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Financing foreign operations and subsidiaries is made safer and simpler by using a new computer model to devise hedging policy

Foreword

Where purely monetary matters are concerned, it is the treasurer's duty to see that his company's financial activities abroad are arranged so that devaluation, should it occur, will not mean disaster. Most treasurers have relied on a seat-of-the-pants approach to making these arrangements. Now a computerized model is available that allows the treasurer of an international corporation to take a quick overview of all the many variables that are involved and come up with a highly rational strategy for hedging—one that is both safe and inexpensive, relatively speaking, for his company to follow.

Mr. Lietaer, a young Belgian, has studied at the Alfred P. Sloan School of Management at M.I.T. and is now employed by Cresap, McCormick, and Paget Inc. He developed the method sketched here while at M.I.T., and has continued to consult on and apply it in international companies.

In many major international corporations, the biggest worry the treasurer has is fluctuations in the value of foreign currencies. Some companies have learned to worry the hard way:

○ The 1967 annual report of the Hoover Company states that its "estimated net losses resulting from the 1967 devaluation of British, Finnish and Danish currencies, less applicable income taxes, amounted to $6,891,408." These losses represented $0.55 per share of net income to be deducted from the total net income of $2.09 per share.

○ Eastman Kodak Company reports that, for 1968, losses resulting from "foreign currency devaluation . . . amounted to $2.5 million in 1968, as against $9.5 million in 1967—of which $8.0 million resulted from the devaluation of the British pound and related currencies."

○ In 1967, International Telephone and Telegraph Corporation reported "extraordinary losses of $3.2 million applicable to the devaluation of the English pound and the Spanish peseta."

○ In its stockholders' report of December 1967, the Firestone Tire & Rubber Company disclosed that "foreign currency devaluation deducted from income amounted to $6.5 million this year [1967] and $4.2 million last year [1966]. The devaluation of the British pound sterling on November 18, 1967, and other affected currencies resulted in no loss to the Company. . . ."

Changes in currency values, in terms of gold or the dollar, are certainly not exceptional. Of 109 currencies studied by the International Monetary Fund, 96 were devalued during the past 20 years, and 69 of these were devalued at least twice. In 22 countries currencies were depreciated more than four times.

Exhibit I. Selected currency depreciations, November 1, 1948 to October 1, 1969

Country	Currency unit	Units per U.S. dollar 1948	1969
Argentina	Peso	3.73	350.00
Belgium	Franc	43.83	50.50
Brazil	Cruzeiro	18.50	3,660.00
France	Franc	214.71	494.00
India	Rupee	3.31	7.53
Mexico	Peso	4.86	12.50
Spain	Peseta	11.22	69.50
The Netherlands	Guilder	2.65	3.64
United Kingdom	Pound	0.25	0.42

The *extent* to which individual currencies have been devalued shows that this kind of crisis can be as dangerous as it is frequent. The figures in *Exhibit I* give some indication of the scope of selected devaluations since 1948. According to the International Monetary Fund survey, total postwar devaluations exceeded 40% of overall currency value for 62 countries, some of them major industrial powers. Of these currencies, 24 have been devalued by more than 75% since 1948.

Mere statistics on the frequency and extent of devaluations, however, understate the frequency with which a company treasurer must actually face the prospect of a devaluation crisis. The British pound has gone through only two parity changes since World War II, but a dozen false alarms throughout the 1960's have kept treasurers uneasy about transactions in sterling.

In most corporations, a foreign exchange crisis is handled in an atmosphere of panic—a last-minute estimate of potential loss is made, and some emergency financial juggling takes place. What has long been needed, and is needed today more than ever, is a systematic and analytical approach to selecting optimal "hedging policies" to minimize the risk (or extent) of loss from fluctuating foreign currency values.

Strategic hedging

A "hedging policy" is a financial strategy that protects a company's profits from injury they might receive through the devaluation of a national currency—it is insurance, in short. The corporate treasurer can develop such a strategy by counterbalancing such quantities as dollar financing, foreign currency loans, and the like, in his company's financing portfolio. (For a short list of instruments treasurers commonly use for international funding, refer to the ruled insert below.) If he has a solid strategy of this kind, the chances are that his company will emerge from a devaluation crisis in good health.

No doubt the whole procedure sounds tricky and formidable—and it is. But a relatively simple computer model has now been devised that lets the treasurer determine whether, when, and how he should hedge to obtain optimum protection for corporate investment and income in a foreign country.

This model has been tested under actual conditions and proved effective. For example, one major U.S. corporation could have saved over

Typical international transactions and their financing and hedging implications

Dollar financing: Credits repayable in U.S. dollars.

Foreign currency credits: Financing repayable in foreign currency, such as foreign bank loans, overdrafts, or other lines of credit.

Discounting or factoring of foreign bills or promissory notes: The borrowing technique by which the company draws a bill or note on its commercial bank (discounting); alternatively, the sale of receivables to a factor (factoring), which accelerates the conversion of foreign currency claims into cash.

Forward exchange contracts: The purchase of foreign currency at a given rate, for future delivery.

Financial swaps: Transactions in which equivalent amounts of dollars and foreign currencies are swapped for a given period, at the end of which both parties return the original amounts of each currency.

Arbi loans (International Interest Arbitrage Loans): Transactions that enable a company to increase financing in a scarce currency by supplementing it with capital from a country where money is abundant and cheap. (Money is borrowed in the cheap money market and simultaneously transferred to the tight money country, and a forward exchange contract is arranged that bears the same maturity as the loan itself.)

Here is a summary of the effects that these various transactions have:

	Cash availability	Net exposure
Dollar financing	Increases	No effect
Foreign currency credits	Increases	Decreases
Discounting or factoring	Increases	Decreases
Forward exchange contracts	No effect	Decreases
Financial swaps	Increases	Decreases
Arbi loans	Increases	Decreases

$1.3 million over a recent 16-month period. Hedging against devaluation of the Brazilian cruzeiro actually cost it $1.6 million. But it was subsequently shown that if the treasurer had used this model, he could have reduced the cost to $275,000 and maintained the same level of safety. The company now uses the model on a regular basis.

What the model does is generate a *selection* of hedging policies from which a treasurer can choose, ranging from very conservative to very aggressive. From these the treasurer can select one that fits his company's policy and his own temperament. The general technique can be adapted to take account of reevaluations, floating exchanges, wider bands, and crawling pegs, as well as common devaluations.

Exposure and devaluation

Depreciation of a national currency means that a company must write off its *net exposure* in that currency by the amount of the devaluation, and net exposure is therefore the key variable for the treasurer to consider in devaluation hedging. I define net exposure as the difference between a company's exposed assets and its exposed liabilities.

We speak of an asset or liability as being "exposed" when a currency fluctuation changes its dollar value. For example:

□ Suppose that a company recorded sales of 10 million French francs just prior to August 11, 1969. The dollar equivalent of these sales would have been calculated at the rate of $0.20255/franc—i.e., as $2,025,500. After the devaluation of August 11, the French franc was worth only $0.18004, and the receivable dollar value of the sales would have amounted to only $1,800,400. In this case, the company would have sustained a net loss on its exposed assets amounting to $225,100.

Accounts receivable in foreign currencies are the most obvious kind of exposed assets, but cash, bank deposits, and other current assets expressed in local currency are also vulnerable.

Exposed assets, however, are only one side of the coin. Devaluation has the opposite effect on an exposed liability—for example, fewer dollars are required to pay back a bank loan in French francs after a devaluation, and a company might realize a foreign exchange profit in such a situation. All accounts and notes payable in a foreign currency constitute exposed liabilities.

Note that the definition of net exposure which I am using here differs from definitions ordinarily used in accounting contexts. For example, the Accounting Research Bulletin #45 defines net exposure as net current assets (short-term assets minus short-term liabilities). This definition usually leads to overstatement of real devaluation losses. Again, in its pronouncement #36, the National Accounting Association views net exposure as net financial denominated assets, an approach that usually leads to understatement of devaluation losses.—*B.A.L.*

Once the treasurer has identified all the company assets and liabilities that are exposed to a foreign currency's fluctuation, he can calculate the company's net exposure. Now, the object of a hedging policy is to reduce net exposure to as close to zero as possible, so that what the company loses on devalued assets it makes up on revalued liabilities.

At times the treasurer may even be able to arrange his hedges so that the company has a *negative* net exposure; in such a situation the gain from revalued liabilities will exceed the loss on devalued assets, and the company will make a profit on the devaluation. This actually happens: on November 19, 1967, the European subsidiary of Xerox had a substantial negative exposure, and immediate devaluations gave it a foreign exchange profit of over $4,000,000. (On the same date, in contrast, Kodak had a large positive exposure and incurred a heavy loss.)

One practical difficulty in measuring net exposure is that some assets or liabilities cannot be readily classified as either exposed or nonexposed. The most important of these, by far, are inventories.

Succinctly, inventories of a product are exposed if a devaluation would cause the dollar replacement and dollar market values of these inventories to change in such a way that profit margins decrease. I have devised a method for analyzing their exposure, but this is not the place to discuss it in detail; rather, let's confine our attention to the funding variables that are under the direct control of the corporate treasurer.

It is quite difficult, even for a professional, to arrange a corporation's international financial transactions so that its investments are properly hedged, for several reasons.

Hedging forecasts are unreliable: The costs of financing and hedging programs vary and cannot be predicted with certainty. The effective

annual interest rate on local loans in Brazil, for example, can vary between 20% and 70%. The cost of a dollar bank loan raised in New York not only is lower, but varies within a relatively narrow range, perhaps 5% to 11%. The risk of making a large error in predicting the cost of a dollar loan is obviously smaller than that for a cruzeiro loan. Nevertheless, a Brazilian loan at 45% may sometimes be preferable to a U.S. loan at 6%, because the Brazilian loan decreases the net cruzeiro exposure of the company, while the dollar loan does not affect it. If the probability and the amount of a cruzeiro depreciation are both high, the Brazilian loan could turn out to be cheaper.

Foreign exchange controls are restrictive: The treasurer must consider such regulations as restrictions on repatriation of profits, ceilings on local borrowing power, multiple exchange rates, and limitations on the availability of swap or forward exchange contracts. In addition to satisfying the company's financial needs, a hedging policy must conform to the financial policies of the countries in which it operates.

Timing is critical: Ideally, the treasurer should do his hedging the day before a devaluation with full knowledge of the devaluation's extent. This is wholly impracticable, though, for two reasons: the exact date of a change in parity is usually a well-kept secret, and the costs of hedging can rise astronomically when a devaluation is imminent—it is too late or too expensive to hedge. The treasurer must plan his hedging policy well in advance of the fact.

The model for hedging that I shall describe naturally does nothing to improve the forecasts on which hedging must be based, nor can it help avoid restrictions. It can, however, alleviate the problem of timing. Also, by virtue of the fact that it allows the treasurer to consider all the relevant variables, including the uncertainty of some of the data, within the framework of company policy, the model has shown itself to be of great practical value.

Minimize cost & risk

The model I advocate for analyzing and solving the problem of hedging against devaluation identifies a whole set of hedging procedures, as I indicated before. Each procedure in the set minimizes the expected cost of hedging and maximizes the company's protection within the company's operational constraints.

In other words, each of the policies insures satisfactorily against loss for a price, but some policies involve lower cost and higher risk than others. The disposition of the company and the treasurer himself toward risk will determine which of the procedures in this set he adopts.

Expected costs are of two kinds:

1. The direct cost of the financing and hedging operations themselves.
2. The loss of profits that the expected devaluation will cause. (This quantity is the product of the amount of the devaluation and the net exposure.)

Reduction of expected costs is the model's first purpose, but it is also designed to maximize protection (or, equivalently, to minimize risk).

Any hedging procedure involves two risks. The first of these is associated with the devaluation itself; it is a combination of smaller risks resulting from the possibility of wrong estimates of (a) the *likelihood* of devaluation and (b) the *amount* of devaluation. This is the devaluation risk itself.

The second risk is the one that results from relying on future financing plans and on hedging possibilities for which the costs are uncertain: a company might not be able to get the swap it wants in six months' time, foreign interest rates may jump, and so forth. All uncertainty arising from sources other than the devaluation estimates themselves should be included in this category.

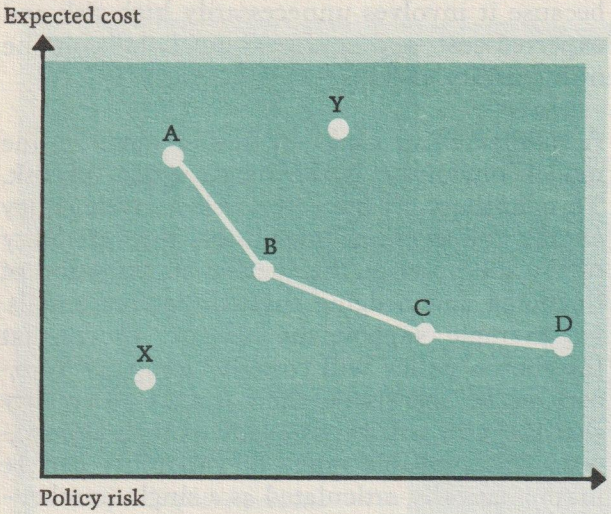
Briefly, the model helps the treasurer solve his hedging problem by minimizing both expected costs and policy risks, subject to all operational restraints.

The efficient frontier

A most important point is that there is not just one optimal solution to a company's devaluation-hedging problem, but an infinite set of optimal solutions. Technically speaking, the model considers a solution to be optimal whenever it cannot find any other policy that has the same expected costs with lower risk, or any other policy that has the same risk with lower expected costs.

At one extreme of the solution spectrum is the combination of financing and hedging decisions which primarily minimizes risks. The ex-

Exhibit II. Efficient frontier of optimal solutions



pected costs are usually very high for this policy (note Solution A in *Exhibit II*). At the other extreme, expected-cost minimization is the only concern, and policy risks are high (Solution D). Between these extremes, a theoretically infinite set of solutions exists (Solutions B and C are examples). As we move along the line of solutions from A to D, increasing weight is placed on expected-cost reduction at the expense of risk avoidance.

All the solutions along the spectrum are optimal, because each represents the best possible choice for a specific kind of person. The extreme conservative will pay almost any price to avoid uncertainty (as in Solution A), whereas the gambler is willing to take considerable risks to reduce expected costs (as in Solution D). Most businessmen find themselves somewhere in between. All the optimal solutions form an "efficient frontier," a term coined about 15 years ago by Harry M. Markowitz. Any solution not appearing on the efficient frontier (the line from A to D) is either unfeasible (like Solution Y) or suboptimal (like Solution X).

The model generates the efficient frontier of financing and hedging policies by introducing a parameter α which gives increasing weight to the expected costs. To take account of this parameter, the strategy for minimization should be restated as follows: subject to all operational restraints, the model minimizes both α times expected costs, and also policy risks.

The parameter α can vary from zero (risk is minimized as completely as possible, without respect to cost) to infinity (relatively complete expected-cost minimization, with little regard for risk). By altering the value of α, the computer determines all the optimal solutions on the efficient frontier.

Choosing among optimal solutions

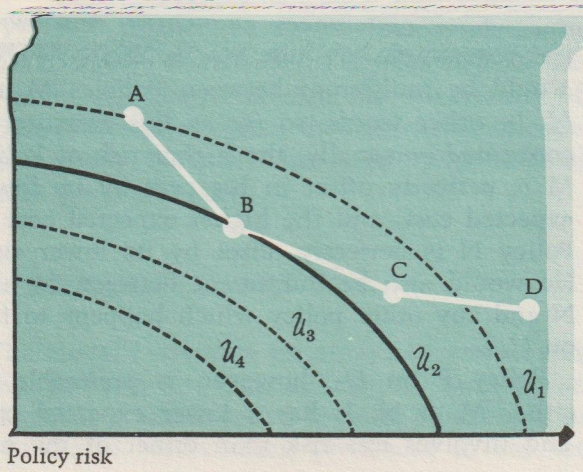
Once the model has generated the infinite set of optimal solutions to the company's hedging problem, the treasurer must pick out one solution to apply. Theoretically, the best way for him to do this is to use a "utility curve" (or possibly more than one) that reflects his own attitude toward risk versus cost.

A utility curve is simply the locus of the policies for which the trade-offs between expected cost and risk leave the treasurer indifferent in his choice. To understand this notion, imagine that you are buying fruit to fill a large bowl in the office reception area, and that you would like bright colors rather than dark colors. Aside from this single preconception, you are interested only in filling the bowl. For example, you don't really care whether you buy more oranges than bananas, but you probably will avoid buying many purple plums.

There are clearly many combinations that would satisfy your goal and your preferences—a utility curve is merely a graphic image that mathematically represents all the combinations that would satisfy you. Analogously, the treasurer has a goal and a preference—he wants to hedge securely, within company policy, and he will do so according to his own preconceptions about risk versus expenditure (bright versus dark in my analogy). There is a standard mathematical technique by which he can represent his predilections as a preference map of utility curves. The four curves U_1 through U_4 in *Exhibit III* constitute such a preference map.

Suppose that Policies M and N both fall on the same utility curve (U_1 in the exhibit) and that Policy P falls on another (U_3). The treasurer whose preferences about risk and cost are represented by this set of utility curves would be indifferent between Policies M and N. In other words, so far as this treasurer is concerned personally, the higher risk of Policy M is perfectly offset in his eyes by its lower expected cost; and the higher expected cost of Policy N is perfectly offset by its lower risk. He would also be indifferent between M and N and any other policy which happens to fall on U_1.

Policy P on U_3, however, is preferable to either M or N. It has a lower expected cost and involves less risk than either of the oth-



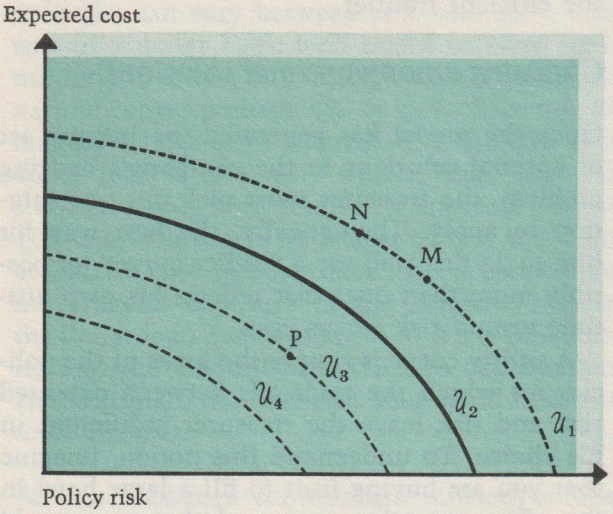
Policy risk

also be chosen—days, weeks, months, quarters, or whatever. One could choose, for instance, a planning horizon of three quarters, divided into monthly time units. The model would then use nine periods.

The second step is to forecast the probability of devaluation for each period, and make three estimates for the amount of the devaluation—the most likely, the maximum, and the minimum amount involved. These three estimates are used to take into account the variability of the devaluation amount, which will be part of the policy risk.

The only source of information on probabili-

Exhibit III. Sample utility curves



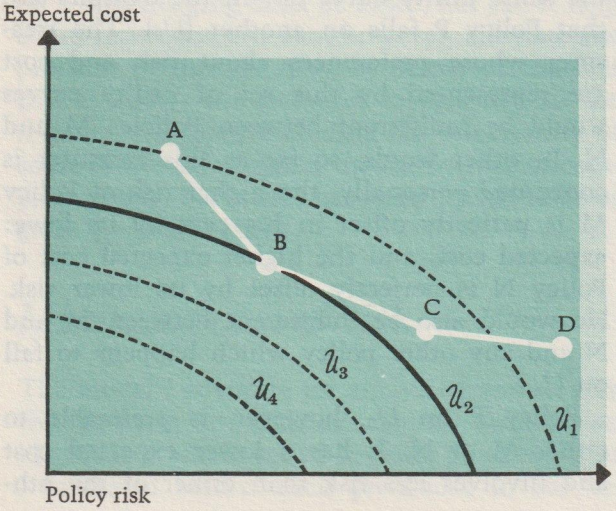
ers; and because it falls on a utility curve, it is acceptable to the treasurer. The direction of preferred choices logically lies toward lower risks and costs. Thus, any policy on U_3 would be preferable to any policy on U_1 (or U_2, for that matter).

By a preference map of this type, then, the treasurer can express his attitude toward risk and cost precisely.

Once the treasurer has both a graph of optimal solutions and a graph of his own preference pattern before him, he can find the optimal solution that pleases him very easily, just by superimposing the two graphs one on top of the other. This has been done in *Exhibit IV*.

The optimal policy for this particular treasurer is the one which falls on the utility curve corresponding to his highest preference. Thus B is the best possible solution to this treasurer's

Exhibit IV. Efficient frontier and utility curves



hedging problem. Policy A is not in the running, because it involves unnecessarily high risk and expected cost; and neither C nor D falls on one of his utility curves.

A mathematical aside: A key element in the model, obviously, is the measurement of risk. To quantitatively state the risk a given policy entails, the treasurer must assess the variability of the total cost of the specific combination of financing and hedging that this policy entails. For example, suppose the treasurer thinks that his chosen policy will cost the company $750,000, but he also thinks there is a .05 probability that this cost will vary upward as high as $800,000. This probable range of variability can be mathematically articulated as a single number—$25,000—the standard deviation.

How this is calculated does not concern us here, but I might note that the calculations involve squared numbers, or quadratic expressions. Accordingly, the optimization technique uses quadratic programming, a fact that may be of interest to the initiated.

I might also note that inasmuch as the parameter α is present, the complete solution technique uses parametric quadratic programming.

Information requirements

The data required to use the model are numerous and detailed (see *Exhibit V*). However, even a "back of the envelope" solution to a hedging problem should account—informally to be sure—for each group of data used in the model.

First, the planning horizon should be determined. The length of the planning period depends on many factors, such as necessity, maturity periods of the decisions involved, and reliability of forecast data. The time units should also be chosen—days, weeks, months, quarters, or whatever. One could choose, for instance, a planning horizon of three quarters, divided into monthly time units. The model would then use nine periods.

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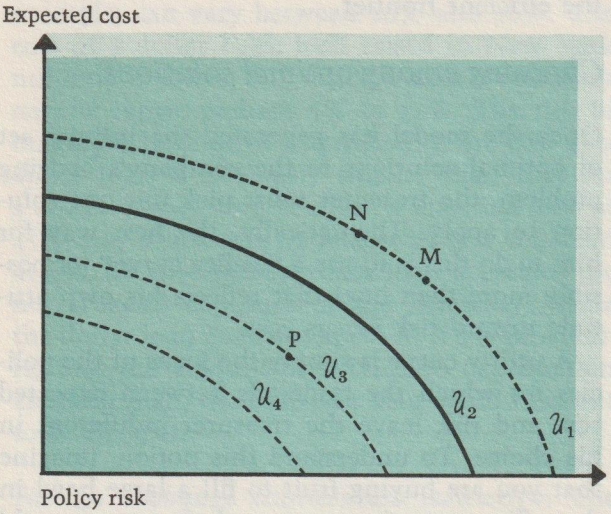

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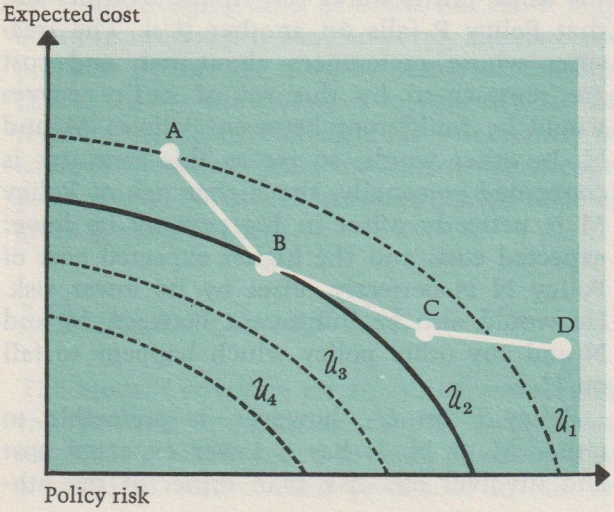

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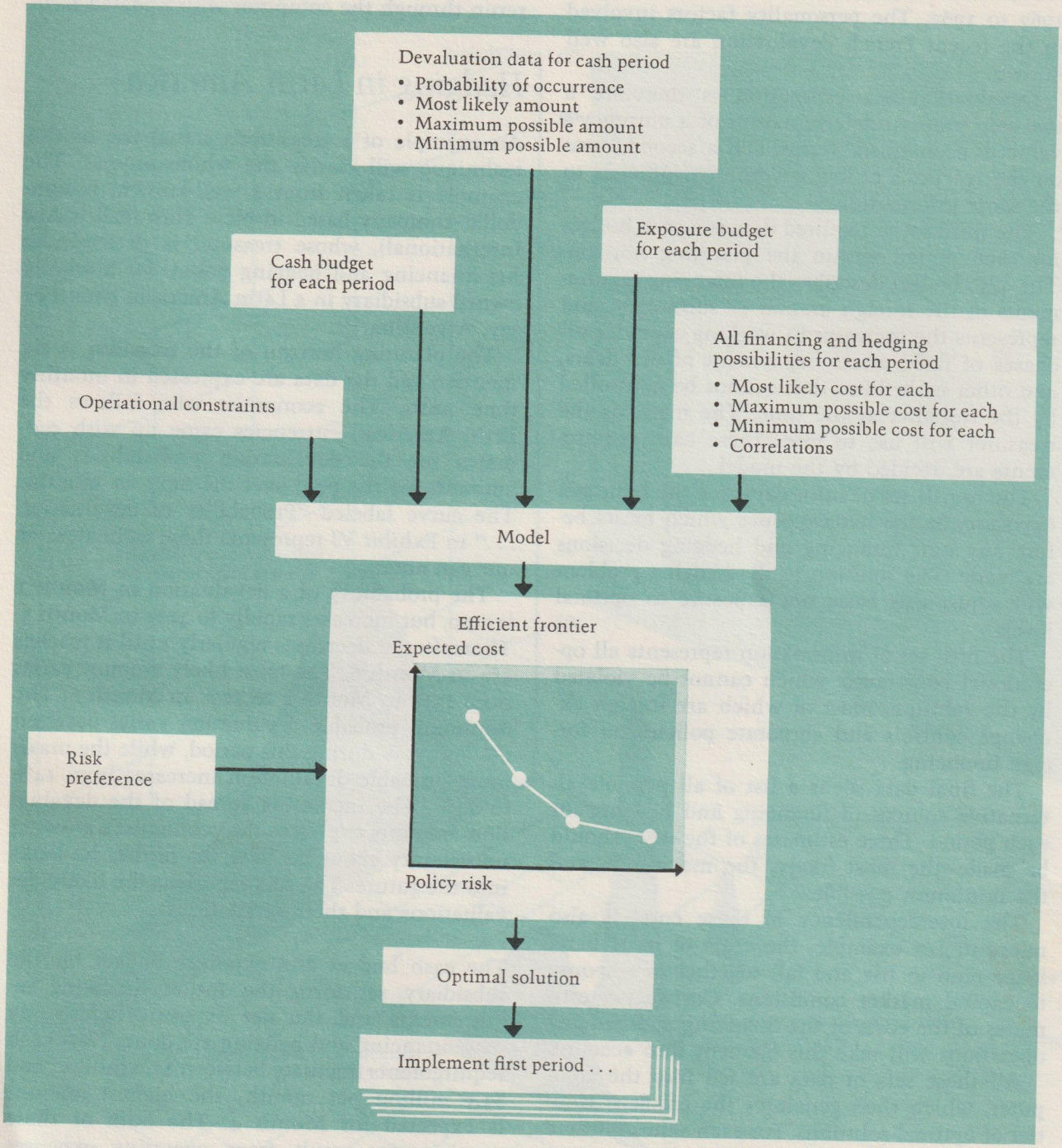
Exhibit V. Integral elements of the model



ties and amounts of devaluation is sophisticated guesswork. After studying the balance of payments, inflation, the history of central bank reserves, and external public-debt position, economists can fairly well determine whether a country *should* change its parity.[1] However, the critical factor in this step is to guess whether the government will actually do what economists think it ought to. Personality factors or political implications are key ingredients in foreign exchange decisions: Britain delayed the necessary exchange rate changes from 1964 to 1967

1. See Peter Lieftinck, *External Debt and Debt-Bearing Capacity of Developing Countries* (Princeton, New Jersey, Princeton University, International Finance Section, March 1966); Paul Einzig, *Foreign Exchange Crisis* and *Leads and Lags* (New York, The Macmillan Company, 1968); David B. Zenoff and Jack Zwick, *International Financial Management* (Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 1969); and Richard D. Robinson, *International Business Policy* (New York, Holt, Rinehart and Winston, 1964).

for electoral reasons, as did West Germany from 1967 to 1969. The personality factors involved in the recent French devaluation are also well known.

Devaluation-data estimation is therefore a two-step process: determination of a currency's value in economists' terms, and a second guess on the reactions of key government officials to the same information.

The third set of required data is a cash budget for each period within the planning horizon. The cash budget describes the financing requirements of the foreign branch or subsidiary, and represents the increases in working capital, purchases of fixed assets, repayment of old debts, and other cash flows that cannot be controlled by the treasurer at the time. The methods the treasurer will use to meet these cash requirements are decided by the model.

The fourth set of information is the basic net exposure, or the net exposure which exists before any new financing and hedging decisions are made. The solution to the hedging problem will adjust this basic net exposure to optimal levels.

The fifth set of information represents all operational constraints which cannot be violated by the solution, most of which are foreign exchange controls and corporate policies on foreign financing.

The final data set is a list of all possible alternative sources of financing and hedging for each period. Three estimates of the costs should be made—the most likely, the maximum, and the minimum possible.

The interdependency of these costs is also relevant. For example, the costs of most bank loans tend to rise and fall together in response to capital market conditions. Correlation estimates of the costs of the financing and hedging operations will take this element into account.

All these sets of data are fed into the computer, which then generates the efficient frontier of optimal solutions. For each solution there will be a total expected cost (devaluation costs plus financing and hedging costs) and the corresponding risk.

Each policy is described in complete detail, including a list of the amounts and kinds of financing to be accepted throughout the total period of each financing and hedging procedure, and a schedule of implementation. The treasurer chooses the policy which fits his cost/risk trade-off by utility curves, and implements his decision for the first period. If any of his estimates must be revised, the problem must be rerun through the computer with updated facts.

Hedging in Latin America

An example of a treasurer's actual use of this technique will clarify the whole process. The example is taken from a well-known, billion-dollar company based in New York (call it Ace International), whose treasurer is determining his financing and hedging policy for a wholly owned subsidiary in a Latin American country—say, Argentina.

The planning horizon of the treasurer is six months, and the data are expressed in monthly time units. The economist who follows the Latin American currencies came up with estimates for the devaluation probabilities and amounts for the peso over the next six months. The curve labeled "Probability of devaluation . . ." in *Exhibit VI* represents these estimates. As one can note:

The probability of a devaluation in Month 1 is zero, but increases rapidly to 40% in Month 3. Thereafter, it decreases regularly until it reaches 5% in Month 6. The most likely amount varies from 13% in Month 2 to 18% in Month 6. The minimum probable devaluation varies between 9% and 15% during this period, while the maximum probable devaluation increases from 14% to 24%. The increasing spread of the devaluation amounts expresses the economist's growing uncertainty about his data the farther he looks into the future. The fins represent the likely devaluations and their variabilities.

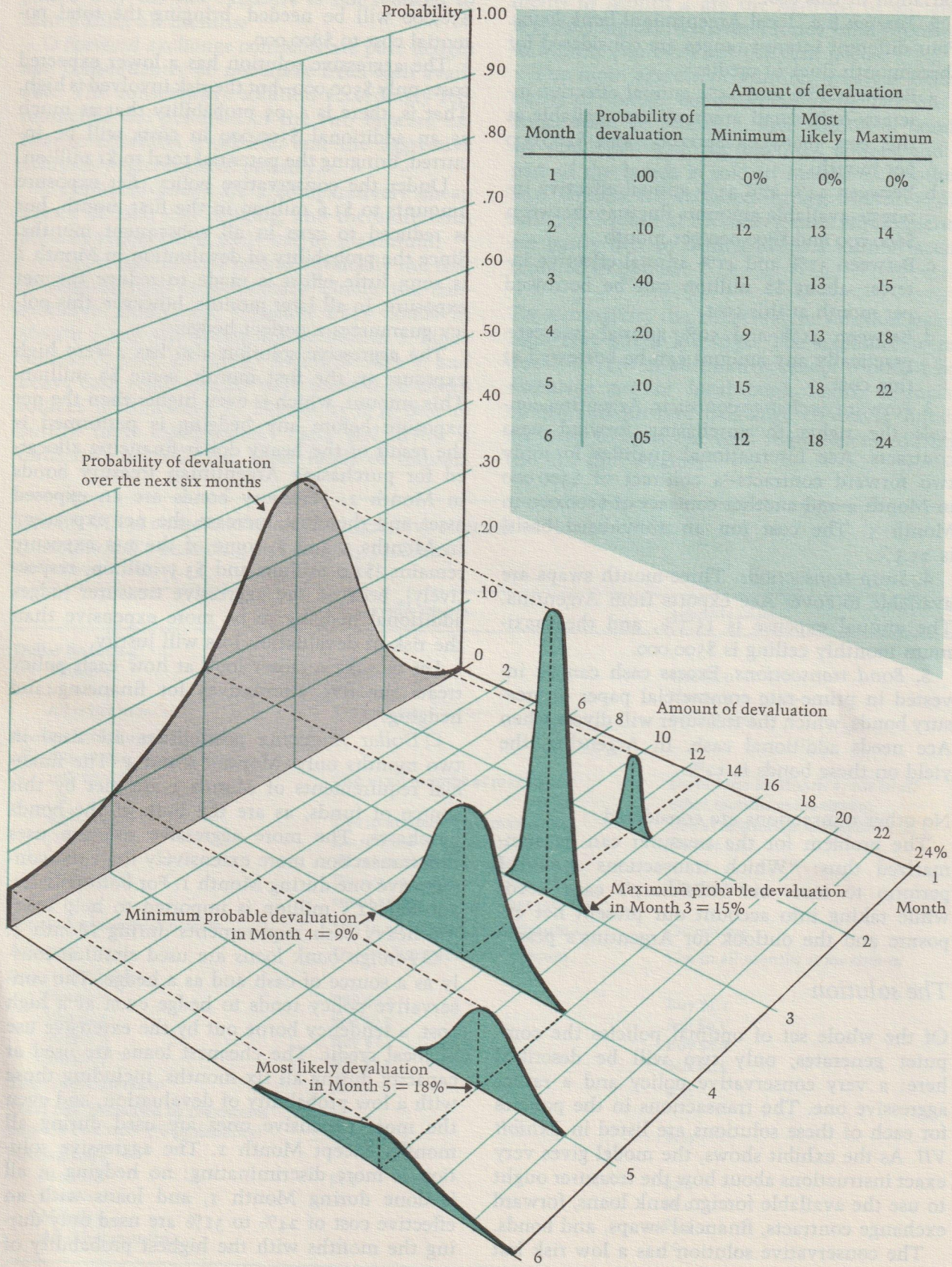
The cash budget and exposure budget for the subsidiary set forth the future financing requirements and the net exposure before any new financing and hedging are done. New cash requirements fluctuate between $1.0 million and $3.5 million per month; the highest amount is expected for Month 4. The bulk of these requirements result from operating expenses and from repayments of old debts. The exposure budget rises steadily from $1.5 million next month to $6.0 million during Month 6. Ace has a policy of not speculating on foreign exchange, and the net exposure will therefore never be negative.

The treasurer has five different types of financing and hedging transactions available from which to choose:

1. *Straight dollar financing.* The effective an-

Exhibit VI. Probabilities and amounts of devaluation of the Argentinian peso, Month 1 through Month 6

Month	Probability of devaluation	Amount of devaluation		
		Minimum	Most likely	Maximum
1	.00	0%	0%	0%
2	.10	12	13	14
3	.40	11	13	15
4	.20	9	13	18
5	.10	15	18	22
6	.05	12	18	24



nual cost of a loan in the United States is assumed to be 11.1%, with a comparatively low variation in this cost.

2. *Foreign* (i.e., local Argentinian) *bank loans.* Four different interest ranges are considered for three-month lines of credit:

a. Between 20% and 24% annual effective interest—only small amounts are available at this cost (between $200,000 and $400,000 per month).
b. Between 24% and 31% annual effective interest—available amounts fluctuate between $600,000 and $800,000 per month.
c. Between 31% and 41% annual effective interest—about $2 million can be borrowed per month at this cost.
d. Between 41% and 50% annual interest—practically any amount can be borrowed at this cost.

3. *Forward exchange contracts.* Argentina controls the rights to purchasing forward peso contracts. Ace International qualifies for only two forward contracts—a contract of $300,000 in Month 4 and another contract of $600,000 in Month 5. The cost (on an annualized basis) is 25.5%.

4. *Swap transactions.* Three-month swaps are available to cover Ace exports from Argentina. The annual expense is 15.3%, and the maximum monthly ceiling is $500,000.

5. *Bond transactions.* Excess cash can be invested in prime-rate commercial paper or treasury bonds, which the treasurer will divest when Ace needs additional cash. In Argentina, the yield on these bonds is 12%.

No other transactions are considered.

The problem for the treasurer can be summarized thus: "Which transactions should I perform to meet our subsidiary's cash needs while taking into account our present net exposure and the outlook for Argentina's peso?"

The solution

Of the whole set of optimal policies the computer generates, only two will be described here: a very conservative policy and a rather aggressive one. The transactions in the policies for each of these solutions are listed in *Exhibit VII.* As the exhibit shows, the model gives very exact instructions about how the treasurer ought to use the available foreign bank loans, forward exchange contracts, financial swaps, and bonds.

The conservative solution has a low risk but a high expected cost—$750,000—for all financing and hedging during the six months. The risk is low—there is a .05 probability that an additional $50,000 will be needed, bringing the total potential cost to $800,000.

The aggressive solution has a lower expected cost—only $500,000—but the risk involved is high. That is, there is a .05 probability that as much as an additional $500,000 in costs will be incurred, bringing the potential total to $1 million.

Under the conservative policy, net exposure amounts to $1.6 million in the first month, but is reduced to zero in all subsequent months. Since the probability of devaluation in Month 1 is zero, little effort is made to reduce the net exposure. In all later months, however, this policy guarantees a perfect hedge.

The aggressive solution also has a very high exposure in the first month, some $2 million. This amount, which is even higher than the net exposure before any hedging is performed is the result of the heavy dollar financing allocated for purchasing Argentinian treasury bonds in Month 1. (Treasury bonds are an exposed asset and therefore increase the net exposure.) In Months 2 and 6, some of the net exposure remains ($1.0 million and $3.5 million, respectively), because the aggressive treasurer judges additional hedging to be more expensive than the risk of devaluation loss will justify.

Let us take a closer look at how each policy treats the five alternatives for financing and hedging:

☐ *Dollar financing* possibilities are used in two months only—Months 1 and 4. The financial requirements of Month 1 are met by this source of funds, as are the bulk of the bonds purchases. The more aggressive solution uses this transaction more extensively than the conservative one during Month 1. For both policies, another $1.5 million is imported to help meet the heavy cash requirements during Month 4.

☐ *Foreign bank loans* are used simultaneously as a source of cash and as a hedge. The conservative policy tends to hedge even at a high cost, a tendency borne out by the extensive use of local credit. The cheapest loans are used at capacity during all six months, including those with a low probability of devaluation, and even the more expensive ones are used during all months except Month 1. The aggressive solution is more discriminating: no hedging at all is done during Month 1, and loans with an effective cost of 24% to 31% are used only during the months with the highest probability of

devaluation—namely, 3, 4, and 5. It completely disregards the more expensive hedges, which explains why the net exposure is not reduced to zero during all months.

☐ *Forward exchange contracts* are pure hedges and consequently do not make fresh cash available. The conservative solution accordingly recommends the purchase of the two forward exchange contracts available, and the aggressive solution neglects them entirely.

☐ *Financial swaps* are a comparatively cheap source of cash and hedging, and therefore both policies recommend their use at maximum.

☐ *Bond transactions* perform basically the task of leveling cash requirements. Under the conservative policy, the treasurer buys bonds in Month 1 and sells them during Month 2. Since sources of cash are cheap during Month 1, and heavy cash requirements have drained all cheap sources of financing in Month 2, it is best to borrow more cheap money early and invest it until it is needed. The same kinds of transactions occur on a larger scale during Months 3 and 4, for similar reasons. The cash requirements of Month 4 are the heaviest of all, and it is thus logical to channel funds from Month 3 to Month 4 to even out the cash needs.

The more aggressive solution involves essentially the same bond transactions, but on a larger scale. In Month 1, $1.1 million of bonds are purchased with the imported dollars, and a part of the bonds is sold in Month 2. Another $0.8 million are acquired during Month 3. Finally, in Month 4, the heavy cash requirements are partly met by selling all $1.4 million accumulated in bonds.

To summarize, the conservative solution has a high cost but a low risk. The exposure is reduced to zero in all months except Month 1 by extensive use of local bank loans, financial swaps, and forward exchange contracts. Bonds are used to level out cash requirements during the first four months.

Exhibit VII. A conservative and an aggressive solution to Ace International's financing and hedging problem
[Dollar figures in millions]

	Conservative solution	Aggressive solution
Dollar financing		
Month 1	Use $1.0	Use $2.0
Month 4	Use $1.5	Use $1.5
All other months	Do not use	Do not use
Foreign bank loans with these effective annual interest rates:		
20% to 24%	Use in all months at maximum	Do not use in Month 1; use in all other months at maximum
24% to 31%	Use in all months at maximum	Use at maximum in Months 3, 4, 5
31% to 41%	Do not use in Month 1; use in all other months at maximum	Do not use
41% to 51%	Do not use in Month 1; use in small amounts in all other months	Do not use
Forward exchange contracts	Use in all months at maximum	Do not use
Financial swaps	Use in all months at maximum	Use in all months at maximum
Bond transactions		
Month 1	Buy $0.5	Buy $1.1
Month 2	Sell $0.5	Sell $0.5
Month 3	Buy $1.1	Buy $0.8
Month 4	Sell $1.1	Sell $1.4
Total expected costs	$0.75	$0.5
Total risk (measured by maximum possible cost with 5% probability)	$0.8	$1.0
Net exposure		
Month 1	$1.6	$2.0
Month 2	0	$1.0
Month 6	0	$3.5
All other months	0	0

The more aggressive solution carries more risk, but it offers a lower expected cost. It relies more heavily on dollar financing, and disregards all the more expensive hedges. The resulting exposure is therefore considerable during the months in which probabilities of devaluation are low. Bond transactions are used more extensively than in the conservative solution.

These solutions are only two of the many on the entire efficient frontier. The conservative solution could correspond to Policy B shown earlier in *Exhibits II* and *IV*, while the aggressive solution could be Policy C. The treasurer picks his solution, once again, by using utility curves. After choosing, he implements all the relevant recommendations for Month 1. Then, if he still has confidence in his estimates at the beginning of Month 2, he implements the model's recommendation for that time unit of the planning period. If he has reason to doubt some of his key estimates, he simply runs the problem through the computer once again.

Model works in other crises

Most foreign exchange crises are devaluation problems, but, as demonstrated by the recent history of the German mark, other types of crises can occur. The model can readily be adapted to handle reevaluations, which are merely negative devaluations.

There is more and more discussion of reforming the international monetary system. The present system obliges governments to keep the value of their currencies within a range of 1% on each side of the official parity with dollars. If the currency fluctuates beyond this margin, an official reevaluation or devaluation is deemed necessary.

This system has been attacked increasingly for its lack of flexibility, and a range of alternative solutions are being considered. The least ambitious would allow the use of a wider range of deviation from the official parity—for example, currencies could be allowed to fluctuate freely within 5% on either side of their dollar parity. The current literature describes this reform as the "wider band" proposal.

A slightly more aggressive reform, described as the "crawling peg," would allow a currency to change parity by a small percentage over specified periods of time (e.g., every month). Formal devaluations or reevaluations would disappear, for the cumulative change over several years would allow the value of currencies to be adjusted by large percentages.

The most drastic solution is the floating exchange, to which the Germans resorted temporarily in 1969. Under this system, the value of the currency fluctuates freely in the open market.

The basic model described here for devaluations in the present monetary system has been adapted and tested for all these possible reforms. The technique would not be outdated by any of these new monetary systems.

Conclusion

The developments reported here constitute one of the first applications of management-science techniques to problems in international finance. They have proved useful in helping management to systematically protect foreign income and investment against currency fluctuations.

As with all management tools, this model cannot replace the experienced decision maker. It does, however, help him by providing a firm basis for choosing financing and hedging policies. The model guarantees that all relevant information and assumptions are consistently taken into account. It also spells out the cost and risk implications of each policy, and the precise kinds, amounts, and timing of all the transactions a manager should perform to follow these policies.

This approach has proved extremely effective in reducing hedging costs and controlling foreign exchange risks. It has been adapted to handle a variety of foreign exchange crises—devaluations and reevaluations under the present monetary system, as well as the fluctuations under the alternative monetary systems currently discussed in foreign exchange circles. The approach also seems to have great promise for handling other international finance problems, particularly in protecting against inflation and the hazards of political risk.

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