VALUATION OF INNOVATION PROJECTS WITH HIGH UNCERTAINTY: REASONS BEHIND THE IMPLEMENTATION OF REAL OPTIONS

MARIO SERGIO SALERNO
University of São Paulo, Production Engineering Department, Brazil
msalerno@usp.br (Corresponding)

LEONARDO AUGUSTO DE VASCONCELOS GOMES
University of São Paulo, Faculty of Business and Economics, Brazil
lavgomes @gmail.com

VINICIUS CHAGAS BRASIL
University of São Paulo, Production Engineering Department, Brazil
viniciuscbrasil@gmail.com

ABSTRACT

Many papers have been discussing the nonadherence of classical financial tools – like net present value (NPV), return on investment (ROI), discounted cash flow in general (DCF) to the evaluation of innovation projects involving high uncertainty. There are an attempt to use some new tools to cope at least partially with the challenge of valuation and selection of right projects. Among these tools, we can find the real options approach. However, they all require data that are unavailable for most radical innovation projects. The later point leads us to the following research question: why firms are looking for new tools for valuation of projects and which are the effective questions behind it? Based on five in-depth case studies based on grounded research in companies in Brazil searching for radical innovation (three Brazilian owned – two multinationals, one startup company; one multinational American owned), where we have longitudinally accompanied specific projects, we propose a discussion on the main issues behind the search for such techniques, and which are the conditions for their successful introduction in an organization. We identify three main issues behind the valuation problem: a) portfolio management (traditional issue); b) commercialization issue (pricing of the technology or price of the company); c) internal disputes for budget. Our conclusions show that the critical success factors for a implementation of real options are: a) the involvement of other people than R&D (e.g. finance, marketing, etc.); b) building capabilities on managing uncertainties ; and c) development of competences on identifying and defining the possible decision points where to exercise the options (abandon, continue, or improve the project).

Key words: innovation management; radical innovation management; valuation of innovation projects; uncertainty management.

INTRODUCTION

In this paper, we discuss the hidden reasons why some managers of radical innovation projects are looking for methods beyond the traditional financial ones to the valuation of their projects. There are many papers discussing innovation processes (Silva et al, 2014, review the literature on the subject), but valuation is much less discussed. Criticisms to traditional financial tools for valuating radical innovation projects are well stablished in the literature (O'Connor et al, 2008). By traditional financial tools, we mean those based on discounted cash flow, as Net Present Value (NPV), Return

on Investment (ROI) and the like. Beyond the criticism of the traditional tools, there is often an organizational reason or an organizational dispute.

Valuation is a critical issue for project management. Valuation is related to the judgment of the viability of a single project and to the relative viability among others projects disputing resources in the portfolio. Although there is several non-financial tools aiming at aid portfolio management, like scoring approaches, bubble diagrams and others (Cooper, Edgett, and Kleinschmidt, 1997a, 1997b, 1999; Goffin and Mitchell, 2010; Mikkola, 2001), the attractiveness of financial tools are much higher.

Brandão *et al*. (2005) pointed out that discounted cash flow is often employed for the valuation of projects. These authors remarked that one most relevant limitation consist of failure in accounting the value of managerial flexibility, present in innovation projects. In spite of several works showing the limits and the biases of traditional financial tools applied to the valuation of innovation projects with high uncertainty (Cooper, Edgett, and Kleinschmidt, 1997a, 1977b; O'Connor *et al*., 2008; Rice et al., 2008;Goffin and Mitchell, 2010), many well-structured and well-managed companies rely on financial tools to manage their portfolios. Nevertheless, it seems to have a growing concern among academics and managers on the necessity of more efficient tools to valuate projects. The real options approach has emerged as a promise to have a more adequate valuation for projects involved in high uncertainty (Huchzermeier and Loch, 2001; McGrath, 1997).

In the course of two research projects on innovation processes and management, we have studied 229 innovation projects. Most cases are traditional, that is, related to companies that perform incremental innovations in mature markets, basing their management on stage-gates like systems and valuating projects via NPV, ROI or similar financial engineering tools. However, there are some companies seeking for innovate radically systematically. These companies face different issues in valuating projects and managing innovation projects portfolio than companies with incremental projects. In Govindarajan and Trimble's (2013) words, the first one is facing R (repeatable) projects, and the second one C (custom) projects. In addition, in such companies the interviewed always have mentioned the valuation problem.

Literature justifies the nonadherence of traditional financial tools by the lack of data. It is not possible to have market data for a radically new product that creates a completely new market -Post It, IPod, Walkman are some of the most quoted examples. When the product is completely new, that is when it does not substitute an existing one, it is virtually impossible to have a minimally accurate market evaluation. When the project relies on a radically new technology or on a new integration of different technologies, it is very difficult to predict future production costs (Salerno *et al*., 2014). That is, it is possible to have a lack of data to analyze the development of a new process to produce industrial commodities – that is the case of renewable chemicals (chemicals from renewable raw materials) for instance. Here, companies use to have a cost objective, but this does not mean that they can predict the real cost they are going to arrive after initial developments, scaling up, etc.

In a more theoretical approach, if we adopt Knight's (1921) definition of uncertainty, which implies that the probabilities of future outcomes "unknowable", by consequence it is impossible to run tools based on data that are unavailable. Many times, data are not reliable, or are obtained because of many simplifications and questionable assumptions. Discounted cash flow technics (NPV, IRR PMT, etc) have also severe limitations – like the need to compare projects with the same time horizon or

that is reasonable to assume that initial conditions will be the kept until a horizon that is the least common multiple of all the projects in analysis (Fleischer, 1969). And we have heard lots of cases of manipulation of data, in order to "adapt" the project to the formal requirements of the company, like changing time horizon, income (price, volumes), expenditures, and prevision of inflation rates.

Summing up, our research question can be set as: what are managers looking for when they search for the implementation of new tools for valuate innovation projects involved in high uncertainty? Which are the hidden motivations in such demand?

Successful companies have an established management system that articulates strategy, structure, resources. Management system can be considered as the set of elements for achieving efficacy and efficiency of an organization. Many authors define the elements of this system. Galbraith (2014) articulates the star model, involving strategy, structure, processes and lateral competences, reward systems, human resources system. O'Connor *et al.* (2008) proposes the following elements of a managerial system: mandate and responsibilities; structure and processes, resources and skills, leadership and governance, metrics and reward systems. Although close, we will adopt O'Connor's approach, since it is articulated around innovation issues - Galbraith's (2014) one, for instance, focus on organizational design. In that sense, we based our field research on the comprehension of the management system and its components in each of the cases.

METHODOLOGY

We have proceeded to a multiple case studies. Our aim was to investigate in deep the reasons why firms or, more specifically, some managers, are looking for new ways of valuating innovation projects, specifically those that involving high uncertainty.

Case studies are the traditional methodology for research questions such as the present one. Our question adheres to the justification of case studies by Yin (1994), Eisenhardt (1989) or Voss *et al.* (2002). In each company, we analyzed one or more projects. The same company can have different projects, some traditional, and some radicals. Often there are different portfolios (R&D projects, process or product improvements, etc.) and projects differently evaluated in the same portfolio (because of balancing objectives). Nevertheless, to study projects means also to consider the company.

We have proceeded to longitudinal studies. We have accompanied some projects during a large period. Radical projects usually take long time to develop (O'Connor *et al.*, 2008; Govindarajan and Trimble, 2013). By following projects, it is possible to depict crossroads, to map decisions taken, to understand disputes.

We have researched projects in five companies, as shown in Table 1.

Table 1: Research details: cases & instruments

Case	Business	Period of research	Research Instruments / Protocol
Green Chemical	Petrochemical in the race for green chemicals. Central R&D and management of radical new projects to be further	Longitudinal (2008-2014), intensified in 2013-4)	Interviews and structured discussion with the CEO, CTO, Director of Innovation, Director of business unit, managers of innovation, manager of projects

Case	Business	Period of research	Research Instruments / Protocol
	transferred to one of the business units (or to create a new one)		office, technical staff of innovation management, finance, investments (separate functions), several times along the years (except with the CEO – 1 time). Participation in an in-company course on project valuation
Traditional petrochemical	Petrochemical based on oil. Organized in internal business unities. Each manager has large power over "its" business.	Longitudinal (2010-2014), intensified in 2014	Interviews and discussion with product & process innovation managers, innovation management manager and staff, R&D professionals.
Specialty chemical	Petrochemical (specialties) fighting against the commoditization of its products.	Longitudinal (2013-2014)	Interviews and discussion with CEO, main investor, R&D director, R&D managers, innovation manager, PMO.
R&D company	R&D company, developing processes for new generation of renewable ethanol production (biotech)	Longitudinal (2014)	Longitudinal research. Interviews with owners (managers), investor (fund). Detailed analysis of one project, aiding the company to introduce RO to its valuation.
Veterinary products	Veterinary pharma, looking for new process (biotech) for a given substance	2013. Immersion in a project	Interviews and discussion with innovation manager, project staff. Dynamics with Project staff and technology supplier

Elaborated by the authors.

In three cases, 1, 4 and 5, the companies have engaged in real options evaluation. Companies of cases 2 and 3 have valuation problems but have not really engaged in a real options approach even if RO is considered. Cases 2 and 3 act as a counterpart, providing the research with other visions of the valuation issue.

CASE STUDIES EVIDENCES

We are going through case studies with the following analytical structure. First, a brief description of the company the sector and its competitiveness issue. The apparent demand follows, that is, which was the problem in the innovation management system of the company according to the discourse of the interviewees. Our analysis leads to the real problem, that is, the one hidden behind the discourse.

Case 1: Green Chemical

Case 1 refers to a petrochemical company Brazilian-owned multinational operating mostly in the Americas. It leads some technological routes and some markets on renewable chemicals. Company has set renewable chemicals (that is, to produce chemical commodities base on renewable sources)

at the center of its corporate strategy, but it has a history of traditional petrochemical production that still is the largest part of the business.

In 2007, this company decided to implement an ambidextrous organizational strategy (the Corporate Innovation Business Unit), which consisted of the creation of a special separated business unit devoted to performance radical technological innovation projects. The expectation associated with this unit was to build the capabilities needed to operationalize the corporate business strategy: to become the leader firm in the emergent green plastic market. The mission of this unit was to prospect internally and externally new ideas; to evaluate and select the best ones; to develop them, overcome the main market and technological uncertainties; to manage of external partners, such as universities and startups; and help introducing a stable technology innovation in incumbent business unit.

Apparent demand: the problem as enunciated by the company

In the beginning, one of most critical challenges faced by managers of new business unit was how to evaluate and select radical innovation projects. The managers had a solid expertise on valuation of projects based on traditional techniques, such as net present value. As the application of such techniques implied in the rejection of projects consider as strategic by the board of company, the managers decided to search for approaches more adequate to evaluate radical innovation projects. Drawn upon specialized literature on innovation, consultancies, and based on previous experiences of strategic partners, the managers identified that the Real Options may be used to account for the value of more radical innovation projects.

As the managers had few valid experiences on Real Options approach, the company decided to hire the service of innovation consultancy. The official discuss adopted by the company was that the aim of this service consisted of employing Real Option in two radical innovation pilot projects. The service should involve all employees and managers of this business unit, in order to transfer knowledge to them and help building an organizational capability on valuation of innovation.

This consultancy service took place for nine months. Initially, the consultancy decided to conduct the valuation of two pilot projects in parallel. However, due the poor data available in identifying critical technological options and market analysis, and difficulties on customizing the Real Options for one of them, the consultants decided to refocus the service, valuating just one project.

The effective demand: issues behind official discourse. Organizational structure and management system

At the beginning, the consultants faced difficulties on accessing data needed to performance the valuation of projects, and low familiarity of business team on Real Options approach, including mathematical and statistics aspects. However, the true barriers were related to hidden agenda of managers of this unit: they wished to use Real Options as way to show to board that this unit employed a well structured method for innovation project valuation. As consequence, the Real Options could help increasing the legitimacy and credibility of this unit, and aided convincing the board to augment the unit's budget.

Since the early days of this new business unit, the managers have suffered lack of power and autonomy. This new business unit was seen as non-disciplined or bad managed, because managers

did not used formal and well structured managerial approaches for conducting innovation projects, differently from the rest of company. As consequence, all decisions related to invest in certain innovation project should take by other business unit, “Corporate Strategic Investment”. The use of Real Options was regarded as way to change the image of Corporate Innovation Business Unit, improving the chances of innovation project being selected.

Conclusions

The valuation problem at company 1, manifested by the portfolio problem, in fact is the manifestation of a search for legitimacy and credibility of an innovation corporate business unit.

Case 2: Traditional Petrochemical

Case description

It is a company that grew by incorporations in several countries. Technology for industrial processes is historically licensed from key actors. But the grew and the internationalization of the company has closed doors with technology suppliers, since they had the perception they were creating a competitor. That leads the company to set a R&D center to develop industrial processes as well as to develop new specifications and new uses for the plastics it produces.

The company has an aggressive policy of semi-autonomous business unities. Each unit is considered as an own company, and its manager has great power on resources allocation and medium-term strategy (that is, the one that does not require large investments as the build of a new facility). Each business unit has its own R, D&E (research, development and engineering) for applications and is client of a central R&D for process improvement.

In a first meeting in 2010 we discussed about the general structure, the bonuses for managers and for all employees, the general innovation process. This process was introduced by a large multinational consultancy company, which has installed the traditional funnel/stage-gates approach based on a central software accessible by terminals. An employee can register its idea in the software; the system envoys it to an expert for a first analysis, and them the idea can go through the traditional flow (activities / decision in committees). In this first round of the research, we have identified that the system, as expected, was conceived for incremental innovations. We followed a case of a radical innovation project (a new way to produce a petrochemical commodity) that was not validated by the process, that is, it was considered not viable. Some years later, because of the persistence of project leaders, the board of directors has decided that the project could go on, and it has given birth to a new business unit. Summing up, there is a problem with the innovation process in the company; it is inadequate to deal with radical innovation.

Along with the process, a kind of PMO (project management office) was created as support to establish general rules of innovation project management. A manager and two people run this innovation management function.

Apparent demand: the problem as enunciated by the company

From 2010 to 2011 we have followed projects on new specifications and new applications for produced raw materials, as new densities for plastics, applications in housing construction, etc. These projects run well in the system. However, late 2013 – early 2014 in discussion with the

innovation manager we were told a problem on the valuation system of projects. The issue was raised as how to scientifically define the horizon of net present value to evaluate projects. Some project leaders were claiming against valuations made by commercial staff by saying they were conservative – short horizon.

Valuation in the company is defined in the first step of the process, named as preliminary analysis. When an idea is registered in the system, the system allocates it for an expert in the theme. The expert is the first gate, in a brief analysis. If the project continues, the leader of the business unit allocates a manager for the project. The manager builds a project team with commercial staff and marketing staff. Commercial and market staff set the parameters for the first valuation produced: prices, volumes and time (horizon). Formally, this initial valuation can further change but in practice, it is not. That is, such valuation may make sense only for incremental projects with low uncertainty - if any. Then the project is evaluated in a committee (a gate).

The official discourse talked about two predefined horizons: 3 or 5 years, according to the kind of project. 5 years means the full stage-gates system implanted; 3 years refers to a simplified process, with merged activities. That definition has occurred years ago, along with the introduction of the software to manage the innovation process. In a joint discussion with three project leaders and the innovation manager we were told that some projects concerning patents (intellectual property) or process development were considered in 10 years. For triangulation purposes, we asked the manager of the innovation function to get real horizons defined for projects. Actually, by listing the characteristics of 200 innovation projects of all kinds we could perceive that horizons varied from 2 to 12 years, in a kind of normal curve. Summing up, they have informally managed to cope with the restriction of 3-5-10.

The effective demand: issues behind official discourse. Organizational structure and management system

The inconsistency between the discourses and data regarding horizons has suggested us that the claim against horizons was he surface of an iceberg. The problem was not the horizon in itself, that being a symptom, not the root of the problem. The real problem was the low adherence of the innovation process formally installed in the company, and the software that supports it. Moreover, the organization in business unities is leading to a short-term approach towards innovation and NPD. BU manager is responsible for resource allocation. Apart from high investments, like those required for expansion, the BU manager decides resources allocation. That means also the amount for R&D, for NPD, for quality. It is an appealing policy. However, is current production operation that measures BU manager success. In addition, there is a management rotation, since well-succeeded managers get promotions, either horizontally by assuming another BU where his bonuses is higher, or vertically by assuming a new business or a directory, since the company is expanding in Brazil and abroad. Summing up, there is no managerial incentive towards long-term innovation activities.

The short-term orientation appears in some important organizational aspects. R&D has no budget, running by project. That is, R&D is not characterized as an organizational function (O'Connor et al, 2008), since at the end of the day it only exists if there are projects approved by the management – that is, by the BU manager.

Accordingly, R&D projects are submitted to the same funnel process as ordinary projects of incremental innovation. The internal system of idea generation is also not segmented. All kinds of

idea arrive at the same point requiring the same treatment. It overloads the team in charge of innovation management. Many ideas were not treated; no answer is given to their proponents.

Defining and implanting a new approach

The discussion of criteria for the definition of horizons in projects has triggered deeper discussions, both in technical aspects and in managerial ones. Technically speaking, NPV was being applied without considering the need to extend the suppositions of each project to the least common multiple of the horizons involved in the analysis in a given moment (Fleischer, 1969). Managerially speaking, company has perceived the need to reframe internal organization to treat separately different types of projects, namely R&D projects, NPD, adaptations of existing products, and applications for existing resins. But to change BU's approach towards a longer-term perspective is much more challenging.

Conclusions

The search for a 'scientific' definition for project horizons was, in fact, the tip of the iceberg of much more complex organizational problems. The organizational structure induces a short-term approach towards innovation. BU's does not have R&D as a function but as a collection of project instead. We could say that the reason behind the search for improving valuation system in company A is organizational inadequacy, not the valuation tool itself.

Case 3: Specialty Chemicals

Case Description

Case 4 refers to a company that produces specialty chemicals like agrichemicals, surfactants, lubricants, specialties for home & personal care (anionic surfactants, mild co-surfactants, specialty ingredients, consistency agents, emulsifiers and emollients, pearlizing agents, humectants, solubilizers, nonionic, anionic and specialty surfactants, as well as green solvents), performance products for textiles and food industry. Recently it has become multinational with production units all over the Americas (North and South) and offices in China and Europe. It has start operations producing a basic petrochemical (commodity). Since prices of this commodity has diminished due to Medium Orient concurrence, the company decided to shift to surfactants. That is, a shift from focus on operational excellence to a core competence on development and innovation. Actually, the beginning of the strategy was classic, since the company started by copying products.

Recently, company 3 has realized that their core products were in a process of commoditization. That is, the effort of some companies to produce internally the same molecules of the market leaders led to a commoditized offer. Although the company develops special products for large customers (e.g., surfactants adapted for a special use), other companies around the world do the same. Worst still, in the meanwhile, new technologies have been developed, gaining market share and depressing company 3 margins. To cope with this strategic risk, company 3 decided to invest in technological development. As a result, the portfolio of development has changed by the incorporation of more radical projects.

Apparent demand: the problem as enunciated by the company

Company 3 has identified a portfolio management problem. Projects are evaluated and compared in the portfolio via discounted cash flow techniques such as NPV (net present value). When R&D center started some more radical projects, the company was unable to evaluate them using the traditional financial tool. That is, the raise in uncertainty led to a lack of data for the parameters necessary to run these kind of tools, like temporal horizon (how many time will last development?), expenditures (which would be the expenditures of the project, comprising R&D, product development, production and commercialization phases?), income. However, these projects were compared in the same portfolios. As VPN was not applied to them, their VPN was assumed as zero. A schizophrenic situation: projects with the highest strategic importance were worst evaluated than simple ones. Managers had always to explain to others that although in zero, these projects were the most important, should attract greater budget.

To contour the situation, the R&D manager was looking for new tools for portfolio management. New approaches, as real options, could better represent reality and would permit a formal tool to evaluate all kinds of projects - that was the dream of company 3.

The effective demand: issues behind official discourse.

An in-depth discussion with R&D functional managers showed us a different panorama. Innovation strategy was not well spread in the company. Although supported by the directors board, innovation strategy was not priority in budget elaboration and in capital allocation. The expressive amount of money to set a new plant or to modernize existing ones had the effect to hidden R&D budget. Then, to gain visibility and resources, radical R&D projects should be evaluated, because this evaluation would facilitate their development. Evaluation here means acknowledgement, acceptation of the project in the company.

Thinking of this, we have proceeded to some further interviews with R&D managers and high management. The executive board discourse attributes high priority to R&D, what makes it possible to develop project without punctuation (VPN equal to zero). But the problem of commoditization is not well perceived in the company, since it is not a traditional commoditization. The company develops special formulations for golden clients, and most of the company sees it as a non-commodity product. That is, the commoditization of surfactants market is not clearly perceived. Accordingly, the shifts from a light development product adaptation from technological platforms development (stronger R&D, looking for disruptive innovation) are not clear. That means that a confrontation between the two models takes place in company 3.

In other words, the valuation problem reflects the contradictions of the move towards stronger R&D. The system of innovation management is still the one designed for the older strategy, and it does not support the new one. For instance, there are no separate portfolios for traditional projects and radical projects with high uncertainty.

Conclusions

The valuation problem at company 3, manifested by the portfolio problem, actually is the manifestation of an inadequacy of the system of innovation management. The company is discussing the foundations of what could be named as its innovation function.

Case 4: Biotech startup

Case description

Case 4 refers to a small Brazilian startup company which focus its activities in research and development of new processes and products based on green and renewable materials. The company has four main acting lines: 1) development of new third generation ethanol production processes; 2) development of herbal drugs and cosmetics; 3) technical analyses and reports about heavy metals contamination; 4) biochemical analysis in general. One special aspect of the company´s vision is the social view. The owners are committed to drive the projects in direction of sharing and offering technology to poor communities as a form to improve the life condition of them. This social driven strategy is known as directed to the "Base of the Pyramid" (BoP).

In this study, we follow specially a project that aimed the development of a new process to produce third generation ethanol. The third generation ethanol is produced using the sugar cane substratum generated after the fermentation realized during the production of first generation ethanol. The substratum is placed in a bioreactor with microorganisms and a second batch of fuel is produced. This technology was patented and the intention of the owners was develop the new technology and license it to small refineries located in some specific communities.

As a traditional scientific research and development project, the need of financial resources is high, as well as the uncertainty involving the technical and financial viability. To finance the project, a venture capital fund, focused on social projects and initiatives, supported the company considering their social driven strategy.

An innovation management consultancy was also contracted to help the startup in clearing and organizing its business model. Along the discussions with the consultancy team, the owners realized that the initial idea of licensing the use of the production process to small refineries could not be the best strategy to diffuse the technology. The lack of control of whose is using it; the complexity to operate a process so sophisticated and the possibility of any refinery copy the process, decreasing the patent value, were some of the factors that influenced the decision to change the strategy. The entrepreneurs decided to try to find a way to sell the patent rights to some huge petrochemical company able to pay a great amount of money, and so, use these financial resources to finance the development of the others research lines, henceforth focused really in the base of the pyramid.

Apparent demand: the problem as enunciated by the company

Along the innovation management consultancy and the definition of the new business model that should be adopted to allow the viability of the project, the team identified the need to quantify the value of the technology and patent. The idea was visualize the real value of them and, at the beginning, the future remuneration that the small licenses could generate, likewise to dimension the size of the value that the project could produce.

According to the high level of uncertainties that the project was subject to, for instance the inability in precise the future technical and cost parameters that the project would reach at the development end, conditions able to derail the project, the consultants decided to conduce a valuation using the Real Options. The Real Options approach is the one indicated to quantify the

managerial flexibility and the options derived from an innovative project, involved in high uncertainties (Copeland and Tufano, 2004).

The owners elaborated 5 scenarios based on different possible technological performance parameters reached and 8 different sizes of the future industrial plant, varying the quantity of third generation ethanol produced in each one. The scenarios built enabled the cash flow projection and the simulation of the future financial reality. These data were used as input in a Real Options mathematical model (Huchzermeier and Loch, 2001) and the valuation was finished. At the end, the entrepreneurs had a value to base the possible future negotiation with companies interested in buying the technology or to know how much should be charged to license the technology.

The effective demand: issues behind official discourse.

The claim for defining a value for the technology developed or for the royalties to be charged of the future users was just the apparent driver for the application of Real Options Approach. The characteristics of the method in covering the managerial flexibility and force the elaboration of decision lattices are attractive from the entrepreneur point of view, once this agent needs to minimize the uncertainties and define the best strategy and the business model.

The biotech startup was not confident enough in how it should deal with the BoP philosophy. Not necessarily the business model based on this drive would be that one appropriate for the circumstances. The stress generated by the use of Real Options approach in developing scenarios and designing the options helped the company to clarify the configuration of the business and to rethink the choices made in the past.

Using the Real Options approach the company realized that the initial idea of licensing the technology to small communities was not viable, besides of representing a risk for the control of technology and its rights and diffusion. Once this new strategic decision was identified, the challenge that emerged was the conduction of the relation with the venture capital fund. The decision of abandoning the initial strategy and sell the technology to a huge company able to pay a great amount of resources and capable to manage the complexity of a technological industrial plant became incoherent with the terms accorded with the fund. In doing so, the Real Options approach was an instrument to negotiate with the fund the future of the partnership and justify the strategy change.

Conclusions

The valuation of a technology using the Real Options may be just an instrument and a tool to understand the possible options that the business has. In this case, the biotech startup used the valuation as a form of thinking its business model and strategy, as well as the value and the rationalization produced using the approach were transformed in arguments to justify a change on the strategy to the stakeholders.

Case 5: Veterinary products

This case refers to a large multinational company specialized in developing veterinary products. This company decided to develop a new generation of a particular veterinary product by using genetic manipulation of coats, in order to obtain a specific protein. Because of this goal, the company

decided to build a partnership with technology-based startup, which had two patents on intermediary products, needed to produce this veterinary product.

Apparent demand: the problem as enunciated by the company

In this case, the company also received support from a consultancy company in employing Real Options for valuating this innovation project. According to the innovation manager of this multinational company, the consultancy service started helping identifying critical uncertainties related to innovation project. To do so, they used the learning plan, as proposed by Rice *et al*. (2008). One of critical uncertainties identified was the model of negotiation with the startup. To cope with, the consultants decided to change the focus of service, and use the Real Options, with three aims: i. valuating the value of technology; ii. valuating different technology options for obtaining the product; and iii. defining some parameters for the best model of negotiation with the startup, which may involve the large company playing a role of venture capitalist, investing in this startup.

It is important to remark that this case did not involve a formal innovation project selection process. The manager had a budget for prospecting, pre developing and investing in some potential technologies.

The effective demand: issues behind official discourse

As the innovation manager had more technical background, her expertise on management and valuation of technology project was not well developed. The consultants helped implementing a systematic approach for coping with uncertainties. This approach led to identify critical uncertainties related to the value of technology and the terms of negotiation with the entrepreneur.

As far as the valuation process advance, it started becoming clear the real agenda of innovation manager. First, the main aim was to obtain more resources from the company in order to invest in other technological options associated with this project. She was not convinced that technology option developed by startup was the best one. Second, she employed the Real Options as instrument to gather data from the entrepreneur and, mainly, to increase her legitimacy, credibility and power, once she dominated a more sophisticated approach for valuation of the technology.

Conclusions

The valuation of a technology using the Real Options may be an important instrument for negotiation. First, the Real Option may increase the comprehension around the structure and features of technology. And, second, the Real Option can be used as way to increase power, legitimacy and credibility.

FINDINGS

Our findings show that the valuation problem reflects hidden tensions and problems in the organizational structure for innovation. Of course, valuation is a problem in itself. There are many issues regarding valuation, as the lack of data in projects with uncertainty, the need discounted cash flow techniques have to compare projects only with the same temporal horizon or to expand horizons until the lowest common multiple of the horizons of all projects (what is a very strong

restriction to such techniques), the building of the decision tree and the percentages allocated to each decision in real options approach, and so on.

Regardless of such problems, there is a search for quantitative valuation approaches even for R&D projects. In some cases, it hides a non-sophisticated innovation management system that mix in the same bowl different kind of eggs, like short-term traditional projects with very low risk and long-term uncertain innovation projects based on new technology development. In other cases, it hides the limits of an organization designed to incentivize autonomy decision in current operations but confining the company to a short-time management. Only in case 4 – the biotech startup, actually an R&D company, the search for real options was related to have a better position to negotiate the technology with stronger third parties.

Synthetizing, three main issues conduct to new approaches for project valuation:

i. The portfolio management problem, the traditional issue on how to compare projects, reflected in cases 2, 3, and, in a less extent, also in case 1;

ii. The commercialization issue, that is, the aim to have a better position for discussing the price pricing of the technology in business models that aims to sale technology instead of final products. That is the case of company 4.

iii. Finally, internal disputes for budget, as in cases 1 and 2. Surprisingly, in these cases radical innovation projects, involving R&D, have to be approved one by one. R&D function has no budget, working accordingly to projects. Although the organizational structure by project can counteract many problems of a functional structure, like slowdown, lack of responsiveness to changing environmental conditions, lack of market vision, as well discussed in organizational theory (Mintzberg, 1992, Galbraith, 2014), in the end of the day it leads to a short-term approach benefitting incremental project and penalizing long-term radical ones. If short-term projects make cash today, long-term radical ones is the cash of next periods. In that sense, without a budget to take riskier options, managers tend to direct efforts to traditional short-term incremental projects. Worst still, managers usually get recompenses for this behavior.

   The only way to solve this contradiction is to build a strong innovation function, as pointed out by O'Connor *et al.* (2008), with a budget free from short-term pressures. Basic organizational theory helps to understand and to act: the same reasoning that organizes differently a high volume production of standardized products (e.g., production lines with dedicated machines) if compared to tailor made individual ones (functional organization, universal machines for small batch production, high skilled people) should be applied to innovation activities and projects.

Critical success factors in the implementation of real options

Our findings also show that the critical success factors for the implementation of real options are:

i. The need to involve other people than R&D (e.g. finance, marketing, etc.), very clear in case 2, which was involved in the past with real option without success, because the responsible for valuating projects did not participate in the discussions. Let us take the example of company 1. Years ago, the company contracted a consulting company for RO, that has made

the technical job, but implementation failed. Years later, in 2013-2014, the company made different. Corporative Innovation managers began a time consuming dialogue with the main internal actors on the RO project. A day out course with the university was organized, involving these actors, where the main issues of valuation and innovation organization were discussed. The company performed a simulation of how to valuate a project with RO, and start valuating a pilot project.

ii. Building capabilities on managing uncertainties. In the cases analyzed uncertainties are under evaluated, radical projects are treated as a more complex traditional one.

iii. Development of competences on identifying and defining the possible decision points where to exercise the options (abandon, continue, or improve the project), and the probabilities associated with each decision. This is critical. The weakness of real options approach is the dependence of a good decision tree that must be defined in the very beginning of the project, and the percentages of success attributed to each option. Defining the options tree requires a very strong technical capability and forecast abilities. Defining the percentages of each option is a very sensitive issue, since results can change depending on the percentages. Of course, it is always possible to proceed to a sensibility analysis on the percentages or even to Monte Carlo simulation. But Monte Carlo simulation, although an elegant tool, it is not practical: most of the managers do not understand it, and others perceive it as artificial, disconnected from the reality they are facing.

CONCLUSIONS

Our research reflects on a sound problem of contemporary innovation management, the valuation of innovation projects. The valuation itself has many theoretical, methodological and practical issues. We have highlighted that in many cases the valuation issue hides a structural one, related to the inadequacy of organizational structures for radical innovation. Many companies have grown due to incremental innovations, creating a strong culture on it. The shift to perform frequently more radical innovation requires new organizational structures, new decision systems.

REFERENCES

Brandão, L.E., Dyer, J. S., and Hahn, W.J. (2005), Using Binomial Decision Trees to Solve Real-Option Valuation Problems. Decision Analysis, 2(2), 69–88

Copeland, T., and Tufano, P., (2004), A real-world way to manage real options. Harvard Business Review, 82(3), 90-101.

Cooper, R.G., Edgett, S.J., and Kleinschmidt, E.J., (1997a), Portfolio management in new product development: Lessons from the leaders-I. Research Technology Management, 40(5), 16 –28.

Cooper, R.G., Edgett, S.J., and Kleinschmidt, E.J., (1997b), Portfolio management in new product development: Lessons from the leaders-II. Research Technology Management, 40(6), 43 – 52.

Cooper, R.G., Edgett, S.J., and Kleinschmidt, E.J., (1999), New product portfolio management: practices and performance. Journal of Product Innovation Management, 16, 333-351.

Eisenhardt, K. (1989), Building theory from case study research. Academy of Management Review, 14 (4), 532-556.

Fleischer, G. A., (1969), Capital allocation theory : the study of investment decisions. New York : Appleton-Century-Crofts.

Galbraith, J. (2014), Designing Organizations: strategy, structure, and process at the business unit and enterprise levels. San Francisco: Jossey Bass

Goffin, K., and Mitchell, R. (2010), Innovation Management: strategy and implementation using the Pentathlon framework. Basingstoke: Palgrave Macmillan.

Govindajaran, V., ND Trimble, C. (2013) Beyond the Idea: how to execute innovation in any organization. New York: St Martin's Press.

Huchzermeier, A., and Loch, C.H., 2001, Project management under risk: using the real options approach to evaluate flexibility in R&D, Management Science, 47(1), 85-101.

McGrath R. G., (1997), A real options logic for initianting technology positioning investments. Academy of Management Review, 22(4), 974-996.

Mikkola, J.H., (2001), Portfolio management of R&D projects: implications for innovation management. Technovation, 21, 423–435.

Mintzberg, H. (1992) Structures in fives: designing effective organizations. New Jersey: Prentice-Hall.

O'Connor, G.C., Leifer, R., Paulson, A.S., and Peters, L.S. (2008), Grabbing Lightning: Building a Capability for Breakthrough Innovation. San Francisco: John Wiley & Sons.

Rice, M.P., O'Connor, G.C., and Pierantozzi, R. (2008), Implementing a learning plan to counter project uncertainty. MIT Sloan Management Review, 49(2), 54-62.

Salerno, M.S. et al. (2014), Innovation processes : which one for which project?. Technovation, in press, 2014. http://dx.doi.org/10.1016/j.technovation.2014.07.012

Silva, D. O., Bagno, R. B., and Salerno, M. S. (2014), Modelos para a gestão da inovação: revisão e análise da literatura. Production, 24(2), 477-490. http://dx.doi.org/10.1590/S0103-65132013005000059

Voss, C, Tsikriktsis, N., and Frohlich, M., (2002), Case research in operations management. International Journal of Operations & Production Management, 22(2), 195-219.

Yin, R. (1994), Case Study Research. Beverly Hills: Sage Publications.