Notes on Bernard Lietaers Master Thesis "Financial Management of Foreign Exchange"

(Jürgen Godau, 2020)

Using the activities of an international trading group as a case study, Lietaer analyzed the organization's financing processes, particularly currency fluctuations and devaluations. The financing of activities such as production and sales over long periods was a specific problem for US companies at that time. If money was invested too early to enable the payment of materials or wages abroad and in the meantime a devaluation of the national currency took place, this meant a direct loss. On the other hand, in such a scenario, it might be advantageous to take out a loan in the local currency, since repayment after a devaluation could lead to a gain. Overall, the costs (interest, fees, etc.) and external restrictions (financial market regulations) had to be considered as well as the financial planning and the company's available funds. The objective is always to determine a strategy that minimizes the anticipated losses (or maximizes profits) taking into account the existing conditions and anticipated currency fluctuations.

Solution Approach

Lietaer divides the problem into three areas:

1. *Expected costs*. These are composed of costs for financial transactions and losses due to a change in exchange rate.
2. *Strategic risk*. This consists of the business risk: the risk posed by unpredictable costs for financing and hedging. This includes all costs not caused by exchange rate fluctuations.
3. *Operational constraints*. These include forecasted needs at specific points in time, legal conditions and company policy decisions.

In Lietaer‘s formulation, risk is measured with the help of the variance (spread) of a value around the expected value (assumed value). The problem can be defined mathematically as the task of minimizing the expected cost$) -$ of risk. The *expected costs* result in a linear equation. The value L is the weighting of the costs opposite the risk, a quadratic expression. The value L is used to determine the one which corresponds to the management‘s propensity for risk from the "infinite" set of possible solutions; it "parameterizes" the problem. If $L = 0$, the riskiest strategy with the highest possible profit is used, if L goes against infinity, the strategy with the lowest risk is used. The method for solving such a problem is called quadratic programming (quadratic optimization). The variance of the underlying random variables is used as a measure of the risk:

$$\text{variance of } \tilde{X} = V(\tilde{X}) = E[\tilde{X} - E(\tilde{X})]^2$$

In the case of currency fluctuations, Lietaer assumes a normal distribution and uses the most probable value Z, the highest possible value A and the lowest assumed value B to determine the variance. Classical probability theory yields $E = [2Z + (A + B)/2]/3$ the expected value and $V = [(B - A)/6]^2$ as the variance of the associated random variables. With the help of the standard deviation $S = \sqrt{V}$, probabilities for possible value ranges can be specified, for example the probability that the actual value deviates by more than the standard deviation upwards or downwards from the expected value is approx. $1/6$. Assuming a non-normally distributed variable with two parameters, *Chebyshev's inequality* still applies for a sample $\tilde{x}$ with mean $\tilde{x}$ and variance S^2:

$$\text{Probability } (|\tilde{x} - \hat{x}| \geq e) \leq S^2/e^2$$

If variance is used as a measure of risk, either (a) a normal distribution must be used or (b) the risk management preference curve must be a quadratic function. As Lietaer deduces from existing literature, condition (a) is rarely met, since most distributions are bimodal; therefore, condition (b) must be met.

The problem posed by currency fluctuations in the financial planning of companies has already been addressed in the literature as portfolio selection, but the usual procedures were based on a one-time decision. Lietaer describes this as the *unitemporal model*. His new model, on the other hand, is *multitemporal*, i.e. the strategy in his model covers several time periods and is adapted to the previous course in each case.

Figure 1 shows input and output values of the model:

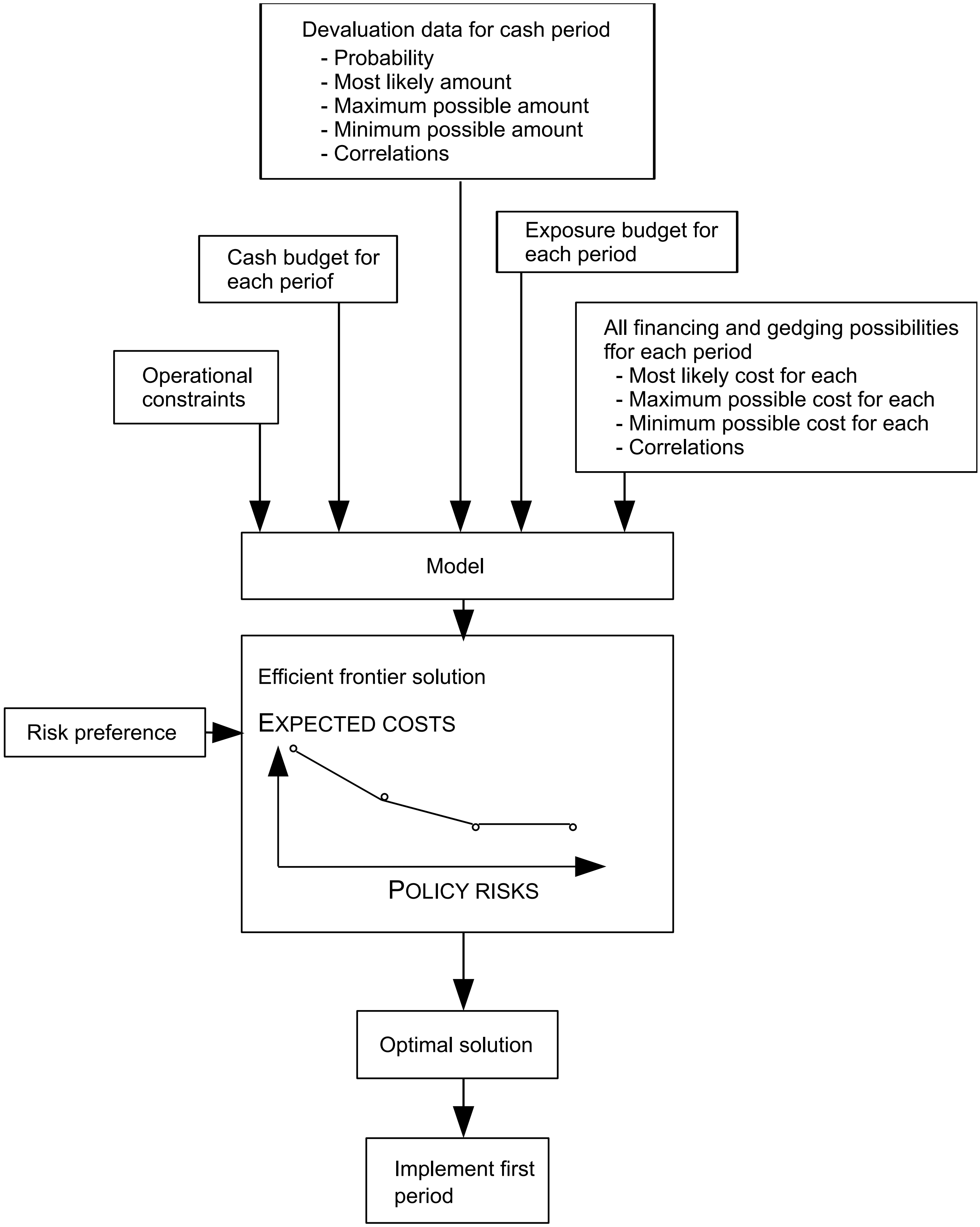

Fig. 1; Inputs and Outputs of the Model

The unitemporal model

Lietaer introduces the *unitemporal model* as the basis of his model. This model is based on the portfolio selection approaches of Markowitz[2] and Sharpe[3]. He extends their approaches by creating mixed probability distributions and (see multitemporal model) splitting them into multiple time periods.For the *i*-th asset or liability he defines the return as
$R_i = A_i + \tilde{C}_i + B_i\tilde{d}(W + \tilde{C}_D)$

The following applies:

- R_i = Return on asset *i* in constant dollars
- A_i = expected yield on asset *i* local currency without a devaluation
- $\tilde{C}_i$ = random variable with a mean of zero and a variance *V*; (expresses nondevaluation uncertainties).
- B_i = Proportion of Asset *i* vulnerable to a devaluation ($-A_i \leq B_i \leq +A_i$)
- $\tilde{d}$ = Random variable random variable
  = 0 if a devaluation does not occur
  = 1 if a devaluation occurs
- P = $P(\tilde{d} = 1) =$ Probability of a devaluation
- D = devaluation amount = $W + \tilde{C}_D$
- W = expected devaluation amount
- $\tilde{C}_D$ = Random variable with a mean of zero and a variance V_D (expresses uncertainty as to the evaluation amount)
- N = Number of asset and liability variables

The difference between *assets* and *liabilities* is that for an *asset*: $A_i > 0$ applies as well as $B_i < 0$; for a *liability*, the signs are reversed $B_i = 0$, meaning that the asset/liability in question is not affected by a change in exchange rates. When the part of the *i*-th asset

2 Harry M. Markowitz, „Portfolio Selection", *The Journal of Finance*, Vol. 7, No. 1 (March 1952), pp. 77-91; Harry M. Markowitz, *Portfolio Selection: Efficient Diversification of Investments*, Cowles Foundation Monograph No. 16, (New York: John Wiley \& Sons, 1959)

3 William Sharpe, `"A Simplified Model for Portfolio Analysis", *Management Science*, Vol. 9, No. 2, (Januar 1963), pp. 277-293.

used is designated (these values determine the composition of the portfolio), the result of a portfolio is

$$R = \sum_{i=1}^{N} X_i(A_i + \tilde{C}_i) + \sum_{i=1}^{N} X_i B_i \tilde{d}(W + \tilde{C}_D)$$

where $X_{N+1} = -\sum_{i=1}^{N} X_i B_i$ indicates the „net exposure" to a devaluation. This includes the expected value

$$A_{N+1} = E(\tilde{d})W + E(\tilde{d})E(\tilde{C}_D)) = PW$$

The expected value of a portfolio or hedging strategy is thus

$$E = \sum_{i=1}^{N+1} X_i A_i$$

the variance is

$$V = \sum_{i=1}^{N+1} X_i^2 V_i + \sum_{i=1}^{N} \sum_{j=1}^{N} X_i X_j cov(\tilde{C}_i \tilde{C}_j) \text{ where } i \neq j$$

The Markowitz model is used to determine the covariances (see above).

Optimal solutions are guaranteed by the condition

$$\text{Maximize } Z = LE - V$$

where

$L =$ Parameters with a value from 0 to ∞,

$$E = \sum_{i=1}^{N+1} X_i A_i,$$

$$V = \sum_{i=1}^{N+1} X_i^2 V_i + \sum_{i=1}^{N} \sum_{j=1}^{N} X_i X_j cov(\tilde{C}_i \tilde{C}_j)$$

with $i \neq j$ and $X_i \geq 0, \quad i = 1, ..., N$ and $X_{N+1} = \sum_{i=1}^{N} X_i B_i$

For each value of the parameter L there is an optimal solution. L indicates the risk willingness of the financial manager. $L = 0$ stands for minimum risk, $L = \infty$ for maximum risk. For each value of L an optimal strategy can be determined. To decide on the strategy to be used, the expected utility theory, founded by Daniel Bernoulli in 1738, is recommended[4]. Lietaer argues that for the final choice of a strategy the specification of a maximum loss with a certain probability can be helpful, since otherwise there are as many optimal solutions as desired.

The multitemporal model

Lietaer developed the multitemporal model out of the unitemporal model. This model offers the most important new contribution of his master thesis to portfolio strategy in the area of currency fluctuations. Here, the entire period for which a strategy is needed is broken down into several consecutive time spans with the strategy is adjusted after each, taking into account the currency fluctuations that have occurred up to that point. It is therefore not fixed for the entire period. Based on Orgler's[5] multitemporal model, Lietaer innovates by including the addition of not only the variances (as a measure of the risk) of the individual periods, but also the covariances in order to take the mutual nature of the decisions into account. For the multitemporal model, this results in:

maximize $$Z = L\sum_{k=1}^{T} E_k - \sum_{k=1}^{T} V_k - \sum_{k=1}^{T}\sum_{m=1}^{T} C_{km} X_{N+k} X_{N+m} - \sum_{k=1}^{T}\sum_{m=1}^{T}\sum_{i=1}^{N}\sum_{j=1}^{N} X_{ik} X_{jm} cov(\tilde{C}_{ik}\tilde{C}_{jm}) \qquad (k \neq m, i \neq j)$$

where

$$E_k = \sum_{i=1}^{N} X_{ik} A_{ik} + X_{N+k} A_{N+k} \qquad k = 1, \ldots, T$$

$$V_k = \sum_{i=1}^{N} X_{ik}^2 V_{ik} + X_{N+k}^2 V_{N+k} + \sum_{i=1}^{N}\sum_{j=1}^{N} X_{ik} X_{jk} cov(\tilde{C}_{ik}\tilde{C}_{jk}) \qquad k = 1, \ldots, T : i \neq j$$

under the conditions

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4 Milton Friedman & Leonard Savage, „The Utility Theory of Choices Involving Risk,"" *The Journal of Political Economy* Vol. LVI, Nr. 4 (August 1948), pp. 279-304.
J. Hirshleifer, „Investment Decisions under Uncertainty: Choice-Theoretic Approaches," *The Quarterly Journal of Economics* Vol. LXXIX, Nr. 4, (November 1965), pp. 505-536

5 Yair Orgler, „An Unequal-Period Model for Cash Management by Business Firms," *Federal Deposit Insurance Corporation*. Lecture from the TIMS/ORSA Joint Meeting, San Francisco, California, Mai 1968

$$X_{ik} \geq 0 \text{ as well as } X_{N+k} = \sum_{i=1}^{N} X_{ik}^2 B_{ik} \qquad k = 1, \ldots, T$$

Here E_k, V_k, C_{km}, B_{ik} represent the expected value, variance, covariance and affected portion in the time period $1 \leq k \leq T$asset $1 \leq i \leq N$. X_{N+1} corresponds to that same variable from the uni-temporal model, related to the time period.

It is also shown that in the case of free exchange rates, the random variables $\tilde{d}_i$ are omitted and instead the case of "no exchange rate change" is represented by the probability $\tilde{C}_{ik}$ distribution for the asset $1 \leq i \leq N$and the period $1 \leq k \leq T$ and its value for 0, where the expected value 0 is no longer mandatory.
There are some examples for the application of the model in the master‘s thesis, but they are difficult to understand because the program Lietaer worked with (on the IBM 360 mainframe) is not readily available.