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**Pictures, language and research:  
the case of finance and financial mathematics**

by

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ABSTRACT. A line of research can be influenced by a particular cognitive and graphical representation of the phenomenon studied. An example of this is offered by the way investments are studied in the Theory of Finance and in Financial Mathematics. The paper aims at showing that: i) a particular visual representation of an investment has a major role in finance and financial mathematics in determining the methodology used for appraising investments; ii) a different graphical description helps changing the cognitive interpretation of the phenomenon and giving rise to an overall, systemic perspective; iii) an alleged inconsistency among three capital budgeting criteria is removed by the systemic approach; iv) the shift in the description of the phenomenon results in an alteration of the *a priori* assumptions of the decision process; v) two different frames of the same issue are connected with different linguistic uses of the same words, due to the shift in the cognitive perception of the decision process.

# PICTURES, LANGUAGE AND RESEARCH: THE CASE OF FINANCE AND FINANCIAL MATHEMATICS

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## Introduction

In scientific research pictures play an important role in more than one sense. Sometimes their role is underrated, as in mathematics, where a prevailing scepticism is shared by researchers (see Brown (1997)), and sometimes it is not even acknowledged. The latter case is given in the Theory of Finance and in Financial Mathematics where academics and practitioners seem to be (or pretend to be)

unaware that the traditional investment decision rules are founded on a particular way of depicting the decision process. I claim that pictures play a role in capital budgeting: They depict a particular way of perceiving the decision process the investor deals with. By changing picture we change the cognitive perspective and are capable of seeing how the choice of a decision criterion can totally rest on the cognitive and graphical framing of a phenomenon. The pictorial shift accomplished is strictly connected with a shift in the linguistic interpretation of the same terms, and makes a long lasting conflict in the literature an idle squabble, overwhelmed by a different use of those words. It also makes us aware of the restrictive *a priori* assumptions implicit in the classical description of the phenomenon.

## 1 The picture

In finance, there often arises the problem of investment decisions. They are one among many other decision processes an economic agent is involved in. The class of these decision problems is known as *capital budgeting*. In capital budgeting, the economic agent faces a decision process with a plurality of alternatives at her disposal, called investments or projects. Sometimes the decision to invest can be deferred and the alternative of waiting can be taken into consideration. This work deals only with now-or-never alternatives, viz. nondeferrable investment opportunities. The latter are evaluated assuming, implicitly or explicitly, that the investor's goal is maximizing her own wealth. She has therefore to select the alternative which shows the highest return. The distinctive trait of an investment is the sequence of cash flows arising at given dates; hence, it seems natural to describe projects with a simple and intuitive picture of the following kind:

time	$t_0$	$t_1$	.....	$t_n$
cash flows	$a_0$	$a_1$	.....	$a_n$

where  $a_s$  and  $t_s$  are real numbers describing respectively the cash flows and the corresponding maturities (henceforth sometimes expirations),  $s = 0, 1, \dots, n$ . Negative cash flows are called payments or expenditures, positive cash flows are called revenues or receipts. An example is given by choosing  $a_s$  and  $t_s$  *ad libitum*:

time	0	1	2	3
<hr/>				
cash flows	- 100	60	50	40

The above investment consists of an initial outlay of 100 and subsequent inflows amounting to 60, 50 and 40 respectively. The sum 100 is often called the capital invested in the project, which generates the above triad of revenues. This way of depicting a project is evidently based on two informational data: i) sign and value of the cash flows and ii) their expirations. All traditional investment decision rules found in the literature are presented starting from such an outlook.

## 2 The classical rules

In this section two criteria for capital budgeting are presented. They are consolidated in the literature and widely used in appraising investments. They are explained in any standard textbook (e.g. Brealey and Myers (1988), Ross, Westerfield and Jaffe (1993)) and are taught to any undergraduate or graduate student in Business Administration and in Economics.

Suppose an investor meets with the opportunity of investing in a project and must decide whether to accept or reject the project. A widespread rule to solve the decision problem is based on the concept of internal rate of return (IRR) and it is called the internal-rate-of-return rule. The IRR is the solution for  $i$  of the following equation:

$$\sum_{s=0}^n a_s (1+i)^{-t_s} = 0 \quad (1)$$

where  $a_s$  and  $t_s$  are respectively the cash flows and the expirations of the project in hand. The left-hand side function is called discounted cash flow (DCF) and the internal rate of return is then said to be that rate  $x$  which makes the DCF zero. The IRR is regarded as the rate of return of the project. To decide whether to accept or not the investment, the agent must ask herself where she would invest money should she decide not to undertake the project. If, for example, the agent currently invests her funds at a rate of  $i^*$ , then the strategy for her is simple: she will invest in the project if and only if  $x > i^*$ . When coping with a plurality of projects the investor should choose the one with the highest internal rate of return (IRR). In case of financing projects, where the investor has the opportunity to raise funds from different sources, the rule is reversed and the internal rate is

regarded as a rate of cost. The IRR rule is (seemingly) intuitive: The investor calculates the return (in terms of a rate) from all alternatives that constitute the decision process, compares the rates of returns and chooses the alternative which ensures the highest return.

A different rule is the net-present-value rule. It differs from the former in that no equation is to be solved and no rate of return is calculated. According to this criterion one should calculate the value of the DCF function at a rate  $i^*$ , known as the opportunity cost of capital, which represents both the rate of return and the rate of cost of an alternative where the investor can invest money and raise funds any time she needs to. The value so calculated is labelled the net present value (NPV). The investor should undertake the project if and only if the NPV is positive, i.e.

$$\sum_{s=0}^n a_s (1 + i^*)^{-t_s} > 0. \quad (2)$$

Among more projects, she should choose the one with the highest NPV.<sup>1</sup> The NPV is regarded as the return, in terms of cash and in present value, that the project in hand yields compared to the alternative business whose rate of return is the opportunity cost of capital (the name ‘opportunity cost’ means that investing in the project the investor gives up the opportunity of investing in a business at a rate  $i^*$ ).

It is worth noting that the essential elements in the two rules are cash flows and corresponding expirations, from which there descend comparisons among rates (IRR rule) or among present values (NPV rule).

### 3 Where do these rules come from?

The cognitive perception and the graphical description shown above give rise to the classical rules through a way of reasoning that is worth investigating.

A loan contract is characterized by three parameters: cash flows, time and rate of interest. For example, suppose that at time 0 agent 1 lends the sum  $C_0$  to agent 2, who has to refund the debt at time  $T$ . Financial mathematics provides many ways to decide how much agent 2 must reimburse at time  $T$ . Firstly, the lender fixes a rate of interest  $j$  to be applied in the loan contract. Secondly, an increasing function  $f$  of  $T$  is chosen. This function is called the *financial law*. The amount  $C_T$  to be paid back to agent 1 is

$$C_T = C_0 f(T). \quad (3)$$

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<sup>1</sup>I will not dwell on another rule, the adjusted-present-value rule (see Myers (1974), Luciano and Peccati (1997) and any standard textbook in the References) for it is only the NPV rule slightly modified. This fact does not invalidate my line of argument.

Four financial laws are commonly used in financial mathematics:

- (i)  $f_1(T) = (1 + j)^t$
- (ii)  $f_2(T) = 1 + jt$
- (iii)  $f_3(T) = 1/(1 - jt)$
- (iv)  $f_4(T) = e^{jt}$

but many others can be easily constructed.<sup>2</sup>  $f_1$  assumes that interest is compounded at each period, that is to say, interest earned during a period is added to the previous principal amount in order to earn interest again. So, at time 1,  $C_0$  becomes  $C_0 + jC_0 = C_0(1 + j)$ . The latter is reinvested for one period yielding, at time 2,  $C_0(1 + j) + jC_0(1 + j) = C_0(1 + j)^2$ , which is in turn reinvested for one period yielding  $C_0(1 + j)^3$  and so on until  $C_T = (1 + j)^T$  at time  $T$ . In this case the picture describing the loan contract is

time	0	$t_1$	$t_2$	.....	$T$
cash flows	$-C_0$	0	0	.....	$C_T$

If the lender selects  $f_1$  as a financial law for the loan contract, then the rate of interest  $j$  used to calculate  $C_T$  is formally nothing but the internal rate of return:

$$C_0(1 + j)^T = C_T \iff -C_0 + \frac{C_T}{(1 + j)^T} = 0.$$

When the loan is to be reimbursed with a sequence of cash flows  $a_s > 0$ ,  $s = 1, 2, \dots, n$ , the lender selects, *in primis*, the financial law and determines, *in secundis*, the value of  $a_s$ . At each maturity the borrower pays back the sum  $a_s$ , contractually predetermined, and his debt amount  $C_s$  decreases according to the difference equation

$$C_s = C_{s-1}(1 + j)^{t_s - t_{s-1}} - a_s \quad s = 1, \dots, n \quad (4a)$$

which means

$$C_0(1 + j)^T = \sum_{s=1}^n a_s(1 + j)^{T - t_s} \quad T \geq t_n \quad (4b)$$

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<sup>2</sup>It can be easily demonstrated that  $f_1$  is a particular case of  $f_4$ .

or, alternatively,

$$-C_0 + \sum_{s=1}^n \frac{a_s}{(1+j)^{t_s}} = 0 \quad (4c)$$

(note that  $T$  is irrelevant for the solution). The cash flows  $a_s$ ,  $s = 1, \dots, n$  are selected so as to satisfy (4). Again, the rate of interest  $j$  is nothing but the internal rate of return (as (4c) shows).

The relation between loan contracts and the IRR rule stems from the application of (4) for *appraisal purposes*. As we will see, the (arbitrary) adoption of (4) for investment evaluations is unwarranted: The cash flows  $a_s$  are fixed and the rate  $j$  is consequently calculated. But this fact causes the IRR to lack a univocal meaning, if it has any: The solution of the equation can have more than one root or even no one. Moreover, when a unique solution can be found, it is often difficult to ascertain whether the solution is a rate of return or a rate of cost, if the cash flows change in sign several times.

As for the NPV rule, the hub lies in the comparison of two final amounts disguised as present values. Suppose that our decision maker has the opportunity to invest in a project whose cash flows are  $a_s$  at time  $t_s$ ,  $s = 0, 1, \dots, n$  and that she can invest (withdraw) funds in (from) an alternative business at a rate  $i^*$  any time she needs to. Let  $E_0 \in \mathbb{R}$  be her wealth at time 0. If she rejects the project her wealth will be worth, at time  $T$ ,  $E_0(1+i^*)^T$ . If she undertakes the project, reinvesting the inflows in and withdrawing the outflows from the alternative business, she will have, at time  $T$ ,

$$(E_0 + a_0)(1+i^*)^T + \sum_{s=1}^n a_s(1+i^*)^{T-t_s},$$

so she should accept the alternative which shows the higher final value of her wealth, i.e. the project if

$$(E_0 + a_0)(1+i^*)^T + \sum_{s=1}^n a_s(1+i^*)^{T-t_s} > E_0(1+i^*)^T, \quad (5)$$

the alternative business otherwise; (5) and (2) are just the same, the former is in terms of final values, the latter is expressed in present values. In all this, the relation between NPV rule and loan contracts lies in the use of  $f_1$  as a financial law for discounting cash flows.



#### 4 The false analogy between loan contracts and projects

Let us wonder what a rate of return is. In order to give it a precise and univocal meaning a rate of return of a project must be a numerical parameter which shows *how fast the capital invested in a project varies over time*. It is, first of all, a *rate*, which means that it expresses a *relative* change in the capital invested. Secondly, it expresses a *return*, which means that we must have something well specified that *changes*, generating a yield in some way or other. A rate of return shows then how much money the investor gains, for any unit of money invested at the outset and in any unit of time. The way we measure the rate of return depends on the hypothesis we can do about the variation of the capital invested over time.

Let us focus attention on those projects with two only cash flows opposite in sign expiring at the maturities  $t_0$  and  $T$  respectively. They are called PIPO (Point Input Point Output). A capital  $C_0$  can lead to the final receipt  $C_T$  in many ways. Four of them are just the financial laws we have seen for loan contracts (others can be obviously used). In capital budgeting (3) is used to get  $j$ , whereas in loan contracts (3) is used to get  $C_T$ , once  $j$  has been fixed. If the assumption of compounding conforms to the *reality* of the project, then  $j$  can be obtained by (3) with the adoption of  $f_1$  or  $f_4$  and what we get is the *internal* rate of return. Of course, nothing prevents us to mix different financial laws for the same project, or to calculate different rates of return corresponding to each period, if the *reality* of the project warrants this interpretation. However, in general, economic agents are often interested in an *average* rate of return. In this case, a single well-specified financial law must be used for a single project. We can therefore use (3) for capital budgeting purposes, thinking of  $C_0$  as a sum lent to someone or something, who (which) will refund the debt paying back the sum  $C_T$  in  $T$ . In doing this, we are assimilating investments to loan contracts by applying to the former a mathematical procedure which refers to the latter. We must be aware that this is an arbitrary interpretation of the phenomenon. We *invent* that  $C_0$  has increased to  $C_T$  by means of a particular financial law and even the choice of the latter is mostly derived by a subjective interpretation of a project. This interpretation is made for evaluation purposes and it can fit well only for PIPO projects. It is also evident that in this view the contractual rate of a loan contract can be seen as the rate of return of the loan contract itself (thought as an investment for the lender) if it is a PIPO project.

Things are different when a decision maker faces projects with a plurality of cash flows  $a_s$ ,  $s=0, 1, \dots, n$ , which is the main case. In the literature, no distinction is drawn between PIPO projects and the other kinds of projects in order to correctly interpret the notions of rate of return and internal rate of return. The IRR is considered to be the rate of return of a project even in the cases we are now dealing

with. I object that, at the very best, it could be only *one* kind of rate of return corresponding to a particular selection of financial law (i.e.  $f_1$ ). Hence, it could be, at the most, that rate of return for which the assumption of compounding makes sense. Also, the IRR rule was born from a conceptual overturn of the relation between rate of interest and cash flows. In a loan contract, the contractual rate of interest is *a priori* determined and the cash flows are then derived through the solution of (4).<sup>3</sup> On the contrary, in a project things are reversed: Cash flows are exogenously fixed first, and a rate of return is searched for afterwards. Conceptually, in loan contracts cash flows are a consequence of the rate:

$$\text{rate} \implies \text{cash flows},$$

in capital budgeting the converse holds:

$$\text{cash flows} \implies \text{rate}.$$

As (4) is an  $n$ -th order equation (assuming, with no loss of generality,  $t_s=s$ ) multiple roots are possible or even no one at all, or the unique solution is not unambiguously interpretable. This fact is astonishing for financial analysts who ask for a unique rate of return with a univocal financial meaning. The IRR is then considered a whimsical index by many authors and the IRR rule is deemed a misleading or even inapplicable investment decision criterion: “When more than one root occurs, which one is ‘the’ internal rate of return? Actually, neither one. [...] Analysis of such a proposal using the internal-rate-of-return method is cumbersome and is more easily accomplished using the net-present-value method” (Finnerty (1986), p. 91). I oppose this view and claim that the IRR is cumbersome only because financial mathematicians arbitrarily apply equation (4) to investments in looking for a profitability index. But (4) stems directly from the classical graphical description of investments which is conceptually founded on two parameters: cash flows and maturities. These can properly represent the reality of a loan contract, not that of a project (as we will see later), and the two do not coincide. By describing a project only through flows and maturities financial mathematics gives rise to a false analogy between loan contracts and business or industrial projects. It is legitimate to get to cash flows from a rate in the former case, but it is absurd to get to a rate from cash flows in the latter. If we interchange the role of rate and cash flows in (4), letting the former be the unknown, we cannot expect of the same equation to have a univocal financial meaning: We

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<sup>3</sup>It is obvious that there are infinite solutions of (4), among which the lender selects the one preferred.

do have changed the phenomenon we are studying. The IRR has no meaning just because (4) has no meaning for investment purposes; it only can be applied for drawing up loan contracts, not for evaluating the return of an investment. As we have seen, the (false) analogy seems to be somewhat fruitful only for PIPO projects, because the solution of (3) exists, is unique and can be thought of as a parameter measuring how fast the capital invested increases over time. In this case the IRR has the unequivocal meaning of average rate of return of the capital invested, choosing  $f_1$  as a financial law, *provided that* the project can be seen as producing return which is compounded at each period (the basic assumption of  $f_1$ ). For all other projects, which represent the most part, the solution of (4) is not a rate of return. As a matter of fact, if we look at these projects as if they were loan contracts we get to nothing: The use of the ‘cash flows-maturities’ picture (henceforth often CF-M) has given rise to a nonsensical IRR rule, whose behavior has been and is a mystery for a large part of the literature. A plethora of articles have been written in the past decades (see References) and some authors have even tried to provide postulates for the internal rate of return, complaining that the IRR behaves well only in loan contracts (see Promislow and Spring (1996)). I underscore that the IRR is only a solution of an equation, so it has a *mathematical* meaning. It has the meaning of rate of return of a project only in the particular case of PIPO projects. The further assumption of periodic reinvestment is also essential, otherwise nothing would prevent us to calculate the rate of return by using a different financial law.

Can we then assign any particular meaning to the IRR of a multiple-flows project? If we pretend the project is a loan contract, there are some favorable cases where it can be regarded of as the periodic return of that capital which is still invested in the project at the beginning of that period. The latter is called *outstanding capital* (see  $C_s$  in (3a)). It fades gradually, from period to period, due to deduction of intermediate cash flows  $a_s$  from the project, and vanishes at the end of the last period. If the outstanding capital decreases monotonically, then the IRR can be considered its rate of return. But the rate of return of the *outstanding capital* is not the rate of return of the *project*. The latter is the return that a specific capital invested at time  $t_0$  generates periodically during the whole life of the project, *assuming that no cash flow is ever subtracted from the project* (viz. PIPO projects). However, some interpretative difficulties arise when the outstanding capital does not decrease monotonically: If this is the case, it means that further money has been invested in the project. But, if we have multiple sums invested at different maturities, what does the solution of (4) refer to? Further troubles arise, moreover, in case the project is such that the outstanding capital changes in sign several times, for it means that it is investment (i.e. lending money)

in some periods and financing (i.e. borrowing money) in other periods,<sup>4</sup> therefore the IRR can by no means be regarded as a rate of *return*: If we are to give the IRR any financial meaning, we are left with the only chance of interpreting it as *that rate of interest that should have been contractually determined (in order to have that particular pattern of cash flows) if the project were a loan contract*. But this analogy is simply false. A business or industrial project cannot be viewed as a loan contract, and even for a loan contract of such a kind, the IRR (i.e. the contractual rate) would have an ambiguous financial nature: It would be, somehow, both a rate of return and a rate of cost, or maybe neither of them.

The very freakishness of the IRR's behavior should have suggested scholars to doubt their representation of facts: It could have been an opportunity to understand the meaningless nature of the IRR in the CF-M approach. On the contrary, starting from the above analogy they have disregarded the assumptions of the CF-M approach and illogically lucubrated about the assumptions of the IRR rule. Some authors have actually acknowledged the difference between rate of return of a project and rate of return of the *outstanding capital* of a project. The former takes into consideration not only the cash flow remaining in the project, but also the reinvestments (or withdrawals) of the intermediate cash flows  $a_s$  leaving from the project. Some authors have actually claimed that the IRR is merely the rate of return of the outstanding capital. To get to this conclusion they have set aside both the assumed analogy between projects and loan contracts and all those cases where the notion of IRR can by no means be meaningful, focusing attention (consciously or unconsciously) on the favorable cases of outstanding capital invariant in sign and monotonically decreasing. In addition, they have reasoned about the IRR so as to make it coincide with a proper rate of return of the project. In fact, many authors assert that the IRR rule makes the implicit assumption of reinvestment of intermediate cash flows at the internal rate of return  $x$  of the project (see the right-hand side of (4) where the IRR  $j=x$  is used to compound cash flows). In this way, we can see the project in hand as a PIPO project (the intermediate net cash flows are zero, because when they arise from the project they are simultaneously reinvested at the same rate  $x$ ; see the left-hand side of (4)) and the IRR does make sense (only) if this assumption is realistic. Some use this result to salvage the IRR rule, some use it to discard it (for its unlikeliness). But what is relevant for our purposes is that in fact no assumption at all is made by the IRR rule about the reinvestment of cash flows, so that the *disputatio* turns to be an idle quarrel. As a matter of fact, there cannot be the assumption of reinvestment at the rate  $x$  for the simple reason that such an assumption leads to

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<sup>4</sup>I remind the reader that we are accomplishing an analogy between projects and loan contracts.

an absurdity. Let us see how this happens.

In a decision process, if any assumption is ever to be made, it must be used to help decision makers to select one action alternative among others. The selection of a course of action is then function of (depends on) an assumption, whereas the converse makes no sense (an assumption cannot depend on the selection of a particular course of action). But this is just what happens by adopting the alleged hypothesis of reinvestment of cash flows at the internal rate of return: One finds out that the assumption changes in consequence of the project selected. In fact, let  $x_A$  and  $x_B$  denote the internal rates of return of projects  $A$  and  $B$  respectively. Suppose the investor undertakes  $A$ . The IRR rule would tell us that the decision maker is assuming that the interim cash flows of  $A$  will be reinvested at the rate  $x_A$ . Suppose now the investor chooses  $B$ ; the IRR rule would assume now that the reinvestment of  $B$ 's interim cash flows is made at the rate  $x_B$ . This means that the rate of reinvestment is given by the rate of return corresponding to the project selected. But then, according to this view, the assumption does not determine the choice of a course of action: It is the latter that determines the implicit assumption in the decision process. The reinvestment assumption is not exogenously fixed *a priori* and does not constitute an element affecting the choice. In this line of argument the relation between assumption and choice is reversed and the former is implicitly inferred by the latter, which is a nonsense.<sup>5</sup> Even when the absence of a particular reinvestment assumption seems to be somehow recognized, it is not used to shed light on the CF-M but to admit again that a particular assumption is implicit (not in the criterion itself) but "in *the decision to use* one or the other of the two criteria" (Dudley (1972), p. 908). But this is not a great difference from the point of view of a decision maker.

So it seems that only PIPO projects could give rise to a meaningful IRR. As we have seen, the false analogy does not prevent us to give the IRR the meaning of that particular rate of return (of the project) for which compounding makes sense. Consequently, one might think that the IRR is a significant index when the investor deals with PIPO projects. Unfortunately, the analogy is fruitful only in a *conceptual* sense, but it is useless in the decision process. In fact, the decision maker needs to measure the return of a unit of money in a unit of time *in order to compare* different returns relative to different courses of action. The IRR, as it stands, tells us *how much profitable* is a project. This information is useful only if it also tells us if an alternative is *more profitable than* another. But analysing

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<sup>5</sup> Alongside such an absurdity there is an implicit unrealistic assumption which I do not intend to dwell on. Just think that as the interim cash flows can be positive or negative, the rate of reinvestment turns to a rate of financing when the cash flow under consideration is negative. So we should unrealistically assume that the rate of interest for financing is the same as the rate of interest for investment.

two or more PIPO projects, we cannot compare their rates of return unless all projects share the same capital invested, the same length, the same maturities. In any other case, the *relativeness* of the rate of return is misleading in three senses:

- (i) relativeness with respect to the capital invested, e.g. 10% with a capital of 100 is different from 10% with a capital of 60 (what about the other 40?);
- (ii) relativeness with respect to time, e.g. a periodic 10% gained for three periods is not the same as 10% gained for one period (what about the other two periods?);
- (iii) relativeness with respect to maturities, e.g. a 10% return gained between  $t_0$  and  $t_n$  has a different meaning from a 10% return gained between  $\tau_0$  and  $\tau_n$ , if  $t_0 \neq \tau_0$  and  $t_n \neq \tau_n$ , even if  $t_n - t_0 = \tau_n - \tau_0$ .

We are then left with a significant rate of return only in those decision processes where the projects under consideration are *homogeneous*, that is they all consist of the same capital invested  $C_0$  at  $t_0$  and a single receipt at the same final maturity  $T$ . The *internal* rate of return is then the (significant) rate of return of *homogeneous* projects, where it is assumed, for all of them, the hypothesis of compounding returns. In any other case, it is useless in the decision process.

To sum up, we can divide investments into two classes, PIPO projects and multiple-flow projects. For PIPO projects the IRR can be thought of as a rate of return, assuming that return is periodically compounded, but this rate of return cannot be used for comparisons between projects, unless they are *homogeneous*. For multiple-flow projects the IRR means nothing if the outstanding capital decreases not monotonically and/or changes in sign at least once; in any other case it is the contractual rate of a *figurative* loan contract which the project is likened to.

Thus, in general, the notion of rate of return or *internal* rate of return is meaningless and/or misleading. The only fruitful case concerns a decision process where only homogeneous PIPO projects are considered. But this happens hardly ever, in the CF-M approach, because of the very CF-M description of investments as loan contracts, focusing on flows and maturities. Therefore when the IRR rule breaks down, it is not for intrinsic flaws: It fits perfectly for *homogeneous* projects. The fact that most investments are not *homogeneous* depends on the particular (conceptual and) visual representation of the CF-M approach, which better conforms to loan contracts. By changing approach we will be able to render all possible investments *homogeneous* and therefore assign the IRR a meaningful role. So, whereas some authors say: ‘Do not use the IRR!’ or: ‘Do use the IRR if it is *unique!*’, or: ‘Do use the IRR if it is *significant!*’, I rather claim: ‘Do not use the IRR rule *in the CF-M approach*, change approach and it will be *unique* and *significant!*’.

## 5 The NPV rule and the CF-M approach

The NPV rule is based on the two classical parameters that arise, conceptually and graphically, from the traditional description previously seen. But the picture is used in a different way: the internal rate of return  $x$  is replaced by an explicit rate of return  $i^*$ , exogenously introduced, and the equation is thus transformed to a number: Unlike its companion, it expresses the profitability of an investment in terms of net present cash flow, the rate  $i^*$  being used to take account of reinvestments (when  $a_s > 0$ ) and withdrawals of funds (when  $a_s < 0$ ); the implicit assumption which gives rise to an opportunity cost of capital is the existence of a single business, which yields (positive and negative) remuneration at the rate  $i^*$  and which represents an alternative of action for the investor. The NPV rule does not show how fast the capital invested has changed. It provides the decision maker with an index representing the comparison, in terms of profitability, of two alternatives, one of which has a rate of return (for investment) and a rate of cost (for financing) equal to  $i^*$ . While a rate of return then expresses the return with respect to the capital invested at time  $t_0$ , the net present value shows the remuneration of the act of undertaking the project compared to the act of undertaking the business whose rate is  $i^*$ . It is then worth noting that as the NPV rule fails to provide the decision maker with a rate of return, it tells us if an investment is more profitable than the one whose rate is  $i^*$ , but does not tell us *how much profitable* it is. Further, the use of  $f_1$  to discount cash flows derives from a *figurative* stipulation of a loan contract. This (false) analogy is made for mathematical convenience, because the use of exponential functions enables to disguise final values as present values by dividing both sides of (5) for  $(1 + i^*)^T$ . Moreover, the opportunity cost of capital is often introduced in the literature in a non rigorous way: Sometimes it is the market rate, sometimes the Weighted Average Cost of Capital,<sup>6</sup> sometimes the rate of assets of equivalent risk, sometimes it derives from the so-called CAPM model,<sup>7</sup> and sometimes it is an accounting parameter called Return On Equity.

In addition to the above remarks, I must stress that the assumption of one single opportunity cost of capital  $i^*$  is incredibly unrealistic, because it entails that wealth is composed of a unique bank account where the investor can turn to any time she needs, and that the rate of interest applied by the bank is the same whether or not the value of the account is positive or negative. But the most striking fact is that the addition of this third parameter in the CF-M approach is not costless, being the rule self-inconsistent.

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<sup>6</sup>See Peccati (1996), where the absurdity of this index is demonstrated.

<sup>7</sup>The CAPM (Capital Asset Pricing Model) is based on utility theory assuming that investors have quadratic utility functions.

For example, according to the NPV procedure, the investor facing a project with uncertain cash flows should discount cash flows with the (internal) rate of return of an alternative comparable in risk. Let  $i_m$  be this rate and consider, for the sake of simplicity, a one-period project with initial outlay  $-C_0$  at time 0 and final receipt  $C_1$  at time 1 with internal rate of return  $x$ . The project should be undertaken if and only if

$$-C_0 + \frac{C_1}{(1+i_m)} = -C_0 + \frac{C_0(1+x)}{(1+i_m)} > 0 \quad (6)$$

or, which is the same,

$$(E_0 - C_0)(1+i_m) + C_1 > E_0(1+i_m) \quad (7)$$

where  $E_0$  is the investor's wealth at time 0. The NPV procedure, resulting in (6), can be summarized as follows (see Magni (1998b) for details):

- (i) a decision maker is faced with two alternatives, 'to do' (n.1) or 'not to do' (n.2);
- (ii) the two alternatives are different in risk;
- (iii) there exists a tenet in the literature which states that it is illicit to compare the rate of return of two alternatives different in risk. This means that the internal rates of return of n.1 and n.2 cannot be compared;
- (iv) to obey this tenet a third alternative is introduced, n.3, equivalent in risk to n.1 and whose rate of return is  $i_m$ ;
- (v) it is claimed that the investor has to compare n.1 with n.3 neglecting (arbitrarily) n.2; but, if n.3 turns out to be the better alternative, then n.2 must be recovered and selected;
- (vi) in fact, step (v) is not followed: n.1 (left-hand side of (7)) is compared with n.2 (right-hand side of (7)) and not with n.3, as previously declared;
- (vii) the comparison between n.1 and n.2 is applied by despoiling both alternatives of their own rates of return and assigning them n.3's rate of return (i.e.  $i_m$ , as in (7));
- (viii) all is condensed in (6) which eliminates  $E_0$  (the investor's wealth is regarded as unimportant in the decision).

As one can see, the procedure is totally illogical and unwarranted. Other kinds of fallacy can be deduced for projects under certainty as well (see Magni (1998c)).

## 6 Changing picture

A picture has historically created the IRR rule in the effort of providing a profitability index which should help economic agents to solve (investment) decision



processes. The NPV rule emerged from the same picture and supporters of either rule conflicted for decades to invalidate the opponents' arguments. Their picture favors a conceptual approach based on differential cash flows and corresponding maturities. The *diachronic* features are clearly depicted and describe what gets in and out of the investor's 'wallet' at any time. In this view the economic agent's 'wallet' (viz. her wealth) is totally disregarded. In (1) and (2) cash flows and maturities are the only elements considered relevant (with the substitution of a fixed  $i^*$  for the unknown  $x$  in (2)), as the classical graphical description suggests. The two methods are thus based on the same framing of the problem and an entire line of research has been conditioned by this particular illustration of the phenomenon. Many efforts have been made to get to a reliable capital budgeting criterion. The NPV rule seems to have won the squabble, for it takes account, according to academics and practitioners, of reinvestments (withdrawals) of funds at a *realistic* (sic) rate  $i^*$ , exogenously fixed, whereas the IRR rule implicitly assumes that cash flows are reinvested (withdrawn) at the same internal rate  $x$  of the project.<sup>8</sup>

Let us now change the frame of the problem by focusing attention on wealth. To this end, let us forget, for the moment, all we have learned about capital budgeting criteria and take a look to the decision problem through a different shaping of it. 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 economic agent (individual or firm) has a net worth composed of more than one business, for example bank accounts, securities, buildings, lands, plants etc. Let us describe the decision maker's net worth as composed of assets and liabilities and let us graph it by means of a table of the following kind:

<u>Assets</u>		<u>Liabilities</u>
$C_{s1}$		$C_{s,k+1}$
$C_{s2}$		$C_{s,k+2}$
...		...
...		...
...		...
$C_{sk}$		$C_{sm}$

where  $C_{sl} \geq 0$  reflects the worth of business  $l$ ,  $l = 1, \dots, m$ , at a given date  $t_s = s$ . The table shows  $m$  activities,  $k$  of which are assets and  $m - k$  are liabilities; any

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<sup>8</sup>But we know that this is not true.

business  $l$  has a rate of return equal to  $i_l$ . The difference between the total worth of the left-hand side (Assets) and the total worth of the right-hand side (Liabilities) provides us with the decision-maker's net worth. Note that the above picture focuses attention on the structure of the net worth, namely the way the wealth is employed at a certain date  $t_s$ . If the businesses that compose the net worth do not interact one another, that is the return of each one of them is reinvested in the very same business that has produced it, the worth of business  $l$  is given by  $C_{sl} = C_{s-1,l} + i_l C_{s-1,l} = C_{s-1,l}(1 + i_l)$ ; otherwise flows can pass from a business to another modifying the structure.

How can we depict an investment on this table? Simply by adding, at time  $t_s=s$ , the worth  $A_s$  of the investment under consideration on the left-hand side of the table and distributing the arising cash flow  $a_s$  across the businesses of the table. As an example suppose  $k=6$ ,  $m=10$  and  $a_s=38$ . Suppose also that  $a_s$  is distributed according to the following partition: 10 is invested in business 1, 15 in business 2, 5 in business 3 and 8 in business 6. The above picture turns to

<u>Assets</u>		<u>Liabilities</u>
$C_{s1} = C_{s-1,1}(1 + i_1) + 10$		$C_{s7} = C_{s-1,7}(1 + i_7)$
$C_{s2} = C_{s-1,2}(1 + i_2) + 15$		$C_{s8} = C_{s-1,8}(1 + i_8)$
$C_{s3} = C_{s-1,3}(1 + i_3) + 5$		$C_{s9} = C_{s-1,9}(1 + i_9)$
$C_{s4} = C_{s-1,4}(1 + i_4)$		$C_{s,10} = C_{s-1,10}(1 + i_{10})$
$C_{s5} = C_{s-1,5}(1 + i_5)$		
$C_{s6} = C_{s-1,6}(1 + i_6) + 8$		
$A_s$		

As another example suppose, *ceteris paribus*,  $a_s=-100$ . Consider the following distribution of the cash flows: 25 is withdrawn from business 7, 40 from business 8, 35 from business 9. We have then

<u>Assets</u>	<u>Liabilities</u>
$C_{s1} = C_{s-1,1}(1 + i_1)$	$C_{s7} = C_{s-1,7}(1 + i_7) + 25$
$C_{s2} = C_{s-1,2}(1 + i_2)$	$C_{s8} = C_{s-1,8}(1 + i_8) + 40$
$C_{s3} = C_{s-1,3}(1 + i_3)$	$C_{s9} = C_{s-1,9}(1 + i_9) + 35$
$C_{s4} = C_{s-1,4}(1 + i_4)$	$C_{s,10} = C_{s-1,10}(1 + i_{10})$
$C_{s5} = C_{s-1,5}(1 + i_5)$	
$C_{s6} = C_{s-1,6}(1 + i_6)$	
$A_s$	

In general, there are infinite ways of partitioning  $a_s$  by ‘activation’ of Liabilities as sources and Assets as applications of funds. Letting  $a_{sl}$  be the cash flow invested in or withdrawn from business  $l$ , the decision maker’s financial status at time  $s$  will be

<u>Assets</u>	<u>Liabilities</u>
$C_{s1} = C_{s-1,1}(1 + i_1) + a_{s1}$	$C_{s,k+1} = C_{s-1,k+1}(1 + i_{k+1}) + a_{s,k+1}$
$C_{s2} = C_{s-1,2}(1 + i_2) + a_{s2}$	$C_{s,k+2} = C_{s-1,k+2}(1 + i_{k+2}) + a_{s,k+2}$
$C_{s3} = C_{s-1,3}(1 + i_3) + a_{s3}$	$\dots$
$\dots$	$\dots$
$C_{sk} = C_{s-1,k}(1 + i_k) + a_{sk}$	$C_{sm} = C_{s-1,m}(1 + i_m) + a_{sm}$
$A_s$	

with

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

Obviously,  $a_{sl}$  increases or decreases the value of account  $l$ . More precisely, if  $a_{sl}$  is a source (leading to a decrease in the Assets or an increase in the Liabilities), then

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

if  $a_{sl}$  is an application the sign is reversed.

## 7 The system

Our double-entry picture has enriched the perspective with which we look at the decision process. The distinctive feature of the CF-M description is the *diachronic* dimension, which expresses the arrival of cash flows as time goes by. It derives, in my opinion, from the attitude of scholars and laymen to dwell on the cash flowing in and out of one's own 'wallet'. In this sense, what remains in the 'wallet' is not so important. To solve the decision process, the rules seen above gather up cash flows and maturities and put them in a formula that offers us a rate of return or a present value. In all this, the *diachronic* dimension is essential: Cash flows arise with time and get in and out of the investor's 'wallet'. The double-entry picture shapes the problem differently. It has not only a *diachronic* dimension but also a *synchronic* one. The latter is given by the multiple businesses the economic agent is simultaneously concerned with. They are investments and financings undertaken in order to increase the investor's net worth. In this sense, the 'wallet' is a system structured in many components interacting with the project through the activation of the businesses as cash flows arise over time. Inflows and outflows are therefore redistributed inside the system so that two more parameters are to be added to correctly represent the phenomenon: the structure of the system and the way any cash flow is distributed across the elements of the system. Graphically, the synchronic dimension is obtained by displaying the collection of businesses on the sheet, the diachronic one is grasped through the time iteration of the picture. The final picture, relating to a pre-fixed terminal horizon  $T$ , shows us the value of the net worth with its structure, under a particular hypothesis of activation of the businesses and a particular hypothesis of project undertaken. The final net worth  $E_T$  is given by

$$E_T = \sum_{l=1}^k C_l^T - \sum_{l=k+1}^m C_l^T. \quad (8)$$

The comparison of final net worths corresponding to different courses of action can help the decision maker to select the preferred alternative.<sup>9</sup>

## 8 Accounting

The new representation of facts casts new lights on another interesting aspect: The relation between finance and accounting as two different (though connected)

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<sup>9</sup>Note that (8) is dependent on the terminal horizon  $T$ , whereas the NPV and the IRR seem to be valid regardless of  $T$ . For further remarks see Magni (1998a).

fields of research.<sup>10</sup> Accounting deals with the need of recording all transactions of an economic agent in order to understand how capital is commonly raised and employed and how net worth varies over time. The most important pictures used in accounting are the balance sheet and the income statement. The businesses of the double-entry picture are but the accounts of a monetary balance sheet, where *accounting* values are replaced by *worths*, viz. cash values. That is, I have applied an accounting approach with forward-looking purposes borrowing a balance sheet to graphically describe the decision process for an agent facing the opportunity of a now-or-never investment. This perspective has enabled us to consider both the diachronic and synchronic aspects of an investment and to realize that the decision maker continuously copes with a system (her wealth) which is structured in multiple components interacting in a nontrivial way with the cash flows released by the project.

In the literature accounting is considered totally misleading in issues concerning investment decisions. Not only financial mathematicians but also some very accountants do refute the idea of using accounting to appraise investments. Their arguments are seemingly convincing: Accounting looks at the past whereas finance is forward-looking, accounting values differ from cash values, accounting is only indirectly concerned with profitability through taxation, accounting does not record alternative ways of action whereas finance deals with several courses of possible actions. They miss, in my opinion, an overall perspective, and fail to recognize that accounting can be important for its peculiar picture. Not as it stands, but for the reason that it changes the way we perceive the phenomenon of investment. So accounting must be considered not for the way it *is* used but for the way it *can* be used. The balance sheet's perspective is epistemologically important because it alters the way we acquire knowledge from a financial phenomenon as well as the methodology we use to rationally appraise an investment. So, to cash flows and maturities we must add the system and its structure. In borrowing a picture from accounting I do not use *accounting* for capital budgeting purposes, I rather use the *way* accounting looks at economic transactions: A systemic outlook for which all transactions are explicitly considered and recorded on income statements and thus on balance sheets (which implicitly incorporate the former).

## 9 The return on equity

It is not correct to say that accounting is backward-looking. To a certain extent, accounting is partly forward-looking. Prospective balance sheets and income

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<sup>10</sup>We are concerned with investment decisions. They constitute a branch of both finance and financial mathematics. I shall henceforth write 'finance' to mean 'finance and financial mathematics'.

statements, forecasts of sources and applications of funds are periodically drawn up for several purposes, one of which is just investment evaluation. Accounting has its own index to appraise an investment and it is called return on equity (ROE). It is used in two different ways for two different purposes. As an overall index, it is used as tool of performance analysis and it is given by the ratio of profit to equity (the *accounting* value of the investor's wealth):

$$E_{s-1}(1 + \text{ROE}) = E_s \iff \text{ROE} = \frac{E_s - E_{s-1}}{E_{s-1}} \quad (10)$$

where  $E_s$  represents equity at time  $t_s=s$ . As an investment index it is used as a profitability measure. In the latter sense, the ROE can have a meaning, if any, only on condition that returns are expressed in monetary terms, not in accounting terms. Once the cash flows of the project are estimated, the prospective average ROE is given by the ratio of total net cash flows to initial outlay. For example, the project

time	0	1	2	3
cash flows	- 100	25	35	50

produces an average ROE of  $(-100+25+35+50)/100=0.1=10\%$ . Unfortunately, even the use of cash flows rather than profits does not prevent the ROE to be incompatible with both the IRR rule and the NPV rule. They often give different rankings for projects and the ROE is commonly considered totally misleading because it does not take time into consideration.

It is interesting to note that the ROE as a profitability index is calculated in the literature by adopting the very CF-M picture, whereas as an overall index it is calculated from a systemic perspective. It is evident that the systemic nature of the overall ROE is distorted when it is used for investment evaluation. Even those who commonly work with accounting and who should be used to a systemic perspective, keep on considering investments from a mere diachronic point of view, neglecting that very synchronic perspective which is typical of their usual activity. I want to demonstrate in the next section that the incompatibility among the three profitability index (IRR, NPV, ROE) derives from that particular cognitive and graphical representation of flows and maturities firmly consolidated in both finance and accounting. By changing picture and borrowing (not the values but)

the interpretation of facts from accounting, we enter a systemic outlook which makes the three rules consistent one another, to such a point that the ROE and the IRR are, from a formal and financial point of view, the same parameter; furthermore, the long-lasting squabble between IRR and NPV turns out to be, in this light, an idle issue.

### 10 The alleged incompatibility and the idle squabble

For convenience of the reader, the definitions of the three parameters are given again, assuming  $t_s=s$ :

(i) the IRR is that rate  $x$  such that

$$\sum_{s=0}^n a_s(1+x)^{-s} = 0$$

(ii) the NPV is the discounted cash flow function calculated at a fixed rate  $i^*$ :

$$\sum_{s=0}^n a_s(1+i^*)^{-s}$$

(iii) the (monetary) ROE is the ratio between total net cash flows and initial outlay:

$$\frac{\sum_{s=1}^n a_s - a_0}{a_0}$$

where we must assume  $a_s > 0$  for all  $s$ .<sup>11</sup> Under the classical diachronic perspective, they offer different rankings of projects. And what about the systemic perspective?

The investor has a net worth  $E_0$  she invests at each period. Suppose she has to choose between two projects, say  $A$  and  $B$ . She selects the way cash flows are to be distributed in the system at each period for both alternatives and then she calculates the corresponding final net worths at a terminal horizon  $T$ . They are denoted respectively by  $E_T^A$  and  $E_T^B$ . In this light, any investment is characterized by two cash flows, initial and final net worth, and the internal rate of return corresponding to each option is given by that *unique* rate such that

$$-E_0 + \frac{E_T^r}{(1+x_r)^T} = 0 \quad r = A, B. \quad (11)$$

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<sup>11</sup>Note how absurd this very definition is: it rests on the assumption that all projects are composed of an initial outlay with subsequent proceeds. This is only one of all possible kinds of investment and is known as PICO (Point Input Continuous Output).

The NPV of any investment calculated at the opportunity cost of capital  $i^*$  is given by

$$-E_0 + \frac{E_T^r}{(1+i^*)^T} \quad r = A, B. \quad (12)$$

The one-period ROE is the solution of (10), as we have seen. As we are in a multiperiodic setting, we can calculate the ROE just considering that the investor invests  $E_{s-1}$  at the beginning of the  $s$ -th period and receives  $E_s$  at the end of that period. As this holds for any  $s$ , the return gained in a period is compounded, namely it is reinvested to produce profit again. So the use of  $f_1$  is legitimate to calculate the average ROE, and we obtain

$$E_0(1 + \text{ROE}_r)^T = E_T^r \iff \text{ROE}_r = \left(\frac{E_T^r}{E_0}\right)^{1/T} - 1. \quad (13)$$

But (11) and (13) coincide, so that the IRR and the ROE are the very same index. There is no reason to name two equal things differently, so I label it internal rate of return of the system (IRRS). But (12) yields the same ranking of the latter since

$$-E_0 + \frac{E_T^A}{(1+i^*)^T} \lesseqgtr -E_0 + \frac{E_T^B}{(1+i^*)^T} \quad \text{if and only if} \quad x_A \lesseqgtr x_B.$$

Therefore, in the systemic perspective the alleged inconsistency among the three indexes is removed: The IRR and the ROE (expressed in monetary terms) are the same index, viz. the IRRS, the NPV concept leads to the same ranking of projects as the IRRS.

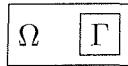
The above result is important for it shows how different results can be achieved starting from different levels of reality. Accounting has a systemic reality where every thing is considered and recorded, nothing escapes from the system, whereas finance has a diachronic framing of the problems which forgets elements relevant for the decision process. To deeply understand why we succeed in removing the inconsistency rising to a different, higher level of reality, we have to think of the semantic use we make of the terms so far used. As we will see in section 12, words and picture are closely related in accomplishing this cognitive shift.

## 11 Multiple objectives

The above result is not the only striking result derived from changing the frame of the problem. It is easy to see that the comparison of final net worths for different alternatives in the systemic approach is a generalization of the NPV rule of the



CF-M approach: Suffice it to say that when  $m=1$  the comparison between two final net worths can be replaced by the comparison between two net present values by dividing both sides of the inequality for the rate of return (opportunity cost of capital) of the only business the investor holds (see, for details, Magni (1998a)). So, we can formally comprehend the allegedly most reliable criterion of capital budgeting<sup>12</sup> in our systemic perspective. This is no surprise, because the CF-M outlook is a mere subset of the systemic perspective, since the former is capable of grasping only the diachronic dimension of the problem:



$\Omega$  = systemic approach (synchronic and diachronic)

$\Gamma$  = CF-M approach (diachronic)

The NPV rule in the CF-M approach rests on the restrictive assumption  $m=1$  whereas the synchronic dimension is attained by allowing  $m>1$ , as the systemic approach does. This generalization does not only provide broader applicability; it also uncovers some fallacies and inconsistencies implicit in the NPV criterion (see Magni (1998b, 1998c)). Above all, the generalization  $m>1$  has a deep impact on the *a priori* assumptions of the decision process. It presupposes the enlargement of the set of objectives for the decision maker. The NPV rule assumes that any investor is concerned with a mere maximization of (liquid) wealth,<sup>13</sup> whereas the systemic approach admits a plurality of objectives: That is just the reason why net worth is structured in a plurality of accounts. A particular structure of the system is always affected by (constraints and) the decision maker's preference system, which in turn influences the way the interim cash flows are periodically

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<sup>12</sup>Though some authors might think to demonstrate some flaws of the NPV rule, in fact they do not, since they only change the decision process adjusting it so as to validate their own approach. See, for example, McDonald and Siegel (1986), Trigeorgis (1986), Smith and Nau (1995), where a different decision process is considered, in particular a *deferrable* option to invest. In addition, it is well known that even the appraisal of a deferrable investment option can be seen as a comparison between two net present values, one of which is the value of waiting and the other refers to the undertaking of the investment (see Dixit and Pindyck (1996)). We are then dealing with a mere enlarged NPV rule.

<sup>13</sup>To give an explanation of the addition of the term 'liquid' is beyond the subject, it is only meant to allow the reader to realize that the set of objectives is extremely restrictive in the CF-M approach.

distributed in the system. In this light, the selection of the preferred course of action is determined not only by the comparison of final net worths (as in the NPV rule, where they are disguised as *present* values) but also by the choice of a particular structure of the system, which is the result of the subjective personality of the decision maker. In this way, the decision process is described so as to embrace a larger spectrum of human needs. These play a major role in any decision process and it is quite strange that finance seems to look at the ‘rational behavior’ as a rigid device suitable for rudimentary subjects rather than highly developed and articulated individuals. The goal of maximizing wealth must be integrated by a deeper understanding of human subjectivity, which is the result of many conflicting drives and desires which are often non-autonomous. Accounting itself and business administration as disciplines show that economic agents face constraints and aim at several ends. Finance tries to simplify things in order to draw simple schemata of human behavior, which are rather simplistic and cause financial decision criteria to fall into frequent self-inconsistencies. The desperate endeavour of finance to help decision makers results in a refusal of individuals as they are, and in the invention of *rational* individuals, whose only rationality consists in adopting way of reasoning finance artificially brings out for them. Rationality turns then to be a *normative* concept, and economic agents have to follow criteria which are simplistically based on a unique goal. It is worth noting that even real options, born to deal with deferrable investment opportunities, are studied within this restrictive context and the techniques used to appraise them (options pricing, dynamic programming, decision tree analysis) are based on the same single-objective assumption. But economic agents are first of all ‘agents’, and are subject to constraints of several types, financial, legal, social, cultural etc. some of which are even self-imposed (Elster (1979)) and which do have nontrivial relations with preferences (Elster (1983), Sen (1997)). They are in turn necessarily influenced by emotions which inevitably affect decision abilities and decision processes themselves (see the somatic-marker hypothesis in Damasio (1994)) and which assist us in framing the decision processes so as to make relevant some elements to the detriment of others and guide us to a preselection of alternatives; for “emotions are among the mechanisms that control that crucial factor of *salience* among what would otherwise be an unmanageable plethora of objects of attention, interpretations, and strategies of inference and conduct” (de Sousa (1995), p. XV). The opportunity-cost-of-capital concept tends to diminish the role of these elements trying to convince us that a decision process should be based only on profitability and thus making use of financial indexes concerning activities which have nothing to do with the decision process, since they have been implicitly or explicitly excluded by the decision maker (see section 5). Finance is

then compelled to cope with logical contortions that lead to a result which is just a confirmation of its unrealistic and unacceptable *a priori* normative assumptions about human behavior. In this sense the systemic approach, arisen from a simple (but not simplistic) picture, seems to be in accordance with an interdisciplinary approach for the analysis of decision processes, structuring the financial status of an economic agent in a plurality of businesses which implicitly presuppose a plurality of objectives and constraints.<sup>14</sup>

## 12 Cognition and semantics in finance

What has healed the inconsistencies among the three rules? What has enlarged the set of objectives altering the *a priori* assumptions? The striking results we have arrived to emerged from the abandon of a picture and a consequent radical shift in cognitive interpretation. But cognition is closely related to language and it is worth investigating thoroughly the semantic shift carried out in changing picture. I have used, throughout the paper, some seemingly unambiguous words such as ‘investment’ and ‘project’, ‘capital’, as well as seemingly unequivocal definitions of ‘internal rate of return’, ‘net present value’, ‘return on equity’. Each of the six terms is commonly used in finance in a particular manner and each one changes meaning by adopting a systemic approach. All six terms are, in a sense, inconsistent one another under a CF-M approach, whereas all are coherent one another under the systemic perspective. And it is the new semantic use we make of them that enables us to consider multiple objectives in the decision process. This different semantic use modifies the framing of the problem and improves understanding of the decision process. Let us see how this happens.

*Investment and project.* Investments and projects are not clearly defined in finance.<sup>15</sup> The term ‘investment’ is sometimes used as a synonymous of ‘project’ and thus it means a sequence of cash flows expiring at different maturities, sometimes it is used in opposition to financing and thus it means money lent to someone who will paid it back later. This confusion contributes to render the IRR freakish and awkward. Whenever a project is neither investment nor financing, what is the meaning of the IRR (provided that it exists and is unique)? Is it a rate of return or a rate of cost? Or maybe either of the two? Surely, the solution of (1) must have a different financial meaning depending on whether the project is investment (the decision maker lends money) or financing (the decision maker

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<sup>14</sup>It is also worth noting that the goal of maximizing wealth, if taken literally, leads us to banish accounting from the class of *rational* disciplines, as it takes into consideration activities with different rates of return.

<sup>15</sup>As far as I know the only formal definition of investment in the literature can be found in Levi (1964) and is founded on a CF-M outlook.

borrow money). Financial mathematicians regard this fact as an anomaly of the internal rate but they do not realize that the anomaly depends on not having a clear definition of what an investment is. So, if we lack a transparent definition of the term ‘investment’ we may not expect of the IRR to remove such an ambiguity. In the CF-M approach this term is ambiguous and is always referred to a sequence of cash flows getting in and out of the ‘wallet’ (viz. the wealth of the decision maker). In the ‘pan-approach’ I have introduced there is one only investment: the investment of the net worth. The ‘investment’ the CF-M approach refers to is therefore embraced in the investment of the net worth. The latter can then be thought of as a ‘meta-investment’, that is an investment subsuming an investment.<sup>16</sup> The CF-M investment represents only a very partial description of what happens at the system: It says something about some cash flows but says nothing about the structure of the system and nothing about the distribution of the flows in the system. A particular stream of cash flows, a particular initial structure, and a particular policy of reinvestment and withdrawal of flows at each period cause a particular way of altering the system. This very alteration is the meta-investment, which is the *only* investment possible for the decision maker, and which can be accomplished in more than one way. A systemic definition of what the term ‘investment’ should indicate could be the following one:

an investment is one of the possible ways of altering the financial system.

Each way is influenced (not determined) by the selection of a particular project, for which we can maintain the traditional definition:

a project is a whatsoever sequence of cash flows expiring at different maturities.

Note that, in the light of what we have seen, we do not even need to distinguish ‘investment’ from ‘financing’. By borrowing a picture from accounting I have adhered to its way of looking at economic transactions. Any of them is a medal with two sides: the source and the application. The double-entry book-keeping system says, according to the so-called fundamental accounting equation, that to a source there must correspond an application of the same amount. That is to say: to the act of lending money there always corresponds the act of borrowing; the former is an application (i.e. use) of funds, the latter is a source.<sup>17</sup> Any

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<sup>16</sup>The first ‘investment’ is used with a systemic meaning, the second ‘investment’ is in CF-M language.

<sup>17</sup>The fundamental accounting equation is simply Net Worth+Liabilities=Assets. The left-hand side represent the sources, the right-hand side the applications.

‘investment’ in the new meaning is composed of a manipulation of sources and funds so as to satisfy the personal desires (and constraints) of the investor. In such a way, we split ‘investment’ and ‘project’ by including the latter in the former and use the term ‘source’ and ‘application’ to distinguish the act of borrowing money from the act of lending. We can summarize the semantic use of the two approaches in the following table:

$$\begin{array}{l} \text{CF-M approach : } \left\{ \begin{array}{l} \text{investment} = \text{project} \\ \text{investment} = \text{lending money} \\ \text{financing} = \text{borrowing money} \end{array} \right. \\ \\ \text{systemic approach : } \left\{ \begin{array}{l} \text{investment} = (\text{a way of altering}) \text{ net worth} \\ \text{project} \subset \text{investment} \\ \text{application} = \text{lending money} \\ \text{source} = \text{borrowing money} \end{array} \right. \end{array}$$

where the symbol  $\subset$  for subset shows that a project is now only an aspect, among others, of an investment. Note that the two first equalities in the CF-M approach should lead to the conclusion that project=lending money, which is obviously wrong.

*Internal rate of return.* As for the definition of IRR, financial mathematicians have applied to projects the same reasoning they follow in constructing loan contracts, but have interchanged the role of unknowns and variables in the same equation. So, the contractual rate of loan contracts is made to be a rate of return for a project. The twist works with homogeneous projects and with the assumption of compounding but not with other types of investments where, in general, it cannot have the meaning of a return at all regardless of any consideration about existence and uniqueness of the IRR itself. Changing the meaning of the term ‘investment’ I have simultaneously changed the meaning of the term ‘internal rate of return’ as well. It does not refer to a project any more, but to the meta-investment of the net worth. It is now a significant profitability index, since we have a PIPO (meta)investment. So equation (1) is replaced by (11). The solution of (11) represents the average rate of return of the investment of the sum  $E_0$ , which generates returns that are reinvested at each period in the system itself (hence, the legitimate use of  $f_1$ ). I rewrite the two equations for convenience of the reader:

$$\frac{a_0}{(1+x)} + \frac{a_1}{(1+x)^2} + \dots + \frac{a_n}{(1+x)^n} = 0 \quad (1)$$

and

$$-E_0 + \frac{E_T}{(1+x)^T} = 0 \quad (11)$$

where I have again supposed, with no loss of generality,  $t_s=s$ . (1) generalizes (11) in the sense that more than two cash flows are allowed, but it always refers to a lower level of reality (a project); (11) generalizes (1) in the sense that the cash flows of the project under consideration are incorporated into the decision maker's net worth  $E$ , so that we rise to a higher omnicomprehensive level. As we have seen, even in a PIPO project the rate of return is not a useful index, because it shows how fast the capital invested in the project increases over time, not how fast *wealth* increases over time, which is a fundamental information an investor needs. So, the comparison of internal rates of PIPO projects is, in general, totally misleading. The only exception is given by *homogeneous* (PIPO) projects. What is an exception in the CF-M approach turns out to be the only type of investment in the systemic perspective. Hence, the comparison among internal rates of return of different investments is correct because all possible investments are *homogeneous*. In sum,

$$\begin{array}{l} \text{CF-M approach:} \\ \text{systemic approach:} \end{array} \left\{ \begin{array}{ll} \text{loan contracts} & \rightarrow x = \text{contractual rate} \\ \text{PIPO projects} & \rightarrow x = \text{rate of return (misleading)} \\ \text{other projects} & \rightarrow x = \text{no (clear) financial meaning} \end{array} \right.$$

$$\left\{ \begin{array}{ll} \text{loan contracts} & \rightarrow x = \text{contractual rate} \\ \text{investments} & \rightarrow x = \text{rate of return (helpful)} \end{array} \right.$$

*Return on equity.* The (monetary) ROE, as it is used for investment decisions, is a mere mathematical ratio devoid of any significant financial meaning. Also, it is applicable only in PIPO and PICO projects, which have a single negative cash flows at time 0 and one or more revenues respectively (which one of the cash flows would be the 'initial outlay' if the first cash flow is positive or if the project consists of more than one outlay?). It is often misunderstood that the ROE used in capital budgeting has nothing to do with the overall ROE derived from accounting: the latter is a one-period index given by the ratio profit to equity calculated on the basis of a systemic double-entry picture; the former is a ratio derived from a CF-M perspective where only differential cash flows are considered. The same word is used but a different interpretation is given. The ROE of the systemic approach is an overall ROE: It refers to the entire wealth of an economic agent, not to projects. The ROE used by the CF-M approach for evaluating projects is not a

real return *on equity*. The ROE has a univocal meaning only if it refers to net worth rather than projects and expresses the same financial meaning of the IRR just seen above, since they derive from the same equation. Formally,

$$\text{CF-M approach} \longrightarrow \text{ROE} = \frac{\sum_{s=1}^n a_s - a_0}{a_0}$$

$$\text{systemic approach} \longrightarrow \text{ROE} = \text{IRR} := \text{IRRS} = \left( \frac{E_T}{E_0} \right)^{(1/T)} - 1$$

where we are forced, in the CF-M approach, to assume  $a_s > 0$  for all  $s > 0$  and where we generalize the one-period ROE to multiple periods (see section 10).

*Net present value.* The net present value finance is concerned with refers to a project whose cash flows are discounted at a rate  $i^*$  called opportunity cost of capital. Also, as previously remarked, it is not able to tell us how fast the capital invested increases over time. Further, it expresses cash in present terms only because of the use of  $f_1$ , which is only one among many other possible financial laws.

In the systemic approach the only possible net present value is that of the net worth. This ensures that the NPV rule leads to the same ranking of the IRRS rule. In fact, the net present value of the net worth is an increasing function of the final value of net worth, and the latter is an increasing function of the IRRS, so that our net present value is an increasing function of the IRRS:

$$x_A > x_B$$

if and only if

$$E_T^A > E_T^B$$

if and only if

$$-E_0 + E_T^A / (1 + i^*)^T > -E_0 + E_T^B / (1 + i^*)^T.$$

It is also clear that the concept of a present value does not make any sense in a systemic context, for the opportunity cost of capital is both uninfluential and meaningless. Roughly speaking, we could say that we have  $m > 1$  opportunity costs of capital relative to the  $m$  businesses the system is structured in. They are already considered in the calculation of  $E_T$ . Finally, it is a striking result that the NPV rule, as it used in the CF-M approach, is subsumed by the systemic approach as a particular case. If we assume that the investor's financial system is de-structured, i.e.  $m=1$ , we can graphically depict it by writing a single account in the left-hand side of the balance sheet (or in the right-hand side, if its value is

negative). The generalization  $m>1$  accomplished by a systemic outlook does not only allow for broader applicability but it also removes the restrictive hypothesis of a unique goal pursued by the decision maker making the systemic perspective a multiobjective approach. To sum up, we have

CF-M approach  $\rightarrow$  NPV = single-objective concept in present terms

systemic approach  $\rightarrow$  NPV = meaningless concept replaced by  $E_T$

*Capital.* What is the ‘capital’ invested in a project? In the CF-M approach, it is the outflow the investor initially pays in order to receive revenues in later periods. Unfortunately, sometimes it is not possible to find the ‘capital’ invested in a project especially when the cash flows often alternate in sign. Consequently, we cannot be sure of a well-specified financial meaning of a rate of return; the ROE cannot even be calculated if we do not have an initial outlay to be called the ‘capital’ invested.

In the systemic approach, the semantic use of the term ‘capital’ is made to rise to a higher level so as to comprehend the sum invested in the project. Now the capital invested by the investor is not the capital related to the project but the current net worth  $E_0$ , which includes the initial sum  $a_0$  in the double-entry picture ( $A_0 = -a_0$ ). Note that moving from a CF-M approach to a systemic view the ambiguity of the term is healed. Referring it to the sum invested in the project, the concept of capital invested is often meaningless, since there are many situations where we cannot find a specific initial outlay to whom there corresponds a stream of revenues. With a systemic view, the capital  $E_0$  employed is the very initial outlay and  $E_T$  is the only receipt. The rate of return we aim to calculate in order to appraise the investment is evidently referred to this investment, not to the project. And by drawing up the double-entry picture we realize that net worth is structured in more businesses, each one with a specific rate of return. So the decision maker has a plurality of opportunity costs of capital to cope with, which advises us to adopt a multiobjective view of the problem. In sum, we have

$$\text{CF-M approach} = \begin{cases} \text{PICO/PIPO projects} & \rightarrow \text{capital} = a_0 \\ \text{other projects} & \rightarrow \text{capital} = \text{ambiguous concept} \end{cases}$$

$$\text{systemic approach} \rightarrow \text{capital} = E_0 \quad (\text{net worth})$$

where the capital in the first meaning, if it exists, is embodied in the systemic view as a part of  $E_0$ .



The parlance of finance is then ambiguous and misleading. Its misuse of the above terms relies on a particular graphical depiction along with a particular linguistic description of the problem, which affect the way a decision maker cognizes it. It is striking that some definitions and classifications change meaning when changing framing, and some others make sense only under a particular representation of facts. For example, the class of investments is partitioned in finance in four subsets: PIPO, PICO, CICO (Continuous Input Continuous Output), CIPO (Continuous Input Point Output). In the systemic approach PIPO investments saturate the class of investments:

$$\boxed{\Pi \quad \boxed{\text{PIPO investments}} \rightarrow \text{turns to} \rightarrow \boxed{\Pi = \text{PIPO investments}}}$$

$\Pi :=$  class of investments

On the other hand, the systemic approach finds it useful to distinguish projects from investments:

$$\boxed{\Pi = \Sigma} \rightarrow \text{turns to} \rightarrow \boxed{\Pi \quad \boxed{\Sigma}}$$

$\Sigma :=$  class of projects

In addition, PIPO investments in finance must be necessarily subdivided in homogeneous and non-homogeneous, whereas they are always homogeneous in a systemic setting, as the capital invested is always  $E_0$  at time  $t_0$ :

$$\boxed{\Pi \quad \boxed{\text{PIPO} \quad \boxed{\text{homogeneous PIPO}}} \rightarrow \text{turns to} \rightarrow \boxed{\Pi = \text{homogeneous PIPO}}}$$

The classification of decision criteria for capital budgeting makes no more sense in the new outlook, for the three rules deriving from the ROE, the IRR and the NPV lead to the same ranking of projects from a profitability point of view. The NPV, derived from the CF-M approach, is put into systemic terms and loses significance, the IRR (derived from the CF-M approach as well) is put into systemic terms and gains significance, the ROE, derived from a systemic perspective but put in CF-M terms for capital budgeting purposes, is brought back to its original systemic world, despoiled of its accounting nature and assigned a monetary value, for which it gains the same meaning of the IRR:

$$\text{CF-M projects} \quad \bullet \quad \text{systemic meta-investment}$$

$$\boxed{\text{IRR}} \neq \boxed{\text{ROE}} \approx \boxed{\text{NPV}} \rightarrow \text{turns to} \rightarrow \boxed{\text{IRR}} = \boxed{\text{ROE}} \sim \boxed{\text{NPV}}$$

Whereas academics underscore the divergences between finance and accounting, I have integrated the two in a unified approach, taking from the former the diachronic features of an investment, from the latter the synchronic one, so that we can see investments as having two sides:

$$\boxed{\Omega = A \cap F}$$

$$\begin{array}{ll} A \rightarrow \text{synchronic (structure)} & A = \text{accounting} \\ F \rightarrow \text{diachronic (cash flows)} & F = \text{Finance} \end{array}$$

It is now evident that mathematics applied to economic decision processes, far from being unambiguous, can give rise to different cognitive realities. The specific reality one lives in influences the directions of a line of research, affecting the shape and the solution of decision problems. Even equations are to be interpreted so as to make them correspond with the lexicon concepts. They offer us a relation among mathematical objects to be satisfied as an identity. As long as the objects are *abstract* no ambiguity arises, but when the *abstract* relation is applied to (physical, chemical, biological, social, cultural and) financial issues, *abstraction* leaves the field and *interpretation* gains ground. When applied to specified decision problem the solution for  $y$  of

$$\alpha_n y^n + \alpha_{n-1} y^{n-1} + \dots + \alpha_1 y + \alpha_0 = 0$$

can have one or more different meanings or maybe no one at all. Likewise, inequalities entail comparisons between mathematical objects which turn to non-abstract elements, whence *interpretation*:

$$\boxed{\sum_{s=0}^n \alpha_s y^s; \quad \alpha_s := a_s, \quad s = 0, 1, \dots, n \quad n \geq 2} \rightarrow \text{turns to} \rightarrow$$

$$\boxed{\sum_{s=0}^n \alpha_s y^s; \quad \alpha_s := 0 \text{ for all } s = 1, 2, \dots, n-1, \quad \alpha_0 := -E_0, \quad \alpha_n := E_T, \quad n := T}$$

which means

$$\boxed{(a_0, a_1, \dots, a_n)} \implies \boxed{a_n y^n + a_{n-1} y^{n-1} + \dots + a_1 y + a_0} \rightarrow \text{turns to } \rightarrow$$

$$\boxed{(a_0, a_1, \dots, a_n)} \implies \boxed{(E_0, E_1, \dots, E_n, \dots, E_T)} \implies \boxed{E_T y^T + E_0}$$

where  $y=(1+i)^{-1}$  and  $T$  is a fixed terminal horizon. Finally, using mathematics differently, the systemic approach makes it necessary to change the *a priori* assumptions about the ends of an economic agent, allowing her to be ‘agent’ and not only ‘economic’. This entails the need of classifying objectives:

$$\boxed{\Gamma} \implies \boxed{\text{one single objective}} \rightarrow$$

$$\text{turns to } \rightarrow \boxed{\Omega} \implies \boxed{\text{objective 1, } \dots, \text{ objective } p}$$

with  $p \in \mathbb{N}$ .

### 13 Conclusions

It is my opinion that pictures alongside language can have a major role in influencing a line of research. I have showed the case of finance where the pictorial and linguistic shaping of thought leads to different use of the same terms, thereby radically changing the *a priori* assumptions and the methodologies, and removing ambiguities, inconsistencies and self-inconsistencies of the CF-M approach. In this sense, I claim that pictures and language produce cognitive schemata that categorize the way we think and the perspectives we take of the reality. Scientific research does not represent an exception since scientists have and construct cognitive perspectives depending on the pictorial and linguistic framing they adopt, as well as any other human being. This fact implies a problem of *translation* from a level of reality to another, but this very translation often entails a radical change in the inner assumptions and hence in the methodologies used to analyse the problem in hand. Such a change uncovers some cognitive illusions arisen within a whole line of research and we might wonder why these biases can be so consolidated as to cause what I think is a fossilization in the development of new ideas, which are rendered suitable for the biased perspective taken by that line of research.

In the light of what we have seen, we might then wonder why finance and financial mathematics have adopted a diachronic picture and a very partial cognitive

interpretation of the phenomenon of investment. There also arises the correlated question why financial analysts and mathematicians *maintained* that particular picture, once introduced. I think that the frequent and deep links of these disciplines with the economic environment has played a major role. Scientists have been and are affected by practitioners, professionals, managers etc. Sometimes the latter provide scientists with problems already framed in a particular way, so that the latter face it without previously trying to re-frame it; sometimes the problem is framed by scientists in such a way that the solution is acceptable by practitioners and managers. But there is maybe something more than this.

A plethora of articles has been written in the literature: authors have tried to circumvent the difficulties given by the IRR finding out conditions ensuring the uniqueness of the internal rate of return (e.g. Norstrom (1972), Arrow and Lehvari (1969)); provided postulates that the IRR itself “should be expected to satisfy” (Promislow and Spring, *op.cit.*); tried to generalize the concept (e.g. Weingarter (1966)); deemed the behaviour of the IRR as “cumbersome” (Finnerty, *op.cit.*, Dybvig (1983, p. 112)); looked for a “well-behaved” internal rate of return (Ross, Spatt and Dybvig (1980), Dybvig, *op.cit.*); made lucubrations about the implicit assumption of intermediate cash flows; attacked the IRR rule for its freakish behavior rather than for the partial perspective they looked at it; invalidated the NPV rule only by changing the decision problem under consideration rather than the perspective<sup>18</sup> or glorified it for its *realistic* (sic) assumptions and its formal elegance; misused the ROE, the only index derived from a systemic perspective, coactively inserting it in a CF-M perspective and thereby making it a useless ratio. An entire line of research have been conducted within well-defined borders without any deviation from the mainstream. So, I think that the connections with markets and firms can perhaps explain the reason why academics have introduced a particular perspective, but not the reason why they have *maintained* it. Cognitive illusions, homage to tradition, proclivity to supinely accept the tenets of their disciplines, dogmatism and ‘taboo reactions’<sup>19</sup> rather than rational arguments are likely to have induced scholars and academics to maintain the classical view. Hopefully, recognizing the role of picture and language in the description of a phenomenon is a little step towards a gradual enrichment in the cognitive perception of financial issues. This could lead to a methodological pluralism consisting

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<sup>18</sup>For example, Smith and Nau, *op.cit.*, point out that the NPV rule leads to incorrect results in capital budgeting and that decision analysis methods and options pricing can better handle investment decisions. But they are concerned with deferrable investments, not with now-or-never opportunities. In the latter case, options pricing, decision analysis methods and NPV rule lead to the same results. On the basis of this coincidence, one could even doubt the reliability of options pricing and decision analysis techniques!

<sup>19</sup>In the sense of Feyerabend (1978, p. 298).

in an interdisciplinary approach, where 'rationality' is not taken from granted and various levels of reality along with scientific findings in neurobiology, psychology, cognitive sciences, decision theory, are taken into consideration in whatsoever decision-making process an individual is concerned with.



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