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**A systemic rule for investment decisions: generalizations of
the traditional DCF criteria and new conceptions**

by

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**A SYSTEMIC RULE FOR INVESTMENT DECISIONS:
GENERALIZATIONS OF THE TRADITIONAL
DCF CRITERIA AND NEW CONCEPTIONS**

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ABSTRACT. This paper radically changes the cognitive perspective financial mathematics adopts in dealing with decision processes. In particular, this work proposes a rule for investment appraisal which is a generalization of both the classical net-present-value (NPV) rule and the adjusted-present-value (APV) rule in more than one sense. To this end an accounting-like approach is used, where accounts have monetary (cash) values. New conceptions arise when adopting a systemic perspective: Far from being only a formal generalization of two capital budgeting criteria, the paper especially aims at showing that the cognitive framing of the decision-making processes followed by financial mathematics is myopic and that the epistemologic consequences (such as multidimensionality of objective) of a different description of an investment are significant for the decision-making process the economic agent is involved in.

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INTRODUCTION

The paper is ideally divided into two parts: The first one comprehends the formal presentation of the proposal, the second one shows the epistemologic assumptions that generate it. The paper is structured as follows: In the first section of the first part I briefly remind the traditional discounted cash flows (DCF) methods, namely the net-present-value (NPV) rule and the adjusted-present-value (APV) rule. The second section is concerned with the presentation of the *systemic* rule. Subsequently it is shown that the traditional DCF rules are merely particular cases of the *systemic* rule. The fourth section presents a simple example of a project appraised by means of the three rules, in order to improve understanding of the new rule, and the fifth one presents some remarks on applicability of the criterion proposed. The second part is concerned with epistemologic speculations: They shed lights on the relations between accounting and investment decisions, and other conceptions are sketched under eight types of generalization. Some remarks are made on the cognitive framing of the problem, then drawbacks of the systemic rule are briefly discussed. A summary and some final remarks conclude the paper.

1. FORMALIZATION

1.1 THE NPV RULE AND THE APV RULE

Consider a nondeferrable project with certain cash flows $\alpha_s \in \mathbb{R}$ at the maturities t_s , $s = 0, 1, \dots, n$. Let E_0 be the worth of the investor's wealth at time t_0 . The NPV rule states that the investor should undertake the investment iff

$$(E_0 + \alpha_0)(1 + i)^{T-t_s} + \sum_{s=1}^n \alpha_s (1 + i)^{T-t_s} > E_0 (1 + i)^T \quad (1)$$

where $T \geq n$ is a fixed horizon. Dividing both sides by $(1 + i)^T$ we get

$$\sum_{s=0}^n \alpha_s (1 + i)^{-t_s} > 0. \quad (1\text{bis})$$

The rate i is called the opportunity cost of capital. The NPV rule rests on the assumption that the investor can invest in a (liquid) “business” any time she needs at a rate i and that she can as well raise funds from the same business at the same rate i .

Suppose now that part of the project is financed by a creditor at a rate δ , and that the cash flows of this financing are $f_s \in \mathbb{R}$ at the maturities t_s , $s = 0, 1, \dots, n$. The APV rule states that the investor should undertake the investment iff

$$(E_0 + \alpha_0 + f_0)(1 + i)^{T-t_s} + \sum_{s=1}^n (\alpha_s + f_s)(1 + i)^{T-t_s} > E_0(1 + i)^T \quad (2)$$

or

$$\sum_{s=0}^n (\alpha_s + f_s)(1 + i)^{-t_s} > 0 \quad (2\text{bis})$$

where it is supposed that

$$\sum_{s=0}^n f_s(1 + \delta)^{-t_s} = 0.$$

In general, if the project is partially financed by $m > 1$ creditors, (2) is generalized by replacing f_s with $\sum_{l=1}^m f_{sl}$, where $f_{sl} \in \mathbb{R}$ is the cash flow withdrawn from or reimbursed to creditor l .

If the opportunity cost of capital changes over time, the investor applies a financial law $\Phi(t_n, t_s)$ such that

$$\Phi(t_n, t_s) = \left[\prod_{k=s+1}^n (1 + i_k) \right]^{-1} = [F(t_s, t_n)]^{-1}$$

where

$$F(t_s, t_n)\Phi(t_n, t_s) := 1$$

and the above rules are called Generalized NPV and Generalized APV.¹

1.2 THE SYSTEMIC RULE

In general, the wealth of any economic agent is structured in a plurality of activities which I shall henceforth call businesses and whose rate of return is different. Hence, each individual or firm has a net worth composed of more than one business, for example bank accounts, securities, buildings, land, plants etc. It is then possible for

¹I shall henceforth use the monograms NPV and APV for both cases of constant or variable interest rates.

any economic agent to draw up a sort of balance sheet showing the structure of the net worth. The latter is intended to be the monetary (cash) value of the net capital employed by the economic agent. In this sense, any account must reflect the worth of the business at a fixed date.² Let m be the number of the businesses k of which are assets and $m-k$ are liabilities. Denoting with $C_l^s \geq 0$ the worth of business l at time t_s , $s \in \mathbb{N} \cup \{0\}$, $l = 1, 2, \dots, m$, the financial status of the investor at a given date t_s is

$$\begin{array}{r|l}
 \text{Assets} & \text{Equities} \\
 C_1^s & C_{k+1}^s \\
 C_2^s & C_{k+2}^s \\
 \dots & \dots \\
 \dots & \dots \\
 \dots & C_m^s \\
 C_k^s & E_s
 \end{array} \tag{3a}$$

where $E_s \in \mathbb{R}$ is the net worth (total wealth in monetary terms) of the agent.³ The fundamental accounting equation

$$\text{Assets} = \text{Equities}$$

implies that

$$E_s = \sum_{l=1}^m K_l^s \tag{3b}$$

where

$$K_l^s = \begin{cases} C_l^s, & \text{if } l \leq k \\ -C_l^s, & \text{if } l > k. \end{cases}$$

Suppose now that the investor has the opportunity to invest in a nondeferrable project with certain cash flows $\alpha_s \in \mathbb{R}$, $s = 0, 1, \dots, n$. She has to decide whether to accept it or reject it. The first question the decision-maker must ask herself is: “Where do I raise funds from and where do I reinvest interim cash flows?”. She can ‘activate’ up to m businesses for each period by altering the value of one or more balance sheet’s

²For this reason I shall never use throughout the paper the term ‘ownership equity’, which is the *accounting* value of the capital employed by the investor.

³If $E_s < 0$ the net worth is recorded on the left-hand side of the balance sheet.

accounts. The cash flow α_s is partitioned into m business; letting $\alpha_{sl} \in \mathbb{R}$ be the change in value of business l , we have necessarily

$$\sum_{l=1}^k \alpha_{sl} - \sum_{l=k+1}^m \alpha_{sl} = \alpha_s \quad \alpha_{sl} \in \mathbb{R} \quad \forall s, l. \quad (4)$$

Therefore α_{sl} increases (if positive) or decreases (if negative) the value of account l . To make clearer the concept, if α_{sl} is a source, then

$$\alpha_{sl} = \begin{cases} < 0, & \text{if } l \leq k \\ > 0, & \text{if } l > k; \end{cases}$$

if α_{sl} is an application, then

$$\alpha_{sl} = \begin{cases} > 0, & \text{if } l \leq k \\ < 0 & \text{if } l > k; \end{cases}$$

in this way, the fundamental accounting equation is satisfied.

In order to evaluate the project the decision-maker should choose, for each period, a ‘strategy of activation’ of the businesses, i.e. she should choose the elements of the balance sheet from which (in which) she will withdraw (invest) the cash flows of the project. Secondly, she should select the ‘intensity of activation’, i.e. *how much* she would like to withdraw from (invest in) account l . This means that she has to fix the value of each α_{sl} for all s and for all l . Once selected both a particular strategy of activation and a particular intensity of activation (henceforth SIA), the decision-maker should compare her net worth at a fixed date $T \in \mathbb{N} \cup \{0\}$ for the following alternatives:⁴

- i. to undertake the project
- ii. to leave things unvaried.

Making use of the indexes Y (Yes) and N (No) respectively for acceptance and rejection of the investment opportunity and supposing, with no loss of generality, that $t_s = s$, the decision-making process is *influenced* by the comparison between the two final net worths E_T^Y and E_T^N , which are obtained by calculating the difference between assets and liabilities for both alternatives. In other words she has to compare

$$\left[\sum_{l=1}^m K_l^T + I_T + S \right]_Y \quad ; \quad \left[\sum_{l=1}^m K_l^T + S \right]_N \quad (5)$$

⁴Note that T is allowed to be smaller than n . This derives from the conceptual framework the method is based on (which I shall clear later).

where I_T is the worth of the investment at time T and S represents the worth, at time T , of other operations already undertaken and not yet completed. As S is shared by both alternatives, it is inessential in the above inequality and we can forget it.

If things remain unvaried, the final net worth will be

$$E_0 \prod_{s=1}^T (1 + j_s); \quad (6)$$

j_s is the so-called return on equity (ROE) for the s -th period and is given by

$$j_s = \frac{\sum_{l=1}^k i_{sl} C_l^{s-1} - \sum_{l=k+1}^m i_{sl} C_l^{s-1}}{E_{s-1}} = \frac{\sum_{l=1}^m i_{sl} K_l^{s-1}}{\sum_{l=1}^m K_l^{s-1}} \quad (7)$$

where i_{sl} is the rate of return of business l in the s -th period.

If the investment is undertaken, the final net worth will be

$$\sum_{l=1}^m C_l^0 F_l(0, T) + \sum_{s=0}^T \sum_{l=1}^m \beta_{sl} F_l(s, T) + I_T \quad (8)$$

where

$$\beta_{sl} = \begin{cases} \alpha_{sl}, & \text{if } l \leq k \\ -\alpha_{sl}, & \text{if } l > k \end{cases}$$

and

$$F_l(\sigma, \tau) = \begin{cases} \prod_{j=\sigma+1}^{\tau} (1 + i_{jl}) & \text{if } \tau > \sigma \\ 1, & \text{if } \tau = \sigma \end{cases} \quad \forall \sigma, \tau = 0, 1, \dots, T. \quad (9)$$

The comparison in (5) boils then down to

$$\sum_{s=0}^T \sum_{l=1}^m \beta_{sl} F_l(s, T) + I_T \leq 0. \quad (10)$$

To understand this, let us draw up the decision-maker's prospective balance sheets for both cases.

Leaving things unchanged we have

$$C_l^s = C_l^{s-1} (1 + i_{sl}) \quad \forall s, l \geq 1$$

or

$$C_l^s = C_l^0 F_l(0, s).$$

The balance sheet at time s , $s = 1, \dots, T$ is

Assets	Equities
$C_1^s = C_1^0 F_1(0, s)$	$C_{k+1}^s = C_{k+1}^0 F_{k+1}(0, s)$
$C_2^s = C_2^0 F_2(0, s)$	$C_{k+2}^s = C_{k+2}^0 F_{k+2}(0, s)$
\dots	\dots
\dots	\dots
\dots	$C_m^s = C_m^0 F_m(0, s)$
$C_k^s = C_k^0 F_k(0, s)$	E_s

(11)

We finally obtain

$$E_T = \sum_{l=1}^k C_l^T - \sum_{l=k+1}^m C_l^T = \sum_{l=1}^k C_l^0 F_l(0, T) - \sum_{l=k+1}^m C_l^0 F_l(0, T)$$

and therefore, looking at (7), we get (6).

If, on the contrary, the project is undertaken, we have

$$C_l^s = C_l^{s-1}(1 + i_{sl}) + \alpha_{sl} \quad \forall s, l \geq 1$$

and

$$C_l^0 = C_l + \alpha_{0l}$$

where C_l represents the value of business l prior to the decision of investment (note that in case of rejecting the project $\alpha_{0l} = 0$ and $C_l^0 = C_l$). Therefore we have

$$C_l^s = C_l^0 F_l(0, s) + \sum_{j=1}^s \alpha_{jl} F_l(j, s) \quad s = 1, \dots, T$$

knowing that, obviously, any α_{sl} is equal to zero for all $s > n$. The balance sheet at time s , $s = 1, \dots, T$ is

$$\begin{array}{ccc}
& \text{Assets} & | & \text{Equities} \\
C_1^s = C_1^0 F_1(0, s) + \sum_{j=1}^s \alpha_{j1} F_1(j, s) & | & C_{k+1}^s = C_{k+1}^0 F_{k+1}(0, s) + \sum_{j=1}^s \alpha_{j, k+1} F_{k+1}(j, s) \\
C_2^s = C_2^0 F_2(0, s) + \sum_{j=1}^s \alpha_{j2} F_2(j, s) & | & C_{k+2}^s = C_{k+2}^0 F_{k+2}(0, s) + \sum_{j=1}^s \alpha_{j, k+2} F_{k+2}(j, s) \\
& \dots & | & \dots \\
& \dots & | & \dots \\
C_k^s = C_k^0 F_k(0, s) + \sum_{j=1}^s \alpha_{jk} F_k(j, s) & | & C_m^s = C_m^0 F_m(0, s) + \sum_{j=1}^s \alpha_{jm} F_m(j, s) \\
I_s & | & E_s
\end{array} \tag{12}$$

where I_s is the value of the project at time s . It is easy to check that the comparison in (5) is reduced to (10), through (6) and (8), as we argued.

Obviously, when facing two mutually exclusive projects the decision-maker should compare the final net worth for each alternative.

1.3 NPV AND APV AS PARTICULAR CASES OF THE SYSTEMIC RULE

Looking at (10) we can easily get the NPV rule. In fact, the latter assumes the existence of one single business which the investor can turn to whenever this is needed. This means that $m=1$, which implies $\alpha_{s1} = \alpha_s$, where 1 is the index of the unique account; further, it assumes $T \geq n$ whence $I_T=0$. Thus, (10) becomes

$$\sum_{s=0}^T \alpha_s F_1(s, T) \leq 0;$$

the left-hand side is in this case independent of T , so it is possible to disguise the final amount as a present value:

$$\sum_{s=0}^n \alpha_s \Phi_1(s, 0) \leq 0. \tag{13}$$

The APV rule, which is itself a generalization of the NPV rule (by picking $m>1$), can be found in our criterion as a particular case by making two further assumptions:

- (i) there is one single account in the Debit side of the balance sheet
- (ii) at time T each debt has been refunded, i.e.

$$\sum_{s=0}^T \alpha_{st} F_l(0, T) = 0$$

for all l of the Credit side of the balance sheet (which in turn implies $C_l^T = C_l^0$).

Both rules implicitly assume that the (net) cash flows are reinvested (withdrawn) at the opportunity cost of capital and, as a consequence, T is uninfluent in the decision-making process. Further, the APV assumes that debt rates are uninfluent for they are directly and entirely reflected in the cash flow streams.

1.4. AN EXAMPLE

Suppose that an economic agent (individual or firm) is faced with the opportunity of investing in a project whose flows are $\alpha_0 = -100$, $\alpha_1 = 40$, $\alpha_2 = 50$, $\alpha_3 = 60$ at the maturities $t_s = s$, $s = 0, 1, 2, 3$. Suppose the opportunity cost changes over time so that $i_1 = 0.1$, $i_2 = 0.04$, $i_3 = i_4 = 0.12$. We have

$$-100 + \frac{40}{(1.1)} + \frac{50}{(1.1)(1.04)} + \frac{60}{(1.1)(1.04)(1.12)} \simeq 26.89 > 0$$

and the investment should be undertaken according to the NPV rule. Suppose now that the project is partially financed by two creditors so that

$$\begin{array}{ccccc} f_{01} = 20 & f_{11} = -10 & f_{21} = -16 & f_{31} = 0 & f_{41} = 0 \\ f_{02} = 40 & f_{12} = 0 & f_{22} = 0 & f_{32} = 0 & f_{42} = -58. \end{array}$$

We have

$$-40 + \frac{30}{(1.1)} + \frac{34}{(1.1)(1.04)} + \frac{60}{(1.1)(1.04)(1.12)} - \frac{58}{(1.1)(1.04)(1.12)^2} \simeq 23.4 > 0$$

and the investment should be undertaken according to the APV rule. Finally, consider the case where the net worth of the investor has $k=5$ assets and $m-k=4$ liabilities. Suppose that only 4 of the 9 businesses are activated for the project and the sources and applications of funds are structured according to the following SIA:⁵

⁵For example, the four businesses could be respectively “bank X account”, “Land”, “accounts payable” and “bonds” or whatever else.

$$\begin{array}{ccccc}
\alpha_{01} = -30 & \alpha_{11} = 20 & \alpha_{21} = 30 & \alpha_{31} = 60 & \alpha_{41} = 15 \\
\alpha_{02} = -50 & \alpha_{12} = 0 & \alpha_{22} = 0 & \alpha_{32} = 0 & \alpha_{42} = 0 \\
\alpha_{06} = 0 & \alpha_{16} = -15 & \alpha_{26} = -20 & \alpha_{36} = 0 & \alpha_{46} = 0 \\
\alpha_{08} = 20 & \alpha_{18} = -5 & \alpha_{28} = 0 & \alpha_{38} = 0 & \alpha_{48} = 15
\end{array}$$

with $\alpha_{sl} = 0$ for any other business (I suppose that the above values satisfy the condition $C_l^s \geq 0$ for all s, l). Let $T = 4$ and consider the following interest rates:

$$\begin{array}{cccc}
i_{11} = 0.1 & i_{21} = 0.1 & i_{31} = 0.1 & i_{41} = 0.12 \\
i_{12} = 0.15 & i_{22} = 0.15 & i_{32} = 0.15 & i_{42} = 0.15 \\
i_{16} = 0.1 & i_{26} = 0.12 & i_{36} = 0.1 & i_{46} = 0.11 \\
i_{18} = 0.12 & i_{28} = 0.12 & i_{38} = 0.12 & i_{48} = 0.12
\end{array}$$

By applying (10) the value of E_T is

$$\begin{array}{ccccc}
-30F_1(0, 4) & +20F_1(1, 4) & +30F_1(2, 4) & +60F_1(3, 4) & +15F_1(4, 4) \\
-50F_2(0, 4) & +0F_2(1, 4) & +0F_2(2, 4) & +0F_2(3, 4) & +0F_2(4, 4) \\
+0F_6(0, 4) & +15F_6(1, 4) & +20F_6(2, 4) & +0F_6(3, 4) & +0F_6(4, 4) \\
-20F_8(0, 4) & +5F_8(1, 4) & +0F_8(2, 4) & +0F_8(3, 4) & -15F_8(4, 4) \simeq 19.58.
\end{array}$$

In Appendix the prospective balance sheets are drawn up for time $s = 0, 1, 2, 3, 4$ under the hypotheses of undertaking the investment.

1.5 APPLICABILITY

The basic idea of the criterion here explained is that the investor aims at calculating the net worth at a fixed horizon T . In general, each economic agent's net worth is structured in more than one business. She can therefore use any of the m accounts. The decision-maker should firstly evaluate the worth of each account at any date; to do this she should ask herself: "How much are my assets and liabilities worth?". This is a difficult question to answer, but by escaping it she will not be able to correctly appraise the investment. For some accounts it is possible to calculate C_l^s on the basis of the financial laws. In fact, for many liabilities this is quite easy: The value is just the outstanding capital for the creditor. As for the Debit side of the balance sheet we often know or are able to forecast the interest rates for bank accounts; we can as

well manage to find a financial law (or an average interest) for lands and buildings by looking at past returns and at forecasts drawn up by analysts. It is then also possible to place a value on interest rates of financial securities on the basis of the term structure of interest rates. The value of the project is given by the outstanding capital if it is a financial contract or by its liquidation value if it is an industrial project. In second place, it is always possible to rely on a sensitivity analysis to test the ‘soundness’ of the project, which is essential for this approach. Thirdly, the investor can always activate whatever account she wants. She can select the most liquid businesses, in order to have safer forecasts of the cash flows, depending on her risk aversion.

So far, I have formalized the systemic rule as an extension of the DCF methods in an obvious sense: It covers a greater number of situations. As we have seen the NPV rule allows for one single account, the APV rule admits the existence of liabilities but does not allow for asset accounts (it therefore does not allow for a decrease in application of funds as a source of funds); further, it does consider only debts with certain cash flows which come due earlier than T (i.e. $n \leq T$). In the next sections I will try to give a brief description of the epistemologic implications of such an approach.

2. EPISTEMOLOGY

The criterion presented in this paper is very general in more than one sense, as we will see, and this could be, *prima facie*, an advantage as well as a disadvantage. It is my opinion that once aware of its epistemologic implications, one can regard the systemic rule as a reasonable (yet not perfect) method to appraise investments and agree that its drawbacks are intrinsic to the decision-making process rather than to the criterion itself.

First of all, I would like to avoid any misunderstanding by reminding the reader that the method proposed is concerned with ‘accept-or-reject’ investments, so that many investment opportunities (e.g. real options) cannot be considered, for the time being, by the systemic rule. Nonetheless, it has the advantage to derive from a conceptual framework that is promising.

2.1 SYSTEM AND ACCOUNTING

Usually, an investment is thought of as an independent stream of cash flows which is separate from the wealth of the investor. In our context the wealth of the decision-maker is a system structured in m components plus the project itself. The latter is just an element of the net worth and the interim cash flows periodically alter the structure of the system, due to the reinvestment into and withdrawal from the m accounts. Any inflow or outflow arising *diachronically* from the project is then distributed *synchronically* across the elements of the system at each time s . The NPV rule is not able to consider the *synchronic* aspects of the decision-making process and is forced

to destructure the system with the unrealistic assumption $m=1$. The NPV supporters are aware that this fact cuts out many situations, so they often try to solve the problem by making use of the Return On Equity (ROE) or the Weighted Average Cost of Capital (WACC). This solution is totally misleading. I will not dwell on this aspect (see Peccati (1996b), Magni (1998c)) but will briefly give an idea of what happens if we let the ROE be the opportunity cost of capital in the NPV rule. For the sake of simplicity suppose a one-period investment with initial outlay I and final receipt I' . The NPV rule states that it is to be undertaken iff

$$-I + \frac{I'}{1 + \text{ROE}} > 0$$

which means

$$(E_0 - I)(1 + \text{ROE}) + I' > E(1 + \text{ROE}). \quad (14)$$

But if we are aware that the wealth of the investor is a structured system whose structure determines the value of the ROE (through the value of the businesses) we are able to see that the ROE on the left-hand side of (14) is different from the ROE on the right-hand side. The former is the return of the investor's net worth in case of acceptance, the latter is the return in case of rejection. The ROE on the left-hand side is given by

$$\text{ROE} = \frac{\sum_{l=1}^k i_{1l}C_l - \sum_{l=k+1}^m i_{1l}C_l}{E_0} \quad (15a)$$

whereas the one on the right-hand side is

$$\text{ROE} = \frac{\sum_{l=1}^k i_{1l}(C_l + I_l) - \sum_{l=k+1}^m i_{1l}(C_l + I_l) + xI}{E_0} \quad (15b)$$

where x is the internal rate of return of the project and $I_l \in \mathbb{R}$ represents the policy of withdrawal of funds from the accounts, so that

$$\sum_{l=1}^k I_l - \sum_{l=k+1}^m I_l = I.$$

Only a systemic approach enables us to correctly handle the appraisal of a project, by thinking of it as an element of the system. This conceptual framework focuses on net worth rather than the investment itself: The latter is subsumed by the former, which can be viewed as a meta-investment whose initial outlay and final amount are respectively E_0 and E_T . This frames the decision-making process in such a way that one find it useful to rely on an accounting philosophy. So we can adopt a sort of

monetary accounting for prospective purposes where the accounts form the net worth rather than the ownership equity. This is in my opinion a natural environment for investment decisions: The NPV and the APV can easily be constructed starting from such a monetary accounting. Furthermore, it is easy to realize that three seemingly different investment rules are just the same. As a matter of fact, the average ROE is given by

$$\text{ROE} = \left(\frac{E_T}{E_0} \right)^{1/T} - 1 \quad (16)$$

which is nothing else but the internal rate of return (IRR) of an investment with cash flows $-E_0$ and E_T at the maturities 0 and T. So the ROE rule and the IRR rule lead, in this sense, to the same ranking of projects. But as the ROE rule implies maximization of the net worth, and as the DCF rules does the same under particular assumptions, we see that the NPV rule and the APV rule are included in the IRR-ROE rule as particular cases (for details see Magni (1998f)).

On the basis of what we have seen, I stress that accounting is much more useful to decision-making process than is usually thought. Accounting and financial mathematics can naturally reconcile and their junction is given by the concept of *system*, totally disregarded by the NPV rule and not sufficiently developed in the APV rule. Both *diachronic* and *synchronic* dimensions are explicitly considered with a systemic approach. We can summarize these two in matrix A :

$$A = \begin{bmatrix} \alpha_{01} & \alpha_{11} & \dots & \alpha_{n1} \\ \alpha_{02} & \alpha_{12} & \dots & \alpha_{n2} \\ \vdots & \vdots & \ddots & \vdots \\ \alpha_{0m} & \alpha_{1m} & \dots & \alpha_{nm} \end{bmatrix}.$$

Any arrow of the matrix is expression of the diachronic dimension of the flows, any column show their synchronic dimension.

2.2 GENERALIZATION I: HORIZON

It is worthwhile noting that (10) is dependent on T and therefore the concept of *present value* loses significance in this context; T is therefore essential in the decision-making process. On the contrary, in the DCF criteria the investor wishes to maximize her net worth *tout court*. This does not make any sense, in my opinion, and contradicts reality. The net worth is an evolving system correlated with the investor's life. If we then consider the meta-investment of E_0 and aim to appraise the return from an investment, we have to fix a terminal date T in order to calculate the ROE as in (16). If we did not, we would not have any final amount and the concept of profitability would

fade out. The NPV rule escapes this issue by destructuring the system; the APV rule escapes it by assuming $\sum_{s=0}^m \alpha_{sl}(1 + i_{sl}) = 0$ (i.e. $C_l^T = C_l^0$) for all l except one; in such a way all the debts are reimbursed within T and the present value is salvaged. The systemic rule can cope with the general case of $T \in \mathbb{N} \cup \{0\}$: The investor can select any T and, notwithstanding, she can finance the project with debts which will come due after T .

The wealth is always dependent on T in such a way that the concept of present value does not make much sense: We do not have any present value and if we do it means that the assumptions of the decision-making process are selected so as to validate that concept: This is quite clear by framing the decision process with a systemic approach.

2.3 GENERALIZATION II: MULTIDIMENSIONALITY OF THE OBJECTIVE

As we have seen, the systemic rule is more general than the classical methods in that it includes a greater number of cases. The NPV assumes that the investor aims at a mere maximization of total wealth. The APV does the same, but admits the opportunity of raising funds by creditors when net worth is insufficient or when there is a possibility of a positive leverage. The rule here proposed not only admits that an economic agent is subject to constraints which force her to hold a plurality of accounts;⁶ it also enlarges the set of objectives: As a matter of fact, the investor has a plurality of objectives, that is just the reason why her net worth is structured in $m > 1$ components. In this sense, the DCF methods are really very rudimental, and unrealistically subsume the existence of individuals characterized by a unique thought in their mind, totally empty in their preferences and desires, and independent of any cultural and social influence. On the contrary, the systemic rule fits perfectly. To such an extent that I have deliberately concealed this aspect in explaining the criterion. I have presented the rule pretending to accomplish a mere formal generalization of the DCF methods. The reader has been induced to follow the explanation having in mind the classical objective of wealth maximization. But, as the reader can check, I have never stated that the investor should choose the most profitable investment. The importance of this issue has led me to split the generalization of the classical DCF rules in two parts as announced in the Introduction. The feature of the rule proposed is not only the broader applicability but also the multidimensionality of the objective. The systemic rule is actually a multi-objective criterion. The investor calculates the final net worth by selecting a particular SIA. I assert that the selection of the SIA is determined not merely by her financial-type constraints (as we have seen) or leverage considerations (as the APV induces us to think), but by her preferences system and, therefore, her subjective personality, which determines the will for a particular SIA

⁶It is really strange that the NPV rule forgets these natural constraints.

and a particular structure of matrix A at time T (or even a preference for a particular path of structures). Matrix A has then another fundamental meaning in this approach: It represents (indirectly) the various objectives.

We can now restate the rule to give it a more general form: The investor should undertake the project iff the pair (A^*, E_T^*) is the preferred one by the decision-maker. It is not my intention to propose a method of extrapolation of the preferred pair from the infinite possible ones, because this is beyond the subject of this work.⁷ The fact I would like to underline is that this rule can handle a plurality of objectives, the traditional DCF methods do not. The project can be undertaken even though the final amount is smaller than that obtained by leaving things unchanged, if this fact is (more than) counterbalanced by a particular preferred structure of the system. It is worthwhile noting that we can imagine cases of alternatives leading to the same net worth at T but to a different structure of the system. These situations, where the DCF rules are stuck, are solved by the systemic rule on the ground of the investor's preferences about the structure, which reflect her subjective personality. The subjective personality of the investor is therefore taken into account by means of both a particular structure A of the net worth and the value E_T of the net worth. Formally, we can restate the criterion in the following way: Let E_{TY} be any possible E_T associated with any possible nonzero matrix A ; let E_{TN} be E_T in case the structure of the net worth remains unaltered (A is then the zero matrix); the project should be undertaken iff there exists a pair (A^*, E_{TY}^*) , such that

$$(A^*, E_{TY}^*) \succ (\mathbf{0}, E_{TN})$$

where $\mathbf{0}$ is the zero matrix. If this happens, a further requirement could be that the investment is to be undertaken by implementation of that pair (A^*, E_{TY}^*) such that

$$(A^*, E_{TY}^*) \succ (A, E_{TY}) \quad \forall A \in \mathbb{M}_{m \times n}, A \neq A^*$$

where $\mathbb{M}_{m \times n}$ is the set of all possible SIAs.

If the decision-maker has the only objective of maximizing her net worth, matrix A is just a *leverage* (or *gearing*) matrix, and shows that there are $2^m - 1$ strategies of activation for each period (see also Magni (1998d)). In case of multiple objectives, A summarizes the possible choices at disposal of the investor. E_T loses importance as long as matrix A turns, so to say, from a *leverage* matrix to a *multiple objectives* matrix, offsetting a possibly decreased net worth.⁸

Moreover, the systemic rule can easily cope with the objective of a particular path of periodic return. The DCF methods offer analysts the opportunity of decomposing

⁷In my Feyerabendian view I would be tempted to say that 'anything goes'.

⁸However nothing prevents A from being that preferred structure of A that maximizes E_T .

periodically the present value of the project (see Luciano and Peccati (1997)). Obviously, we cannot decompose a present value in the systemic rule, for the simple reason that the concept of present value is now meaningless. But we are able to decompose the return of the meta-investment by using the internal rate of return of our system, i.e. the ROE.

From the prospective balance sheets we can easily calculate the IRR for the s -th period:

$$j_s = \frac{E_s}{E_{s-1}} - 1.$$

In such a way the investor can face the problem of optimizing the path of the average return. The flexibility of the rule as a multiobjective criterion is such that we could even restate it again by replacing the pair (A, E_T) with the triad $(A, E_T, j_s \ s = 1, \dots, T)$.

2.4 GENERALIZATION III: RISK AVERSION

It is worth to briefly dwell on the previously introduced concept of risk aversion. As the calculation of the value of the businesses (and therefore of their financial laws) is a risky process, the investor could be influenced by her risk aversion in selecting the accounts to be activated. This is quite natural, since it is a consequence of the assumed complex personality of the decision-maker. Forecasts will be surer for financial contracts in which a financial law is agreed *a priori*. Other accounts can be so risky that an evaluation is a formidable task (e.g. the amount to be realized in case of disposal of plants). The investor determines the selection of the SIA on the basis of her personal perception of risk.

From this point of view the DCF rules can now be seen in a new light. Whenever

- (i) the decision-maker holds one single highly liquid business
- (ii) fixes T so that $T \geq n$
- (iii) is completely risk-averse in the sense that she considers too risky to use businesses whose monetary values are too difficult to forecast (and hence it is too risky to base the project evaluation on the uncertain forecasts of the other businesses),

then the systemic rule gives the same answer as the NPV rule. If, in addition,

- (vi) the investor wants (or has to) apply to some creditors,
- (v) fixes T so that all debts come due earlier than T ,

then the systemic rule gives the same answer as the APV rule. As we see we have another kind of generalization based on the concept of risk aversion. This is connected with the problem of attaching monetary values to the accounts composing the net worth. I would like to stress that this is not only a matter of applicability of the rule but also has to do with risk propension. The DCF methods are based on the extreme

assumption of maximum risk aversion. The systemic rule has the flexibility to face any degree of risk aversion through the selection of the SIAs.

2.5 GENERALIZATION IV: USE OF UNCERTAIN RATES OF INTEREST FOR CERTAIN CASH FLOWS

One might be astonished in reading about 'risk aversion' since I have assumed, throughout the paper, that outlays and receipts from the project are certain. This is true, but the interest rates of the m accounts are, in general, uncertain: This is just the reason why the investor needs to forecast a monetary value for those businesses selected for activation (and, as we have seen, it is easy for some, much harder for others). This is an important aspect: If the cash flows are certain, then the DCF rules provide us with a risk-free rate of interest. That is: The DCF rules assume that the only business the investor holds has a certain rate of return. This contradicts reality where one can stipulate a financial contract with certain cash flow withdrawing and reinvesting the interim cash flows in a business having an uncertain rate of return. Analogously, the DCF criteria appraise a project under uncertainty by using an opportunity cost of capital taken from an investment with equivalent risk. Again, this contradicts reality, since it forces an investor to discount cash flows at a rate relating to a security which has never been part of the decision-making process. As a matter of fact, the systemic rule admits the opportunity to use rates of interest related to businesses with different degrees of risk. This should not cause scandal, since it is a natural consequence of the multidimensionality of the decision maker's objective.

Why should the investor care about a security if the latter is not *a priori* included in the decision-making process? Why should she take it into account if funds are drawn from her bank account or by selling a piece of land or a building or whatever else and reinvested in businesses other than the security with equivalent risk? From a systemic multiobjective perspective the decision-maker does not have to follow this tenet of 'homogeneity of comparison' stated in any standard text-book (which, *inter alia*, causes logical fallacies and inconsistencies: See Magni (1998a, 1998b)). It is only the risk aversion of the investor that determines the businesses (and therefore the interest rates) to be activated, on the basis of their degrees of uncertainty and the objectives of the decision-maker. Hence, it is not hard to formulate the systemic rule for investments under uncertainty: It is just the same! The heart of the matter is that any project is included in a system evolving in an uncertain environment, so it makes no formal difference if the cash flows are certain or uncertain. The methodology of appraisal remains the same, and any other consideration is part of the cognitive perception of the economic agent and her preference system.

2.6 GENERALIZATION V: NET WORTH AS OUTSTANDING CAPITAL AND LIQUIDITY

E_T is an amount whose degree of liquidity depends on the initial structure of net worth and on the selected A , i.e. on the selected SIAs. It does not coincide with ownership equity, which relates to the accounting value of the net capital invested by the economic agent, it is the *worth* of the capital invested. It can then be viewed as the algebraic sum of the worth of m businesses having different degree of liquidability. The net worth is in this sense a sort of *outstanding capital*, that is the amount of resources invested and not yet reimbursed, remunerated at the ROE, where the latter is expressed in monetary terms. The DCF rules assume that the economic agent has the objective of maximizing *liquid* wealth or, from another point of view, that the investor's wealth has a maximum degree of liquidity. Moreover, the APV assumes that the outstanding capitals of the m creditors at time T are zero. The systemic rule considers these assumptions only one of infinite possible cases.

2.7 GENERALIZATION VI: REINVESTMENT IN THE PROJECT

The systemic rule enables the decision-maker to consider a partial reinvestment in the project itself. If the project must be 'disactivated' (i.e. a reinvestment is not possible) by the amount α_s the value of the project at time s is given by

$$I_s = I_{s-1} F_I(s-1, s) - \alpha_s \quad (17a)$$

where F_I is an internal financial law for the project. If, on the other hand, it can be 'reactivated' (i.e. a partial reinvestment is possible) then $\sum_{l=1}^m \beta_{sl} \neq \alpha_s$ and (17a) becomes

$$I_s = I_{s-1} F_I(s-1, s) - \alpha_s + \left(\alpha_s - \sum_{l=1}^m \beta_{sl} \right) = I_{s-1} F_I(s-1, s) - \sum_{l=1}^m \beta_{sl}. \quad (17b)$$

Then we have three cases:

- (i) if $T \geq n$ and the project is disactivated at any stage, (8) holds with $I_T = 0$,
- (ii) if $T < n$ and the project is disactivated at any stage, (8) holds with $I_T \neq 0$. The latter represents the value of the project at time T (if it is a financial contract, I_T is just the outstanding capital, otherwise the investor must determine a monetary value to the project based on its liquidability),
- (iii) if the project is reactivated at some stage, (8) holds with $I_T \neq 0$, whatever the value of T .

In particular, in case of reactivation at time s , from (17b) we get

$$I_T = I_0 F_I(0, T) - \sum_{s=1}^T \sum_{l=1}^m \beta_{sl} F_I(s, T). \quad (18)$$

(10) boils then down to

$$\sum_{s=0}^T \sum_{l=1}^m \beta_{sl} F_l(s, T) + I_0 F_I(0, T) - \sum_{s=1}^T \sum_{l=1}^m \beta_{sl} F_I(s, T) \leq 0. \quad (19)$$

Thanks to the equalities $I_0 = -\alpha_0 = -\sum_{l=1}^m \beta_{0l}$ we get finally

$$\sum_{s=0}^T \sum_{l=1}^m \beta_{sl} F_l(s, T) \leq \sum_{s=0}^T \sum_{l=1}^m \beta_{sl} F_I(s, T). \quad (20)$$

2.8 GENERALIZATION VII: SIMULTANEOUS INVESTMENTS

I intend to shed some lights on an important aspect related to the SIAs. I have defined α_{sl} in a general way, here restated for convenience of the reader:

$$\alpha_{sl} \in \mathbb{R} \quad \sum_{l=1}^k \alpha_{sl} - \sum_{l=k+1}^m \alpha_{sl} = \alpha_s.$$

This implies that the investor can even fix it so that

$$\alpha_{sl} > \alpha_s \quad \text{for some } l.$$

If this is the case, the investor is accomplishing one more *gearing* by the amount $\alpha_{sl} - \alpha_s$. Since anything that alters the structure of the system is an investment she is just doing one more investment which is different from the project in hand: She withdraws the amount $\alpha_{sl} - \alpha_s$ from an account l and reinvests it in another one (as an example, just pick $\alpha_s=100$, $m=k=4$, $\alpha_{s1}=130$, $\alpha_{s2}=-30$, $\alpha_{s3}=0$, $\alpha_{s4}=0$).

Furthermore, it is possible to fix some λ such that

$$\sum_{\lambda: 1 \leq \lambda < m} \alpha_{sh} = \alpha_s$$

and there exist two or more accounts μ such that

$$\sum_{\mu: 1 < \mu < m} \alpha_{sh} = 0, \quad \alpha_{sh} \neq 0$$

where $\lambda + \mu = m$ (as an example, pick $\alpha_s=100$, $m=k=4$, $\alpha_{s1}=60$, $\alpha_{s2}=40$, $\alpha_{s3}=20$, $\alpha_{s4}=-20$).⁹

⁹Another example is that of section 1.4, where in the last period the amount 15 is withdrawn from account 8 and reinvested in account 1.

So E_T will be determined not only by the SIAs directly related to the project but also by one more or many more alterations of the system. This makes easy to handle the evaluation of multiple investments: Only net worth matters. It is worthwhile noting that the traditional DCF methods have nothing to say about a change in structure accomplished at a given date s without any addition of accounts: According to the DCF rules there has not been any project, so nothing has happened. Instead, according to the systemic rule, some accounts have been altered in value and a consequent change in the periodic ROE has been accomplished. The framework we adopt enables us to think in terms of a portfolio of investments (whether or not they are projects in the traditional sense). The evaluation of the portfolio depends on the net worth at a given date T , on the periodic ROEs, and on the selection of the SIA. The latter do refer to a portfolio but we can now realize that the concept of portfolio can be misleading: It simply relates to a particular SIA of the accounts, whether or not the number of businesses is changed. A portfolio is, just like an investment, an alteration of the structure of the system accomplished by the selection of a particular SIA. The choice among different portfolios will then result in comparison among different pairs (A, E_T) or triads $(A, E_T, j_s \ s = 1, \dots, n)$ on the basis of a plurality of objectives.¹⁰

2.9 GENERALIZATION VIII: INVESTMENT AS A ZERO-SUM GAME

On the basis of what we have seen, we could say that a project (a stream of payments and receipts) is not an investment! The only investment is the meta-investment of the net worth and is accomplished through the alteration of the structure of the system. A project is only an element of the system, namely an account, a business: It generates cash which is distributed among the businesses giving rise to a change in the value of the ROE. When a project is undertaken, the investor adds an element to the system. But she does not even need any project to invest money: By withdrawing funds from one or more accounts and reinvesting them in other ones she accomplishes a particular modality of the investment of the net worth. This is the so-called *leverage* or *gearing*. An investment is a leverage, regardless of existence of a specific project. Anything that alters the structure of the net worth (not only a project) is an investment. The latter can be then regarded of as a *see-saw*, with businesses going up and down in value.

This remark could suggest the idea for a description of investment as a repeated zero-sum game with $m+1$ (or $m+2$) players. In fact, let us have a look at the balance sheet of the decision-maker: The game starts with $m+1$ or $m+2$ players (the m accounts plus the net worth and the possible addition of a project). They aim at maximizing their worth. All players have an ability of increasing their wealth (depending on the

¹⁰The remarks made in this section also explain why the investor could even fix $T=0$: The investment is just represented by the alteration of the structure at time 0.

value of their $F_l(0, s)$) and try to steal money away from any other player (these are withdrawals and reinvestments). At each stage of the game there are transitions of resources from one player to another (these are leverages). Each player bargains with the last player (the net worth) to steal money from the others (this is an effect of the different objectives).¹¹ The game is played $T+1$ times and the values of C_l^T , I_T and E_T represent the final payoffs for the players.

2.10 COGNITION

The generalizations seen above bear strong relations to the cognitive framing of the decision-making process. The hub lies in the graphical representation of an investment stemming from the way financial mathematicians and analysts perceive the phenomenon. In the literature projects are (perceived and) depicted through a picture of the following kind:

time	t_0	t_1	t_n
cash flows	a_0	a_1	a_n

Accounting describes wealth as follows:

<u>Assets</u>		<u>Equities</u>
C_1^s		C_{k+1}^s
C_2^s		C_{k+2}^s
...		...
...		...
...		C_m^s
C_k^s		E_s

As can be seen, financial mathematics' description of an investment illustrates only cash flows and maturities. Accounting representation of wealth focuses on the value

¹¹The relation between an account and an objective is not direct and this view is a simplification. The transition from business to business is an *indirect* reflection of the different objectives of the investor.

and the structure of the wealth at a particular point in time. Therefore, the cognitive process subsumed by financial mathematics focuses on a diachronic dimension, the one subsumed by accounting is synchronic. Neither of the two aspects can be neglected in the decision-making process. I have tried to integrate financial mathematics with accounting to create what I think is a natural environment for appraising investments, coherent both to accounting and financial mathematics perspectives. The dichotomy between accounting and finance in capital budgeting, highly claimed in any standard textbook of finance (see References), is an illusion. Academics and practitioners underscore for example that accounting values differ from cash values and that accounting looks at the present and past whereas project selection is forward-looking. For our aims, these remarks are totally uninformative: The distinctive trait of accounting is that it describes a system, structured in several components. I have therefore made use of the philosophy of accounting rather than of accounting itself, and have applied it to investment decisions.

The result becomes even more significant if one thinks of the plethora of articles written on the dichotomy of the NPV rule and the IRR rule and on the problem of multiple rates of return (see References). If in the past decades academics and practitioners had described an investment by means of sequential balance sheets in monetary terms rather than through a table recording cash flows and corresponding time, no such problem would have arisen. It is striking to note how pictures and illustrations are psychologically important to frame problems and how, in our case, a line of scientific research has been strongly influenced by a particular graphical illustration of an investment.¹² The radical cognitive shift here accomplished allows for a *unique* investment: The meta-investment of the net worth, which is an investment with one single initial outlay and one single final receipt; anything else is included in the system. In such a way the IRR is *unique*, has a well specified financial meaning, coincides with the ROE and is a more general index of the NPV. The 'present value' world, whose roots trace back to the first half of this century (see Fisher (1974)), is still so consolidated in the literature that there has been no endeavor, as far as I know, to change its rigid cognitive perspective. We do not even have, in the literature, any standard definition of what an investment is: Sometimes it is used as synonymous of project and sometimes it is used as opposite of financing. So, strangely, we have criteria appraising something that is not (clearly) defined. The only formal definition I know of investment as opposed to financing pays homage to the NPV concept (see Levi (1964)) and is constructed so as to confirm it. A rigorous definition of investment can allow to see things differently (Magni (1998d, 1998g)). The concept of present value itself is based on an arbitrary cognitive representation of facts and on assumptions grounded on a particular frame of the phenomena, which leads to self-contradictory

¹²For relationships between pictures and mathematics, see Brown (1997).

consequences (see, for the latter, Magni (1998a, 1998b)). The NPV world is such as to create its own reality and we can endorse the constructivist proposition according to which reality is always an *invented* reality, grounding itself on theory and language (see Watzlawick (1981)).

3. DRAWBACKS

Disadvantages of the systemic rule with respect to the DCF methods could be found especially on the problem of quantifying the value of each account. But as a generalization of the DCF methods the rule is remarkably flexible and the possible selection of the most liquid accounts (also) depends on the risk aversion of the decision-maker. I regard this point as a matter of risk rather than a matter of advantage/disadvantage. We cannot cancel risk and we cannot pretend our wealth to be like the NPV single business, which is an idealization of the environment the economic agent lives in. This disadvantage relates to the world we live in rather than to the systemic rule.

A more convincing argument against the rule proposed is that it is not able to deal with the so-called 'real options', for example deferrable projects. But, first of all, this issue is beyond the scope of this paper. In second place, the same argument applies to the DCF methods. Rather, it seems to me that future researches with a systemic perspective can lead to cope with real options. In fact I have proposed a conceptual framework naming it 'systemic' and advising the decision-maker to frame the decision problem by means of a new cognitive process ('new' with reference to the usual representation of decision problems in financial mathematics). And I have a hunch that real options can somehow benefit from this framework. In fact, the options pricing approach is not able to cover more than one objective for the investor: The maximization of the net worth (disguised as a present value and assuming one single business).¹³ In Magni (1998e) a methodology is suggested where a plurality of objectives are considered without adopting a systemic approach. However I think that a systemic approach can cope with real options in a satisfying way. Just think of the value of a real option: It can be derived by an application of stochastic dynamic programming by framing the problem as an optimal stopping problem (see Dixit and Pindyck (1996)). The value of the real option is the maximum between the (expected) net present value of the project and the continuation value. The latter is nothing else than another (expected) net present value. So the investor should compare the two present values and act consequently. This means that real options are evaluated through a dynamic generalization of the NPV rule. The criterion here proposed generalizes the NPV rule,

¹³Moreover, the options pricing approach rests on the assumptions of a single random variable following a geometric Brownian motion. Many difficulties arise when more than one variable is considered, since the solution of a (stochastic) partial differential equation is required.

so we can think of a dynamic generalization of the systemic rule in order to cope with multiple objectives for real options.

4. SUMMARY

We can summarize the salient elements of the systemic rule as follows: The systemic rule

- (1) has a broader applicability than the DCF rules, for the simple reason that the latter are included in the former; it considers both diachronic and synchronic elements
- (2) is a multiobjective criterion
- (3) fits for any subject for which a set of accounts can be kept; the terms ‘economic agent’, ‘decision-maker’, ‘investor’ are then as general as possible. Entities as well as individuals are included, each of which has its own different objectives
- (4) is a conceptual bridge linking financial mathematics with accounting. Any investment appraisal can be derived from a sort of monetary accounting. The junction concept is: The system
- (5) shows that the DCF rules can be derived from the double-entry book-keeping system
- (6) shows that ROE, IRR and NPV are consistent one another
- (7) allows for various degrees of liquidity of the investor’s net worth (whereas the DCF rules allows for a single (maximum) degree of liquidity of the net worth)
- (8) is dependent on the risk aversion of the decision-maker in the sense specified in section 2.4. The DCF rules are models assuming complete risk aversion
- (9) enables to use rates of interest of businesses with different risk. The concept of ‘investments with equivalent risk’ loses any significance
- (10) requires the fixing of T and allows T to be smaller than n
- (11) includes the possibility of reactivation of the project
- (12) fits for certain as well as uncertain projects
- (13) is able to decompose the return of the investment and interprets the decomposition as one of the possible objectives
- (14) allows to think of an investment as anything that alters the structure of the system
- (15) allows to think of an investment as a $T+1$ -stage zero-sum game
- (16) allows to cope with a portfolio of investments, or to say better, with an infinite number of strategies and intensities of activation, regardless of existence of r projects, $r \in \mathbb{N}$.

A final remark concerns the famous TRM model (see Teichroew, Robichek, and Montalbano (1965a, 1965b)): It is a generalization of the NPV rule only in that it covers a

wider number of cases. In fact, it merely assumes that the opportunity cost of capital changes with the value of the business, but does not represent a shift in conceptual framework. Nevertheless, it does represent a little though isolated step towards the disconfirmation of the NPV rule, since it shows that the concept of present value is founded on unrealistic assumptions (needless to say, the systemic rule includes the TRM model as a particular case).

5. CONCLUSIONS

This paper has formalized a proposal for evaluating investments and sketched some epistemologic and cognitive implications of the criterion. It is worth investigating these implications thoroughly, but this is beyond the scope of this work. I only wish to stress that decision-making processes are much complex: One should regard economic agents as subjects concerned with constraints of several types, financial, social, legal, cultural, some of which are self-selected, some others are imposed. Constraints are intertwined with multiple objectives, some of which are actually achievable only as secondary effects of states that are undertaken for other ends (see Elster (1983), ch.2). Objectives are influenced by preferences and preferences depend (also) on constraints and on the set of available options (see Elster (1983), ch.3) as well as on emotions. Emotions, in turn, help cognitive perception (see the somatic-marker hypothesis in Damasio (1994)) and “control that crucial factor of *saliency* among what would otherwise be an unmanageable plethora of objects of attention, interpretations, and strategies of inference and conduct” (de Sousa (1995), p. XV). I think that an interdisciplinary approach involving decision theory, finance, mathematics as well as cognitive science and neurobiology can turn to be very helpful in decision-making processes and, in particular, in appraising financial and industrial investments.

APPENDIX

Balance Sheet at time 0 (prior to the initial outlay)

<u>Assets</u>		<u>Equities</u>
C_1		C_6
C_2		C_7
C_3		C_8
C_4		C_9
C_5		E_0

Balance Sheet at time 0 (just after the initial outlay)

<u>Assets</u>		<u>Equities</u>
$C_1^0 = C_1 - 30$		$C_6^0 = C_6$
$C_2^0 = C_2 - 50$		$C_7^0 = C_7$
$C_3^0 = C_3$		$C_8^0 = C_8 + 20$
$C_4^0 = C_4$		$C_9^0 = C_9$
$C_5^0 = C_5$		
$I_0 = 100$		E_0

Balance Sheet at time 1

<u>Assets</u>		<u>Equities</u>
$C_1^1 = C_1^0(1.1) + 20$		$C_6^1 = C_6^0(1.1) - 15$
$C_2^1 = C_2^0(1.15)$		$C_7^1 = C_7^0 F_7(0, 1)$
$C_3^1 = C_3^0 F_3(0, 1)$		$C_8^1 = C_8^0(1.12) - 5$
$C_4^1 = C_4^0 F_4(0, 1)$		$C_9^1 = C_9^0 F_9(0, 1)$
$C_5^1 = C_5^0 F_5(0, 1)$		
$I_1 = I_0 F_I(0, 1) - 40$		E_1

Balance Sheet at time 2

<u>Assets</u>		<u>Equities</u>
$C_1^2 = C_1^1(1.1) + 30$		$C_6^2 = C_6^1(1.12) - 20$
$C_2^2 = C_2^1(1.15)$		$C_7^2 = C_7^1 F_7(1, 2)$
$C_3^2 = C_3^1 F_3(1, 2)$		$C_8^2 = C_8^1(1.12)$
$C_4^2 = C_4^1 F_4(1, 2)$		$C_9^2 = C_9^1 F_9(1, 2)$
$C_5^2 = C_5^1 F_5(1, 2)$		
$I_2 = I_1 F_I(1, 2) - 50$		E_2

Balance Sheet at time 3

<u>Assets</u>		<u>Equities</u>
$C_1^3 = C_1^2(1.1) + 60$		$C_6^3 = C_6^2(1.1)$
$C_2^3 = C_2^2(1.15)$		$C_7^3 = C_7^2 F_7(2, 3)$
$C_3^3 = C_3^2 F_3(2, 3)$		$C_8^3 = C_8^2(1.12)$
$C_4^3 = C_4^2 F_4(2, 3)$		$C_9^3 = C_9^2 F_9(2, 3)$
$C_5^3 = C_5^2 F_5(2, 3)$		
$I_3 = I_2 F_I(2, 3) - 60 = 0$		E_3

Balance Sheet at time T=4

<u>Assets</u>		<u>Equities</u>
$C_1^4 = C_1^3(1.12) + 15$		$C_6^4 = C_6^3(1.11)$
$C_2^4 = C_2^3(1.15)$		$C_7^4 = C_7^3 F_7(3, 4)$
$C_3^4 = C_3^3 F_3(3, 4)$		$C_8^4 = C_8^3(1.12) + 15$
$C_4^4 = C_4^3 F_4(3, 4)$		$C_9^4 = C_9^3 F_9(3, 4)$
$C_5^4 = C_5^3 F_5(3, 4)$		E_4

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