with $i = 1, \ldots, L^f$ for the liquidity traders in the forward market.

2.3 The location of the expected spot rate within the forward and spot bid and ask quotes

The location of the expected spot price within the forward and spot bid and ask quotes is now determined. This requires finding the conditions under which each type of traders buys or sells the forward or spot currency.

Informed traders buy at time t one unit of foreign currency forward if the increase in the value of the forward contract to occur at time $t+1$ is larger than the lowest ask commission,

$$\delta_{t+1} > a_t^f. \tag{13}$$

Conversely, informed traders sell at time t one unit of foreign currency forward if the decrease in the value of the forward contract to occur at time

$t+1$ is larger than the lowest bid commission,

$$\delta_{t+1} < -b_t^f. \tag{14}$$

Similarly, informed traders buy at time t one unit of the spot currency if they expect a profit from borrowing the domestic currency, converting it into foreign currency, and investing the proceeds in the foreign bond,

$$-\left(1+r_{1,t}^{T'}\right)A_t^s + (1+r_{2,t}^{T'})(E[s_{T'}|\phi_t] - E[\eta_{t+1}|\phi_t] + \eta_{t+1}) > 0, \tag{15}$$

Using the definitions of the "adjusted expected spot currency", $v_t^{T'}$, and the lowest ask commission, equation (15) is rewritten,

$$\left(\eta_{t+1} - E[\eta_{t+1}|\phi_t]\right)\rho_t^{T'} > a_t^s. \tag{16}$$

Conversely, they sell at time t one unit of the spot currency if,

$$\left(1+r_{1,t}^{T'}\right)B_t^s - (1+r_{2,t}^{T'})(E[s_{T'}|\phi_t] - E[\eta_{t+1}|\phi_t] + \eta_{t+1}) > 0, \tag{17}$$

which, using the definitions of $v_t^{T'}$ and the lowest bid commission, is rewritten,

$$(\eta_{t+1} - E[\eta_{t+1}|\phi_t])\rho_t^{T'} < -b_t^s. \tag{18}$$

The buy and sell conditions (16) and (18) obtained for the spot currency are similar to the two conditions (13) and (14) obtained for the forward currency. Two differences appear, however. The first one pertains to the presence of a drift term for the spot currency. This arises because the drift of the change in the value of the spot currency might be different from zero unlike its forward currency counterpart. The second difference pertains to the presence of the interest rate differential $\rho_t^{T'}$ for the spot currency. This reflects the fact that the market participants trade the "adjusted expected spot currency", $v_t^{T'}$, rather than spot currency, s_t, which is not an asset *per se*.

The buy and sell conditions for the liquidity traders are simple. Liquidity trader i in the forward foreign currency market buys one unit of foreign currency forward if,

$$z_{t,i}^f > a_t^f, \tag{19}$$

and sells if,

$$z_{t,i}^f < -b_t^f, \tag{20}$$

Similarly, liquidity trader i in the spot foreign currency market buys one unit of foreign currency spot if,

$$z^s_{t,i} > a^s_t, \tag{21}$$

and sell if,

$$z^s_{t,i} < -b^s_t, \tag{22}$$

The aggregate demand (offer) is, on the spot or on the forward market, the sum of the informed traders demand (offer) and the liquidity traders demand (offer). Let $1_{\{D\}}$ denote the indicator function of the event D where the function takes a value equal to one if the event occurs, and zero otherwise. Let $\omega^f_{t,A}$ denote the number of units of forward foreign currency ordered at the ask at time t. Then, using (13) and (19), $\omega^f_{t,A}$ is equal to,

$$\omega^f_{t,A} = I^f.1_{\{\delta_{t+1} > a^f_t\}} + \sum_{i=1}^{L^f} 1_{\{z^f_{t,i} > a^f_t\}}. \tag{23}$$

Similarly, let $\omega^f_{t,B}$ be the number of units of forward foreign exchange offered by the informed and liquidity traders at the bid at time t. Then, using (14) and (20), $\omega^f_{t,B}$ is equal to,

$$\omega^f_{t,B} = I^f.1_{\{\delta_{t+1} < -b^f_t\}} + \sum_{i=1}^{L^f} 1_{\{z^f_{t,i} < -b^f_t\}}. \tag{24}$$

Analogously, let $\omega^s_{t,A}$ and $\omega^s_{t,B}$ denote the total order flow in the spot market at the ask and the bid, respectively. Then, using (16) and (13), $\omega^s_{t,A}$ is equal to,

$$\omega^s_{t,A} = I^s.1_{\{(\eta_{t+1} - E[\eta_{t+1}|\phi_t])\rho^{T'}_t > a^s_t\}} + \sum_{i=1}^{L^s} 1_{\{z^s_{t,i} > a^s_t\}}. \tag{25}$$

Finally, using (18) and (14), $\omega^s_{t,B}$ is equal to,

$$\omega^s_{t,B} = I^s.1_{\{(\eta_{t+1} - E[\eta_{t+1}|\phi_t])\rho^{T'}_t < -b^s_t\}} + \sum_{i=1}^{L^s} 1_{\{z^s_{t,i} < -b^s_t\}}. \tag{26}$$

The trading system is assumed to be competitive. The market makers set, accordingly, the bid and ask quotes such that they make zero profits on average. This yields the following conditions in the forward market. At the ask, the zero expected profit condition is,

$$E[\omega_{t,A}^{f}(A_t^f - f_T^T)|\phi_t] = 0. \tag{27}$$

Similarly at the bid, the zero expected profit condition is,

$$E[\omega_{t,B}^{f}(f_T^T - B_t^f)|\phi_t] = 0. \tag{28}$$

Substituting equations (9), (6) and (25) into (27) yields,

$$\begin{aligned} & E[\omega_{t,A}^{f}(A_t^f - f_T^T)|\phi_t] \\ = \;& E[(I^f 1_{\{\delta_{t+1} > a_t^f\}} + \sum_{i=1}^{L^f} 1_{\{z_{t,i}^f > a_t^f\}})(f_t^T + a_t^f - f_t^T - \sum_{\tau=t+1}^{T} \delta_\tau)|\phi_t] \\ = \;& a_t^f I^f E[1_{\{\delta_{t+1} > a_t^f\}}|\phi_t] + a_t^f L^f E[1_{\{z_{t,1}^f > a_t^f\}}|\phi_t] - I^f E[\delta_{t+1} 1_{\{\delta_{t+1} > a_t^f\}}|\phi_t] \\ = \;& 0. \end{aligned} \tag{29}$$

For the bid quote, substituting equations (10), (6) and (26), into (28) yields,

$$\begin{aligned} & E[\omega_{t,B}^{f}(f_T^T - B_t^f)|\phi_t] \\ = \;& E[(I^f 1_{\{\delta_{t+1} < -b_t^f\}} + \sum_{i=1}^{L^f} 1_{\{z_{t,i}^f < -b_t^f\}})(f_t^T + \sum_{\tau=t+1}^{T} \delta_\tau - f_t^T + b_t^f)|\phi_t] \\ = \;& b_t^f I^f E[1_{\{\delta_{t+1} < -b_t^f\}}|\phi_t] + b_t^f L^f E[1_{\{z_{t,1}^f < -b_t^f\}}|\phi_t] + I^f E[\delta_{t+1} 1_{\{\delta_{t+1} < -b_t^f\}}|\phi_t] \\ = \;& 0. \end{aligned} \tag{30}$$

Similarly, in the spot foreign exchange market, the market makers make zero profits on average, adjusted for a fair return in the domestic and foreign bond markets. Consequently, at the spot ask quote, the zero expected profit condition is,

$$E[\omega_{t,A}^{s}(A_t^s - v_{T'}^{T'} \rho_t^{T'})|\phi_t] = 0. \tag{31}$$

At the spot bid quote, the zero expected profit condition is,

$$E[\omega_{t,B}^{s}(v_{T'}^{T'} \rho_t^{T'} - B_t^s)|\phi_t] = 0. \tag{32}$$

This leads to the following proposition,

Proposition 1 : *If the distribution of $z^f_{t,i}$ and δ_{t+1} is symmetric around zero, respectively, the lowest ask and bid commissions in the forward market are equal, namely $a^f_t = b^f_t$.*

Proposition 1 states that, under the assumption of a symmetric distribution for the change in the forward price and the signal received by the liquidity traders, respectively, the forward price, f^T_t, is halfway between the forward bid and ask quotes. Further, since $f^T_t = E[f^T_T|\phi_t] = E[s_T|\phi_t]$, an unbiased predictor of the expected spot rate is exactly in the middle of the forward bid and ask quotes,

$$f^T_t = E[s_T|\phi_t] = \frac{1}{2}(A^f_t + B^f_t). \quad (33)$$

If, however, the distribution of a change in the forward rate (δ_{t+1}), for example, is asymmetric, equation (33) does not hold, and an unbiased predictor of the future spot rate is not halfway between the forward bid and ask quotes.

A similar proposition can be established for the spot exchange rate.

Proposition 2 : *If the distribution of $z^s_{t,i}$ and η_{t+1} is symmetric around zero and its mean, respectively, then the lowest ask and bid commissions in the spot market are equal, namely $a^s_t = b^s_t$.*

The lowest ask and bid commission, a^s_t and b^s_t, respectively, are defined with respect to $v^{T'}_t$, the "adjusted expected spot currency". Therefore, under the assumption of a symmetric distribution for the change in the spot price and the signal received by the liquidity traders, respectively, proposition 2 states that the "adjusted expected spot currency", $v^{T'}_t$, is halfway between the spot bid and ask quotes. Further, given that $v^{T'}_t = E[s_{T'}|\phi_t]\,\rho^{T'}_t$, the expected future spot rate, $E[s_{T'}|\phi_t]$, is also halfway between the spot bid and ask quotes, if and only if $\rho^{T'}_t = 1$,

$$v^{T'}_t = E[s_{T'}|\phi_t] = \frac{1}{2}(A^s_t + B^s_t), \quad \text{iff} \quad r^{T'}_{1,t} = r^{T'}_{2,t}, \quad (34)$$

i.e., when the domestic and foreign interest rates are equal. The parameter $\rho^{T'}_t$ is not equal to 1 in general. Further, the domestic and foreign interest rates are stochastic which precludes any deterministic relation between s_t and $v_t^{T'}$. The model, therefore, does not impose any constraints on the expected spot rate $E[s_{T'}|\phi_t]$. In particular, $E[s_{T'}|\phi_t]$ need not be inside the spot bid and ask quotes at time t.

3 Implications of the model

The empirical implications of the model for the tests of the unbiasedness hypothesis are now investigated. Few empirical implications can be drawn from proposition 2 because of the unobservability of $v_t^{T'}$, the "adjusted expected spot currency". Proposition 1 is shown, however, to have serious implications for the tests of the unbiasedness hypothesis.

3.1 The market microstructure effects of pending government intervention

Proposition 1 gives the conditions under which the expected spot rate, equal to the forward rate under the null hypothesis, is halfway between the forward bid and ask quotes. One condition is the symmetry of the distribution of the unexpected change in the value of the forward contract, *i.e.*, δ_τ. The assumption of a symmetric distribution is questionable, however. Pending government intervention introduces skewness in the expectation of the future spot rate. Government intervention can take several forms ranging from outright devaluation/revaluation to direct market intervention, such as open market operations. Under government intervention, the distribution of changes in the spot rate as perceived by investors, and market makers in particular, is skewed since there is a low probability of a large loss.

Suppose, for example, that the market makers expect the devaluation of a currency. From equation (30), the expected loss due to sell orders from informed traders in the forward foreign exchange market is equal to,

$$I^f E[(\delta_{t+1} + b_t^f) 1_{\{\delta_{t+1} < -b_t^f\}}|\phi_t]. \tag{35}$$

The expected loss, when evaluated at the bid commission the market makers would charge in the absence of government intervention, *i.e.*, under symmetric expectations, increases. From equation (30), the expected gain due to sell orders from liquidity traders,

$$b_t^f L^f E[1_{\{z_{t,1}^f < -b_t^f\}} | \phi_t], \tag{36}$$

remains unaltered. Confronted with this expected loss, the market maker increases the bid commission until the zero profit condition is again satisfied.[7] In contrast, the expected losses and gains at the ask side of the market are unlikely to change. The ask commission should, therefore, neither increase nor decrease. The increase and the asymmetry of the bid–ask spread results from the increased bid commission and the unaltered ask commission. The expected future spot rate is, therefore, closer to the forward ask quote than to the forward bid quote. The asymmetry works in the other direction when a revaluation is expected, *i.e.*, the expected future spot rate is closer to the forward bid than to the forward ask quote.

Though expectations about government intervention change over time, the market knows when it is most likely to occur. Decisions about currencies are mostly taken during week–ends when the foreign exchange markets are closed. All realignments within the European Monetary System, henceforth E.M.S., for example, have been decided during week–ends. The distribution of the price change of the forward currency should, therefore, be more skewed on Fridays than on any other day of the week. Consequently, assuming that 1) government intervention is the only source of superior information, and 2) the information becomes public knowledge after one period taken to be one business day, bid–ask spreads should be larger on average on Fridays than on any other day of the week. Further, the future spot rate should not be located halfway between the forward bid and ask quotes on Fridays.[8]

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[7] Pathological cases can be thought of, however, that require a *decrease* in the bid commission for the zero–profit condition to be re–established. These cases are not examined.

[8] These arguments have interesting implications for the distribution of the daily changes in the spot and forward exchange rates. More specifically, daily changes in the spot and forward exchange rates could be drawn from a mixture of distributions, one for the Friday observations and the other one for the Monday through Thursday observations. This could explain why the hypothesis of a normal distribution is typically rejected.

Government intervention is not the only explanation to the observed increase in bid–ask spreads on Fridays, however. Brock and Kleidon (1989), for example, show, that exogenous changes in demand for transactions due to the upcoming week–end closing of the foreign exchange markets lead to higher bid–ask spreads on Fridays. Similarly, the cost for the market makers of carrying a foreign exchange inventory over the weekend might also generate higher bid–ask spreads on Fridays. [9] It is reasonable, however, to expect a similar phenomenon in a closely related market such as the eurocurrency market. As documented in section 4.1, the bid–ask spreads of eurocurrency rates do not increase on Fridays. This result casts doubts on either the exogenous transactions demand or inventory theory as an explanation to the higher bid–ask spreads on Fridays in the spot and forward foreign exchange markets.

Empirical tests of the unbiasedness hypothesis ignore the potential increase in the bid–ask spread on Fridays. Further, traditional tests are based on a particular combination of the bid and ask quotes, typically the average of the bid and ask quotes, *i.e.*, they ignore the asymmetric feature of the forward bid–ask spread. Tests of the unbiasedness hypothesis that take explicitly into account the characteristics of the bid–ask spread, are devised next.[10]

3.2 Econometric Implications

Tests of the unbiasedness hypothesis of the foreign exchange market are typically performed by regressing the relative change in the spot rate onto

[9] See Garman (1976), Amihud and Mendelson (1980), and Ho and Stoll (1981).

[10] The modelling of the bid–ask spread somewhat alleviates the so–called Peso effect. The Peso effect arises when market participants expect a substantial change in the exchange rate which subsequently does not occur within the sample period. When allowing the expected future spot rate to be anywhere within the forward bid–ask spread, the unbiasedness hypothesis is tested independently of Peso effect problems. The only restriction imposed by the unbiasedness hypothesis is that the expected future spot rate is *somewhere inside the bid–ask spread.* The resulting estimate of the location of the expected future spot rate within the forward bid–ask spread will be biased, however.

the relative forward premium,

$$\frac{s_T - s_t}{s_t} = a + b\,\frac{f_t^T - s_t}{s_t} + e_T, \tag{37}$$

where e_T is the unanticipated part of the relative change in the spot rate that cannot be predicted with time t information. The "true" values of the forward and spot rates are not observable, however, and have to be estimated, generally as the average of their respective bid and ask quotes. Substituting these values for s_t, s_T, and f_t^T in (37), and using B_t^s instead of s_t to obtain stationarity, yields,

$$\frac{1}{2}\frac{[(A_T^s + B_T^s) - (A_t^s + B_t^s)]}{B_t^s} = \alpha^* + \beta^*\,\frac{1}{2}\frac{[(A_t^f + B_t^f) - (A_t^s + B_t^s)]}{B_t^s} + \epsilon_T. \tag{38}$$

Under the null hypothesis, and assuming that the true forward and spot rates are halfway between their respective bid and ask quotes, the intercept and slope coefficients of the regression, *i.e.*, α^* and β^*, should be equal to zero and one, respectively. An interesting issue is to examine the impact on the regression coefficients a and b in (37) of estimating the spot and forward rates as in (38) when their true values are not halfway between their respective bid and ask quotes. Estimates rather than the true values of the dependent and explanatory variables are used in (38). Econometric problems, such as inconsistency arising from an errors–in–variables problem, can, therefore, be expected when estimating α^* and β^*.

A regression equation which can be used to test the unbiasedness hypothesis without imposing any constraints on the location of the true forward and spot rates within their respective bid–ask spreads is first derived. The statistical properties of the regression parameter estimates are then compared to those obtained from (38).

3.2.1 Tests of the unbiasedness hypothesis and the modelling of the bid–ask spread

For the sake of simplicity, the location of the expected future spot rate and the spot rate within the forward and the spot bid–ask spreads, respectively, is assumed to be constant over time. Let γ and θ be two constants such that,

$$E[s_T|\phi_t] = \gamma A_t^f + (1-\gamma)B_t^f, \quad (39)$$
$$s_t = \theta A_t^s + (1-\theta)B_t^s. \quad (40)$$

The forward bid and ask commissions must both be positive. Consequently, the parameter γ must be in the interval $[0,1]$. The same restriction would hold in the spot market if the bid and ask quotes, A_t^s and B_t^s, respectively, were expressed relative to the spot currency s_t. This is not the case, however, since they are both defined with respect to the "adjusted expected spot curency", $v_t^{T'}$. Further, the relation between $v_t^{T'}$ and s_t depends on the stochastic domestic and foreign interest rates, and is thus non–deterministic. No restriction can, therefore, be imposed on the parameter θ, the location of s_t within the spot bid and ask quotes.

Under the assumption of rational expectations, equation (39) can be rewritten,

$$s_T = (\gamma A_t^f + (1-\gamma)B_t^f) + \xi_T, \quad (41)$$

where ξ_T is a prediction error, uncorrelated with information publicly available at time t. Substituting the expression in 40 for s_T and subtracting the spot bid at time t, *i.e*, B_t^s, from (41) yields,

$$B_T^s - B_t^s = \theta\,(B_T^s - A_T^s) + \gamma\,(A_t^f - B_t^f) + (B_t^f - B_t^s) + \xi_T. \quad (42)$$

To obtain stationarity, the left and right hand sides of equation (42) are scaled by B_t^s, which yields,[11]

$$\frac{B_T^s - B_t^s}{B_t^s} = \theta\,\frac{B_T^s - A_T^s}{B_t^s} + \gamma\,\frac{A_t^f - B_t^f}{B_t^s} + \frac{B_t^f - B_t^s}{B_t^s} + \xi_T. \quad (43)$$

Equation (43) shows that the change in the relative bid spot quote over the period $[t,T]$ can be decomposed into four terms. The first two components are proportional to the bid–ask spreads in the spot market at time T, and in the forward market at time t, respectively. The last two components are the forward premium at time t, and the prediction error, respectively. The second and third terms are in the information set at time t, and are,

[11]The division of the error term by B_t^s is not reflected in the notation, but this should not create any confusion.

thus, uncorrelated with the error term, ξ_T. The first term, however, will, in general, be correlated with the prediction error, ξ_T, since the future spot bid–ask spread is likely to be affected by past unexpected changes in the spot price.

The unbiasedness hypothesis can, therefore, be tested by running the regression,

$$\frac{B_T^s - B_t^s}{B_t^s} = \alpha + \theta \frac{B_T^s - A_T^s}{B_t^s} + \beta \gamma \frac{A_t^f - B_t^f}{B_t^s} + \beta \frac{B_t^f - B_t^s}{B_t^s} + \xi_T, \qquad (44)$$

and testing whether the intercept and slope coefficient, i.e., α and β, are equal to zero and one, respectively. In addition to testing the unbiasedness hypothesis, the regression can also be used to infer whether the true forward rate is in the middle of the forward bid and ask quotes, i.e., whether γ is equal to $\frac{1}{2}$. Unfortunately, no inference can be drawn about θ, the location of the true spot rate within the spot bid and ask quotes, since the spot bid and ask commissions have been defined with respect to the "adjusted expected spot currency" $v_t^{T'}$ rather than s_t. Unlike (38), the regression equation does not constrain either the spot rate or the forward rate to be halfway between their respective bid and ask quotes. The regression is complicated by the correlation between the error term and the future spot bid–ask spread to prevail at time T. This econometric problem can be solved with an instrumental variables procedure. The choice of appropriate instruments is an important issue examined in a subsequent section.

3.2.2 The inconsistency of the regression parameter estimates when the bid–ask spread in not explicitly modelled.

The two regression equations (38) and (44) can be used to test the unbiasedness hypothesis but only the latter explicitly takes into account the bid–ask spreads in the spot and forward foreign exchange markets. Interesting inferences on the statistical properties of the regression parameter estimates α^* and β^* in (38) can be drawn from their comparison with α and β in (44). To facilitate the comparison, equation (44) is rewritten in such a way to have the same dependent variable as (38). This is achieved by substracting the change in the spot price over the period $[t, T]$ estimated at the average of the bid and ask quotes from (41), and replacing s_T by the value obtained from (40). These two steps yield,

$$\begin{aligned} \tfrac{1}{2}[(A^s_T + B^s_T) - (A^s_t + B^s_t)] &= (\tfrac{1}{2} - \theta)[(A^s_T - B^s_T) - (A^s_t - B^s_t)] \\ &+ \tfrac{1}{2}[(A^f_t + B^f_t) - (A^s_t + B^s_t)] \\ &+ (\gamma - \tfrac{1}{2})(A^f_t - B^f_t) + \xi_T. \end{aligned} \quad (45)$$

Suppose initially that only the spot rate is in the middle of the spot bid and ask quotes. Setting θ equal to $\frac{1}{2}$ in (45), and dividing by B^s_t to obtain stationarity, the unbiasedness hypothesis can be tested by running the regression,

$$\begin{aligned} \tfrac{1}{2}\frac{[(A^s_T+B^s_T)-(A^s_t+B^s_t)]}{B^s_t} &= \alpha + \beta\{\tfrac{1}{2}[\frac{[(A^f_t+B^f_t)-(A^s_t+B^s_t)]}{B^s_t}] \\ &+ (\gamma - \tfrac{1}{2})[\frac{(A^f_t-B^f_t)}{B^s_t}]\} + \xi_T. \end{aligned} \quad (46)$$

The comparison of equations (38) and (46) clearly shows that the regression parameter estimates α^* and β^* are inconsistent when $\gamma \neq \frac{1}{2}$. The inconsistency follows from the measurement error in the explanatory variable used in (38), *i.e.*, $(\frac{1}{2}[(A^f_t + B^f_t) - (A^s_t + B^s_t)]/B^s_t)$. The error, *i.e.*, $(\gamma - \frac{1}{2})(A^f_t - B^f_t)/B^s_t$, is proportional to the bid–ask spread in the forward market. This is a classical errors–in–variables problem. The inconsistency is a function of 1) the correlation between the forward premium and the forward bid–ask spread, and 2) whether γ exceeds $\frac{1}{2}$ or not. The sign of the correlation between these two variables is hard to predict, however. Moreover, the value of γ is generally unknown. Let us assume, for the sake of analysis, that the latter exceeds $\frac{1}{2}$. The Ordinary Least Squares estimate of the slope coefficient β^* will then be biased downward if the error is uncorrelated with the explanatory variable. The bias will worsen if the correlation is positive. The bias might disappear, however, if the correlation is negative.

The analysis becomes more complicated when the assumption that the spot rate is in the middle of the spot bid and ask quotes, *i.e.*, $\theta = \frac{1}{2}$, is relaxed. The unbiasedness hypothesis can be tested with the following regression equation,

$$
\begin{aligned}
\frac{1}{2}\frac{[(A_T^s+B_T^s)-(A_t^s+B_t^s)]}{B_t^s} = \alpha + & \left(\tfrac{1}{2}-\theta\right)\left[\frac{[(A_T^s-B_T^s)-(A_t^s-B_t^s)]}{B_t^s}\right] \\
& + \beta\left\{\left[\tfrac{1}{2}\frac{[(A_t^f+B_t^f)]-(A_t^s+B_t^s)}{B_t^s}\right]\right. \\
& \left. + \left(\gamma-\tfrac{1}{2}\right)\left[\frac{(A_t^f-B_t^f)}{B_t^s}\right]\right\} + \xi_T .
\end{aligned} \tag{47}
$$

The comparison of equations (38) and (47) shows that a term proportional to the change in the bid–ask spread in the spot market over the period $[t,T]$ is missing, in addition to a term proportional to the bid–ask spread in the forward market. There is, thus, one additional term compared to the previous case where θ was assumed to be equal to $\frac{1}{2}$. The effect of the first term, *i.e.*, $(\frac{1}{2}-\theta)[(A_T^s-B_T^s)-(A_t^s-B_t^s)]/B_t^s$, on the regression parameter estimates α^* and β^* are difficult to assess because of its correlation with the error term ξ_T. Little can be said apart from the inconsistency of the regression parameter estimates.[12]

The effect of substituting the average spot and forward quotes for the spot and forward rates, as in (38), when the true values are not halfway between their respective bid–ask spreads, is clear. Ordinary Least Squares produce inconsistent estimates of a and b in (37). The inconsistency of the regression parameter estimates invalidates the tests of the unbiasedness hypothesis. More reliable inferences can be obtained using a regression equation which explicitly models the bid–ask spread, such as the one defined in (44). The analysis so far is limited, however, since the location of the spot and forward rates within their respective bid and ask quotes is assumed to be fixed over time. Relaxing this hypothesis complicates the analysis. The estimates α^* and β^* are still likely to be inconsistent, however.

[12]Because of possible government intervention during week–ends, it is on Fridays more than on any other day of the week that the spot rate and the forward rate are the least likely to be in the middle of their respective bid and ask quotes. Monday through Thursday observations should therefore be preferred to Friday observations when the unbiasedness hypothesis is tested with weekly data. Friday data were used in the past, however. See, for example, Fama (1984).

4 The empirical evidence

The data is described first. The empirical evidence about the intra–week patterns of the forward and spot bid–ask spreads and the tests of the unbiasedness hypothesis is presented next.

4.1 The sample

The data on the foreign exchange market, namely the spot rates, the one–month forward rates, and the one–month eurocurrency rates, are obtained from Data Resources Incorporated. Daily observations for the period starting in June, 1st 1973 through June, 13th 1988 are available for nine currencies, namely the British pound, the Canadian dollar, the Danish krone, the Dutch guilder, the French franc, the Italian lira, the Japanese yen, the Swiss franc, and the Deutsche mark. The foreign currency exchange rates, quoted in U.S. dollar, are expressed as bids and offers reflecting the New York opening market.[13] The daily one–month eurocurrency rates are also available for the same period of time.[14] The data are quoted London mid–morning rates except for the euro–pound which is quoted mid–morning Paris.[15]

The characteristics of the bid–ask spreads in the spot currency, the forward currency, and the eurocurrency markets are first examined. The empirical evidence on the tests of the unbiasedness hypothesis are presented next.

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[13]The rates are updated daily at 8:30 AM (PST) with the current day's data. The source is the Bank of America in San Francisco. The European markets are not closed yet when markets open in New York. The trading volume is substantial at that time. Thin trading is, therefore, unlikely to explain the results reported below.

[14]All eurocurrency rates are quoted on a 360–day basis except for the British Pound quoted on a 365–day basis.

[15]The rates are updated daily at 9:30 AM (PST) with the current day's data. The source is the Bank of America in San Francisco. The foreign exchange and eurocurrency data are nonsynchronous. The lag is approximately three hours.

4.2 The intra–week patterns of the bid–ask spread in the foreign exchange market

The intra–week patterns of the bid–ask spread are first examined. Bid–ask spreads are conjectured to be higher on Fridays on average because of pending government intervention during week–ends and the fears of market makers to trade with informed investors. To test this hypothesis, the bid–ask spread is computed each day as the difference between the ask and the bid quotes for the spot and the forward currency, and also for the eurocurrency rates. Univariate and multivariate statistics are used to test the equality of the bid–ask spread on Friday to its Monday, Tuesday, Wednesday, and Thursday counterpart.[16] More specifically, the univariate t–statistics are used to test the hypothesis that,

$$[\text{Ask}^k_{(5)} - \text{Bid}^k_{(5)}] = [\text{Ask}^k_{(j)} - \text{Bid}^k_{(j)}], \quad j = 1, \ldots, 4, \quad k = s, f, e, \qquad (48)$$

where the subscript j, with $j = 1, \ldots, 5$, designates the day of the week, starting with day 1 on Monday and ending with day 5 on Friday. The superscript k, with $k = s, f, e$, designates the spot currency, the forward currency, and the eurocurrency rate, respectively. Multivariate F–statistics are also used to test the equality of the bid–ask spread each day of the week,

$$[\text{Ask}^k_{(1)} - \text{Bid}^k_{(1)}] = [\text{Ask}^k_{(2)} - \text{Bid}^k_{(2)}] = \cdots = [\text{Ask}^k_{(5)} - \text{Bid}^k_{(5)}], k = s, f, e. \quad (49)$$

The tests are successively performed on the U.S. dollar and the French franc.[17] There are no substantial differences between the two sets of tests and only the latter is reported, accordingly. Tables 1 and 2 present the empirical evidence for the foreign exchange market and the eurocurrency market, respectively.

Three important conclusions can be drawn from the empirical evidence in these two tables. First, bid–ask spreads in both the forward and the spot foreign exchange markets are significantly larger on Fridays. This

[16]These statistics are not adjusted for heteroskedasticity.

[17]The U.S. dollar and the French franc are treated as the *foreign currency* in the subsequent discussion. Hence, consistent with the definitions in the theoretical part of the paper, quotes are expressed as number of domestic currency per U.S. dollar or French franc.

result, obtained for all the currencies with an average sample size of 700 observations *per* day of the week, holds regardless of the currency, *i.e.*, the U.S. dollar or the French franc, and is robust to the choice of an estimator, *i.e.*, the univariate or multivariate statistics. The probability levels are generally less than .01. Second, the difference between the bid–ask spread on Friday and its Monday, Tuesday, Wednesday, or Thursday counterpart is slightly larger for the forward currency than for the spot currency. The difference, however, seems less statistically significant for the latter than for the former.[18] Third, unlike what is observed in the foreign exchange market, the bid–ask spreads in the eurocurrency market are not larger on Fridays. Further, no systematic pattern is observed on any other day. Since the eurocurrency and foreign exchange markets are closely related, the latter finding casts doubt on exogenous transactions demand or dealer inventory as an explanation for the increase in the forward and spot exchange bid–ask spreads on Fridays.

Additional characteristics of the bid–ask spreads are presented in table 3 which reports, for Fridays, the average forward bid–ask spread, the average forward premium, measured using the average bid and ask quotes, and the correlation between these two variables. All variables are scaled using the spot bid quote. The correlation is particularly important to obtain information on the bias of the regression parameter estimates obtained by running the regression defined in equation (38), as discussed in the previous section. Table 3 shows that the correlations are negative for the French franc with respect to all the currencies. The highest correlation is equal to -.64 and most estimates are above -.50 and are statistically significant. The results are different for the U.S. dollar. Certain correlations are found to be positive, such as with the Swiss franc and the Deutsche mark, for example, and negative with other currencies, such as with the Italian lira. These results give certain indications about the direction of the bias displayed by the OLS regression parameter estimates of equation (38). Unambiguous statements cannot be made, however, since the bias also depends on the value of the unknown parameter γ.

[18]It is interesting to note that the bid–ask spread is larger for the forward currency than for the spot currency. This result is not surprising, however. According to the interest rate parity theorem, the forward bid–ask spread should reflect the bid–ask spreads of the domestic and foreign eurocurrency rates in addition to the spot bid–ask spread.

4.3 Tests of the unbiasedness hypothesis

The two regressions defined in equations (38) and (44), respectively, are performed to test the unbiasedness hypothesis. The former constrains the forward and spot rates to be halfway between their respective bid and ask quotes. The latter does not impose such a constraint. The latter can be used to test the unbiasedness hypothesis, *and* test whether the true forward rate is halfway between the forward bid and ask quotes. The Generalized Method of Moments estimator, henceforth GMM, of Hansen (1982) is used to estimate the regression coefficients and test the restrictions jointly across currencies. The restrictions are imposed on the intercept and the slope coefficients, *i.e.*, α^* and β^* in (38), or α and β in (44), which, under the null hypothesis, should be equal to zero and one, respectively. The GMM estimator is similar to the Seemingly Unrelated Regression estimator, henceforth SUR, employed by Fama (1984) to test the unbiasedness hypothesis. The GMM estimator, unlike the SUR, does not impose the assumption of no serial correlation, however.[19]

The following instruments are used with the GMM estimator. Consistent with equation (44), four instruments are selected. Two of them are the last two explanatory variables of (44), namely, the forward bid–ask spread at time t, and the forward premium evaluated at the bid at time t, *i.e.*, $(A_t^f - B_t^f)/B_t^s$ and $(B_t^f - B_t^s)/B_t^s$, respectively. A third instrument is a vector of one. The choice of the fourth instrument is more difficult. As mentioned earlier, one of the explanatory variables on the right hand side of (44), namely the future spot bid–ask spread, *i.e.*, $(B_T^s - A_T^s)/B_t^s$, is correlated with the error term. To solve the problem, the square of the future spot bid–ask spread, *i.e.*, $[(B_T^s - A_T^s)/B_t^s]^2$, is taken as an instrument. This variable is *not* in the information set at time t, but is unlikely to be correlated with the error term.[20]

[19]Hodrick and Srivastava (1986) claim that the residual of (38) may be characterized by weak serial correlation. They, accordingly, use the GMM estimator. More importantly, the overlap that follows from the use of *weekly* observations on *one-month* forward rates can be easily taken into account by the GMM estimator. The MA(3) component is explicitely modelled in the tests performed below.

[20]Other instruments will be used in a future version of the paper. See also section 5.

4.3.1 The volatility of the risk premium and government intervention uncertainty

Table 4 presents the results obtained by running the regression specified in (38), where the forward and spot rates are estimated as the average of their respective bid and ask quotes. These regressions are similar to those performed by Fama (1984). The U.S. dollar results are reported in panel A, whereas the French franc results can be found in panel B. The empirical evidence in panel A is very similar to the results reported by Fama (1984), and Hodrick and Srivastava (1986). The slope coefficients are negative and statistically significant at the 5% or 1% level. They vary between a minimum of -2.73 with respect to the Swiss franc, and a maximum of .04 with respect to the French franc. This is much larger than the range found by Fama (1984), namely -1.15 and -.21, respectively, for the same two currencies. Four of the intercepts are statistically different from zero. The empirical evidence is, therefore, consistent with a volatile risk premium.

The results obtained by running the same regression for the French franc instead of the U.S. dollar singularly contrast with the previous findings. The slope coefficients are much closer to one than in the previous case. The range varies between -.21 with respect to the Canadian dollar to .55 with respect to the Deutsche mark. Further, the two negative coefficients, obtained with respect to the Canadian dollar and the British pound, are not statistically different from zero. Except in two cases, the intercepts are not statistically different from zero. The unbiasedness hypothesis seems to be rejected at a much lower significance level for the French franc. The slope coefficients are much closer to one than for the U.S. dollar, which suggests that the risk premium is less volatile.

The uncertainty about the timing, the type of government intervention, *i.e.*, devaluation/revaluation as opposed to open market transactions, and the direction of the change, might explain the decrease in the volatility of the risk premium. The empirical evidence is consistent with less uncertainty about government intervention on the French franc than on the U.S. dollar. This is not surprising, as the French franc is part of the European Monetary System. The currencies in the E.M.S. are frequently devalued or revalued. Further, the timing of the E.M.S. realignments are relatively easy to predict. The same can be claimed about the direction of the realigments. Certain currencies are systematically revalued and others systematically devalued. The Deutsche mark and the Dutch guilder belong to the first group, while the French franc and the Italian lira belongs to the second group. Since the timing and the direction of the change are easier to predict for European currencies than for the U.S. dollar, one would expect to find a less volatile risk premium for the French franc.

To more formally test the unbiasedness hypothesis, the intercepts and slope coefficients, *i.e.*, the α^*'s and β^*'s, of the regression, are constrained to be equal to zero and one, respectively. A χ^2 statistic is used to test the constraints jointly for the seven currencies. The number of degrees of freedom is equal to 28, since the four instruments described above are used for each currency and no parameter is estimated.[21] The results are presented at the bottom of table 4.B. The probability level is equal to .001. The unbiasedness hypothesis is, therefore, rejected at a very high significance level.

The estimates in table 4 are biased, however, if, as explained in section 3.2, government intervention causes bid–ask spreads to be asymmetric. The correlations in table 3 provide certain indications on the direction of the bias. Unambiguous statements cannot be made, however, since the bias also depends on the unknown parameter γ, which gives the position of the expected future spot rate within the forward bid and ask quotes. As discussed previously, a value of γ larger (smaller) than $\frac{1}{2}$ indicates that the market expects a devaluation (revaluation). Reliable inferences on the direction of the bias are, therefore, impossible without making predictions about the unknown γ.

Let us consider the U.S. dollar and the French franc vis a vis the Swiss franc and the Deutsche mark. Suppose that, over the time period being investigated, the market expected the U.S. dollar and the French franc to be systematically devalued with respect to the Swiss franc and the Deutsche mark. Stated differently, suppose that γ exceeds $\frac{1}{2}$.[22] Since the correla-

[21]The number of degrees of freedom is equal to the total number of orthogonality conditions less the total number of parameters to be estimated. Four instruments are used for each of the seven currencies. This yields 28 moment conditions, and thus 28 degrees of freedom since no parameter is estimated.

[22]This assumption is questionable for the U.S. dollar but not unrealistic for the French franc.

tion between the forward premium and the bid–ask spread in the forward market is either zero or positive for the U.S. dollar in table 3, the slope coefficient in panel A of table 4 should be *downward* biased. Conversely, since the correlation between the forward premium and the bid–ask spread in the forward market is strongly negative for the French franc, the slope coefficient in panel B of table 4 should be *upward* biased. The results reported in table 4 do not substantially differ across panels once the biases are taken into account. Expressed in terms of the volatility of the risk premium, these results suggest that the U.S. dollar risk premium is less volatile than what can be inferred from table 4. Conversely, the French franc risk premium is more volatile. More reliable inferences, however, can be drawn after estimating the γ parameter explicitly. This is done next.

4.3.2 The asymmetry of the bid–ask spread

The empirical evidence obtained by running the regression defined in equation (44) is now examined. This regression is used to test 1) the unbiasedness hypothesis and 2) whether the true forward rate is halfway between the forward bid and ask quotes.

The two parameters θ and γ, to be estimated in the regression, indicate the location of the spot rate and the expected future spot rate within the spot and forward bid–ask spreads, respectively. If the model developed in the previous section provides little guidance on the possible values of θ, the estimates of γ should be between 0 and 1. The model also constrains the two parameters θ and γ to be constant, *i.e.*, the model assumes that the direction and the expected change in the value of the currency are constant during the sample period. This assumption is acceptable for the French franc with respect to certain E.M.S. currencies but is clearly unrealistic for the U.S. dollar. The regression coefficients of equation (44) are consequently only estimated with French franc data.[23]

The results are presented in table 5. As discussed above, little can be said about the coefficient θ which varies between -2.20 with respect to the Canadian dollar and .25 with respect to the Swiss franc. There does

[23]The assumption of a constant γ's will be relaxed in a future version of the paper as discussed in section 5.

not seem to be any consistency in the sign of θ with respect to "strong" currencies, such as the Swiss franc and the Deutsche mark, and "weak" currencies, such as the Italian lira. The information embodied in γ is far more interesting. The point estimates obtained for γ vary between .11 and 1.18. Consistent with the predictions of the model, the parameter estimate is around one, *i.e.*, around the ask, for currencies against which the French franc has systematically been devalued, such as the Deutsche mark, the Swiss franc, and the Dutch guilder.[24] Conversely, the parameter estimate is close to zero, *i.e.*, close to the the bid, for currencies against which the French franc has systematically been revalued, such as the Italian lira. The estimate is halfway between the forward bid and ask quotes only for the Japanese yen. The empirical evidence clearly shows that the forward bid–ask spread is asymmetric. This implies that the coefficients of the regressions relating the change in the spot rate to the forward premium, when the forward and spot rates are estimated as the average of the forward bid and ask quotes, as in (38), are inconsistent.

The χ^2 statistic can be used to test the restrictions that the intercepts and slope coefficients are equal to zero and one, respectively, jointly across currencies, *i.e.*, to test the unbiasedness hypothesis. Since two parameters are estimated and four instruments are used for each of the seven currencies, the number of degrees of freedom is equal to 14. The results are presented at the bottom of table 5. The probability level associated with the χ^2 statistic indicates that the unbiasedness hypothesis is rejected at a high significance level.

[24]Within the European monetary system, the Deutsche mark was revalued relative to the French franc by the following amount on the following dates, $5\frac{1}{2}$% on June 29 1973, 2% on October 18 1976, 2% on September 24 1979, $5\frac{1}{2}$% on October 5 1981 accompanied by a devaluation of 3% of the French franc with respect to the Danish krone, the Belgium franc, and the Irish pound, $4\frac{1}{2}$% on June, 14 1982 accompanied by a devaluation of the French franc of $5\frac{3}{4}$% with respect to the other currencies in the E.M.S. $5\frac{1}{2}$% on March 21, 1983 accompanied by a devaluation of the French franc of $2\frac{1}{2}$% with respect to the other currencies in the E.M.S., 3% on April 7 1986 accompanied by a devaluation of the French franc of 3% with respect to the other currencies in the E.M.S., 3% on January 10 1987. The Deutsche mark has never been devalued relative to the French franc. The Dutch guilder was revalued relative to the French franc on almost all those dates by a similar amount.

5 Conclusion and suggestions fo future research

The hypothesis that the forward rate is an unbiased predictor of the future spot rate in the foreign exchange market is typically rejected by the data. This suggests the existence of a time–varying risk premium. Government intervention, viewed as a form of market inefficiency, has already been proposed as an explanation to the rejection of the unbiasedness hypothesis.[25] This paper focuses on the market microstructure impact of government intervention. Its purpose is to investigate whether an explicit modelling of the bid–ask spread explains, at least in part, the strong rejection of the unbiasedness hypothesis.

An asymmetric information model is developed and tested. Drawing upon Admati and Pfleiderer (1988b), a competitive dealer market with asymmetrically informed agents is hypothesized. The market makers are assumed to face two different types of investors, informed and liquidity traders, in both the spot and forward markets. The model enables one to derive the conditions under which the expected spot rate is in the middle of the forward and spot bid ask quotes. These conditions are violated under pending government intervention. Consequently, the expected future spot rate is not located halfway between the forward and spot bid and ask quotes, *i.e.*, the bid–ask spreads are asymmetric.

The model has serious empirical implications for the tests of the unbiasedness hypothesis. First, based on the observation that decisions on government intervention usually are taken and revealed during week–ends, bid–ask spreads in the foreign exchange market should be larger on Fridays. The increase in the bid–ask spread is a response of market makers to the likelihood of trading with informed investors. Second, an important econometric implication of the asymmetry of the bid–ask spread is the inconsistency of the parameter estimates of the regression employed to test the unbiasedness hypothesis. The tests are typically performed by regressing the change in the spot rate onto the forward premium. In this regression, the forward and spot rates are usually estimated as the average

[25] See Fama (1984).

of their respective bid and ask quotes. When bid–ask spreads are asymmetric, the true spot and forward rates differ from these averages. The inconsistency of the regression parameter estimates arises, therefore, from an errors–in–variables problem.

The contribution of the paper to the empirical literature on the tests of the unbiasedness hypothesis is threefold. First, bid–ask spreads in the spot and forward foreign exchange markets are found to be larger on Fridays. No such effect is observed in the eurocurrency market. Second, when the spot and forward rates are estimated as the average of their respective bid and ask quotes, the slope coefficients of the regression relating the change in the spot rate to the forward premium are closer to one for the French franc than for the U.S. dollar. The risk premium is, therefore, less volatile for the French franc than what is typically found (empirical studies have invariably investigated U.S. dollar data). Third, the forward rate is not located halfway between the forward bid and ask quotes *i.e.*, the forward bid–ask spread is asymmetric, and the location is consistent with the history of currency realignments. These results support the implications of the model.

Certain issues need to be addressed more satisfactorily in a future version of the paper. In particular, the assumption that the location of the expected future spot rate within the forward bid–ask spread is constant over the sample period needs to be relaxed. This can be achieved by selecting appropriate instrumental variables which capture changes in expectations. A possible instrument could be a weighted difference estimator of implied volatilities from foreign currency call and put options. The volatilities would be "implied" from option prices using a model such as the Black–Scholes. [26] Currency realignments should cause a pronounced skewness in expectations. Consequently, a systematic bias should appear in the implied volatilities from call *versus* put options. The direction of the bias can be used to infer the nature of the skewness. The bias should, therefore, provide

[26] The Black–Scholes model assumes that exchange rates are lognormally distributed. The lognormal distribution is skewed but the skewness should be minor for exchange rate changes over a period of say one month. The probability of exchange rate changes exceeding, say 5%, over a month is very low. The skewness keeps the exchange rate from becoming negative. Consequently, the skewness necessary to avoid negative values of the exchange rate at the end of the month is negligeable.

a measure of the direction and intensity of expected realignments.[27]

[27]We would like to thank Alan Shapiro for suggesting to us the use of option prices as an instrument to capture expectations.

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Table 1

Univariate and multivariate tests of the difference between the (ask-bid) on Fridays and the (ask-bid) on Mondays, Tuesdays, Wednesdays, and Thursdays, respectively, for the spot and forward FF

Panel 1.A: The spot FF

Spot	Sample Size	Δ_1 ($t(\Delta_1)$)	Δ_2 ($t(\Delta_2)$)	Δ_3 ($t(\Delta_3)$)	Δ_4 ($t(\Delta_4)$)	F-Test* p.-val.
FL/FF	729	.00016	.00021	.00014	.00013	13.20
		(5.15)	(6.82)	(3.89)	(3.88)	(< .01)
DM/FF	680	.00012	.00014	.00010	.00007	14.45
		(5.95)	(6.97)	(4.32)	(2.96)	(< .01)
SF/FF	753	.00015	.00019	.00015	.00011	18.26
		(6.41)	(8.02)	(6.23)	(4.45)	(< .01)
£/FF	711	.00003	.00003	.00002	.00002	11.17
		(5.40)	(6.33)	(3.30)	(4.21)	(< .01)
CA$/FF	738	.00004	.00005	.00002	.00002	10.34
		(4.09)	(6.11)	(2.16)	(2.76)	(< .01)
Yen/FF	729	.00857	.01371	.01122	.00929	13.46
		(4.07)	(7.24)	(5.02)	(4.62)	(< .01)
Lira/FF	731	.05300	.08024	.07021	.07623	10.27
		(3.31)	(5.93)	(4.74)	(5.35)	(< .01)

Panel 1.B: The forward FF

Forward	Sample Size	Δ_1 ($t(\Delta_1)$)	Δ_2 ($t(\Delta_2)$)	Δ_3 ($t(\Delta_3)$)	Δ_4 ($t(\Delta_4)$)	F-Test* p.-val.
FL/FF	729	.00024	.00032	.00023	.00012	15.40
		(5.23)	(7.29)	(4.52)	(2.29)	(< .01)
DM/FF	680	.00018	.00020	.00012	.00005	11.35
		(5.10)	(5.66)	(3.24)	(1.29)	(< .01)
SF/FF	753	.00014	.00026	.00017	.00011	12.98
		(2.58)	(7.08)	(4.37)	(2.76)	(< .01)
£/FF	711	.00004	.00004	.00003	.00002	9.17
		(5.11)	(5.47)	(3.21)	(3.31)	(< .01)
CA$/FF	738	.00005	.00008	.00005	.00003	11.69
		(3.24)	(6.22)	(2.97)	(2.24)	(< .01)
Yen/FF	729	.01812	.03328	.02360	.00982	8.51
		(2.49)	(5.27)	(3.54)	(1.57)	(< .01)
Lira/FF	731	.04151	.12317	.08259	.06090	8.32
		(1.50)	(5.23)	(3.37)	(2.52)	(< .01)

Remarks:

.$\Delta_1 = [Ask_5 - Bid_5] - [Ask_1 - Bid_1]$, where the subscripts 1 and 5 stand for Monday and Friday, respectively.
.$\Delta_2 = [Ask_5 - Bid_5] - [Ask_2 - Bid_2]$, where the subscripts 2 and 5 stand for Tuesday and Friday, respectively.
.$\Delta_3 = [Ask_5 - Bid_5] - [Ask_3 - Bid_3]$, where the subscripts 3 and 5 stand for Wednesday and Friday, respectively.
.$\Delta_4 = [Ask_5 - Bid_5] - [Ask_4 - Bid_4]$, where the subscripts 4 and 5 stand for Thursday and Friday, respectively.
* The multivariate F-statistic tests the hypothesis that $\Delta_1 = \Delta_2 = \Delta_3 = \Delta_4 = 0$.

Table 2

Univariate and multivariate tests of the difference between the (ask-bid) on Fridays and the (ask-bid) on Mondays, Tuesdays, Wednesdays, and Thursdays, respectively, for eurocurrency rates

Eurocurrency Rate	Sample Size	Δ_1 ($t(\Delta_1)$)	Δ_2 ($t(\Delta_2)$)	Δ_3 ($t(\Delta_3)$)	Δ_4 ($t(\Delta_4)$)	F–Test* p.–val.
FL	672	.00278	-.00131	.00336	.00209	.259
		(.574)	(-.148)	(.862)	(.516)	(.904)
DM	674	-.00234	.00295	.00180	.00364	1.543
		(-.618)	(1.204)	(.712)	(1.723)	(.188)
SF	649	.00159	.00795	-.00630	.00427	.886
		(.184)	(1.106)	(-.406)	(.584)	(.472)
£	634	.00297	.00294	-.00501	.00137	.227
		(.415)	(.421)	(-.581)	(.213)	(.923)
CA$	385	.00019	-.00275	.00324	.00032	2.792
		(.057)	(-.958)	(1.118)	(.095)	(.0262)
Yen	381	.00177	-.000363	.00328	.00175	.561
		(.549)	(-.089)	(1.03)	(.528)	(.691)
Lira	337	-.00241	.0300	.03078	.03200	1.075
		(-.094)	(1.21)	(1.298)	(1.52)	(.368)
FF	677	-.00147	.0209	.03813	.00885	2.885
		(-.065)	(1.064)	(2.217)	(.478)	(.0219)
US$	682	.00333	.00672	.00382	.00145	3.09
		(.990)	(2.59)	(1.03)	(.466)	(.0154)

Remarks:

.$\Delta_1 = [Ask_5 - Bid_5] - [Ask_1 - Bid_1]$, where the subscripts 1 and 5 stand for Monday and Friday, respectively.

.$\Delta_2 = [Ask_5 - Bid_5] - [Ask_2 - Bid_2]$, where the subscripts 2 and 5 stand for Tuesday and Friday, respectively.

.$\Delta_3 = [Ask_5 - Bid_5] - [Ask_3 - Bid_3]$, where the subscripts 3 and 5 stand for Wednesday and Friday, respectively.

.$\Delta_4 = [Ask_5 - Bid_5] - [Ask_4 - Bid_4]$, where the subscripts 4 and 5 stand for Thursday and Friday, respectively.

* The multivariate F–statistic tests the hypothesis that, $\Delta_1 = \Delta_2 = \Delta_3 = \Delta_4 = 0$

Table 3

Correlation between the forward premium and the difference between the forward ask and bid quotes

Panel 3.A: US $ exchange rate

Currency	μ_1	μ_2	ρ	p
FL/US$	.00116	.00231	.066	.071
DM/US$	.00082	.00031	.043	.231
SF/US$	.00133	.00467	.119	.001
£/US$	.00083	-.00201	.128	<.001
CA$/US$	.00054	-.00083	-.060	.100
Yen/US$	.00139	.00235	-.210	<.001
Lira/US$	.00233	-.00611	-.273	<.001
FF/US$	.00157	-.00231	-.670	<.001

Panel 3.B: FF exchange rate

Currency	μ_1	μ_2	ρ	p
FL/FF$	.00270	-.00461	-.399	<.001
DM/FF$	.00237	-.00537	-.631	<.001
SF/FF$	.00287	-.00692	-.551	<.001
£/FF$	.00240	-.00031	-.602	<.001
CA$/FF$	.00211	-.00142	-.673	<.001
Yen/FF$	.00291	-.00460	-.124	<.001
Lira/FF$	.00391	.00387	-.035	.333

Remarks:

.μ_1 is the average difference between the forward ask and bid quotes defined as $(A_t^f - B_t^f)/B_t^s$.

.μ_2 is the average forward premium, defined as $\frac{1}{2}[(A_t^f + B_t^f) - (A_t^s + B_t^s)]/B_t^s$.

.ρ is the correlation between the forward premium and forward bid-ask spread.

.p is the probability value of the hypothesis that $\rho = 0$.

Table 4

Tests of the unbiasedness hypothesis.
The forward and spot rates are constrained to be halfway between their respective bid–ask quotes.

$$\frac{1}{2}\frac{[(A_T^s + B_T^s) - (A_t^s + B_t^s)]}{B_t^s} = \alpha^* + \beta^* \, \frac{1}{2}\frac{[(A_t^f + B_t^f) - (A_t^s + B_t^s)]}{B_t^s} + \epsilon_T$$

Panel 4.A: US \$ exchange rate

Currency	$\hat{\alpha}^*$	$\hat{\sigma}(\alpha^*)$	$\hat{\beta}^*$	$\hat{\sigma}(\beta^*)$
FL/US\$	.00359	.00241	-.381	.641
DM/US\$	.01107	.00402**	-2.667	1.221*
SF/US\$	.01783	.00402**	-2.732	.790**
£/US\$	-.00465	.00246	-1.862	.668*
CA\$/US\$	-.00280	.00088**	-1.416	.531**
Yen/US\$	.00587	.00239**	-.035	.385
Lira/US\$	-.00615	.00329	-.412	.309
FF/US\$	-.00018	.00253	.040	.571

Panel 4.B: FF exchange rate

Currency	$\hat{\alpha}^*$	$\hat{\sigma}(\alpha^*)$	$\hat{\beta}^*$	$\hat{\sigma}(\beta^*)$
FL/FF	-.00063	.00124	.414	.188*
DM/FF	.00003	.00127	.547	.213*
SF/FF	-.00132	.00227	.515	.292
£/FF	.00079	.00178	-.121	.648
CA\$/FF	.00083	.00235	-.208	.594
Yen/FF	-.00489	.00239*	.121	.306
Lira/FF	.00339	.00170*	.015	.362

χ^2 test of $\alpha = 0$ and $\beta = 1$		
d.f.	χ^2	p–val.
28	58.00	.001

Remarks:

* significant at the 5% level.

** significant at the 1% level.

Table 5

Tests of the unbiasedness hypothesis.
The forward and spot rates are not constrained to be halfway between their respective bid–ask quotes.

$$\frac{B_T^s - B_t^s}{B_t^s} = \alpha + \theta \frac{B_T^s - A_T^s}{B_t^s} + \beta\gamma \frac{A_t^f - B_t^f}{B_t^s} + \beta \frac{B_t^f - B_t^s}{B_t^s} + \eta_T$$

with $\alpha = 0$ and $\beta = 1$.

Currency	$\hat{\gamma}$	$\hat{\sigma}(\gamma)$	$\hat{\theta}$	$\hat{\sigma}(\theta)$
FL/FF	.995	.291**	-.192	.194
DM/FF	1.181	.408**	-.416	.618
SF/FF	1.046	.479*	.251	.941
£/FF	1.051	.693	-.407	.994
CA $/FF	.952	.635	-2.204	1.898
Yen/FF	.497	.581	.856	1.150
Lira/FF	.112	.111	-.074	.731
χ^2 test of $\alpha = 0$ and $\beta = 1$				
d.f.	χ^2		p–val.	
14	45.70		$< .001$	

Remarks:

* significant at the 5% level.

** significant at the 1% level.

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1988

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1989

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