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SHORT- AND LONG-TERM HEDGING FOR THE CORPORATION

Bernard Dumas

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Bernard Dumas

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Centre for Economic Policy Research
25–28 Old Burlington Street
London W1X 1LB
Tel: (44 71) 734 9110

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ABSTRACT

Short- and Long-term Hedging for the Corporation*

Exchange risk hedging in a static (i.e. one-period) setting is extremely straightforward. The variance-minimizing hedge of a particular future cash flow involves a forward contract equal but opposite in sign to the exposure of the cash flow. The exposure is the regression coefficient of the cash flow on the exchange rate. In a multi-period setting, the matter is much less straightforward. Information concerning a future cash flow evolves over time. For that reason, a hedge undertaken early on may have to be revised several times. These revisions themselves increase the level of risk. In this paper I explore the case for deliberately leaving a cash flow unhedged for some time, initiating a hedge at some appropriate time and thereafter, perhaps, leaving the hedge untouched until the cash flow is received or paid. The precise mathematical theory in support of this idea has yet to be developed.

JEL Classification: F3, G3, L1
Keywords: exchange risk, hedging, corporations, international trade, floating exchange rate

Bernard Dumas
Department of Finance and Economics
HEC School of Management
78351 Jouy-en-Josas Cedex
FRANCE

Tel: (33 1) 39 67 7282

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Submitted 23 November 1994

NON-TECHNICAL SUMMARY

Firms that buy or produce goods in one country and sell them in another have become the rule rather that the exception. Firms in this situation are exposed to the potential of wild gyrations in exchange rates which can make it almost impossible to plan sales and production beyond six months ahead.

Exchange rate volatility is almost certain to be a hindrance to international trade and to erode the efficiency of production world-wide, unless firms have at their disposal instruments which allow them either to respond effectively to the exchange rate change *ex post* or to hedge the exchange rate change *ex ante.* It has been frequently argued that a firm which has access to the forward market can hedge away the risk of exchange rate fluctuations.

Most research which pursues that line of argument, however, is couched in static terms. It is assumed that a firm is started up at time 0 and that it expects to receive a random cash flow at time 1. The firm may add to the terminal cash flow the gain or loss on a forward contract undertaken as a hedge at time 0. It is easy to compute the size of the forward contract which minimizes the variance of the cash flow after hedging, from the point of view of a given currency (the home currency). That hedge size or hedge ratio is the coefficient of a regression of the pre-hedge cash flow (expressed in home currency) on the exchange rate. The more sensitive the pre-hedge translated cash flow is to the exchange rate, the larger should be the size of the hedge.

When one sets out to implement the hedge, the meaning of time 0 becomes almost mythical – it is evidently impossible to assume that all of the firm's hedging contracts were undertaken at the time of Methuselah. The question naturally arises: how early, prior to a given future cash flow date, must the firm undertake a hedging plan targeting that cash flow? If the hedge is undertaken comparatively late, we shall say that the firm hedges short term; if it is undertaken a long time in advance we shall say that it hedges long term. This paper is about the comparative effectiveness of long-term versus short-term hedges.

The earlier that a hedging programme for a particular cash flow is initiated, the more numerous will be the future revisions, and the more cumbersome will be the hedging programme. Furthermore, the statistical problem of estimating time-varying conditional exposures is formidable. Managers – perhaps reacting to a no-regret criterion – are loath to initiate a hedge which may later have to be reversed; they view this as speculation. Indeed, it should be clear that the random cash flows generated by revisions work against the objective of variance reduction.

Accepting the idea that late hedging is preferable, provided the attendant increase in risk is negligible, I then argue that the decision to hedge early or late should depend on whether the cash flow to be hedged is correlated with changes in the exchange rate or with its level. I point out that, in many commercial situations, a firm's cash flow depends on the level (more precisely the degree of over- or under-valuation) of the exchange rate. I discuss this matter in the simplest possible setting. I consider the situation of an importing firm which has no manufacturing activity and simply buys goods in one place to sell them in another.

The dependence of cash flow on the level of the exchange rate raises a major problem for firms. The essence of the matter is that the pay-off of a forward contract depends on the change in the exchange rate over the period separating the purchase of the contract from its unwinding. Such a pay-off is ideal when it comes to hedging a cash flow – such as a financial cash flow – which also depends on the change in the exchange rate over the same period. But a short-term forward contract is entirely inappropriate when attempting to hedge a cash flow – such as a commercial cash flow – which depends on the level of the exchange rate.

1. Introduction

Firms which buy or produce goods in one country and sell them in another have become the rule rather than the exception. Firms in this situation are exposed to the wild gyrations in the exchange rates which make it almost impossible to plan sales and production ahead beyond six months.

Exchange rate volatility is bound to be a hindrance to international trade and to erode the efficiency of production worldwide,[1] unless firms have at their disposal instruments which allow them either to respond effectively to the exchange rate change *ex post* or to hedge the exchange rate change *ex ante*. It has been frequently argued that a firm which has access to the forward market can hedge away the risk of exchange rate fluctuations.[2]

However, most of the work which pursues that line of argument is couched in static terms. It is assumed that a firm is started up at time 0 and that it expects to receive a random cash flow at time 1. The firm may add to the terminal cash flow the gain or loss on a forward contract undertaken as a hedge at time 0. It is easy to compute the size of the forward contract which minimizes the variance of the cash flow after hedging, from the point of view of a given currency (the home currency). That hedge size or hedge ratio is the coefficient of a regression of the prehedge cash flow (expressed in home currency) on the exchange rate. The more sensitive the pre-hedge translated cash flow is to the exchange rate, the larger should be the size of the hedge.

When one sets out to implement the hedge, the meaning of time 0 becomes

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[1]See Hooper and Kohlhagen (1978), Cushman (1983, 1986, 1988), Akhtar and Hilton (1984), Gotur (1985), Thursby and Thursby (1985). The opposite point of view is taken by Franke (1991) on theoretical grounds and by Klein (1990) and Barone-Adesi and Yeung (1990) on empirical grounds.

[2]Baron (1976), Ethier (1973), Dumas (1978), Adler and Dumas (1984).

somewhat mythical. It is evidently impossible to assume that all the firm's hedging contracts were undertaken at the time of Mathusala. The question naturally arises: how early, prior to a given future cash flow date, must the firm undertake a hedging plan targeting that cash flow? If the hedge is undertaken comparatively late, we shall say that the firm hedges short term; if it is undertaken a long time in advance we shall say that it hedges long term. This paper is about the comparative effectiveness of long-term vs short-term hedges.[3]

I discuss this matter in the simplest possible setting. I consider the situation of an importing firm which has no manufacturing activity and simply buys goods in one place to sell them in another.

The paper is organized as follows. Section 2 aims to further define the problem under consideration by analyzing the extent to which the hedging problem of a commercial and industrial firm differs from the hedging problem of a financial firm or portfolio manager. Section 3 discusses the case in principle for and against long-term hedging. In Section 4, I show that the choice between the two forms of hedging depends closely on whether the future cash flow to be stabilized is related to a future level of the exchange rate or to a future change in the exchange rate. I next illustrate in Section 5 that, for the simple case of an importing firm, the dependence of the net cash flow (or profit) on the level of the exchange rate is related to the degree of passthrough, while the dependence on the change is related to the timing of passthrough. In Section 6, I consider a case illustration. Finally, in Section 7, I raise the question of the proper econometric method to be used to

[3] A recent paper by Brealey and Kaplanis (1991) addresses the same question, in somewhat different terms.

simultaneously estimate the dependence on the level and changes of the exchange rate.

2. Hedging commercial activity contrasted with hedging financial activity

While there is a lot in common between these two endeavors, hedging the activities of a commercial firm against exchange risk differs in at least two ways from the standard problem of hedging a portfolio of securities against exchange risk. These two differences warrant a somewhat different approach.

A portfolio manager frequently has the ability to trade the securities included in his portfolio at any time. For each of these securities, in the purest case, a price is quoted almost continuously. For this reason, it is legitimate for the portofolio manager to focus on the rate of return (cash inflow plus capital gain over beginning of period price) achieved over a relatively short holding period. Hence, the natural objective of the hedging program is to reduce the conditional variance of the rate of return of each period, by attaching to each investment a hedge, in the form of a forward contract (or a currency option).

Because the gain or loss on the forward contract, to a first order of approximation, depends on the change in the exchange rate over the holding period, the size of the hedge is determined by the extent to which the holding period return on the portfolio is related to the change in the exchange rate. In the simple case in which securities rates of return, as well as exchange rate changes, display no serial dependence, there is no need for setting up hedges a long time in advance. A hedge can be included in the portfolio at the beginning of the period for the purpose of reducing the conditional variance of the period's rate of return.[4] What will happen in later periods, especially far away periods, does not call for immediate hedging.

The situation faced by a commercial or industrial firm differs from the portfolio situation in two major ways. First, a firm's assets, which means a firm's future cash flows, are not usually tradable. A firm which undertakes an investment project, for instance, has the option to shut down the project; a division of a firm can be sold to another firm. However, such decisions involve considerable costs and, above all, are not easily reversed. When devising the hedging plan, it is best to assume that the firm will own for a long time the cash flow or profit stream which is the object of the hedging program.

That is not to say that the cash flows or profits in question are immutable. Frequently, the commercial policy of the firm, such as its selling price, will be adjusted in response to exchange rate movements.[5] More drastic measures, such as moving production from one country to another, can also be anticipated in case of a large movement in the exchange rate. Here again, adjustment costs will be incurred at the time of this move and further costs must be anticipated if the move has to be reversed later. For these two reasons, drastic moves are rare. To the extent that they will occur under some circumstances, the hedging plan must evidently take their possibility into account. It remains, however, that, in the context of the corporation, the

[4] Serial dependence would induce one to set up hedges for purposes of intertemporal diversification of risk. See Merton (1971).

[5] Future hedging decisions (e.g., revisions of the hedge) will have an impact on the future cash flow and must, of course, be taken into consideration in deciding on today's hedging plan.

possibility of trading claims to future operational cash flows is much more limited than is the possibility of trading financial claims in the capital market.

This first difference between the portfolio problem and the corporate problem is one strong reason why corporate officers are forced to focus their hedging program on the stabilization of cash flows (or profits) rather than on the stabilization of rates of return.[6] The corporate officer stabilizes the cash flow of his firm whereas the portfolio manager is concerned with hedging the cash flow received plus the capital appreciation of his portfolio. Capital appreciation is not a relevant quantity for the corporate officer to include in his stabilization program if there is no prospect of selling the firm within the horizon of the hedging plan.[7]

The inability to trade cash flows also forces corporate officers to devise longer term exchange-risk hedging plans than is the case for portfolio managers. We return to this point in the next section.

The second difference between the portfolio and the corporate approaches is, in a way, a consequence of the first one. Profits or cash flows from operations are apt to be correlated not only with recent changes in the

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[6]Notice that I do not propose value maximization as an objective for the hedging plan. Even if I did, this objective would be justified by the ability of *financial market investors* to buy and sell the firm, not by the firm's ability to trade its cash flows.

[7]However, if, for some reasons, the hedging of a cash flow stream is carried out by means of one short-term forward contract only at each point in time, that contract must cover the imputed present value of the entire cash flow stream (the discount rates for the calculation of this present value are not given; they are shadow rates which are known once the optimal program has been calculated); see Losq(1978) or Adler and Detemple (1988) or Svensson and Werner (1991). For simplicity of reasoning (if not for convenience of implementation), think of hedging each cash flow separately by means of a forward contract maturing on the date on which the cash flow occurs; then my argument stands.

exchange rate, but also with the current *level* of the exchange rate. This is because cash flows are associated with a commercial activity. The exchange rate is not simply the relative price of two monies. Because of (largely unexplained) stickiness in the price of goods in each country, the exchange rate acts in many ways as the price of goods produced abroad relative to the price of goods produced at home. The *level* of the exchange rate plays a role similar to the price of wheat relative to the price of cloth. It affects competitiveness and quantities sold across the world. Therefore, it affects cash flows.

This is a sharp contrast indeed with the way the exchange rate may affect the rate of return of a security. Exchange rate changes and securities rates of return make up a vector of returns which is, to a first approximation, independently, identically distributed.[8] The covariance between securities rates of return and exchange rate changes is all one needs to know to design a portfolio hedging plan. Such is not the case when it comes to corporate cash flows. Corporate cash flows generally depend on levels *and* changes in exchange rates, which means that they are related to past and current exchange rate via a *distributed-lag* relationship. The lags are linked to the production-shipment-inventory-sales-payment cycle of the firm. The relationship between cash flows and exchange rate levels is a long-run relationship around which short-term deviations occur. The corporate treasurer must be aware of these effects before he puts together the structure of his hedging plan.

One immediately sees that the corporate hedging problem requires more intricate knowledge and requires many times more intimacy with the behavior

[8] This is not to deny the recent studies which have concluded in favor of the predictability of financial rates of return. That predictability exists but is limited.

of the thing to be hedged, than does the portfolio hedging problem.

The two problems have one dimension in common, however. The hedging instrument, be it forward contract, currency options or foreign currency debt, is usually tradable. Hence, both the portfolio hedger and the corporate hedger will be in a position to revise their hedge. Complete freedom is retained even after the hedge has been put in place. Of course, hedge revisions will generate interim gains or losses which must, in both cases, be taken into account in setting up the original hedge.

3. The case for and against long-term hedging

The terms "short-term" or "long-term" hedging can take on two very different meanings. They can make reference to the time to maturity of the hedging instruments; one may, for instance, hedge a cash flow expected in six months with a six-month forward contract or with a one-month forward contract rolled over five times. When one is not concerned with the randomness of interest rates, the choice of maturity is irrelevant and the same hedge (except for cost) can be achieved with one contract or an infinite string of infinitely short forward contracts. I leave aside the question of maturity choice.

The other meaning of the terms is the one I shall be interested in. One hedges "short term" if a cash flow expected in six months is deliberately left unhedged for some time, and a hedge is initiated for the purpose of covering that cash flow at some later date, some time prior to receiving or paying it. To the opposite, one hedges long term if a hedging program for that cash flow is initiated without delay. Because this often means hedging a future cash flow before the corresponding transaction has been made (i.e. has been entered in the books), long-term hedging is sometimes referred to as "preemptive hedging".

The issue I wish to raise is, therefore, the following: how far in advance of a cash flow must one initiate a program to hedge it?

Prior to addressing that question, observe that it is feasible, at least approximately, to hedge cash flows against exchange risk extremely far in advance. When no forward contract is available to hedge a very distant cash flow and when interest rate risk is not a major consideration, one may use a forward contract with a shorter maturity than that of the cash flow and later roll it over. The amount of the forward contract must then be tailored not to the cash flow itself but to the present value of the cash flow computed back to the maturity date of the forward contract to be used. By this mechanism "perpetual hedging" is conceivable, although imperfect. All cash flows beyond a certain cutoff date, for which no hedging instrument is available in the market, may be hedged with one contract (of, perhaps, the longest maturity available) equal in size to the capitalized value of all subsequent cash flows. This possibility gives rise to the concept of value hedges: one hedges the discounted value of subsequent flows.[9] Clearly, the corporate treasurer has full play in deciding whether to hedge early or to hedge late.

In theory, however, no such question arises. Putting aside for a second the need to anticipate revisions, the conditional-variance minimizing hedge ratio

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[9]Observe that the matter arises only for lack of a proper hedging instrument. A distinction should be maintained with the portfolio hedging situation (see Section 2). The prospect of rolling over -- not the prospect of trading the cash flow claims -- is the reason for the introduction of a present discounted value. In the absence of interest rate uncertainty, the hedge ratio may equivalently be computed as the present value of the stream of regression coefficients computed for each cash flow posterior to the cut-off date or (more conveniently) as the regression coefficient of the present value of the subsequent cash flow stream.

is at all times equal to the *conditional* regression coefficient of the cash flow on the exchange rate.[10] Hence, the prescription is: hedge immediately for an amount equal to the conditional regression coefficient and gradually adjust it so that it remains equal to that coefficient, itself a moving target since incoming information causes it to be updated. If the conditional regression coefficient calculated very early on happens to be very small, the hedge is of small size and may later be increased. Hence. there should be no discrete decision to start hedging at some point in time. One hedges immediately but in an amount which is to vary continuously as time goes by.[11]

If there are to be revisions, the earlier hedge ratios should not simply be set equal to the regression coefficient of the cash flow to be hedged considered by itself. They should be equated to the regression coefficient of the cash flow plus the additional cash flows which will be generated by the later state-contingent revisions. A regression coefficient of future regression coefficients shows up in the process. Brealey and Kaplanis (1991) have worked out a set of formulas giving the best value hedge for a particular process of incoming information concerning future cash flows.[12]

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[10] If, as in the case of distributed lags, the cash flow of time t is related to the exchange rate prevailing at time t and at earlier times, one must use a multiple regression and multiple hedge ratios but the point is the same.

[11] See Adler and Dumas (1974). Many corporate officers object that too little is known far ahead a distant cash flow to initiate a hedging program to protect it. Brealey and Kaplanis (1991) show that imperfect information concerning the future cash flow leaves unscathed the principle which I have just expounded: value- or perpetual hedges are in principle the most effective.

[12] They considered value hedges because they considered only one-period forward contracts. In the absence of interest-rate uncertainty, this is perfectly legitimate and equivalent to hedging each cash flow for its amount, using a contract with a maturity date coinciding with the date of the cash flow.

The earlier one initiates a hedging program for a particular cash flow, the more numerous the future revisions, and the more cumbersome the hedging program. Furthermore, the statistical problem of estimating time-varying conditional exposures is formidable (see Section 7). Managers -- perhaps reacting to a no-regret criterion -- are loath to intitiate a hedge which may later have to be reversed; they view this as speculation. Indeed, it should be clear that the random cash flows generated by revisions work against the objective of variance reduction. While, at each point in time, revisions aim to minimize the then-conditional variance, they also make a positive contribution to the original or *ex ante* risk.

While the dynamic programming theory of this problem has not yet been worked out, it is clear that, at least from the practical point of view, there are distinct advantages to initiating a hedge late, provided little is lost in overall variance reduction. In view of the unreliability of estimated time-varying exposures, it may even be *more* advantageous, from the point of view of variance reduction, to hedge at some well chosen point in time, after which one would leave the hedge unchanged (no revisions), than to embark early on into a long-winded hedging program which involves numerous revisions of questionable value. Perhaps, the formal theory of this question could be worked out by introducing a cost of computation or a cost of transactions or simply incorporating into the analysis the sizable estimation risk associated with time-varying regression coefficients.

4. Hedging the level vs the change in the exchange rate

Accepting the idea that late hedging is preferable, provided the attendant increase in risk is negligible, I now wish to argue that the decision to hedge early or late should depend on whether the cash flow to be hedged is correlated with changes or with the level of the exchange rate.[13]

For this purpose, consider first the case of a random cash flow X to be received at some future time t and which is related, functionally or stochastically, to a recent change, $S_t - S_{t-\tau}$, of the spot exchange rate:

$$X_t = X(S_t - S_{t-\tau}, \omega_t)$$

where ω_t represents all factors influencing the cash flow, other than the exchange rate. It will actually be more convenient to make explicit the dependence of X on the deviation of the time-t spot rate from the time $t-\tau$ forward maturing at time t:

$$X_t = X(S_t - F_{t-\tau}, \omega_t)$$

Let b be the regression coefficient of X_t on $S_t - F_{t-\tau}$, conditional on $F_{t-\tau}$ and $\omega_{t-\tau}$ (not ω_t). A hedge initiated at time $t - \tau$ for maturity t, in the form of a forward contract for a contract size -b, generates a gain or a loss equal to $-b\times(S_t - F_{t-\tau})$. Putting together the original cash flow X and its associated hedge, we get an overall cash flow at time t equal to:

$$X(S_t - F_{t-\tau}, \omega_t) - b\times(S_t - F_{t-\tau}).$$

By construction, this cash flow is linearly independent of $S_t - F_{t-\tau}$, conditional on the information of time $t - \tau$ and its conditional variance has

[13] Obviously, in the intermediate case in which it depends on both, in a separable way, a part of the cash flow can be hedged early and the other late.

been reduced by the use of the forward contract, as much as is possible. This is the conditional-variance minimizing hedge. Further, if successive exchange rate changes are identically, independently distributed, and if the ω factors are assumed to be independent of the exchange rate at any lag, the hedge also minimizes the variance conditional on the information of any time prior to time $t - \tau$. If that is true, nothing has been lost by initiating this hedge at time $t - \tau$ rather than at an earlier time.

Consider now a cash flow which depends on the level of the exchange rate:

$$X_t = X(S_t, \omega_t).$$

Here again, a forward contract initiated at some time $t - \tau$ brings a payoff which is proportional to $S_t - F_{t-\tau}$. Putting together the original cash flow and the payoff of the forward contract, we get:

$$X(S_t, \omega_t) - b\times(S_t - F_{t-\tau}).$$

This combination may succeed in eliminating exchange rate risk running from time $t - \tau$ to time t but it evidently cannot be the variance-minimizing hedge conditional on the information of some time prior to time $t - \tau$. To put it simply, the last expression shows that the S_t risk has been eliminated but only to be replaced by the $F_{t-\tau}$ risk. This represents in many cases the best risk reduction achievable with a hedge put in place at time $t - \tau$. But variance can be reduced to a much greater extent[14] by hedging at the earliest

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[14]Approximately $t/(t - \tau)$ times more.

possible opportunity which is today's date, time 0.

The essence of the matter is that the payoff of a forward contract depends on the change in the exchange rate over the period separating the purchase of the contract from its unwinding. Such a payoff is ideal when it comes to hedging a cash flow -- such as a financial cash flow -- which also depends on the change in the exchange rate over the same period. But a short-term forward contract is entirely inappropriate when attempting to hedge a cash flow -- such as a commercial cash flow -- which depends on the level of the exchange rate.

5. Passthrough and its timing

In order to provide an illustration of a cash flow's dependence on levels and changes of the exchange rate, I now address the specific problem of an import/export firm which endeavors to hedge its trading activity against exchange risk. In most cases, we should not be content with measuring the statistical relationship between cash flows and exchange rate. In the hope of improving reliability we also wish to understand for what reasons the cash flow depends to a greater or smaller extent on the level or the changes in the rate. In the case of an import/export firm, the matter hinges crucially on the degree to which the firm can pass through to the customer recent increases or decreases in import prices. It also depends on the speed at which this passthrough can be achieved.

Consider a firm of a country called "home" which imports a good from a country called "foreign". The good is stored and processed or packaged in the home country for one month prior to be being sold at time t for a home-currency price y_t. The firm contracts for the good in the foreign country during month t - 4; the good is shipped at time t - 2 from the foreign country. We call x_{t-2} the foreign-currency price of a unit of that shipment (although that price was set already at t - 4). The good takes a month to be transported to the home country where it arrives at time t - 1. Payment takes place at that time when the home currency value of the foreign currency is S_{t-1}.

The precise scenario which we have just described corresponds to a lag of two months between foreign shipment and final sales. In fact, we do not know that the lag is two months or even that the lag is unique. Of the goods sold at home at time t, some may have been shipped at time t - 4, some at time t - 3, some at time t - 2, some at time t - 1. In all cases, the pure transportation lag is assumed to be one month so that a unit of goods shiped at time θ - 1 is paid for at time θ, its procurement cost being, therefore, equal to $S_\theta x_{\theta-1}$.

Home selling prices reflect the cost of procuring the good abroad. Assuming that the home market for the good is purely competitive, one firm's price is in line with that of other firms. The original procurement cost which a firm applies to a particular unit of good being sold depends on the length of the inventory-cum-processing lag which prevails in the industry at large more than it does that firm's specific procurement costs. In order to identify the industry lag structure, one can relate statistically (by regression) the home price of month t sales, y_t, to the following variables:

. procurements costs lagged 1 to 4 months: $S_t x_{t-1}$ to $S_{t-3} x_{t-4}$. These reflect the cost of the shipments which has just arrived home and the cost of shipments which have arrived in earlier months.

. the contemporaneous procurement cost: $S_t x_t$ and the leading cost $S_t x_{t+1}$.

These are meant to reflect the potential impact on the home price of current information, already obtainable from transactions being made with foreign suppliers, concerning the cost of future shipments.

In running this regression, we assume a particular model of price formation. We assume 100% passthrough. To the extent that the home price is larger than the cost of goods sold, the difference represents a markup with a constant percentage ϕ. The regression equation is:

$$y_t = (1 + \phi)\times[\ a_1 S_t x_{t+1} + a_0 S_t x_t + b_1 S_t x_{t-1} + b_2 S_{t-1} x_{t-2} + b_3 S_{t-2} x_{t-3} + b_4 S_{t-3} x_{t-4}] + \varepsilon_t \quad (5.1)$$

where: $a_1 + a_0 + b_1 + b_2 + b_3 + b_4 = 1$.

Once this relationship has been established, a particular firm's profit may be decomposed into a part which depends on the changes in the exchange rate and a part which depends on the level of the rate. Supposing, for instance, that a particular firm operates with a lag of two months exactly, its margin per unit, equal to $y_t - S_{t-1}x_{t-2}$, can be decomposed into:

$$\begin{aligned} y_t - S_{t-1}x_{t-2} &= \phi\times[\ a_1 S_t x_{t+1} + a_0 S_t x_t + b_1 S_t x_{t-1} + b_2 S_{t-1} x_{t-2} + b_3 S_{t-2} x_{t-3} + b_4 S_{t-3} x_{t-4}] \\ &+ a_1(S_t x_{t+1} - S_{t-1}x_{t-2}) + a_0(S_t x_t - S_{t-1}x_{t-2}) + b_1(S_t x_{t-1} - S_{t-1}x_{t-2}) \\ &- b_3(S_{t-1}x_{t-2} - S_{t-2}x_{t-3}) - b_4(S_{t-1}x_{t-2} - S_{t-3}x_{t-4}) + \varepsilon_t. \quad (5.2) \end{aligned}$$

The last two lines of this equation (not including ε_t) represent the deviation of this firm's cost structure from the industry average. That part of profit depends on the change in the exchange rate. The first two lines of the equation represents the margin per unit collected by the industry.

The following short-term hedging program will be very successful in hedging the part of the profit which depends on the changes in the exchange rate:[15]

- at time t - 3, buy forward b_4 times the cost of anticipated month-t sales,[16] maturity t - 1 (two-month contract);
- at time t - 2, buy forward b_3 times the cost of anticipated month-t sales, maturity t - 1 (one-month contract);
- at time t - 1, sell forward $a_1 + a_0 + b_1$ times the cost of anticipated month-t sales, maturity t (one-month contract).

Roughly speaking, this policy amounts to hedging $b_4 + b_3$ times purchases one and two months prior to the payment of the purchases,[17] and then hedging $a_1 + a_0 + b_1$ times future sales at the time shipments are received and paid for. With this hedging plan, the firm in effect mimicks the lag structure of the industry. If passthrough is complete, a lag structure identical to that of the industry provides a perfect hedge.

The remainder of the margin per unit -- which is also the margin per unit after short-term hedging -- depends on the level of the exchange rate as it is equal to:

$$\phi \times [\, a_1 S_t x_{t+1} + a_0 S_t x_t + b_1 S_t x_{t-1} + b_2 S_{t-1} x_{t-2} + b_3 S_{t-2} x_{t-3} + b_4 S_{t-3} x_{t-4}]$$

This part must be hedged long term. As the case example of the next section will show, such an endeavor may prove daunting in practice.

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[15] I neglect the interest-rate differential between the foreign and the home currencies.

[16] This is the fraction of the cost of month-t sales arising from t - 4 shipments from the foreign country.

[17] Implicitly, that is, purchases are partially hedged by subsequent sales, to the tune of $1 - b_4 - b_3$.

Prior to examining the case example, we now discuss two assumptions of the previous model which may not be appropriate in many cases. They concern the timing of passthrough and the degree of passthrough.

The timing of passthrough should, in principle, depend on the storability/perishability of the good. If the good is perishable (beyond four months),[18] the firm has little room to play with its inventory. The goods are sold to customers as soon as possible and we are entitled to assume that the selling price is related to cost according to a distributed-lag relationship, as has been done above. If, however, the good is storable, the inventory should be adjustable and the passthrough should be immediate. Indeed, if a lag in passthrough existed, firms, after a rise in the foreign price or in the exchange rate, would know that the home price will rise. They would then rationally (and competitively) hoard the good, thereby causing an immediate rise in the home price. Then the cost-price relationship is not the one we have assumed. The link between the timing of passthrough and inventory policy is a close one.

The second assumption that I wish to discuss briefly concerns the degree of passthrough. There the link is with the pricing policy of the firm. In the above specification, we have assumed a constant rate of markup, ϕ. This assumption may not be consistent with competitive behavior unless the markup is not a markup but is, instead, interpreted as a home marginal cost. It is hard to see, however, why a home marginal cost should be proportional to the foreign procurement cost of the good. In the case of a firm facing a demand curve, as is true when the industrial situation is one of monopoly or

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[18] Or, if the firms behave as if it is perishable.

oligopoly, the rate of markup need not be constant. Marston (1990) shows[19] that the rate of markup is constant if and only if the firm faces a demand curve with constant price elasticity. In all other cases the rate of markup depends on cost and therefore on the exchange rate: passthrough may be more or less than 100%. The rate of markup may also vary as home costs vary over time.

The nature of the good and the industry structure, therefore, play a role in specifying the statistical model needed to measure exposure and to devise a hedging plan.

6. A case example

XYZ plc is a British firm which imports into Britain a good called CXX. CXX is purchased from Southern states of the United States, transformed in the U.S., shipped to Britain, further processed in Britain and sold to British customers as building material.

Every time XYZ orders some CXX, it faces a situation entirely described by two anticipated cash flows: one is a disbursement of dollars which is 100% dollar denominated and the other is a receipt of Pounds at sales collection time. The dollar disbursement, without doubt, creates a negative exposure to the dollar. XYZ has, so far, endeavored to cover that exposure selectively by means of forward purchases of dollars, maturing at the disbursement date.

As for the amount of Pounds to be received, it is by no means set in advance. Quite to the opposite, the selling price is geared, to a great extent, to the Pound value of the dollar. Implicitly, therefore, the British sale transaction is, in part, a dollar transaction; it induces a positive exposure to the dollar. If this exposure were to be hedged separately, it

[19] See also Feenstra (1987), Mann (1986), Ohno (1988) and Schembri (1988).

would require forward sales of dollars.

6.1 Diagnosis: a model of the British price

The Pound selling price is determined late in the cycle and depends on the recent values of the dollar and the U.S. price of CXX, as it is driven by the shipments being distributed in the market. Not only are the shipments of the four major British distributors spread out over the year, but some distributors tend to receive more frequent shipments of smaller size than does XYZ. These shipments, as well as the close monitoring of procurement costs by dealers, maintain a close relation between the Pound sale price and the exchange rate of the dollar. The passthrough of exchange rate changes into British prices is a crucial matter which needs to be investigated in detail.

For this purpose, I use a five-year history of monthly observations for the following variables: (i) the U.S. dollar purchase price, (ii) the GBP/USD exchange rate and (iii) the selling price of CXX in Britain. Equation 5.1 is fitted to the available data.

The statistical results are in Table 1 (symbolic notations as in equation (5.1) above):

Table 1

Coefficient (1)	Value of coeff. (2)	Std Err of coeff. (3)	t-stat (4)	Normalized value[20] (5)
Lead 1	0.0540621	0.125017	0.432439	a_1 = 0.04725
0	0.123159	0.132571	0.929009	a_0 = 0.10764
Lag 1	0.0757307	0.125240	0.604683	b_1 = 0.06619
Lag 2	0.365451	0.161394	2.26434	b_2 = 0.31941
Lag 3	0.162143	0.168919	0.959887	b_3 = 0.14171
Lag 4	0.363609	0.125381	2.90003	b_4 = 0.31780
Total	$1 + \phi$ = 1.144156			

[20] Column 2 divided by 1.144156.

The bottom line number in Table 1, marked "Total", shows XYZ's average margin over the five-year period: $\phi = 14.42\%$. The table also shows how the selling price has been determined historically: the procurement costs of the CXX shipped two months and four months before sale have been dominant in setting the selling price. This is indicated by the t-statistic which is greater than 2 for these two lags.

Figure 1 shows a graph of the British selling price and of the cost of procurement synchronized to pertain to the same unit of CXX being sold. The fit is excellent. For later reference, I summarize the information of Table 1 by means of one number, viz. the average percentage margin of 14%, plus the industry's empirical lag structure shown in column 5 of Table 1 and in Figure 2. The lag structure is obtained simply by scaling down the numbers of the second column of Table 1 so that they sum to 100%. It is to be read as follows: the price of sales made at time t behaves as if 31.8% of those sales are from shipments made in the U.S. at time t - 4.

6.2 XYZ's profit series

In order to reconstruct XYZ's profit series, I assume that their supply of CXX is shipped from the U.S. two months before sale and paid for one month before sale. In other words, I take XYZ's lag structure as having a single peak of 100% falling on Lag 2, in contrast to the industry's structure which we have depicted in Figure 2. I do this for illustrative purposes. It will soon be clear that the opportunity for short-term hedging arises from a difference between the industry's and XYZ's inventory lag structures.

Calling BP_t the price in Britain, USP_t the price of supplies in the United States, XR_t the GBP/USD exchange rate, profit per unit in month t is then

Figure 1: A model of the British price

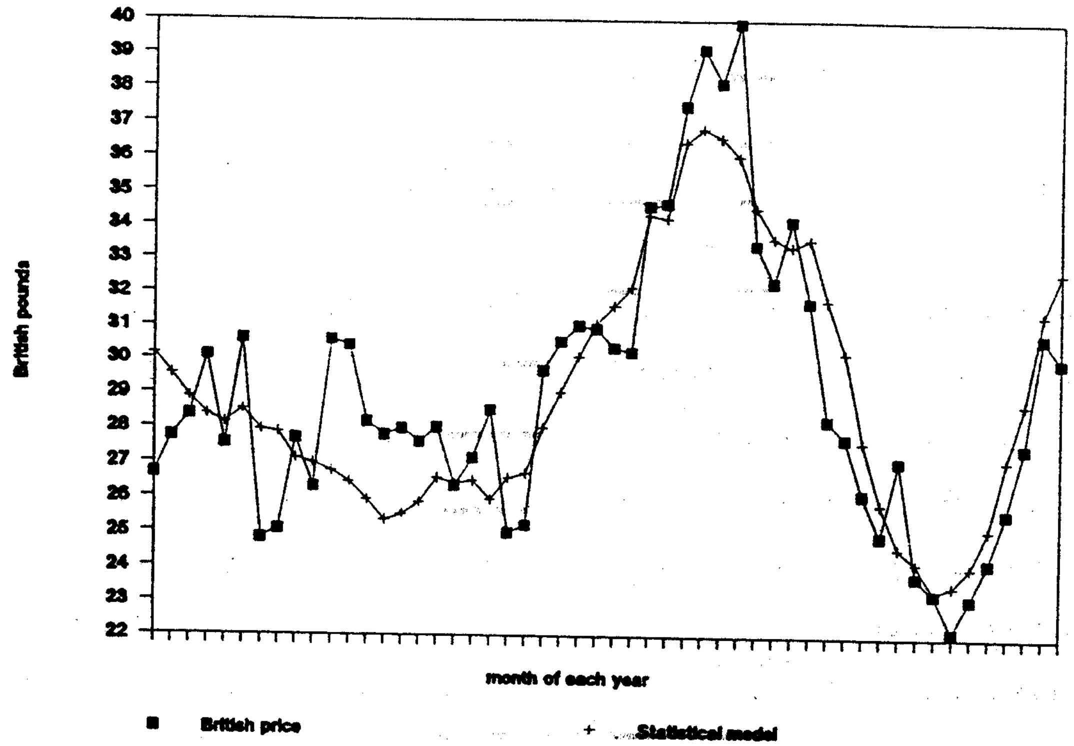
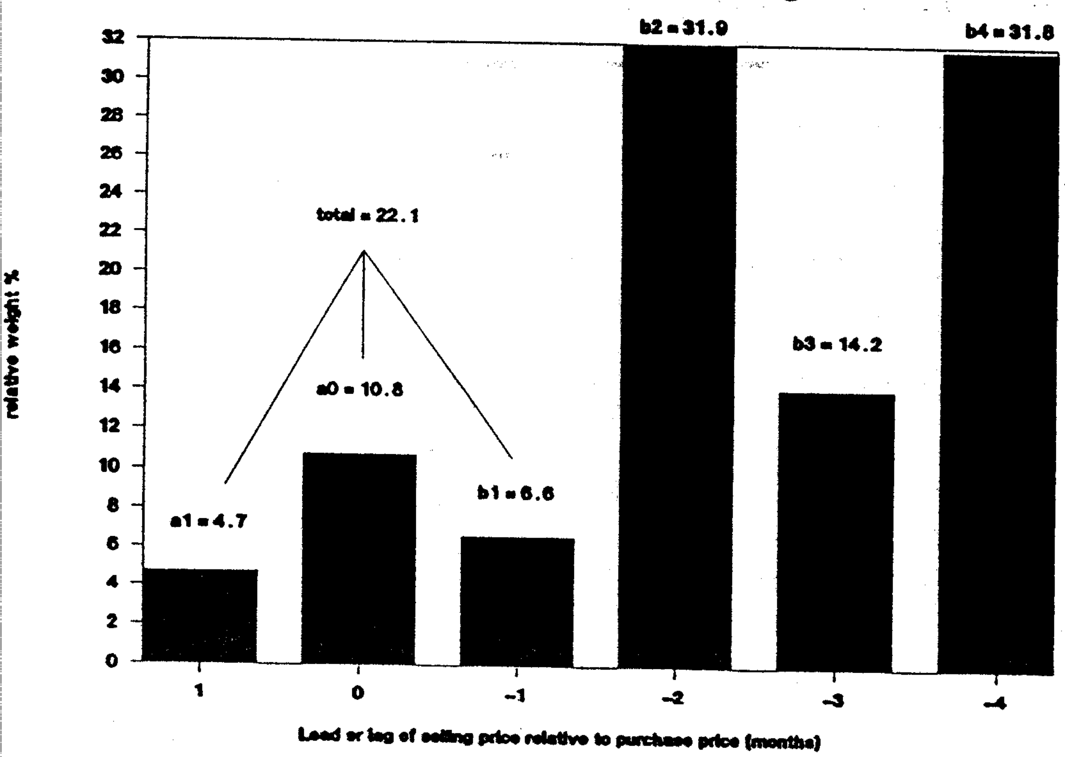


Figure 2: The industry's estimated lag structure



given by:

$$\text{Profit}_t = BP_t - XR_{t-1} \times USP_{t-2}.$$

The time plot of XYZ's monthly profits so reconstructed -- as they have been over the years, or more exactly as they would have been under the strict sequencing of events which I have assumed -- is shown as a sequence of black squares on Figure 3. The average profit per unit is 3.64 Pounds or 14% of cost, as indicated earlier.

Since, to a large extent, the British selling price reflects one for one the fluctuations of both the dollar price and the exchange rate, profit is much less clearly related to either of these two random variables than is the British price itself. The volatility (standard deviation) of unit profit is equal to 2.32 Pounds or 9% of average unit cost. The frequency distribution of profit per unit is shown as black bars on Figure 4.

6.3 Short-term hedging

The close statistical association between the British selling price and the translated U.S. cost implies that XYZ, to a large extent, enjoys a natural hedge of its currency risk. XYZ makes payments on its dollar purchases of CXX, but its sales also implicitly have a "dollar content". One hedging policy is, therefore, *not* advisable. It is the policy of hedging the purchases of CXX in the United States, without any consideration for the sales of CXX in Britain. Such a policy would destroy XYZ's natural hedge and generally increase risk.

The dollar content of sales, and the proper way to hedge it, is revealed to us by the industry's estimated lag structure of Table 1 and Figure 2. If

Figure 3: The effect of short-term hedging on profit

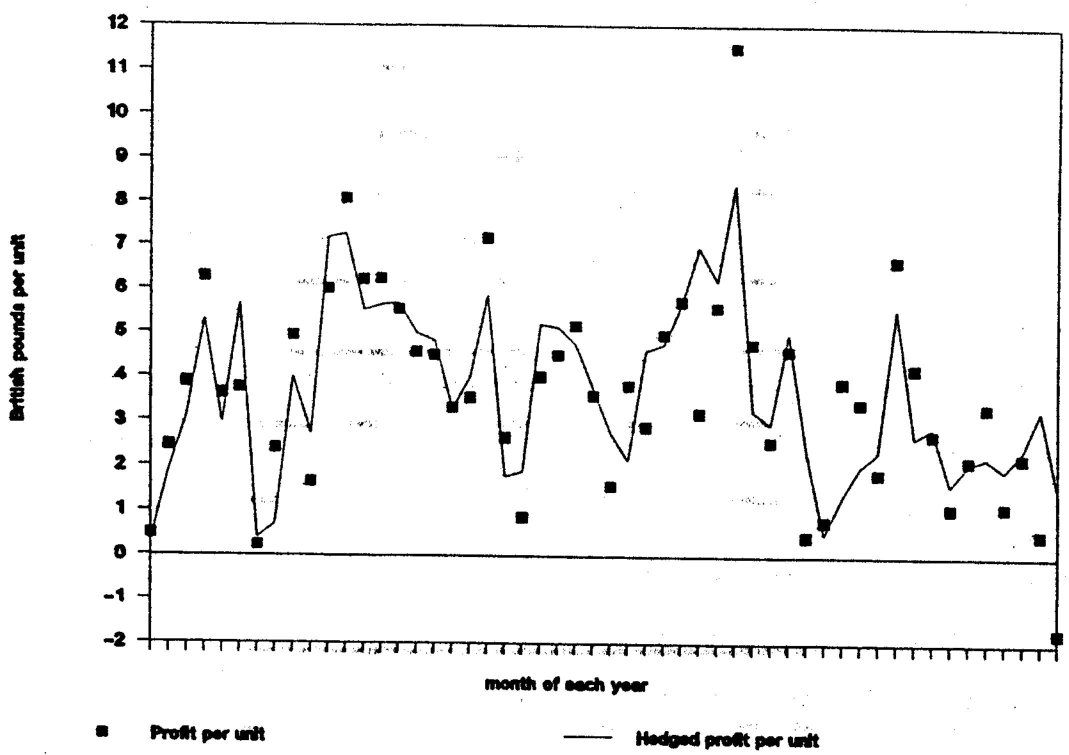
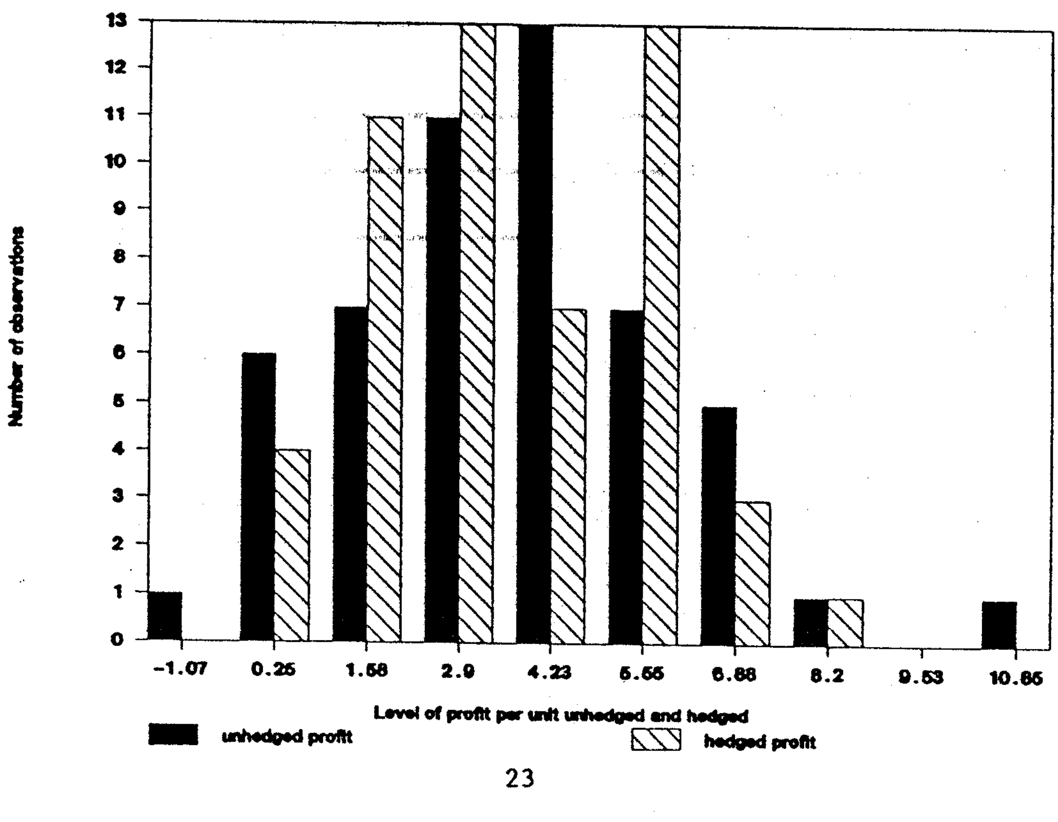


Figure 4: Frequency distribution of profit



XYZ' inventory lags and schedule of shipments and payments matched this pattern exactly, there would be no scope for hedging. Assuming, as we have, that there may a difference in this respect between XYZ and the competition, there is scope for short-term hedging, with the goal of artifically mimicking the lag structure of the industry.[21]

Reading off the chart of Figure 2 and assuming that XYZ's payments on purchases are made one month before sales,[22] we establish a short-term hedging plan as suggested in Section 5. Roughly speaking, this policy amounts to hedging 31.8 + 14.2 = 46% of purchases one and two months prior to the payment of the purchases,[23] and then hedging 22.1% of future sales at the time shipments are received and paid for.

The performance of this policy is shown in Figures 3 and 4.[24] In Figure 3, the timepath of hedged profit is shown as a solid line (recall that the timepath of profit prior to hedging is shown as small black squares). It is apparent that the hedging policy succeeds in shaving off the worst peaks and troughs of profit. Figure 4 shows that the frequency distribution of profit after hedging is more bunched together than was the distribution prior to hedging. The volatility of profit is reduced from 2.32 Pounds per unit to 1.96 Pounds per unit, or reduced from 9% to 7.7% of average unit cost.

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[21] In this way, XYZ would remain free to run its operations (e.g., inventories) as it pleases, without concern for the exchange-risk exposure that a change in inventory policy may open. The exchange-risk exposure would be kept in check separately, thanks to the short-term hedges.

[22] On Figure 2, a payment made one month before sales is shown as "Lag 2" as it relates to CXX shipped from the U.S. two months before sales.

[23] Implicitly, that is, purchases are 54% hedged by subsequent sales.

[24] The calculations neglect the change in the U.S. price over a three-month span. I.e., it treats as identical the short-term hedging of cost and the short-term hedging of exchange rates. Performance is overstated slightly.

In its current rendition, the design of the proposed hedging policy is heavily dependent on the statistical measurement of the industry lag structure of Figure 2, which is assumed known and constant over time. In fact, the industry lag structure is not known; it is only estimated. This may mar the effectiveness of the hedging policy. But, in the real world situation, XYZ's treasurer has more information than we have used here. He can get information on the state of inventories in the industry compared to XYZ's inventories. This allows him to adjust the hedging policy to current circumstances. When the industry's inventories are turning over more slowly than do XYZ's and the difference is more than what we have assumed here, he should put his hedges in place earlier on. If, to the opposite, they are of the same length as XYZ's, he should do nothing.

Observe that the lag pattern of Table 1 and Figure 2 is not only influenced by the industry's inventory and payment schedule. It may also be influenced by the industry's average currency hedging policies. For instance, if the competitors' treasurers hedge their dollar purchases of CXX -- in effect, buying their dollars weeks or months before receiving shipments, -- this may result in a lengthening of the lag between movements in the translated dollar price and movements in the British price. There lies the mechanism by which the competition's hedging policy should affect XYZ's hedging policy. XYZ and its competitors can coordinate on the horizon of their hedging policy. It is immaterial to them which horizon is chosen, so long as they all have the same horizon. Only the British consumer sees the difference in the way in which the Pound price of CXX reacts to the U.S. price and the exchange rate.

6.4 Yearly hedging programs

Once XYZ has mimicked the competition's lag structure by means of appropriate short-term hedges, it is left with a margin of profit whose risk content is identical to that of the industry at large. In all likelihood, this risk content is a positive exposure to the dollar since XYZ, and the industry, collect a margin on a product whose price is most stable in the United States, in terms of dollars. Can we superimpose on the short-term hedging plan a yearly, or longer, hedging program aimed at reducing the risk content of the margin?

A model for the behavior of the margin, after short-term hedging, comes out of the statistical model of Section 5. Calling π_t the margin per unit at time t, we have:

$$\pi_t = .144\times[\ 0.04725\times XR_t\times USP_{t+1} + 0.10764\times XR_t\times USP_t + 0.06619\times XR_t\times USP_{t-1}$$

$$+ 0.31941\times XR_{t-1}\times USP_{t-2} + 0.14171\times XR_{t-2}\times USP_{t-3} + 0.31780\times XR_{t-3}\times USP_{t-4}] + \varepsilon_t \quad (6.1)$$

where ε is a residual, independent of the other terms, and therefore largely unrelated to the exchange rate.

Because this margin of profit depends not on changes in the exchange rate, but on the levels of the exchange rate at various times, no short-term forward contract is capable of hedging it. A longer-term hedging plan may be called for. First, I investigate yearly hedging plans which are initiated in November of each year, at the beginning of the yearly purchasing campaign.

A difficulty is encountered in devising a medium-term hedging policy. It arises from the fact that the actual purchase price is not known when hedges are put in place, as early as November. The success or failure of currency hedging may depend on our ability to anticipate the actual dollar purchase price. In what follows, I adopt a naive attitude. I use the November price as a forecast of the purchase price for the whole of the following year.[25]

Each year in November, I sell dollars forward for a fraction of the anticipated unit cost of sales, the fractions to be hedged, or hedge ratios, being given by the coefficients of Equation (6.1). Again, future purchases and future costs of sales are based on the November U.S. dollar price of CXX without any update. Keeping this handicap in mind, the performance of such a policy may be appreciated from Figure 5 which shows the timepath of profit per unit under the short-term hedging policy of Section 6.3, and under the combined short-term and yearly hedging plan. It is immediately apparent that the contribution of the yearly plan to a reduction of volatility is negligible. Indeed, the volatility is reduced from 1.96 Pounds per unit to 1.91 Pounds only; decidedly, a negligible reduction.

In order to confirm that conclusion, I reestimated from scratch a model of the margin after short-term hedging, as it relates to exchange rates.[26] I then used the newly estimated coefficients to devise a yearly hedging plan. This brought the volatility down to 1.90 Pounds! I also tried revising the yearly plan during the year, to take account of the new information coming in concerning U.S. prices.[27] I had no more success. Finally, I tried a yearly hedging plan by itself as an alternative to short-term hedging; the resulting

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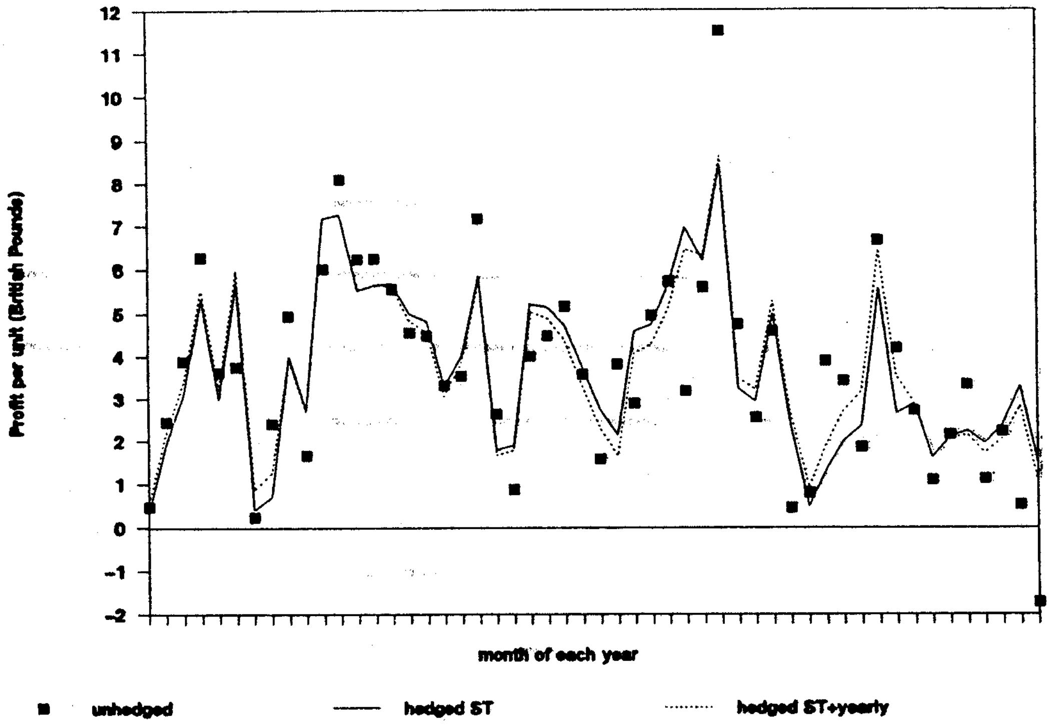
[25] Later in the year, however, we could revise the November hedges as new information comes in concerning U.S. prices.

[26] The difference with the above is the variation of the U.S. price over the year. In running the regression, I now keep the U.S. price fixed at the November level in order to exactly represent the hedging situation.

[27] This is as opposed to setting up the hedges in November, on the basis of the November U.S. price, and leaving them untouched over the entire year.

Figure 5: The effect of short-term plus yearly hedging



volatility was 2.22 Pounds per unit.

The next logical idea is to envisage very-long-term hedging, beyond one year. Going all the way, I simulated "perpetual hedging" in the form of hedges put in place in month 0 of our history, covering each cash flow through the final month. A reestimated perpetual hedging policy added to the short-term one produced a volatility equal to 1.92 Pounds per unit, while a perpetual hedging policy used as an alternative to short-term hedging resulted in a volatility equal to 2.22 Pounds. Finally, the combination of a short-term, a yearly and a perpetual hedge (without reestimation) yielded a volatility of 1.94 Pounds.[28]

It is clear that none of the long-term policies adds measurably to the short-term hedge. The case example has illustrated that the benefits of long-term hedging are hard to reap.

7. Econometric considerations

The manner in which Equation 5.1 ought to be estimated statistically is by no means obvious.[29] Two econometric issues must be raised. First, some of the variable in the equation, such as the exchange rate itself, may follow a nonstationary process. Second, the coefficients of the equation should, perhaps, be seen as time varying.

The issue of nonstationarity in estimating trade equations has already been considered in the work of Clarida (1991a, 1991b). In particular, Clarida (1991a) estimates a profit equation which relates corporate profits to

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[28] Each contract of the perpetual hedging plan matured in November of each year, and was rolled into yearly hedges at that time.

[29] In the case example of Section 6, I used the Generalized Method of Moments.

exchange rates. Nonstationarity is present, for instance, when a process possesses a unit root (a so-called I(1) process).

Nonstationary processes tend to wander very far off. For this reason, it is possible to estimate the long-run relationship between two nonstationary variables without consideration for their joint short-run behavior. The technique to do so is called "co-integration". To illustrate, Equation (5.1) could perhaps be estimated in two steps. If it has been established[30] that the home price, y_t, and the foreign translated price, $S_t x_{t-1}$, are non stationary, one could first estimate their long-run relationship as:

$$y_t = \gamma S_t x_{t-1} + u_t. \qquad (7.1)$$

If the two processes y_t and $S_t x_{t-1}$ are co-integrated, u_t is a stationary variable, by definition.

Ordinary Least Squares produce a consistent but biased estimate of γ. To obtain an unbiased estimate, Clarida (1991a, b) uses a technique proposed by Stock and Watson (1988) and Phillips and Loretan (1991). This is an "error correction" technique wherein leading and lagging values of the regressors are added to the right-hand side of Equation (7.1). If a t-test of co-integration run on the residuals u_t then rejects the hypothesis of no cointegration between the two variables, it makes sense to interpret the estimate of γ so obtained as being an estimate of $(1 + \phi)$.[31]

As a second step in our econometric analysis, we seek to establish the short-term relationship between home and foreign prices which is so valuable

[30] By means of a Dickey-Fuller extended unit-root test.

[31] Another, equally good estimate would have been obtained by relating y_t to $S_{t-1} x_{t-2}$.

in designing short-term hedging policies. This can be done by estimating the following equation in a heteroskedasticity-consistent way:

$$u_t = (1 + \phi)\times[\ a_1\times(S_t x_{t+1} - S_t x_{t-1}) + a_0\times(S_t x_t - S_t x_{t-1})$$
$$+ b_2\times(S_{t-1}x_{t-2} - S_t x_{t-1}) + b_3\times(S_{t-2}x_{t-3} - S_t x_{t-1}) + b_4\times(S_{t-3}x_{t-4} - S_t x_{t-1})] + \varepsilon_t$$

When the policies of the import/export firm -- for instance, its inventory, pricing and hedging policies -- are optimized, special attention must be given to the question of nonstationarity. Clarida (1991b) follows Hall's (1978) work on the martingale behavior of optimal consumption. He points out that the costate variable of any dynamic program would follow a martingale.[32] That costate variable appears in the first-order conditions which determine the decisions of the firm. When estimating these first-order conditions (which are the inverses of the demand or supply equations, if we are talking about quantities), the nonstationary nature of the costate variable must be handled explicitly. This means that the estimation of optimal behavior is intimately linked to the econometrics of nonstationary processes, most prominently to the technique of co-integration.

The second econometric issue which I would like to discuss, pertains to the time-varying specification of Equation (5.1). In estimating this equation, we are particularly interested in the value of the coeffcients of S_t, S_{t-1} etc.. because these are the coefficients which will tell us what the hedging program should be. Notice that the coefficient of S_t is:

$$(1 + \phi)\times[\ a_1 x_{t+1} + a_0 x_t + b_1 x_{t-1}].$$

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[32] Such is the meaning of the Hamilton-Jacobi-Bellman differential equation.

The coefficient of S_{t-1} is $(1 + \phi)\times b_2 x_{t-2}$ etc.. I have made these coefficients depend on the foreign purchase prices because it is obvious that these contain valuable information which should be used in the hedging program (if the foreign price rises, more units of foreign currency need to be bought forward). It is, therefore, natural to let the coefficient of the exchange rate in this equation be time-varying.

However, we may have been careless in the specification of the time-variation of the coefficients. Suppose that the considerations of Sections 4 and 5 on short-term vs long-term hedging -- such as they are -- have lead to the decision that a hedging plan should be initiated τ months before each home sale (τ a constant) and that there should be no revisions. When the first forward contract is purchased at time $t - \tau$, the foreign prices of the good, x_{t+1}, x_t etc.. are not yet known. Hence, if we want our estimates to be implementable measures of exposure, we are not at liberty to specifiy the coefficient of S_t, S_{t-1} .. the way we have done it. When spelling out the hedging plan of Section 5, the imprecise phrase: "buy forward .. times *the cost of anticipated month-t sales*" was a way of glossing over this difficulty. Implementable estimates must only be functions of information concerning the month-t home price which is available at time $t - \tau$, such as, at the most, $x_{t-\tau+2}$.. . I have overextended the available information set.

In some sense, however, I have also cut my information set too short. Any information available at time $t - \tau$ is allowable; one is not restricted to the foreign price. Include the foreign prices x into a wider set of variables which make up a row vector Z, whose value $Z_{t-\tau}$ is known at time $t - \tau$. Then we respecify Equation (5.1) more cleanly as:

$$y_t = Z_{t-\tau}\times\left[\ \delta_0 S_t + \delta_1 S_{t-1} + \delta_2 S_{t-2} + \delta_3 S_{t-3} + \delta_4 S_{t-4}\ \right] + \varepsilon_t$$

In this equation, δ_0, δ_1 ... are column vectors of constant coefficients. The residual is restricted to being linearly independent of S_t, S_{t-1} .. *and* $Z_{t-\tau}$. We want the residual to have zero correlation with the exchange rate because we wish to design the variance-minizing hedge and we want the residual with the information Z because we want to fully exploit the information set in forming our estimates. This is enough restrictions to identify all the δ coefficients.

The time varying-coefficient $Z_{t-\tau}\delta_0$, for instance, is interpreted as the exposure of y_t to S_t, *measured from the vantage point* $t - \tau$. Since the exposure is now explicitly time-varying, future revisions should really be taken into account in the estimation. I shy away from that undertaking.

8. Conclusion

This paper has taken the form of a research program. It has spelled out what we really do not know about corporate hedging. I have argued that there should exist an optimal time at which to initiate a hedge aimed at protecting a given cash flow. I have tried to indicate some of the theoretical arguments which would go into determining this optimal time of initiation. I have also tried to discuss some of the econometric arguments which would form the basis for the practical implementation of my idea. Most of the work remains to be done.

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