Journal of International Financial Management and Accounting 8:2 1997

A Real Options Approach to Economic Exposure Management

*Jeannette Capel**

Limburg Institute of Financial Economics, University of Maastricht

Abstract

Exchange rate volatility is not only a source of concern for firms but also of profit opportunities. If adjustment costs and lags are low, managers can adjust their input or output decisions to raise the firm's expected profits. Notwithstanding the resulting higher profit variability, the actual risk perceived by the managers may fall as they are probably more averse to *downside* risk—such as financial distress—than to risk in general. Hence, this paper argues that optimal economic exposure management consists of exploiting the upward profit potential of real exchange rate volatility, while keeping downside risk under control. It is shown that option theory provides useful new principles for economic exposure management by bringing out the crucial role of adjustment costs.

1. Introduction

> *It has often been joked at Philips that in order to take advantage of currency movements, it would be a good idea to put our factories on board a supertanker, which could put down anchor wherever exchange rates enable the company to function most efficiently. ... In the present currency markets ... (this) ... would certainly not be a suitable means of transport for taking advantage of exchange rate movements. An aeroplane would be more in line with the requirements of the present era.* (Snijders, 1989, p. 71)

In the quote above Mr. Snijders from Philips addresses two essential issues that have attracted surprisingly little attention in the literature on economic exposure management. The first is that exchange rate uncertainty is not only a source of concern to the firm. It also creates the potential for supernormal gains. In the ideal situation, production takes place wherever the firm can "function most efficiently" or "take advantage of exchange rate movements". The second neglected issue is that the firm's ability to react is higher, the shorter its adjustment lag (or the lower adjustment

* This paper's ideas are based on my PhD thesis "Exchange rates and strategic decisions of firms" (1993), for which valuable intellectual input was provided by Mark Casson, Henk Jager and Eelke de Jong. I also benefitted from comments to an earlier version of this paper by Arthur Stonehill and Jeroen Ligterink. Finally, the suggestions of Richard Levich and an anonymous referee of the JIFMA have substantially improved the paper. Any remaining error is, of course, mine.

costs), and that the ability to respond swiftly is more valuable, the more uncertain the exchange rate. The "supertanker" that was useful in the past, is considered to be too cumbersome in the turbulent waters of today. The modern firm should move as fast as an "aeroplane".

These two issues are combined in this paper. Its starting-point is that most firms can change the currency composition of some commercial cash flows after a certain adjustment period or the payment of adjustment costs.[1] Some firms have a choice whether to purchase their inputs at home and pay in the home currency (HC) or to purchase abroad and incur foreign currency (FC) costs. Other firms can switch between HC and FC sales. In these cases the relative cost or return of the HC versus the FC strategy is determined by the (firm-specific) real exchange rate and is thus variable over time.[2] Now this paper's main point is that with low enough adjustment costs and lags managers can exploit the variability of the firm's real exchange rate to raise the firm's expected cash flows or market value. It will also be argued that this policy does not necessarily raise the firm's exchange risk if managers are averse to downside risk rather than to risk *per se*.[3]

Of course, the mere assertion that uncertainty opens up the potential for profit opportunities is nothing new. For instance, Oi (1961) demonstrates the benefits of price uncertainty and Oxelheim and Wihlborg (1987) explicitly discuss the profit opportunities that exchange rate variability entails. Also not new is the idea that flexibility enables the firm to reap these benefits (e.g., Lessard and Lightstone, 1986; Kogut and Kulatilaka, 1994). However, this study is the first to show in detail *how* firms make optimal decisions while facing real exchange rate uncertainty, considering their dual objective of maximizing value and keeping risk at an acceptable level. Moreover, the ideas developed below are not just applicable to real exchange rate uncertainty—as shown in this paper—but to relative price uncertainty in general. Within one country, for instance, the relative price between sectors is subject to change. Firms with adjustable cash flows can exploit intersectoral profit opportunities (cf. Oxelheim and Wihlborg, 1987). Finally, this article concentrates on the exploitation of real exchange rate variability by switching *between* HC and FC cash flows. Firms that face low storage costs and that, accordingly, have inventory flexibility can also benefit by adjusting the pattern of FC cash flows *over time* (i.e., buy more FC inputs or produce more abroad when the FC is relatively cheap and use inventories when the FC is relatively dear).

This study provides a real options approach to economic exposure management. A firm with adjustable cash flows owns an option. A firm that is

implementing the HC strategy has the opportunity to switch to the FC strategy as soon as future real exchange rate developments make this profitable. This opportunity is comparable to a *call* option, since in effect the firm has paid a price (the option premium) for the right to pay a fixed "exercise" price (the adjustment costs) and obtain the FC strategy. If the firm presently has the FC strategy, it basically owns a *put* option namely the opportunity to cease the FC strategy and adopt the HC strategy. A firm with adjustable cash flows can switch to the FC strategy to exploit favorable exchange rate movements but switch back to the HC strategy when too large exchange rate induced losses occur. The result is that, just like the holder of a financial option, the firm can in principle benefit from unlimited profit opportunities, while there is a maximum to its potential loss. However, to obtain these "switching options" the firm often has to make an investment in flexibility first. This investment can be seen as the price (i.e., the option price or option premium) paid by the firm to acquire the option.

This paper will first elaborate on the logic behind the points touched upon in this introduction and then further illustrate the main points by examining a simple numerical case. The next section gives a brief overview of the literature. In Section 3 the basic assumptions that underlie the real options approach are discussed, whereas Section 4 introduces a new objective of economic exposure management based on downside risk aversion. After that, Section 5 suggests which general principles managers can adopt to realize profitable and prudent economic exposure management within the firm. The numerical example is presented in Section 6 and gives managers the procedure for setting up a firm-specific economic exposure management scheme. Finally, the paper's conclusions and guidelines for implementation are given in Section 7.

2. Overview of the Literature

The impact of exchange rates on a firm's actual performance depends on (1) the variability of the exchange rates that are relevant to the firm and (2) the sensitivity or so-called exposure of the firm to these currency movements. Exposure determines the extent to which exchange rate changes affect the firm's performance. An idea of the size of exposure can be obtained from the sensitivity of the firm's performance to exchange rate changes. Prudent management requires that the firm keeps its exposure to unfavorable exchange rate changes limited.

In the literature several concepts of foreign exchange exposure are used, differing with respect to the indicator for performance chosen. This

article concentrates on *economic exposure* which determines the degree to which the *value of the firm* (or the discounted sum of its future cash flows) is affected by exchange rate changes. Economic exposure can be separated into two components: transaction exposure and real operating exposure (see e.g., Shapiro, 1994, p. 227). A firm has transaction exposure if it has contractual payables or receivables in FC. Real operating exposure refers to the firm's non-contractual future cash flows. Economic exposure should be carefully distinguished from *accounting exposure* (also called translation exposure). The latter governs the extent to which the balance-sheet value of the *owners' equity* is influenced by a multinational's obligation to translate FC financial statements of affiliates into a single reporting currency (see e.g., Eiteman, Stonehill and Moffett, 1995). Economic exposure thus refers to the firm's market value, whereas accounting exposure concerns book values.[4] To judge the firm's longer-term chance of survival, economic exposure is, of course, the more important exposure concept.

In practice, it is hard to assess a firm's economic exposure because it depends on a multitude of factors (see e.g., Shapiro, 1994; or Flood and Lessard, 1986). Among other things, it is determined by the geographical scope of the markets (local versus world markets) on which the firm buys its inputs and sells its output and on the nature of competition that it faces (e.g., Moffett and Karlsen, 1994). Even a domestic firm that has no foreign operations is economically exposed, if the terms of trade and thus domestic consumers' wealth, or the quantity supplied by the firm's competitors, is affected by exchange rate changes. In both cases there is an indirect effect of the exchange rate on the demand for the firm's products (see e.g., Luehrman, 1990; or Adler, 1994).

The market value of a firm is the present value of its expected future cash flows. So far, the literature on economic exposure management has focused on two basic procedures to limit the exposure of these cash flows to exchange rate changes. Firstly, the firm could reduce the net size of its individual FC cash flows. For example, a German exporter with dollar denominated returns and costs incurred in German marks, could switch to local production in the U.S. Secondly, the firm could reduce its exposure to any particular exchange rate by building a "portfolio" of different FC cash inflows and outflows. If a firm's total cash flow in terms of the HC in a period is negatively affected by a depreciation (appreciation) of an FC, its position is comparable to that of an individual holding an asset (liability) in that FC. A well-known result from portfolio theory is that, if the returns on assets are imperfectly correlated, the return on a portfolio

of assets is less variable than the summed variability of the returns on the individual assets. As actual exchange rate movements are not perfectly correlated, a firm can diminish their impact on a period's total cash flow by diversifying cost and returns over different currencies.[5] So the German exporter could decide to change its input decisions or marketing procedures so that its costs are partially in Japanese yen or its revenues partially in pounds sterling with the idea that changes in the yen/dollar and pound/dollar rate are not synchronized with fluctuations in the mark/dollar rate.

This illustrates that economic exposure management should be an integral part of the firm's strategic management. Decisions on input mix, plant location, market selection, product diversification etc. should all take account of economic exposure (e.g., Srinivasulu, 1981; Cornell and Shapiro, 1983; Aggarwal and Soenen, 1989). Since it is the nature of the firm's business that creates economic exposure, the role of financial executives in economic exposure management is somewhat subordinate. Their task is to arrange financial affairs in such a way as to minimize the real effects of exchange rate changes subject to the costs of such rearrangements (Cornell and Shapiro, 1983). This can be done, for example, by selling or buying FC forward or by diversifying the currency denomination of the firm's financial liabilities or assets.

As explained in the introduction, the present study provides an option perspective on economic exposure management. Option models have been used before to examine strategic decisions of firms that typically take place under uncertainty and entail sunk adjustment costs. Dixit and Pindyck (1994) discuss the intuition and techniques of real option models and apply them to several "investment under uncertainty" models. Kogut and Kulatilaka (1994) has focused more closely on the option value generated by the flexibility to shift production between countries if real exchange rates are uncertain. But as far as I know, there does not yet exist a real options approach to managing economic exposure. While some authors—like Giddy (1994) and Giddy and Dufey (1995)—have focused on financial options as an instrument to manage economic exposure (or to raise the value of the firm to shareholders), so far little attention has been paid to the opportunities for economic exposure management provided by the firm's *real options*.

3. Underlying Assumptions

The real options approach to economic exposure management is based on three pillars. The first pillar consists of two essential assumptions about

real exchange rate behavior to be discussed in this section. Secondly, the approach requires that managers are only averse to downside risk or—if they have a general risk aversion—that profit maximization plays a role in economic exposure management (see Section 4). Finally, the approach can only be applied in firms that have cash-flows which are adjustable under the prevailing exchange rate variability (see Section 5). The focus will be on non-financial firms with adjustable *commercial* cash-flows, since financial markets provide few (if any) profit opportunities for these firms.

(1) Deviations from the Law of One Price are Substantial and Exploitable for Flexible Firms

Empirical evidence shows that deviations from purchasing power parity (PPP) and the law of one price (LOP) are often substantial, especially in the short run (see e.g., Froot and Rogoff (1995); Obstfeld (1995) for an overview of empirical research). Exchange rates have the characteristics of the price of a financial asset, as they adjust rapidly to new information. Prices of goods and inflation rates, on the other hand, are sticky in the short run. Real exchange rates are thus subject to change. In addition, a production firm is frequently in a good position to exploit deviations from the LOP, since it has good information about its input and output markets. Obviously, the size of potential gain depends on what kind of input and output markets the firm operates on. For goods and services traded on international markets, the deviations from the LOP are usually smaller than for products sold on segmented markets.

(2) Exchange Rate Forecasts Become Less Uncertain with the Passage of Time

Suppose that a forecast has to be made of a particular real exchange rate prevailing on 1 January 2000. If the forecast is made today (1 January 1997) there will be more uncertainties than if the forecast is made on, say, 1 July 1999. The reason is that new information will become available between now and then, such as additional real exchange rate observations. These constitute valuable information given the approximately random walk properties of real exchange rates in the short run (see Obstfeld (1995) for an overview of relevant literature). Moreover, over a period of 6 months forward exchange quotations are available and price stickiness is a reasonable assumption, which may not be the case for longer time horizons.

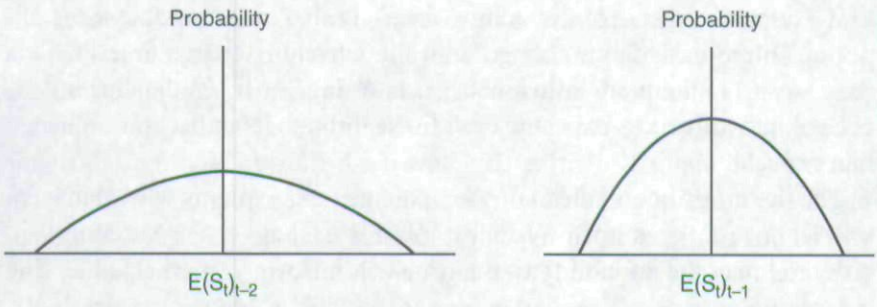

Figure 1. Probability Distributions Attached to the Real Exchange Rate at Time t

Of course, the uncertainty about the near future can still be considerable, for example in times of election. Moreover, there may be a longer term tendency for real exchange rates to revert to their PPP levels which implies that there may be less uncertainty today about a forecast made for the long run than about a forecast made for the medium run. But these facts do not falsify the proposition that the passage of time narrows down the range of scenarios for a particular future exchange rate. As the remainder of this paper will show, a value-maximizing firm can use this information to its advantage if its adjustment costs and lags are not too high. The assumption is illustrated in Figure 1 where $E(S_t)_{t-1}$ and $E(S_t)_{t-2}$ refer to the forecast of the spot rate on time t made on time t-1 and t-2.

4. The Objective of Economic Exposure Management

Economic theory predicts that in the absence of adjustment costs and lags, a risk-neutral firm prefers exchange rate uncertainty to fixed exchange rates. The reason is that it can benefit from exchange rate variability by adjusting input and output decisions, so that its expected cash flows and market value become higher (cf. Oi (1961) and von Ungern-Sternberg & von Weiszäcker (1990)). In the real world, where switching takes time and involves costs, firms can still benefit (albeit to a lesser extent) as long as adjustment lags and costs are not prohibitively high (see the examples below).

If a firm makes use of exchange rate induced profit opportunities, its periodical cash flows become a function of exchange rate behavior. This implies that "switching firms" have more variable cash flows than otherwise similar firms that consistently keep their foreign exchange exposure

low. The market value of "switching firms" is also more variable if the expected future cash flows change with the current exchange rate. This is the case if (1) there are adjustment costs or lags or if (2) the current exchange rate influences expected cash flows through its impact on exchange rate expectations.

The theory on economic exposure management explains why managers may choose to give up the benefits of real exchange rate variability in order to lower the variability of the firm's cash flows or market value. The most popular explanation is that managers wish to reduce the firm's default risk or costs of financial distress or, more generally, to protect investors against exchange rate related losses.[6] Other explanations are the managers' desire to realize a stable level of internally generated funds if external funds are costly (as in Froot, Scharfstein & Stein (1993)) and the fact that attaining a more stable level of profits may be optimal considering the tax structure or the manager's private compensation scheme (see e.g., Smith & Stulz (1985)).[7]

Yet it seems that an important question has escaped attention in the literature: does economic exposure management originate from a *general* aversion to exchange risk or from an aversion to *downside* exchange risk in particular? Considering the explanations just given, managers should only have an aversion to downside risk. The desire to reduce default risk, the possibility of loss or the costs of financial distress are clear examples of a concern for downside risk. Moreover, costly external funding may provide a reason to avoid low levels of internally generated funds, but high levels should still be welcome. Finally, managers, of course, like to lower the chance of large decreases in their compensation but to maintain the chance of large increases.

The distinction between general and downside risk aversion is important because of its implications for risk measurement. Managers with a general risk aversion like to reduce the *variability* of the firm's performance. An indication of the firm's total business risk is then given by the overall variance of the firm's cash flows or market value. Moreover, the exchange risk run by the firm can be measured as the contribution of exchange rates to cash flow or market value variability (the familiar "beta" measure). If managers have a general aversion to risk, they can decide to exploit real exchange rate behavior but not before an explicit trade-off is made between the level of profits and profit variability.

If managers only have an aversion to downside risk, risk is the likelihood and magnitude of an *unfavorable* outcome. The variance of the firm's market value or cash flows is no longer a good indication for business risk

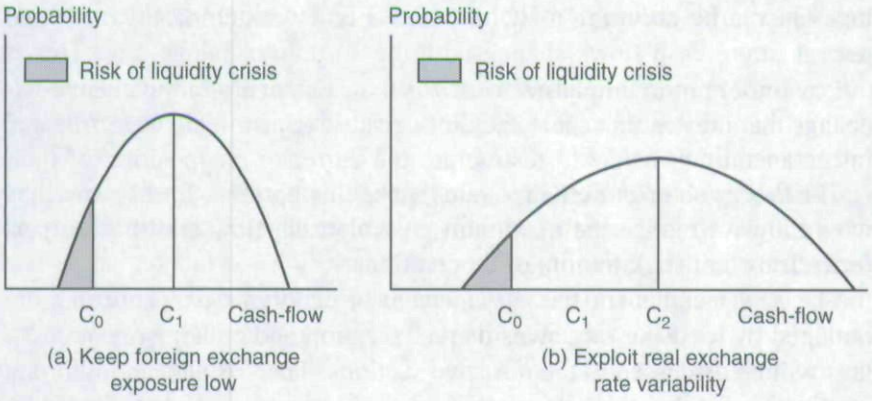

Figure 2. The Probability Distribution of Future Operational Cash Flows

and the β measure for the firm's exchange rate risk is no longer appropriate. Rather risk should be measured as the probability of business disruption (or as the "expected time to ruin", cf. Copeland, Joshin and Queen, 1996). The result is that profit maximization and risk minimization may go hand in hand. This is illustrated in Figure 2. Suppose that the firm's managers attempt to avoid a liquidity crisis which occurs if operational cash flows do not cover the firm's debt service obligations C_0. In Figure 2(a) the managers' strategy is to minimize foreign exchange exposure (by sticking to HC strategies or by matching FC costs and FC returns) so that future operational cash flows are not so volatile. In Figure 2(b) the managers adjust foreign exchange exposure to exploit real exchange rate volatility, so that expected operational cash flows are higher (C_2 instead of C_1) and more variable (as exchange risk has become an additional source of cash flow volatility). The familiar β measure would indicate an increase in exchange risk. However, the risk of a liquidity crisis, which is represented by the shaded areas in the figures, is lower in Figure 2(b).[8]

Consequently, this article states that the proper objective of economic exposure management is to raise the firm's expected cash flows as long as the probability of a drop below a certain benchmark is sufficiently small. If the firm has revenues (costs), for which HC and FC alternatives exist, the firm's operational objective is to maximize expected revenues (minimize expected costs) as long as the probability of below-target returns (above-target costs) is sufficiently small. Only if the "risk of ruin" of exploiting exchange rate behavior is considered too high, the firm limits

its exposure by choosing a HC alternative or by matching FC costs and returns.

It is important to emphasize that it is the existence of adjustment costs or lags that creates downside exchange risk. If adjustments were free and instantaneous, firms could restructure the currency composition of their cash flows as soon as exchange rates make this optimal. In this way they would always realize the maximum possible cash flow and thus outperform firms that stick to domestic operations.

The new insights for the *management* of economic exposure that are obtained by focusing on downside risk aversion and on adjustment costs/lags will be discussed in the next two sections. There is also an important implication for the *measurement* of economic exposure. As was argued by Adler and Dumas (1984), economic exposure can be measured by means of a simple regression. The method requires that every possible state of the exchange rate at time t can be associated with a particular HC cash flow. Time t exposure is then the coefficient in a linear regression of the HC cash flow on the spot exchange rate across the different states of nature (cf. Adler and Dumas, 1984, p. 44).[9] If adjustments are costly and firms exploit real exchange rate changes, this method can no longer be applied. As will be shown below, this implies that the HC cash flow in time t not only depends on the prevailing state of the exchange rate, but also on decisions taken before time t (and thus on past exchange rates).

5. Principles for Profitable and Prudent Economic Exposure Management

This section provides the intuition for some new important principles for profitable and prudent economic exposure management. The numerical example presented in the next section illustrates the same principles, while discussing the procedures in more detail.

(1) Fast Adjustment Procedures Lower the Firm's Exchange Risk and Raise its Cash Flows

The first action required from managers is to question which commercial cash flows of their firms are relatively easy to adjust given the deviations from the LOP on the relevant market (of course, switching does not make sense if the LOP holds). The answer depends on the nature of the firm's business. For instance, the degree of capacity utilization is not an ideal instrument for managing economic exposure for firms that face high costs

when training new personnel, whereas firms requiring inputs of constant high quality would not fancy the idea of varying purchasing policy in response to exchange rate developments. If exchange rates become more variable, more cash flows are potentially adjustable, since adjustment costs become a less significant barrier.

Now turn to the example of a firm that is able to switch between HC and FC inputs. For the moment it is assumed that this firm incurs no adjustment costs when switching between suppliers, but that it does face an adjustment lag in the sense that it has to order its inputs three months in advance. Without adjustment costs, a planning horizon of one quarter is sufficient. Obviously, if this firm can purchase the FC forward or pay the foreign supplier with the HC the managers can eliminate risk completely, although usually at some cost. The firm's input division does not have to worry about exchange risk and can simply take cost-minimizing decisions. However, in reality the firm cannot always hedge or determine the currency denomination of contracts. For instance, its planning horizon may be longer than existing maturities of forward contracts or it may not have access to the foreign capital market. Risk management is then also part of the input division's responsibilities. This case is further examined here.

If the input division has a role to play in economic exposure management, FC inputs should only be purchased if (1) their expected costs are lower than the certain costs of HC inputs and (2) the risk of costs exceeding a certain benchmark—for instance, the level at which liquidity becomes problematic—is considered sufficiently small. This idea is reflected in Figure 3(a). Based upon a presumed probability distribution of the future real exchange rate (such as in Figure 1), the probability distribution of the costs of purchasing FC inputs is determined. Suppose that in Figure 3, C_1 represents the certain costs of HC inputs, C_0 the lower expected costs of FC inputs and C_2 the risk benchmark. Profitable and prudent economic exposure management implies that FC inputs are ordered if the shaded area is small enough (i.e., lower than some acceptable percentage).

The example can be used to illustrate the first principle for economic exposure management: efficient adjustment procedures lower the firm's exchange risk and increase its expected cash flows and thus market value. If the delivery time for inputs can be reduced to 1 month, the firm is less uncertain about its exchange rate forecast (see Section 3). With the expected costs of FC inputs at C_0 as before, the probability of costs exceeding C_2 is now lower (compare Figure 3(b) to 3(a)). Hence, an investment into shorter adjustment lags raises the firm's potential to reap the fruits of exchange rate variability and lowers the risk of liquidity problems. In the

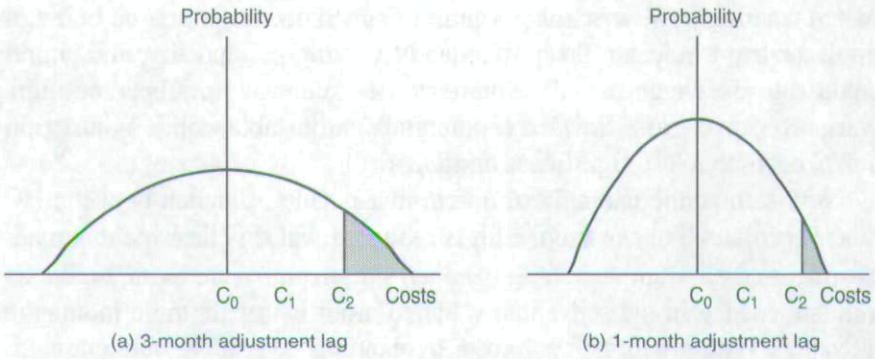

Figure 3. Probability Distribution of the Costs of Purchasing FC Inputs

extreme case of instantaneous adjustment possibilities, the risk of financial distress is, of course, even zero. Finally, the example shows that the firm's willingness to incur economic exposure should not only depend on the length of the adjustment lag but also on the degree of exchange rate uncertainty in general and the expected level of the exchange rate. The shaded areas in Figure 3 are smaller the lower uncertainty and the lower C_0.

(2) A Multi-period Framework is Required if there are Adjustment Costs

Frequently, a switch between strategies does not only entail time but also costs. Here these adjustment costs are assumed to be fixed and non-recurrent.[10] In the example above, the costs of negotiating a new input contract are probably higher than the costs of prolonging an existing contract. If adjustment costs exist, the optimal strategy of today is not independent of decisions taken in the past. With adjustment costs it is, for instance, never optimal to switch to FC inputs if their expected costs are equal to the costs of the HC strategy. But if the firm was already buying abroad, it will continue doing so. Hence, if there are adjustment costs, a multi-period framework for economic exposure management is called for, in which the firm's planning horizon depends on the way the firm's activities are organized. For instance, the time span over which projections for the future are made of expected future sales, outputs or inputs is an important consideration.

Within such a multi-period framework, cost-minimizing decisions can be obtained by means of either option theory/contingent claim analysis

(CCA) or stochastic dynamic programming (SDP). As discussed in detail by Dixit and Pindyck (1994), CCA and SDP are conceptually similar and yield the same results but are based on different assumptions. For this paper SDP is the more suitable approach. In particular, the assumption required for CCA of a "replicating portfolio" or of "spanning assets" would be contentious (cf. Dixit and Pindyck, 1994, Chapter 4).

Option theory shows that the higher the asset value volatility, the greater the value of the option and therefore the greater the value to the holder of the option of waiting to exercise it. The reason is that the right to change your mind later, which is given up by exercising, is more valuable with higher variability (see e.g., Cox and Rubinstein, 1985, p. 143). Analogously, when considering a switch between FC and HC strategies using SDP, the firm explicitly incorporates that a decision to switch now may be regretted in the future (see Dixit and Pindyck (1994) and also the numerical example in the next section for a more detailed explanation of SDP).

In Table 1 the steps that have to be taken to obtain a framework for profitable and prudent economic exposure management are summarized. The numerical example below will demonstrate how exactly managers can use such a framework to assess the consequences for the firm of investing in lower adjustment costs or of implementing any other of the new principles for economic exposure management.

In (3) and (4) below I assume that the firm cannot determine a contract's currency denomination and does not have financial hedging opportunities. In (5) I will show that if adjustment involves costs, neither financial instruments nor the choice of the currency denomination provide a perfect shield against exchange rate changes. Hence, marketing and production divisions necessarily have a responsibility in exchange risk management.

(3) Investing in Flexibility Raises Expected Cash Flows and Lowers Risk

In Section 4 it was argued that if managers have downside risk aversion and face no adjustment costs, they can raise the firm's expected profits and lower its exchange risk by exploiting real exchange rate variability. If adjustment costs do exist but are low enough to enable firms to actually make adjustments under the prevailing real exchange rate uncertainty, firms can still benefit (albeit to a lesser extent) from favorable exchange rate movements while being able to avoid part of the costs associated with unfavorable developments (the numerical example below will illustrate this point).

Table 1. *A Framework for Economic Exposure Management*

1.	*Action:*	Formulate domestic and foreign strategies for a commercial cash-flow
2.	*Action:*	Determine the adjustment costs of switching between strategies*
3.	*Action:*	Specify the adjustment lag or how often the strategy is normally reviewed
4.	*Action:*	Determine a proper planning horizon
5.	*Action:*	Give the expected nominal exchange rate for all future periods within the planning horizon. Forecast the relevant prices and calculate the implicit real exchange rate
	Comment:	Nominal exchange rate forecasts can e.g., be obtained from forward market data or interest rate differentials. Price forecasts should incorporate general inflation data and firm-specific developments in input/output markets
6.	*Action:*	Estimate real exchange rate uncertainty in all future periods within the planning horizon.
	Comment:	By how much have exchange rates and prices diverged from expected levels in the past? Will real exchange rate variability be different in the future?
7.	*Action:*	Formulate a stochastic real exchange rate process that is consistent with real exchange rate expectations and the estimated uncertainty (i.e., with steps 5 and 6).
	Comment:	A simple stochastic process such as the binomial distribution is recommended**
8.	*Action:*	Perform a scenario analysis by means of stochastic dynamic programing to determine which decisions maximize expected cash flows. Assess for every time period and every possible state of the real exchange rate whether the firm is better off sticking to its prevailing strategy (home or foreign) or switching to the alternative
9.	*Action:*	Is the risk embodied in cash-flow maximizing decisions acceptable? YES: Implement decisions NO: Formulate alternative with acceptable downside risk
	Comment:	Risk has to be evaluated as part of the entire conduct of business, i.e., it should be examined how the strategy affects the firm's total exchange rate risk

* If adjustment costs are negligible, the firm's planning horizon is just the adjustment lag (step 4) and all future variables and their uncertainty have to be forecasted only one period ahead (steps 5 and 6). In this case the real exchange process specified (step 7) does not have to be discrete and could, for example, be the normal distribution.

** The binomial distribution can give a good approximation to many practical real exchange rate processes. It can incorporate a trend by setting upward and downward moves of different size or by letting the probabilities of appreciation and depreciation differ.

Having said this, a logical next step is to question what happens if the firm invests in lower adjustment costs. For instance, a firm can spend resources on keeping contract with both domestic and foreign suppliers of inputs, even though it makes active use of only one at the time. If then at some future date it is optimal to turn to the other supplier, the firm will incur lower adjustment costs. A firm that manages economic exposure by varying the capacity utilization of different plants can invest in various

measures that facilitate production reallocation between countries. Some laborers could be hired on a temporary basis from employment agencies or extra capacity in all plants could be created to make it easier to shift production if exchange rates dictate so. Also the firm could delegate part of its activities to subcontractors, because in general it is easier to change subcontractor than to adjust the own production structure.

These investments in lower adjustment costs raise the firm's recurrent (production) costs (e.g., the services of an employment agency have to be paid). These costs should be weighed against the benefits of investing in flexibility which are: (1) an increase in the firm's expected cash flows and (2) a reduction in its downside risk. The lower the firm's adjustment costs, the better it is able to exploit favorable exchange rates and to shield itself against unfavorable exchange rates by switching back to the HC strategy.

The managers' priority may be to lower the risk of exchange rate induced loss. In that case they can invest mainly in a smooth transition from the FC to the HC strategy. For instance, the firm could offer some foreign employees temporary contracts and create domestic overcapacity to make it easier to switch from foreign to domestic production than vice versa. Moreover, by staying familiar with the domestic input market, the firm can turn to HC supply sources more easily when required and thus lower downside risk.

Finally, a consequence of all this is that a policy that at first sight seems unattractive can actually be optimal under real exchange rate uncertainty by virtue of its flexibility. It may be, for instance, economically sensible to incur higher recurrent costs than necessary if this yields flexibility for the future. So the firm may commit itself to purchase a minimum amount of inputs from both the domestic and the foreign supplier. This is a cost because a certain amount has to be purchased on the more expensive market. However, if the commitment also gives flexibility (for instance, the size of orders to both suppliers can be changed without incurring adjustment costs) the commitment may be worth considering. In general it can be said that if marketing and production divisions face different strategies to choose from, they should carefully evaluate the amount of flexibility allowed by each. Flexibility is worth more, the more uncertainty there is.[11]

(4) "Trigger Exchange Rates" and "Wait and See Zones" can be Useful Measures

As argued above, cash-flow maximizing decisions are not optimal if the firm considers the downside risk attached too high. Then it should take

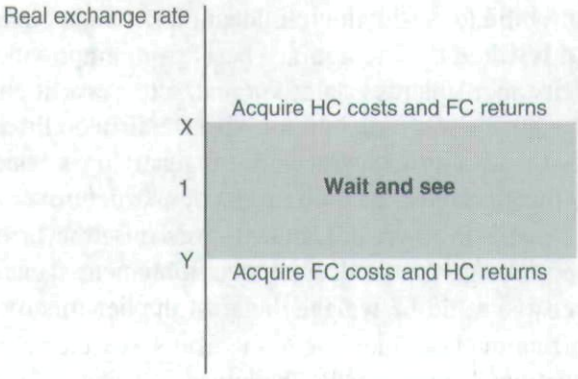

Figure 4. "Trigger Exchange Rates" and "Wait and See" Zones

direct actions to limit downside risk. One way of achieving this is "trigger exchange rates": economic exposure managers could give the production division guidelines to switch to HC costs if the real exchange rate is above a certain value X (with $X > 1$), to turn to FC costs if it is below a value Y (where $Y < 1$), and to "wait and see" (i.e., to stick to the prevailing strategy) as long as the real exchange rate fluctuates between these two values. The literature shows that if the firm takes profit-maximizing decisions, the difference between X and Y should be larger, the higher uncertainty and adjustment costs are (e.g., Dixit, 1989). The reason is that the right to change your mind later is more valuable with higher uncertainty and higher adjustment costs. Exchange risk can be purposefully lowered by setting X closer to 1 (or Y further below 1). Analogous guidelines can be issued with respect to the firm's revenue pattern (see Figure 4 and the numerical example).

(5) Economic Exposure Managers should not Rely Too Much on Financial Instruments

Financial instruments can be quite useful to reduce the "transaction exposure" part of economic exposure. They are of limited use in managing "real operating exposure" for the following three reasons. Firstly, financial instruments deal with nominal exchange rate uncertainty, whereas the firm judges nominal exchange rate developments in relation to the price developments on its input and output markets. In other words, the firm's main concern is its (firm-specific) real exchange rate uncertainty (i.e., the

deviations from the LOP) for which financial instruments in general only provide partial relief.

Secondly, financial instruments have a fixed maturity that may be shorter than the firm's planning horizon. In that case the firm could enter several successive financial contracts. However, if meanwhile exchange rates change, the expected exchange rates and thus the price of future financial contracts will be affected. Hence, financial contracts can diminish *intra*-period variability, but not eliminate *inter*-period variability (cf. Dufey and Srinivasulu, 1983, p. 61). The same applies to the choice of the currency of denomination.

Thirdly and finally, even if the available maturities are sufficient in relation to the firm's planning horizon, it may not be in its interest to use financial instruments. By engaging in long-term financial hedging a firm may actually raise its exposure in the long run. For instance, think of a firm that exports to a foreign market and that diminishes its exposure by means of an FC loan. If real exchange rates change so that at some future date it is no longer profitable to sell on the foreign market, the firm ends up having FC costs and no FC revenues (if the loan does not allow for accelerated redemption).[12]

This does not mean that financial instruments have no role at all in economic exposure management. For all firms financial instruments can be important in dealing with the contractual part of economic exposure, i.e., transaction exposure.[13] Moreover, some firms have little flexibility by their nature of business and thus have to resort to imperfect financial instruments for their economic exposure management. For example, a steel factory buys a part of its inputs (e.g., energy) and sells its output on international markets where prices are quoted in U.S. dollars, while production reallocation requires enormous investments. Finally, firms with adjustable cash flows can use financial instruments to reduce intra-period variability and to "buy" time for adjustments in the real sphere.

This section's main point is that, if possible and not too costly, adjustments in real variables should take the brunt of economic exposure management. As phrased by Adler:

> Corporate hedging decisions ... are designed to reduce the variance of the firm's cash flows, *conditional on the level of* the exchange rate. The effectiveness of hedging for protecting the firm against shifts in the *conditional cash flow distribution itself* is limited (Adler, 1994, p. 165).

Hence, for an apt response to changes in the *level* of the exchange rate, strategic decisions are required. Hedging decisions should, in turn, be

based on the firm's strategic behavior and thus on the considerations specified in Table 1 (see Adler (1994) for examples).

6. Numerical example

(1) The Case

The case to be presented here is simple: the firm's profit equals its net cash flow and its economic exposure is easy to assess. Consider a U.S. firm that services the U.S. market receiving dollar-denominated returns, which—by assumption—are not affected by exchange rates. Economic exposure is managed by means of purchasing policy for which there are two strategies: U.K. inputs requiring payment in pounds sterling and U.S. inputs requiring U.S. dollars. Inputs have to be ordered a quarter in advance (i.e., the adjustment lag is three months). Switching between suppliers costs a (non-recurrent) $25 (i.e., adjustment costs in the base case are $25). At the beginning of each new quarter the input division obtains an estimate of required inputs in the first four coming quarters making a four-period planning horizon appropriate. So on 1 January estimated inputs are obtained for the 2nd, 3rd and 4th quarter of this year and for the 1st quarter next year. These quantities are all set at 100 units. The real exchange rate determines whether the U.K. or U.S. inputs are cheaper. For simplicity the real exchange rate is assumed to be 1 on 1 January and to follow a basic binomial process with an equal chance of a 10% real appreciation and a 10% real depreciation. Hence, expectations in the present case are assumed static (the current rate is expected to prevail in the future). The possible real exchange rate developments over the firm's planning horizon are reflected in the binomial tree of Figure 5.[14]

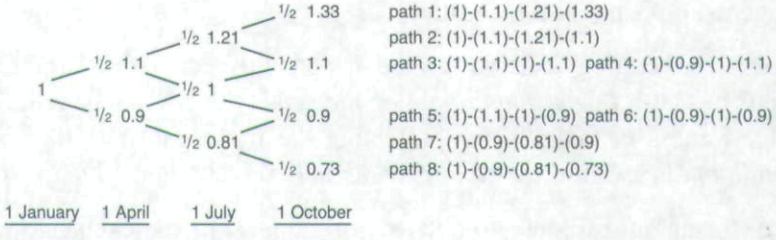

Figure 5. Numerical Example—Exchange Rate Paths

(2) The Procedure: Stochastic Dynamic Programming

The value-maximizing decisions (i.e., decisions minimizing expected input costs) are determined first and then their risk implications will be assessed (see next page). Value-maximizing decisions are not directly obvious, since the optimal decisions at any time (1) depend on decisions taken in the past due to the existence of adjustment costs and (2) have to be made facing exchange rate uncertainty. Stochastic dynamic programming (SDP) is the standard procedure for such decision-making. The first step is to calculate optimal decisions for the last period for all possible exchange rates and for the two input strategies with which the firm may have entered the period. Cost-minimizing decisions for all possible states are obtained by comparing the costs of continuing the existing strategy to the costs of switching to the other strategy. Then, having obtained the best decisions for 1 October, those for 1 July can be determined and so on. This procedure is illustrated in Table 2 below which also shows that the optimal decision in each period depends on (1) the prevailing real exchange rate and (2) where the firm was purchasing its inputs before.

The calculations in this table show that a profit-maximizing firm that has ordered U.S. inputs in the past should definitely stick to this strategy until 1 July and should only switch to U.K. inputs on that date if the real exchange rate has become 0.81 (i.e., as soon as it turns out that the actual real exchange rate will take path 7 or 8). Analogously a firm which currently orders U.K. inputs should not change its strategy until the real exchange rate becomes 1.21 on 1 July (i.e., the actual real exchange path should be known to be either 1 or 2). Finally, note that the SDP procedure used in these calculations is the same as the procedure used to determine the value of an American option (see Cox, Ross and Rubinstein (1979) on binomial option pricing formulas).

(3) Risk Implications

The probability distribution of input costs, and hence the risk implications of cost minimization, can be obtained by tracking the 8 possible future exchange rate paths (as given in Figure 5) and determining cost-minimizing decisions in each case (as illustrated in Table 2). The reader may like to check how columns (a) and (b) can be derived directly from Table 2 (note 4 under the table gives one example). Columns (c) and (d) can be obtained by applying the SDP procedure to the case of adjustment costs of $10.

Table 2. *Deriving Cost-minimizing Decisions by Means of SDP*

Real exchange rate	*Existing strategy*	*$ costs of continuing existing strategy*	↔	*$ costs of switch to alternative strategy*
		*Cost-minimizing decisions on 1 October**		
1.33	U.S.	100		133 + 25 = 158
1.10	U.S.	100		110 + 25 = 135
0.90	U.S.	100		90 + 25 = 115
0.73	U.S.	100		73 + 25 = 98
1.33	U.K.	133		100 + 25 = 125
1.10	U.K.	110		100 + 25 = 125
0.90	U.K.	90		100 + 25 = 125
0.73	U.K.	73		100 + 25 = 125
		(Expected) Cost-minimizing decisions on 1 July		
1.21	U.S.	100 + ½(100 + 100) = 200		121 + 25 + ½(125 + 100) = 263.5
1.00	U.S.	100 + ½(100 + 100) = 200		100 + 25 + ½(110 + 90) = 225
0.81	U.S.	100 + ½(100 + 98) = 199		81 + 25 + ½(90 + 73) = 187.5
1.21	U.K.	121 + ½(125 + 110) = 238.5		100 + 25 + ½(100 + 100) = 225
1.00	U.K.	100 + ½(110 + 90) = 200		100 + 25 + ½(100 + 100) = 225
0.81	U.K.	81 + ½(90 + 73) = 162.5		100 + 25 + ½(100 + 98) = 224
		(Expected) Cost-minimizing decisions on 1 April		
1.10	U.S.	100 + ½(200 + 200) = 300		110 + 25 + ½(200 + 225) = 347.5
0.90	U.S.	100 + ½(200 + 187.5) = 293.75		90 + 25 + ½(200 + 162.5) = 296.25
1.10	U.K.	100 + ½(200 + 225) = 322.5		100 + 25 + ½(200 + 200) = 325
0.90	U.K.	90 + ½(162.5 + 200) = 271.25		100 + 25 + ½(187.5 + 200) = 318.75
		(Expected) Cost-minimizing decisions on 1 January		
1.00	U.S.	100 + ½(293.8 + 300) = 396.9		100 + 25 + ½(322.5 + 271.3) = 421.9
1.00	U.K.	100 + ½(322.5 + 271.3) = 396.9		100 + 25 + ½(293.8 + 300) = 421.9

* The $ costs of the decision that minimizes (expected) costs is underlined.

(4) The Value of Flexibility

Table 3 illustrates the points discussed in Section 5:

1. Firms with relatively low adjustment costs benefit from real exchange rate uncertainty.
   Table 3 shows that expected input costs for a firm that switches optimally are $396.9 regardless of its initial strategy, whereas a firm that starts with U.S. inputs and sticks to them come what may, pays a certain $400. Adjustment costs should be assessed relative to the

Table 3. *The Value of Flexibility. Outcome of Cost-minimizing Decisions under Different Real Exchange Rate Scenarios*

	Case I[1] *Strategy 1/1*		*Case II*[2] *Strategy 1/1*		*Case III*[3]
Real exchange rate path	*U.S.* *(a)*	*U.K.* *(b)*	*U.S.* *(c)*	*U.K.* *(d)*	*U.S. + U.K.* *(e)*
Path 1: (1)–(1.1)–(1.21)–(1.33)	400	435[4]	400	410	416
Path 2: (1)–(1.1)–(1.21)–(1.1)	400	435	400	410	410.25
Path 3: (1)–(1.1)–(1)–(1.1)	400	420	400	410	405
Path 4: (1)–(0.9)–(1)–(1.1)	400	400	410	400	395
Path 5: (1)–(1.1)–(1)–(0.9)	400	400	400	410	395
Path 6: (1)–(0.9)–(1)–(0.9)	400	380	390	380	385
Path 7: (1)–(0.9)–(0.81)–(0.9)	396	361	371	361	370.75
Path 8: (1)–(0.9)–(0.81)–(0.73)	379	344	354	344	358
Average:	396.9	396.9	390.6	390.6	391.9

[1] In Case I adjustment costs are $25 for switches in both directions.

[2] In Case II adjustment costs are $10 for switches in both directions.

[3] Case III is a flexible alternative. The firm commits itself to purchase at least 25 units on each market in exchange for the promise that it can change the size of its order without incurring extra costs (i.e., there are no adjustment costs to changing existing input contracts).

[4] A firm that enters the year with U.K. inputs will continue to order them on 1 January and 1 April (costs: $100 + $110), so that the firm will use U.K. inputs in its production process up to the third quarter inclusive (because of the adjustment lag of one quarter). If on 1 July the real exchange rate happens to be 1.21, the firm starts to order U.S. inputs (costs: $25 adjustment costs + $100) and will continue to do so on 1 October (costs: $100). These U.S. inputs will be used in the fourth quarter of this year and the first quarter of next year. Total costs are: $(100 + 110 + 125 + 100) = $435.

degree of uncertainty. With periodical changes in the real exchange rate of 5% instead of 10%, it is never optimal to switch so that expected inputs costs are $400. However, with periodical changes of 20%, expected input costs are only $384.9.

2. Investing in flexibility raises expected cash flows and lowers risk. Comparing (c) and (d) with (a) and (b) shows that investing in lower adjustment costs yields two benefits: Expected input costs fall (from $396.9 to $390.6) and so does risk (the worst scenario costs now $410 instead of $435). Hence, the investment should definitely be made if it costs $6.3 or less (i.e., $396.9–$390.6). If it costs more, it may still be worthwhile if enough value is attached to the risk reduction.
3. Risk-reduction can be given explicit priority.
   Exchange rate induced loss may be lowered by investing mainly in a smooth transition from the FC to the HC strategy. Suppose that the firm of our example continuously stays familiar with U.S. market

conditions, so that the adjustment costs from U.K. to U.S. inputs become \$10 whereas those of the opposite switch are \$25. Columns (a) and (d) give the results for a firm starting with U.S. and U.K. inputs.[15]

4. Flexibility embodies value.
   A strategy that at first seems unappealing may be worthwhile by virtue of its flexibility. Assume that if the firm commits itself to purchase at least 25 units on both markets it can, in return, change the order size without incurring adjustment costs. This may seem to be a sacrifice, but as column (e) shows the commitment is actually favorable both in terms of lower expected input costs and lower downside risk.
5. "Trigger exchange rates" and "wait and see zones" can be useful measures.
   Column (b) shows that in the worst scenario a firm starting with U.K. inputs ends up paying \$435 for inputs in the coming year. If this risk is considered too high, managers could order the input division to start ordering U.S. inputs if on 1 April the trigger value of 1.1 is realized. For the first four scenarios this strategy costs \$425 (instead of \$435, \$435, \$420 and \$400) meaning expected costs of \$398.1 (instead of \$396.9). The difference of \$1.2 is the price paid for risk reduction.
6. Economic exposure managers should not rely too much on financial instruments.
   To illustrate this point assume that the firm orders 100 U.K. inputs on 1 January as it did in the recent past. With financial instruments the firm can hedge short-term (3 months) or longer term ($>$ 3 months). Both strategies have a serious disadvantage. The problem with short-term hedging is that if expectations change, the price of new financial instruments is affected. In the example 100 U.K. inputs ordered on 1 January, cost the firm \$100 plus the transaction costs of the forward contract (assuming that the forward rate equals the expected future spot rate and that expectations are static). If the rate is 1.1 on 1 April, U.K. inputs ordered on 1 April cost the firm \$110 plus the costs of forward cover. Hence, with short-term financial instruments the firm deals with *intra*-period variability but not *inter*-period variability. Long-term financial hedging has the disadvantage of either lost flexibility or ending up with unnecessary foreign exchange exposure. In the example the firm could plan to buy U.K. inputs during the whole year—given that current and all expected real exchange rates equal 1—and purchase pounds 3, 6, 9, and 12 months forward. The firm has now complete certainty but the

price paid for this is not only the transaction costs of four forward contracts but also the opportunity costs of lost flexibility (i.e., the difference between the costs of consistently buying U.K. inputs and the expected costs of a cost-minimizing strategy). Alternatively, should the firm decide to switch to U.S. inputs within the year, it has ended up with an exposure because of the forward contract. For more sophisticated and thus more expensive financial instruments, like currency options, this last problem does not occur.

7. Conclusions and Guidelines

(1) Investing in Flexibility Serves a Dual Purpose, Especially if Uncertainty is High

The motivations for economic exposure management are primarily based on an aversion to downside risk. This implies that the objective of economic exposure management should be to exploit the variability of exchange rates in order to increase the firm's market value, while ensuring that the downside risk of exchange rates remains sufficiently small. In Table 1—as well as in the numerical example—it was suggested how firms can set up their own framework for profitable and prudent economic exposure management.

In practice real exchange rates take a long time to revert to their Law of One Price levels. Therefore a firm that can switch between a home currency and a foreign currency strategy for a certain operation is better off than an otherwise equal firm that has only access to one strategy. This means that a cash flow maximizing firm should be aware of the alternatives it has to existing operating strategies. It was shown that by investing in lower adjustment costs or faster adjustment procedures the firm can attain its dual objective of raising expected cash flows and limiting the downside risk of exchange rate changes. Moreover, strategies that at first sight seem unattractive may actually be optimal by virtue of their higher flexibility. Especially if exchange rate uncertainty is high, the firm should consider measures that facilitate future adjustments in the cost and revenue structure. For instance, it can create extra capacity in all plants or have part of its labor force on temporary contracts so that production reallocation is easier. In general, an investment in flexibility also costs something in the form of higher recurrent (production) costs. These costs should be weighed against the benefits: the increase in the firm's expected cash flows and the reduction in risk.

A firm that is particularly concerned about its downside risk can mainly invest in the downward flexibility of exposure. For example, a firm with productive capacity but no sales in a particular foreign country can engage foreign subcontractors, offer foreign laborers temporary contracts and create domestic overcapacity so that it is relatively easy to switch from foreign to domestic production.

Finally, managers can formulate "trigger exchange rates" and "wait and see zones" to give the different divisions an indication about when to switch between domestic and foreign strategies and when to stick to existing policies. If they want to be on the safe side, decisions to reduce the firm's economic exposure to a particular foreign currency are taken earlier than decisions to increase it.

(2) *Close Cooperation Between the Treasury, Production and Marketing Divisions is Vital*

Financial instruments were shown to be not ideal for managing real operating exposure. Consequently, the production and marketing divisions are at least partially responsible. The suggestions made above clearly require close cooperation between the treasury and those divisions. The treasury's task is to provide nominal exchange rate forecasts and to give some information on their uncertainty. The production and marketing divisions should gather information on existing cost and revenue structures and on possible alternatives to prevailing strategies. Also they should estimate the adjustment costs of switching and specify the stochastic process of the firm's prices and costs over time.

The treasury assembles these data to get a picture of the probability distribution of the relevant future real exchange rates. It can then set up a framework for economic exposure management along the lines suggested in Table 1 and provide the production and marketing divisions with the appropriate software to enable these divisions to weigh the costs and benefits of different policies. Alternatively, the treasury can play an advisory role by supplying information and issuing general guidelines for economic exposure management. A possible guideline is that investments in lower adjustment costs or flexible strategies should be contemplated, if real exchange rate uncertainty is high. Flexibility lowers risk and raises expected profits and these benefits of higher flexibility should be compared to its costs. Also, the treasury can suggest that the production and marketing divisions formulate "trigger exchange rates" and that they seriously consider switching to an alternative strategy, once the real exchange

rate approaches this trigger value. Of course, for switches involving large adjustment costs (such as production reallocation) "trigger exchange rates" are further apart than for activities with smaller adjustment costs (like changing the supplier of a firm's inputs).

Notes

1. For firms that do not have adjustable cash flows at all, this paper's recommendations are not useful and traditional methods of economic exposure management have to be relied on.

2. The firm-specific real exchange rate is defined as the nominal exchange rate (the price of the FC in terms of the HC) multiplied by the ratio between the firm's foreign and domestic price. To compare domestic and foreign purchases (sales), input (output) prices are used. In this way the firm can calculate a real exchange rate for each commercial operation, for which there is a choice between HC and FC strategies.

3. Formally it is real exchange rate *variability* (the fact that the real exchange rate fluctuates) that is in principle exploitable and real exchange rate *uncertainty* (the fact that future fluctuations are unknown) that entails risk. However, in practice an increase in variability is accompanied by an increase in uncertainty. In the literature the two concepts are often used interchangeably and this paper does so too.

4. Most authors use the concept of economic exposure for what is defined real operating exposure above and distinguish three basic forms of exposure: economic exposure, transaction exposure and accounting exposure. Because the firm's contractual cash flows are a component of the firm's future cash flows or market value, transaction exposure is in my view a sub-category of economic exposure rather than a separate category.

5. Note that the currency of denomination of a contract may be of little importance. For instance, energy costs may be quoted in terms of local currency, but these costs usually vary with the dollar and are thus effectively dollar costs (see e.g., Shapiro, 1994, p. 238).

6. The basic assumption underlying this argument is that the firm's shareholders or stakeholders have less information or fewer instruments to deal with exchange risk than the firm's managers. See Adler and Dumas (1983) and Dufey and Srinivasulu (1983) for a complete overview of the market imperfections that underlie the case for corporate foreign exchange management.

7. The last explanation is not valid if executive compensation contracts contain "golden parachutes".

8. Of course, it is also possible that managers with downside risk aversion raise the risk of a liquidity crisis by exploiting real exchange rate volatility. This happens if the probability distribution in Figure 2(b) lies more to the left. In that case an explicit trade-off should be made between the increase in the firm's expected cash flows, which is obtained by exploiting exchange rate behavior, and the increase in liquidity risk associated with it.

9. This formulation assumes that domestic inflation is zero. If it is not, the regression should be done on a purchasing power variable instead of the spot exchange rate (cf. Adler and Dumas, 1984, p. 43).

10. In practice, the size of adjustment costs is usually related to the adjustment period. The faster the firm wants to adjust, the higher the adjustment costs. Moreover, in reality often part of the adjustment costs is a periodical expense. Financial managers could incorporate these two features into the framework suggested by this paper.

11. This also implies that past investments in flexibility become worth less if an environment with lower real exchange rate uncertainty emerges, as is likely to happen within the EMU-bloc.

12. Of course, this problem does not arise if a firm pays a fixed periodical premium to have credit facilities in different currencies which can be used at discretion or only attracts FC loans that allow for accelerated redemption. Alternatively, a currency option could be purchased although this does not eliminate exposure if—as seems likely—the contingencies that determine whether or not the option should be exercised differ from whether or not the firm actually has FC exposure (cf. Dufey and Giddy, 1995).

13. The management of this contractual exposure should be conducted conditional on the non-contractual exposure that is left after the real options approach has been employed.

14. The numbers in the figure have been rounded off so that the same value of the exchange rate shows up in different periods. For instance, one of the exchange rates given for 1 July is 1 (which is the value of the rate on 1 January). The exact value would be 1*0.9*1.1 = 0.99.

15. Note that in the present example it is not optimal to switch more than once during the planning horizon—see Table 2. If multiple switching can occur, the case of "asymmetric adjustment costs" would require a separate calculation.

References

Adler, M., "Exchange Rate Planning for the International Trading Firm," in *Exchange Rates & Corporate Performance*, Y. Amihud and R. M. Levich, eds. (Burr Bridge: Irwin Professional Publishing, 1994), pp. 165–179.

Adler, M. and B. Dumas, "Exposure to Currency Risk: Definition and Measurement," *Financial Management* (Summer 1984), pp. 41–50.

Aggarwal, R. J. and L. A. Soenen, "Managing Peristent Real Changes in Currency Values: The Role of Multinational Operating Strategies," *Columbia Journal of World Business* (Fall 1989), pp. 60–67.

Copeland, T., Y. Joshi and M. Queen, "How to Evaluate FX Risk Management Programs," working paper (McKinsey & Company, 1996).

Cornell, B. and A. C. Shapiro, "Managing Foreign Exchange Risk," *Midland Corporate Finance Journal* (Fall 1983), pp. 16–31.

Cox, J. C., S. A. Ross and M. Rubinstein, "Option Pricing: A Simplified Approach," *Journal of Financial Economics*, 7 (1979), pp. 229–263.

Cox, J. C. and M. Rubinstein, *Options Markets* (New Jersey: Prentice Hall, 1985).

Dixit, A., "Entry and Exit Decisions under Uncertainty," *Journal of Political Economy*, 97 (1989), pp. 620–638.

Dixit, A. and R. Pindyck, *Investment under Uncertainty* (Princeton NJ: Princeton University Press, 1994).

Dufey, G. and S. L. Srinivasulu, "The Case for Corporate Management of Foreign Exchange Risk," *Financial Management* (Winter 1983), pp. 54–62.

Eiteman, D. K., A. I. Stonehill and M. H. Moffett, *Multinational Business Finance* (Reading MA: Addison-Wesley, 1995).

Flood, E. and D. R. Lessard, "On the Measurement of Operating Exposure to Exchange Rates: A Conceptual Approach," *Financial Management* (Spring 1986), pp. 25–36.

Froot, K. A. and K. Rogoff, "Perspectives on PPP and Long-Run Real Exchange Rates," in *Handbook of International Economics* Volume 3, G. Grossman and K. Rogoff, eds. (Amsterdam: North-Holland, 1995), pp. 1647–1688.

Froot, K. A., D. S. Scharfstein and J. C. Stein, "Risk Management: Coordinating Corporate Investment and Financing Policies," *Journal of Finance*, 48 (1993), pp. 1629–1658.

Giddy, I. H., "Exchange Rate Volatility, Hedging and the Cost of Capital" in *Exchange Rates & Corporate Performance*, Y. Amihud and R. M. Levich, eds. (Burr Bridge: Irwin Professional Publishing, 1994), pp. 155–161.

Giddy, I. H. and G. Dufey, "Uses and Abuses of Currency Options," *Journal of Applied Corporate Finance*, 8 (1995), pp. 49–57.

Kogut, B. and N. Kulatilaka, "Operating Flexibility, Global Manufacturing and the Option Value of a Multinational Network," *Management Science*, 40 (1994), pp. 123–139.

Lessard, D. R. and J. B. Lightstone, "Volatile Exchange Rates Can Put Operations at Risk," *Harvard Business Review* (July/August 1986), pp. 107–114.

Levi, M. D., "Exchange Rates and the Valuation of Firms," in *Exchange Rates & Corporate Performance*, Y. Amihud and R. M. Levich, eds. (Burr Bridge: Irwin Professional Publishing, 1994), pp. 37–48.

Luehrman, T. A., "The Exchange Rate Exposure of a Global Competitor," *Journal of International Business Studies*, 21 (1990), pp. 225–242.

Moffett, M. H. and J. K. Karlsen, "Managing Foreign Exchange Rate Economic Exposure," *Journal of International Financial Management and Accounting*, 5 (1994), pp. 157–175.

Obstfeld, M., "International Currency Experience: New Lessons and Lessons Relearned," *Brookings Papers on Economic Activity*, no. 1 (1995), pp. 119–220.

Oi, W., "The Desirability of Price Instability under Perfect Competition," *Econometrica*, 29 (1961), pp. 58–64.

Oxelheim, L. and C. G. Wihlborg, *Macroeconomic Uncertainty—International Risks and Opportunities for the Corporation* (Chichester: John Wiley and Sons, 1987).

Shapiro, A. C., *Foundations of Multinational Financial Management* (Needham Heights MA: Allyn and Bacon, 1994).

Smith, C. W. and R. M. Stulz, "The Determinants of Firms' Hedging Policies," *Journal of Financial and Quantitative Analysis*, 20 (1985), pp. 391–405.

Snijders, D., "Global Company and World Financial Markets," in *Financing the World Economy in the Nineties*, J. J. Sijben, ed. (Dordrecht, the Netherlands: Kluwer Academic Publishers, 1989), pp. 59–74.

Srinivasulu, S. L., "Strategic Response to Foreign Exchange Risks," *Columbia Journal of World Business* (Spring 1981), pp. 13–23.

von Ungern-Sternberg, T. and C. C. von Weizsäcker, "Strategic Foreign Exchange Management," *Journal of Industrial Economics*, 38 (1990), pp. 381–395.