STOCKS OF KNOWLEDGE AND ORGANIZATIONAL PERFORMANCE: A DYNAMIC RELATIONSHIP

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Abstract
The relationship between the level of knowledge and organizational performance has been studied by the academic community and is receiving growing attention from decision makers in organizations. However it is not the case of the feedback relationship between performance and the level of knowledge, although this relationship has a dynamic pattern of behavior on both variables. This research poses a conceptual approach that involves a causal model of this feedback relationship, theoretically founded on the resource based view and the behavioral theory of the firm. The methodology involves the design and use of a system dynamics simulation model based on a pharmaceutical company which relates stocks of knowledge, innovation capability, financial performance and investments on knowledge stocks. The concept of "managerial dynamic hypothesis" is defined and used to explain, via the prospect theory, how much managers decide to invest over time on knowledge stocks. Simulations, based on managerial dynamic hypotheses with two different levels of complexity, were carried out. The results show that the more complex the hypothesis is the more stable the investment flow is and a better performance is achieved.

Keywords: knowledge stocks, organizational performance, system dynamics, organizational knowledge, prospect theory, simulation.

1. INTRODUCTION

The influence of variables related to knowledge (knowledge management, stocks of knowledge, organizational learning) on organizational performance, has been the subject of numerous studies. It has not occurred in the same way with the study of the influence of the performance itself on these variables. It should then be asked, is organizational performance just a result of these variables, or does it, in turn, influence them? If so, how this interaction occurs and what its dynamic behavior is? There are few studies exploring this relationship, although several authors suggest a relationship of mutual interaction between learning and performance (Argyris and Schön, 1978, Lee et al., 1992, Mintzberg et al., 1995) and that has raised the importance of considering the performance as an endogenous variable (not just as a dependent variable) within the models formulated in strategic management research in general and particularly in organizational learning research (Bontis et al., 2002). Other authors, mainly from the perspective of organizational behavior theory (Cyert and March, 1963; March, 1991) have studied the influence of performance on organizational change processes as a one-way relationship, with the exception, relevant for this research, of the work of Greve (2003) which establishes a dynamic feedback between learning and organizational performance by means of the "theory of learning from performance feedback" (Greve, 2003, 10). The scarcity of research on the dynamic relationship between learning, knowledge and performance, despite its obvious relevance (Bontis et al., 2002) , may be justified in part by the methodological difficulties that longitudinal studies entail (von Krogh, Erat & Mackus, 2000), and partly by the high complexity involved in developing formal models capable of describing this relationship. To cope with these difficulties, several authors have made use of the development of simulation models as a methodological proposal that allows, usually based on secondary data, both development and verification of theory (Davis, Eisenhardt and Bingham, 2007), and makes possible the formulation of complex models involving, as in the case of this proposal, the integration of diverse but complementary theoretical perspectives. Among the methodological approaches to the development of simulation models, it is of particular interest for this proposal the *system dynamics* approach. Developed by Forrester (1961), this methodology is based on the presence of structures of feedback between constituent variables of complex systems (e.g. organizations) and uses the concepts of stocks and flows to define the variables that constitute the core of the model. Simulation models based on system dynamics provide the methodological basis of some recent studies that are of special interest for the development of this proposal, like the one by Rahmandad, Repenning and Sterman (2009) that explores the effects of the delays in obtaining performance feedback on learning, and the one by Gary and Wood (2011) that explores the mutual influence between the accuracy of mental models of decision makers and organizational performance. These studies, although pose feedback relationships between variables of interest for this proposal, do not study explicitly the performance itself as a trigger factor of decisions that affect, a posteriori through knowledge generation, the performance, in an iterative way.

This research proposal formulates a model that dynamically links organizational learning, knowledge and performance, and intends, based on the related academic literature, the development of a simulation model that allows the application of a longitudinal study. Finally, we intend to use the simulation model for conducting an empirical study to validate the propositions that may arise as a result of the research.

The object of study of this research is the firm, viewed from the perspective of those making investment decisions (budget) within it, and is framed within the strategic issue, that is, the achievement of the long-term objectives of the organization.

2. CONCEPTUAL MODEL PRECEDENTS

2.1. Stocks and flows of knowledge

Within the vast literature related to the topic of knowledge management is particularly interesting the proposal from Bontis, Crossan & Hulland (2002), regarding the framework that it provides for defining and linking the issues of organizational learning, intellectual capital and knowledge management , doing so through the analogy of stocks and flows of knowledge. The Bontis, Crossan and Hulland proposal identifies the intellectual capital with the stocks of knowledge and states that intellectual capital, so defined, should be considered at the level of individuals, groups and organization. Organizational learning will then represent the flow of knowledge that feeds these stocks, and proper knowledge management should have as one of its objectives the alignment of these flows and stocks at all levels, in order to improve performance of the organization. The dynamic relationship between the stocks of each level with each other and the organization's performance turns out to be another important and interesting aspect of this framework, since it suggests to consider both relationships, the forward one (feed-forward) between knowledge stocks (individual / group / organization) and its feedback one (organization / group / individual). In fact, one of the suggestions therein made for future research is to expand the framework of the dynamic relations between stocks, to go beyond the influence of the stock of knowledge on organizational performance and include the feedback relationship between organizational performance and the stock of knowledge. Does this relationship exist? Mediated by which variables? These are some of the questions that gave rise and justification to this research.

2.2. Stocks, flows and sustainable competitive advantage

The relationship between organizational performance and stocks of knowledge implies a strategic pint of view. The theoretical proposition of Dierrickx & Cool (1989) is not only suitable but relevant for a strategic approach. This research considers that in order to sustain a competitive advantage, a stock of strategic assets must be accumulated and that this accumulation is achieved by choosing time paths of flows that properly feed these stocks. The difference between stocks and flows is illustrated by the metaphor of the bathtub, where the stock of water is determined by the level of water in the bathtub, which is in turn the result of flows feeding and draining the bath, accumulated over time. For example, according to Dierickx and Cool, the amount of water in the tub could represent the stock of know-how at a given moment in time, while investment in R & D would be represented by the inflow and the depreciation of know-how by the outflow.

An important point, illustrated by the bathtub metaphor, is the fact that stocks do not change instantaneously, since management wants a change in stocks it should make decisions affecting the flows that, in turn, modify these stocks, and since these changes only occur after a period of time, these decisions should take the form of policies that make these flows consistent over time. A competitive position, associated with a potential payoff, will come from selecting time paths that are appropriate to accumulate stocks of strategic assets, defined as assets that are non-tradable, non-imitable and not substitutable. Suffice it to say here that the stocks of knowledge, those that are of particularly interest for this research, fit, in general, within the latter definition. It should be mentioned also that the accumulation of strategic stocks depends on the level of other interrelated stocks.

From what has been described here it can be concluded that the proposal of Dierrickx and Cool, allows us, considering the stock of knowledge as a strategic asset stock, to close the dynamic cycle that concerns us (stocks of knowledge → performance → stocks of knowledge) through considering the investments in strategic assets as the variable that mediates between performance and the strategic assets themselves. We must remember that what may change are the flows in and out of stocks and not the stocks themselves, which means that investments will be the flows that affect the stocks. For our case then, investments are the flows that affect the stock of organizational knowledge and the dynamic causal structure of the proposed model (Model 1), will include the relationship between performance feedback and stocks of knowledge, mediated by investment flows in organizational knowledge (see Figure 1).

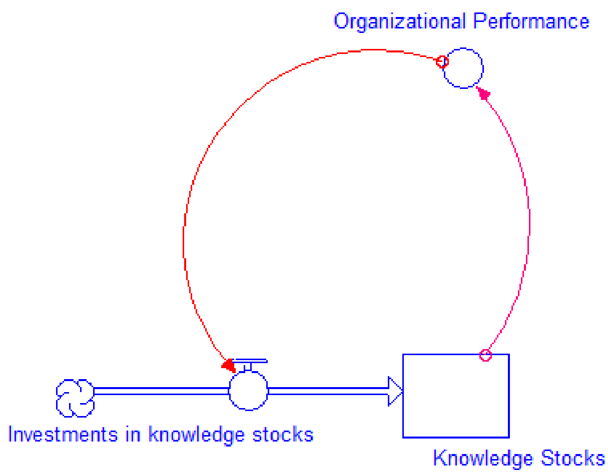

Figure 1. Model 1.

2.3. Intellectual Capital

Among the approaches to the subject of knowledge, are of particular relevance to this research those that Oltra (2002) calls "measurement focused approaches". Within this category, the one proposed by Roos, Roos, Dragonetti & Edvinsson (1997) that defines intellectual capital as the sum of human capital and structural capital, agrees with our proposal in the formulation of a dynamic feedback between knowledge (implicit in human capital and structural capital) and financial performance (financial capital). Figure 2 illustrates this relationship. There, human capital is defined as the sum of skills, attitudes and intellectual agility of employees, and structural capital as everything that is owned by the company and whose value for the company is greater than its material value.

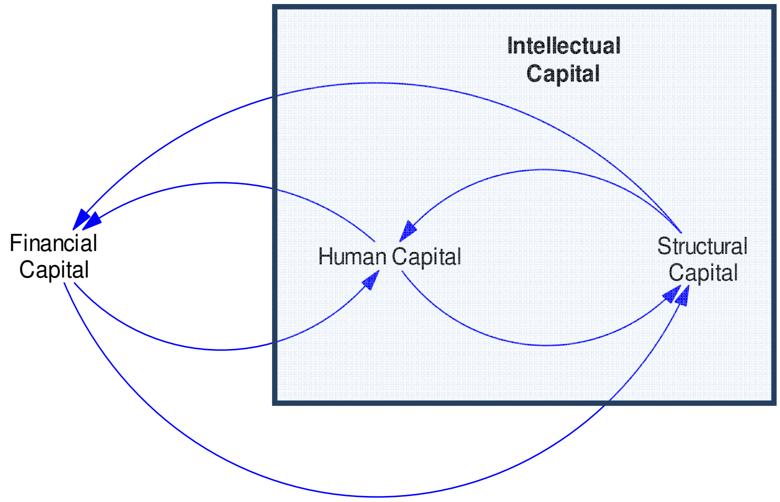

Figure 2. Relationships between intellectual capital components. Adapted from Roos et al (1997).

Furthermore, Sveiby (1998-2001) mentions the tendency to consider only the static aspects of knowledge and emphasizes the desirability of approaching knowledge as a dynamic process.

Although useful, the concept of intellectual capital brings its own difficulties. Roos et al (1997) highlight three of them:

1. Delays: an increase in intellectual capital does not produce an immediate increase in total value
2. Non-linearity: big investments in intellectual capital do not necessarily produce big results (and vice versa).
3. Units of measurement: each company has its own definition of intellectual capital. Units of measurement of the intellectual capital components are heterogeneous.

2.4. Resources, Capabilities and Strategy Maps

Grant (2010) approaches the strategic topic from the resource-based theory or resource based view (Barney, 1991) and define resources as the productive assets owned by the firm, and capabilities as what the firm can make, and states that resources alone do not confer competitive advantages but must be combined to generate organizational skills, being these capabilities those that enable superior performance. Thus, resources - classified by Grant as tangible resources, intangible resources and human resources - generate organizational capabilities and these, in turn, performance.

Grant suggests that one way to identify organizational capabilities is relating them to major functional areas of the firm and proposes a hierarchy of these capabilities, where the most important from the strategic performance point of view, are those that involve the participation of several functional areas (e.g., new product development, customer service, quality management). Finally, we would like to mention two concepts from Grant (2010) that relate significantly to this research: 1) "in terms of resources, knowledge is recognized as an extremely important productive resource" and 2) "capabilities can be seen as the manifestation of the knowledge of the organization" (Grant, 2010,159).

Using a similar approach, Kaplan and Norton (2004) present in what they call a strategic map, a sequence of causal relationships between elements of the four perspectives previously outlined in the concept of balanced scorecard (Kaplan and Norton, 1992) and propose a number of elements constituent of these four perspectives (financial, customer, internal processes, and learning and growth).

Some similarities with the proposal of Grant (2010) can be noticed. The learning and growth perspective includes what Grant called human resources and intangible resources. The internal process perspective is similar to the functional classification of capabilities by Grant. Both proposals consider the effect on final performance, but Kaplan and Norton (2004) include the value proposition to the customer (customer perspective) as a variable that mediates between the organizational skills and performance and emphasize financial performance (financial perspective). Finally, neither proposal establishes a feedback (dynamic) relationship between performance and the generation of intangible resources.

At this point, having reviewed the relationship between knowledge and performance, then we can wondered what does make the performance lead to investments in organizational learning, or, put in other words, if investment is a decision managers make, what variable or variables influence this investment decision and the amount of such investment?

2.5. Dominant logic and investment decisions

A concept related to the process of making investment decisions , appropriate for its inclusion in our model, is that of "general management dominant logic" or simply "dominant logic" (Prahalad, CK & Bettis, RA, 1986) , that considers the managers as groups of individuals who significantly influence the allocation of key resources (Donaldson and Lorsch, 1983), and is defined as "the way in which managers conceptualize the business and make critical decisions for allocating resources either in technology, product development, distribution, advertising or human resource management. "(Prahalad, CK & Bettis, RA, 1986, 490). It can be concluded then, that one of the decisions on allocation of key resources, influenced by the dominant logic is the investment in organizational knowledge.

A relevant source within the scarce literature found related to empirical application of the concept of dominant logic is the work of von Krogh, Erat and Mackus (2000), who approach the dominant logic through a dynamic analysis and describe it by means of a construct based on two conceptual domains (internal and external conceptualization) and six categories (people, culture, product and brand, competitors, customers, and technology), and develop a numerical value for the "bandwidth" (Bettis and Prahalad, 1995) of the dominant logic. The causal model proposed by von Krogh, Erat and Mackus, is shown in Figure 3. As can be seen, feedback influences are established between the strategic actions, including investments in organizational learning, performance, and the dominant logic, generating a dynamic cycle that is similar to the one previously defined as our Model 1 (see Figure 1). For their empirical study, von Krogh, Erat and Mackus decided to take into account only the relationship between dominant logic and performance. This longitudinal work was based on secondary data collected over a period of three years in two companies in the telecommunications sector (Nokia and Ericsson).

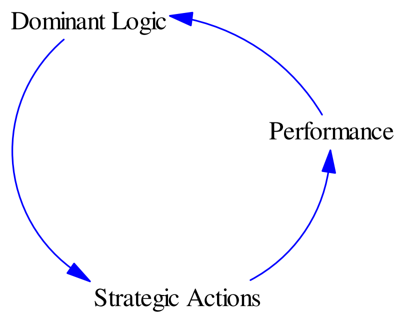

Figure 3. von Krogh, Erat & Mackus causal model. Adapted from von Krogh, Erat & Mackus (2000)

2.6. Dynamic hypothesis and prospect theory

One element that we pose as relevant within the dominant logic is the *dynamic hypothesis*. The idea of incorporating this variable in the model comes from our experience in consulting and in teaching in graduate courses, through which we have noticed the existing gap between the actual behavior over time of the results of a given action, and the expected dynamic behavior of that action by those who have taken the decision to initiate such action. Then, we define the *dynamic hypothesis* as *the dynamic behavior of the outcomes of a given action, expected by those who have taken the decision to initiate that action*. The dynamic hypothesis thus defined, can be considered as a component of the dominant logic and then will determine what is the expected outcome of an investment in intellectual capital in terms of financial results, after a period of time. In turn, the gap between the expected and the actual outcome will determine the new flow of investment in intellectual capital. But how will this new flow of investment be determined? This decision, in the model, will be a function of the value curve proposed by the *prospect theory* (Kahneman andTversky,2000b ;Tversky and Kahneman, 2000). A typical value function curve based on this theory is shown in Figure 4.

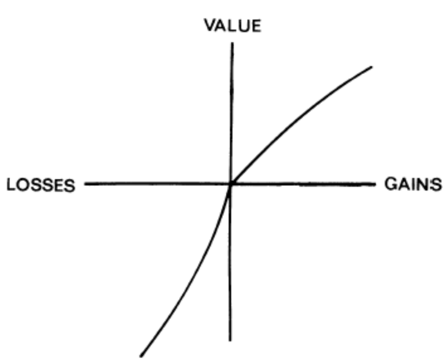

Figure 4. A hypothetical value curve. Source: Kahneman andTversky (2000b).

According to the *expected utility theory* (von Neumann and Morgenstern, 1947), commonly used in decision making studies, decision makers assign values of utility and probability of occurrence to the possible outcomes of their decisions and choose that decision with the greatest weighted value of utility and probability. However, despite its widespread use, numerous studies have shown that, in practice, decision makers do not follow the theory of expected utility. To fill the need for a theory that is closer to the criteria used in reality, Kahneman and Tversky (2000b) formulated the theory of perspective, which, in contrast to the theory of expected utility, states that decision makers do not consider the expected monetary value resulting from the decision, but assign a subjective value to the result depending on whether it is above (gain) or below (loss) a value or *reference point*. The magnitude of the subjective value assigned to each gain or loss will be given by a curve similar to that shown in Figure 3. As can be seen, this figure is concave in the area of gains and convex in the area of losses, implying loss aversion, that is to say, the decision maker will assign a greater magnitude (loss) to a value lower than the reference point, than to a value that is at equal distance greater than the reference point (gain) and, moreover, in decisions involving only losses, the tendency will be to take risks (risk seeking behavior) and in decisions that involve only gains the trend will be avoid risk (risk aversion behavior). The shape of the figure implies a *reduction in sensitivity*, that is, to the extent that the values go far from the point of reference, either way, an increase or decrease in the result will represent an increasingly smaller increase or decrease in subjective value. Figure 5 shows an example of loss aversion. There is a difference of magnitude between points L1 and L2, to the left of the reference point PR (loss), equal to that between points G1 and G2, to the right reference point (profit), but, as can be seen, the increase in the subjective value of loss (RL2 - RL1) is greater than the increase in the subjective value of gain (RG2 - RG1).

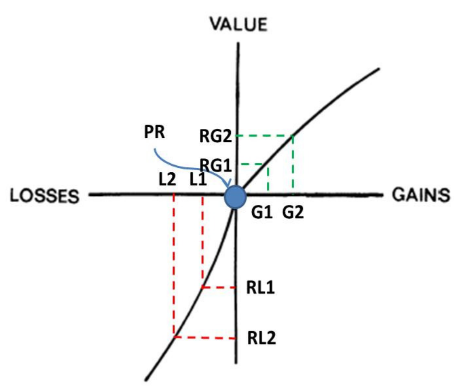

Figure 5. An illustrative example of loss aversion.

Within this proposal, the reference point of the value function is the expected outcome in a given moment in time, in terms of performance, of an investment decision, and will be determined by the dynamics of the decision maker hypothesis. Figure 6 shows an illustrative example of how the dynamic hypothesis relates to the theory of perspective. The graph shows the expected result (performance) and the actual outcome, for two different dynamic hypothesis, from an investment made in month 1. The blue line represents a simple dynamic hypothesis (hypothesis 1) where it is simply expected to have a result of 100 in month 12. The red line represents a more elaborated dynamic hypothesis (hypothesis 2) in which the result of 100 is achieved around month 48. The green line represents a hypothetical actual performance behavior. The graph shows what would happen if the performance is reviewed after 18 months from the time investment was made (brown dotted line). The intersection points PR1 and PR2 will correspond to the reference point in the value function curve (PR in Figure 5) for scenarios 1 and 2 respectively, and the RR point will correspond to actual performance (points L1, L2, G1, G2,Figure 5). Since the values for PR1, PR2, and RR are 100, 80 and 88 respectively, the decision maker that uses the hypothesis 1 (decision maker 1) will interpret the result as a loss because RR is lower than PR1 and will assign a subjective value to that loss (RL1, RL2 in Figure 5), while the decision maker that uses the hypothesis 2 (decision maker 2) will interpret the result as a gain because RR is greater than PR2 and will assign a subjective value to that gain (RG1, RG2 in Figure 5). The value function that defines the curve on which subjective values are assigned, follows the equation (Kahneman and Tversky, 2000)

$$v(x_j) = (x_j)^{\alpha} \text{ si } x_j > 0, \quad \text{y} \quad v(x_j) = -\lambda(-x_j)^{\beta} \text{ si } x_j < 0 \qquad \text{(Equation 1)}$$

Where $v(x_j)$ is the subjective value assigned to x_j, and α, β, y λ, are parameters that depend on decision maker.

Thus, what kind of decisions might be expected from the subjective values assigned in each case? Prospective theory suggests that, in the case of decision maker 1 a risk-seeking behavior could take place, that would increase the amount of investment or, if the result is far from the reference point, decision maker 1 might decide to keep the same amount of investment, reduce it or go out from investment (decreased sensitivity); in the case of decision maker 2, according to the prospect theory a risk-averse behavior could take place, that would led the decision maker to maintain or reduce the amount of investment.

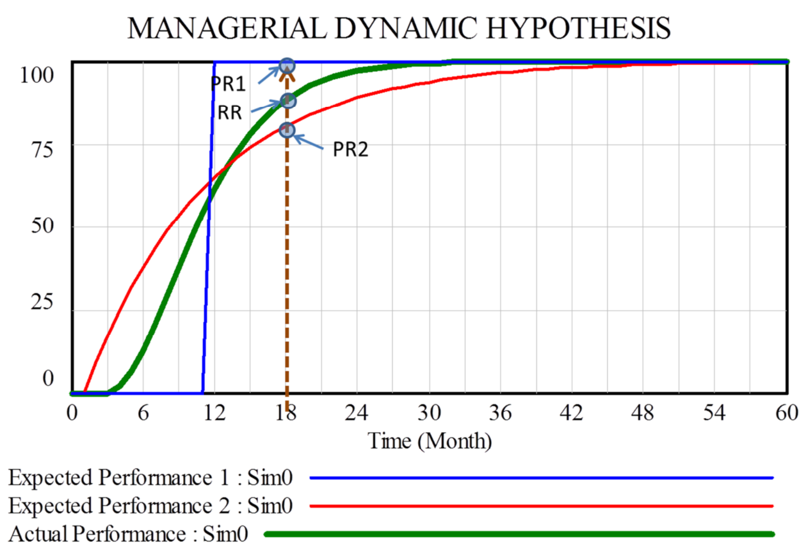

Figure 6. An illustrative example of the relationship between the dynamic hypothesis and prospect theory.

3. METHODOLOGY

3.1. Simulation

Because we are going to study a series of dynamic relationships between variables, the study should be longitudinal. In fact, von Krogh, Erat and Mackus (2000), state that any study involving the dominant logic as a variable, must be longitudinal (von Krogh, Erat and Mackus, 2000, 85). The object of study should be organizations located in highly dynamic sectors, where intellectual capital and innovation capability are considered as strategic resources.

Due to the difficulties inherent to conducting a longitudinal empirical study, we decided to use simulation as a research method. This method is gaining increasing acceptance within the academic community for studies like the one we are proposing, that involves dynamic and longitudinal phenomena (Repenning, 2002; Zott, 2003), and even for the study of complex theoretical relationships between constructs, where there are serious limitations in the availability of empirical data (Zott, 2003). When is simulation justified, what type of simulation to use and what should be the methodology for research that uses simulation, are questions that are answered in a paper written by Davis, Eisenhardt, and Bingham (2007), who argue that "simulation is particularly useful when the theoretical approach is longitudinal, nonlinear, or involves processes, or when empirical data are difficult to obtain "(Davis, Eisenhardt and Bingham, 2007, 481).

3.2. System dynamics

Within the existing simulation methods we have chosen the system dynamics approach in part because the use it makes of the hydraulic analogy posed by Dierickx and Cool (1989) for describing the evolution of strategic assets, as knowledge, and partly because it is the most suitable for studying the behavior of systems with high dynamic and causal complexity (Davis, Eisenhardt and Bingham, 2007). Besides, simulation models based on system dynamics provide the methodological basis of some recent studies that are of special interest for the development of this research, like the one by Rahmandad, Repenning and Sterman (2009) that explores the effects of the delays in obtaining performance feedback on learning, and the one by Gary and Wood (2011) that explores the mutual influence between the accuracy of mental models of decision makers and organizational performance. Studies using system dynamics to build models that include prospect theory are scarce, the only one study found in this preliminary stage of the research was that of Gonzalez and Sawicka (2003) that seeks to explain why people choose not to follow prescribed safety measures in high risk environments.

The need for further empirical verification and the method used for this verification will depend on the results obtained through experimentation with the model.

3.3. Conceptual model

As has been mentioned previously, the study of a dynamic relationship that involves feedback and delays between cause and effect, necessarily entails the application of a longitudinal study. Given the time constraints for conducting this research, we will use secondary data, so that the operationalization of the model should be based on the availability of data from empirical studies or databases. This limitation has been considered for the definition and subsequent measurement of the variables involved in the final model of this research.

3.3.1. Relationship between investments in knowledge, stocks of knowledge and performance

From the point of view of data availability, which appears as a major difficulty in conducting longitudinal studies, it is convenient to use the VAIC model (Pulic, 2000, 2004) to measure intellectual capital, not only because it is based on data gathered from the financial statement of companies, which are audited and publicly available, but because it establishes, through the extended model of Nazari et al (2007) a relationship between investment and intellectual capital. Although VAIC has a number of limitations, highlighted by Matidinos et al (2011), it is increasingly used to explore the relationship between intellectual capital and financial performance. Among the empirical studies examining this relationship using the VAIC, are of particular interest to this proposal those from Riahi-Belkaoui (2003), Chen et al (2005) and Tan et al (2007), since they establish meaningful relationships between intellectual capital measured by VAIC and financial performance, and also meaningful inter-temporal relationships among these variables, that is, how intellectual capital affect future performance, a relationship that is not considered in most studies using VAIC and that has been already mentioned as critical earlier in this document. The three works mentioned use some kind of return on assets as a measure of financial performance. Chen et al (2005) use return on investment (ROI) as a proxy measure of financial performance, coinciding with other authors who have studied the relationship between intellectual capital and financial performance like Firer and Williams (2003), Shiu (2006), and Zégal and Maaloula (2010). For the model we will use ROI as the final measure of organization's financial performance, and income from new products will be used as the measure of financial performance that determines the flows on investments that feed knowledge stocks . Regarding investments in intellectual capital (knowledge stocks), and following the definitions of the extended model of VAIC proposed by Nazari et al (2007) that directly relate investments in R & D to structural capital (innovation capital) and investment in salaries and benefits to human capital, we will focus in these two types of investments within the model making clear that we are referring in the model to people involved in R&D when we refer to human capital . Innovation capability (defined as a function of the level of stocks of knowledge) will mediate the relationship between intellectual capital and income from new products via new product development.

3.3.2. Relationship between financial performance, dynamic hypothesis and investment in intellectual capital

Earlier in this document, it was explained by an illustrative example, how the dynamic hypothesis will be related to investment decisions through the theory of perspective, and the equation of the curve through which a value is assigned subjective to a given outcome was described. There was mentioned that the curve is determined by the parameters α, β, and λ, that depend on the decision-maker. To define these parameters within our model, we will refer to the work of Bromiley (2009), who develops a model of resource allocation to R & D, previously defined as one of the investments that will be included in the model, based on the perspective theory. Therefore, we will adopt the range of values assigned by Bromiley (2009) for these parameters in our proposed model. Based then, on what has been previously exposed, the model of our proposal adds to the variables involved in the Model 1 (see Figure 1) the variable *managerial dynamic hypothesis* as a mediator between the financial performance measured as return on net assets, and the decision to invest in intellectual capital, specifically R & D, salaries and benefits. The level of organizational knowledge, defined as intellectual capital is measured through the level of knowledge stocks. The final conceptual model (Model 2), including these modifications is shown in Figure 7.

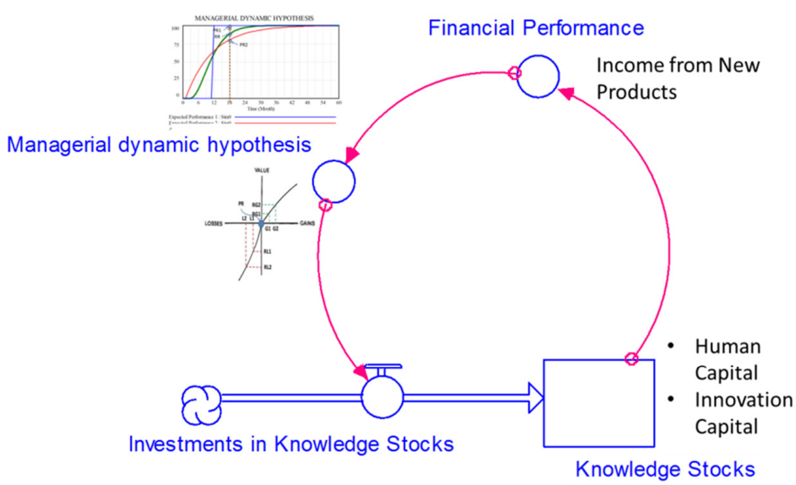

Figure 7. Proposed model.

3.4. Simulation model

3.4.1. Innovation capability, new products and financial performance

In the simulation model, intellectual capital, measured as *Intellectual Capital Index*, is a function of the level of knowledge stocks (*Human Capital* and *Innovation Capital*). *Human Capital* stock is increased by the flow of *Investments in Human Capital* and reduced by *Human Capital Erosion* (personnel rotation, knowledge obsolescence) whilst *Innovation Capital* stock is increased by the flow of *Investments in R&D*, and reduced by *Innovation Capital Obsolescence*. The level of knowledge stocks determines *Innovation Capability* that, in turn, influences how many new product projects start and how much time the development process takes, that is, how many new products are developed in a period of time. These *New Products* increase *New Products Portfolio* which is depleted by those products that have gotten a certain lifetime period (New Products Maturity Time) and must be classified as mature products.

3.4.2. Financial performance

Three indicators are used to measure financial performance: *Income from New Products*, determined by *New Products Portfolio* size, *Return on Investment* (ROI) defined as the ratio between *Income from New Products* and *Investments in Intellectual Capital*, and *Margin*, defined as the difference between *Income from New Products* and *Investments in Intellectual Capital*.

3.4.3. Managerial dynamic hypothesis and investments in intellectual capital

The decision on how much, as a fraction of *Income from New Products*, will be invested in intellectual capital in each period, is determined by the *Relative Value* that management assigns to that income. This relative value is calculated through the prospect theory function (Equation 1) in which the reference point, used to calculate "x" is set according to the managerial dynamic hypothesis, and α, β, and λ, are the median of the values used by Bromiley (2009), that is $\alpha=\beta=0.88$, and $\lambda=2.25$.

Two different managerial dynamic hypothesis are used, an elaborated one (Hypothesis 1), that takes into account the delay between investments and their impact on financial performance, and a simple linear one (Hypothesis 2). Both hypotheses are shown in Figure 8.

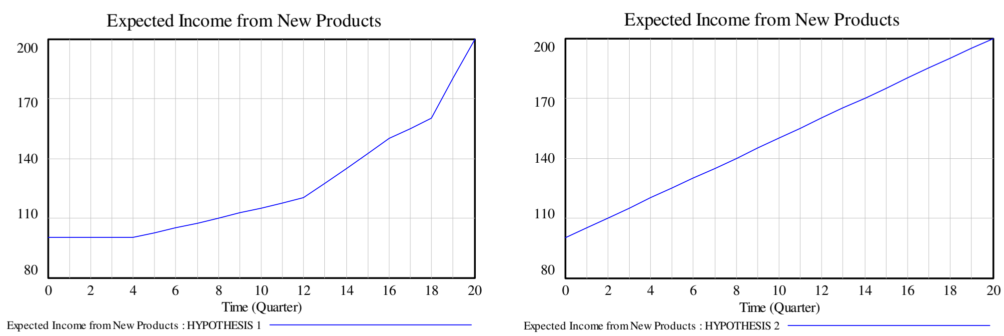

Figure 8. Managerial dynamic hypothesis. Hypothesis 1 (left) and Hypothesis 2 (right).

As it can be seen from Figure 8, the time unit used is quarter and the simulation time horizon 20 quarters (five years). The *Expected Income from New Products* (goal) is 200 in the 20th quarter for both of the hypothesis. An investment policy of 25%, as a maximum, of *Income from New Products* to be reinvested in intellectual capital is assumed.

A simplified version of the simulation model structure is shown in Figure 9.

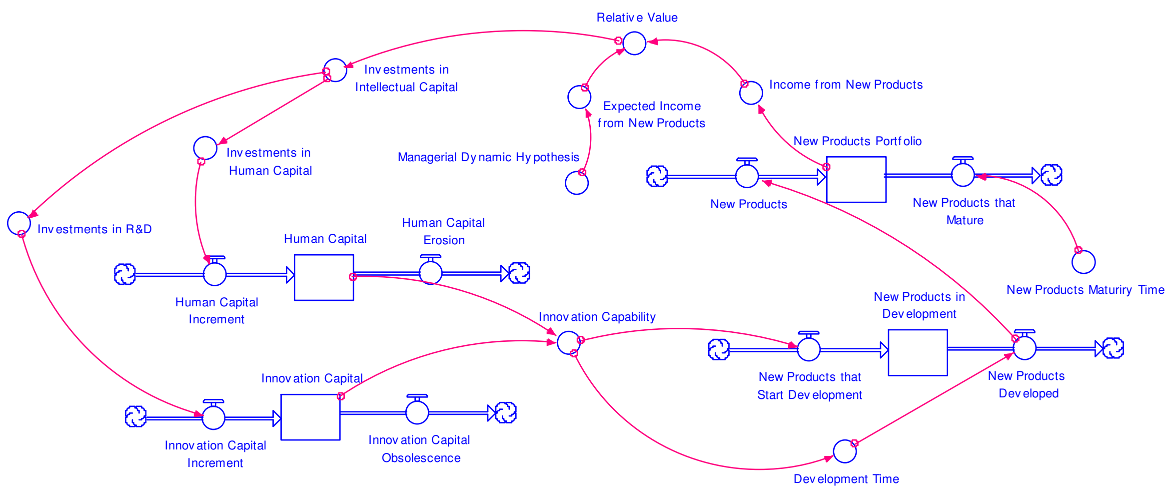

Figure 9. Simulation model structure.

4. RESULTS

4.1. Financial performance

Figure 10 shows simulation results for *Income from New Products*, comparing investment decisions made with Hypothesis 1 (blue line 1) and Hypothesis 2 (red dotted line 2). *Income from New Products* shows a growth behavior after the 10th quarter as a result of investments delayed impact. This growth is higher in the case of Hypothesis 1, with a final result of 173.1, relatively close to the goal of 200. For Hypothesis 2, growth in income is lower with a final result of 156.9.

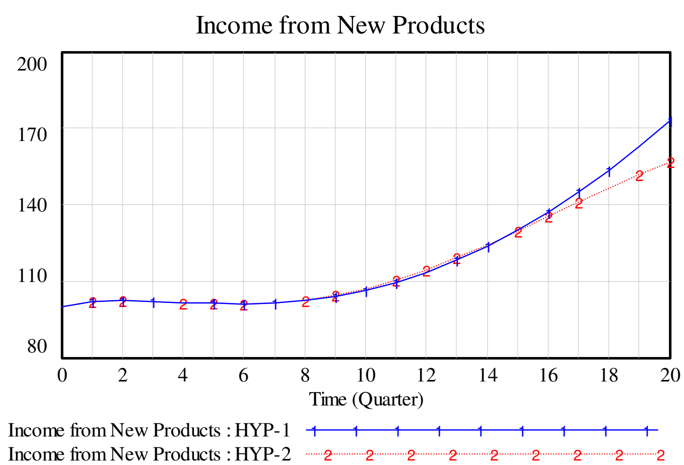

Figure 10. Simulation results for Income from New Products.

4.2. Investments in knowledge stocks and fraction invested in innovation capital

Behavior over time of *Investments in Knowledge Stocks* and *Fraction Invested in Innovation Capital* is shown in Figure 11. *Investments in Knowledge Stocks* shows a growing behavior from the 6th quarter on with a final value of 43.3 in the case of Hypothesis 1 (blue line 1), and a decreasing behavior from the 6th quarter on with a final value of 22.2 that tends to be stable, in the case of Hypothesis 2 (red dotted line 2). This behavior follows what should be expected as an effect of the aversion to losses (section 2.6) affecting the *Innovation Capability* and explaining the results obtained for *Income from New Products* (Figure 10). On the other hand, the *Fraction Invested in Innovation Capital* shows a rather stable oscillatory behavior (around a value of 0.55) in the case of Hypothesis 1 (blue line 1) that follows the risk averse behavior predicted by the prospect theory, whilst in the case of Hypothesis 2 (red dotted line 2) the results show a higher amplitude oscillation curve with a peak of 0.8 by the 10th quarter and a further stabilization around a value of 0.71, following the risk seeking behavior predicted by the prospect theory.

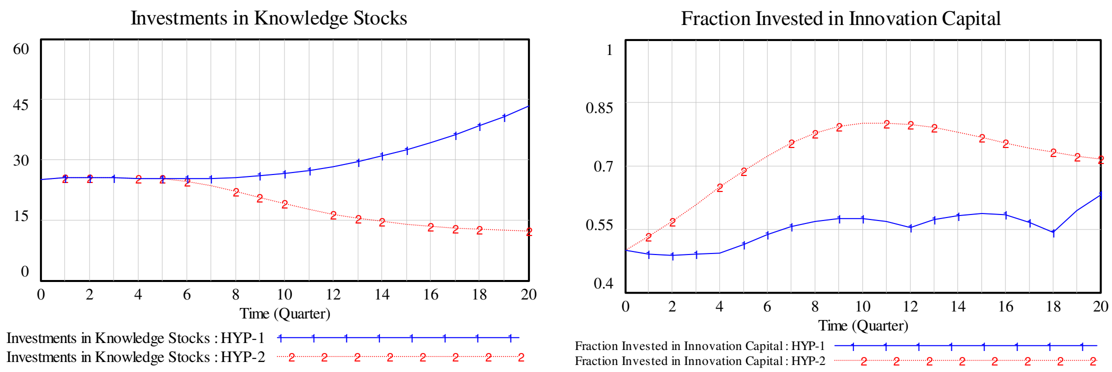

Figure 11. Simulation results for Investments in Knowledge Stocks (left) and Fraction Invested in Innovation Capital (right).

5. CONCLUSIONS

A managerial dynamic hypothesis that does not take into account the delay between investments in intellectual capital and its impact on financial performance, may lead to decisions, based on short term results, that reduce or cut investments in a premature way, resulting in poor financial performance.

The results obtained from the simulation are consistent with those which should be expected from the application of the prospect theory.

An empirical validation of the results should be made through experimentation with decision makers, using a management flight simulator based on this simulation model.

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