VINICIUS CHAGAS BRASIL

Portfolio management of radical innovation: towards a multi-level organizational approach

São Paulo
2020

VINICIUS CHAGAS BRASIL

Portfolio management of radical innovation: towards a multi-level organizational approach

Original Version

Thesis presented to the Graduate Program in Production Engineering at the Polytechnic School, University of São Paulo, Brazil, to obtain the degree of Doctor in Science.
Supervisor: Prof. Dr. Mario Sergio Salerno

São Paulo
2020

Catalogação-na-publicação

Brasil, Vinicius

Portfolio management of radical innovation: towards a multi-level organizational approach / V. Brasil -- São Paulo, 2020.

98 p.

Tese (Doutorado) - Escola Politécnica da Universidade de São Paulo. Departamento de Engenharia de Produção.

1.Innovation 2.Radical Innovation 3.Portfolio Management 4.Innovation Management 5.Innovation Strategy I.Universidade de São Paulo. Escola Politécnica. Departamento de Engenharia de Produção II.t.

AGRADECIMENTOS

Agradeço aos meus pais, Lena e Ronan, por investirem e vibrarem com meus sonhos e conquistas, além de me formarem para ser um adulto e bom cidadão. O que quer que eu seja, é consequência do que me forneceram e proporcionaram.

Ao meu irmão, Gabriel, que se tornou companheiro de ideias, alavancando o meu crescimento intelectual (e por ter me explicado a diferença entre economia ortodoxa e heterodoxa).

Ao meu orientador, Prof. Mario Sergio Salerno, que não apenas me aceitou na pós-graduação, como se tornou conselheiro e exemplo, transmitindo não só conhecimento, mas também valores. Também agradeço pelos inúmeros cafés, caronas, explicações sobre como jogava o Edu no Santos FC e por torcer pelo "pessoal".

Ao Prof. Raoni Bagno, da UFMG, que incentivou e patrocinou esta empreitada, ajudou na construção do trabalho, e sempre inspirou ao desenvolver pessoas.

Ao Prof. Leonardo Gomes, da FEA-USP, o Leo, que, com toda generosidade me acolheu não só na academia como em São Paulo, tornando-se um grande amigo.

Ao Prof. J.P. Eggers, da NYU, que, com toda boa vontade, proporcionou a minha inserção na academia americana, me deu o privilégio de poder aprender como seu parceiro de pesquisa, e segue sendo referência acadêmica.

Aos professores Roberto Marx, Davi Nakano, Celma Oliveira, João Amato, Marly Carvalho, da Poli-USP; Prof. Abraham Yu, da FEA-USP; Prof. Glauco Arbix, da FFLCH-USP; e Profa. Marlei Pozzebon, da EAESP-FGV e da HEC Montreal; que me guiaram em minha formação como pesquisador e indicaram caminhos para a excelência acadêmica.

Aos amigos, colegas e funcionários do Departamento de Engenharia de Produção e do LGI, que compartilharam momentos de alegria, mas também de angústia e aflição, possibilitando a superação dos desafios do doutoramento. Um agradecimento especial à Lidy, Pryscilla, Ana Facin, Simone, Ana Paula, Rafael, Júlio, Jaime, Felipe, Fred.

Aos amigos que São Paulo me deu, por terem se juntado na descoberta da nova, excitante e desafiadora cidade.

Aos brasileiros, que, por meio da CAPES, ajudaram no financiamento desta pesquisa; e aos paulistas, que aceitaram e bancaram um mineiro na USP.

Por fim, um agradecimento à Vovó Filhinha (*in memoriam*), Vovô Haroldo (*in memoriam*) e Vovó Elyanne, pilares morais e intelectuais que motivam esta caminhada.

ACKNOWLEDGMENTS

I am grateful to my parents, Lena and Ronan, for shaping me into an adult and a good citizen, investing on and vibrating with my dreams and achievements. Whatever I am, that is a consequence of what they have provided and taught me.

To my brother, Gabriel, who has become a partner in ideas, stimulating my intellectual development (and for having explained to me the difference between orthodox and heterodox economics).

To my supervisor, Prof. Mario Sergio Salerno, who not only accepted me in graduate school, but became a tutor, being both advisor and example, with his ability to transmit not only his knowledge but also his values. I also thank him for the countless coffees, car-rides, explanations on how Edu used to play for Santos FC and for cheering for the "*pessoal*".

To Prof. Raoni Bagno, from UFMG, who encouraged and sponsored this quest, helped on the development of this work and has always been an inspiration.

To Prof. Leonardo Gomes, from FEA-USP, Leo, who, with all his generosity, welcomed me not only into the academic environment but to São Paulo city as a whole, becoming a great friend.

To Prof. J.P. Eggers, from NYU, who, with all his goodwill, has provided my insertion into the US academic environment, giving me the privilege to learn as a research partner and serving as an academic reference.

To professors Roberto Marx, Davi Nakano, Celma Oliveira, João Amato, Marly Carvalho, from Poli-USP; Prof. Abraham Yu, from FEA-USP; Prof. Glauco Arbix, from FFLCH-USP; and Profa. Marlei Pozzebon, from EAESP-FGV and HEC Montreal; who guided me during my training as a researcher and indicated paths to academic excellence.

To friends, colleagues and employees of the Production Engineering Department and LGI, with whom I shared both joyful and anxious moments. These all have enabled me to overcome the challenges of the PhD road. Special thanks to Lidy, Pryscilla, Ana Facin, Simone, Ana Paula, Rafael, Júlio, Jaime, Felipe, Fred.

To the friends that São Paulo gave me, who have joined me into the discovery of this new, exciting and challenging city. To all Brazilians, who, through CAPES, funded part of this research; and to *paulistas*, who have accepted and financed a *mineiro* at USP.

Finally, thanks to Vovó Filhinha (*in memoriam*), Vovô Haroldo (*in memoriam*) and Vovó Elyanne, moral and intellectual pillars that motivate this journey.

"If I have seen further it is by standing on the shoulders of Giants."

Sir Isaac Newton

SUMMARY

LIST OF FIGURES

LIST OF TABLES

RESUMO

Desenvolver inovações radicais é um fator chave para empresas construírem futuras vantagens competitivas, apoiarem a renovação organizacional e responderem à mudança tecnológica e de mercado. Entretanto, a inovação radical é cercada por diferentes tipos e altos níveis de incertezas. A impossibilidade de obter informações com dados confiáveis sobre prazo, mercado, custos, receitas futuras e paradigmas tecnológicos emergentes fazem a gestão da inovação radical mais complexa que a da inovação incremental – tipicamente previsível e conhecida por empresas. Essas diferenças de natureza - aliadas a tendências nas empresas de privilegiar produtos e clientes atuais – levaram a inovação incremental a ser beneficiada durante processos de gestão do portfólio de inovação. Todavia, as práticas correntes de gestão de portfólio indicadas para gerir a inovação radical (ferramentas financeiras não-tradicionais e *strategic buckets*) não têm sido bem-sucedidas em proteger a inovação radical, e os portfólios estão se tornando cada vez mais incrementais. Para entender este fenômeno, a presente tese pretende investigar como empresas protegem e fomentam a inovação radical durante os processos de gestão de portfólio, para garantir que a inovação radical não seja prejudicada ao longo do tempo. Seguindo uma abordagem evolutiva, esta pesquisa foi baseada em seis fases, produzindo dois artigos publicados em revistas científicas internacionais, dois artigos em revisão em revistas científicas internacionais, um artigo publicado em uma conferência internacional, um artigo publicado como capítulo de uma enciclopédia online e um artigo que ainda está em processo de escrita. Os artigos foram desenvolvidos com base em múltiplos estudos de caso, seguindo a metodologia de Eisenhardt, junto de revisões de literatura, sendo um deles uma revisão sistemática de literatura. A pesquisa teve início com foco no entendimento sobre o uso de métodos não tradicionais de valoração (especialmente a precificação por Opções Reais), que tinha a intenção de superar os desafios impostos pelas incertezas da inovação radical e calcular o valor dos projetos, para viabilizar a comparação com os projetos incrementais. Identificou-se que os métodos de precificação de Opções Reais não eram efetivos para atingir a sua tarefa, e que empresas ainda buscam formas de valorar a inovação radical. Este trabalho, então, investigou as razões por trás desta busca, o que revelou que o problema não é a valoração, mas o sistema de gestão da inovação utilizado pelas empresas, que requer que gestores procurem legitimidade em diferentes níveis organizacionais. Desta forma, a segunda fase da pesquisa, ao analisar o uso de Opções Reais em diferentes níveis organizacionais, identificou que, quando as empresas não

podem valorar inovações radicais, elas carecem de uma integração multi-nível para lidar com a incerteza em diferentes níveis organizacionais. Em sequência, a pesquisa investigou como as empresas gerenciam a incerteza em múltiplos níveis organizacionais e identificou o papel da gestão de portfólio em orquestrar esta gestão. A partir daí, revisões de literatura indicaram que os textos referentes à gestão de portfólio seguem abordagens em nível tanto macro quanto micro - e propuseram que para gerenciar a inovação radical, uma separação organizacional multi-nível que conecte as duas visões é necessária. Por fim, o estudo sinalizou empiricamente que uma separação multi-nível forte para a gestão de portfólio de inovação é necessária, e que a inovação radical requer um sistema de gestão único, que una os níveis ambiental, estratégico, de portfólio, de projeto e individual, por fim formando uma capacitação dinâmica ambidestra para gestão de portfólio. Esta tese contribui para a literatura de gestão de portfólio nos níveis micro e macro e apresenta guias gerenciais para práticos.
Palavras-chave: Gestão de portfólio. Gestão de portfólio de inovação. Inovação radical. Análise multi-nível, Strategic Buckets. Opções Reais. Ambidestria. Capacitações dinâmicas.

ABSTRACT

Developing radical innovation is a key factor for firms to build future competitive advantages, support the renewal of their organizations in face of adaptational challenges and respond to technological and market change. However, radical innovation is surrounded by different types and levels of uncertainty. As there are no means of obtaining reliable data on time-frame, market, costs, future revenues, and emergent technological paradigms of products that do currently do not exist, the management of radical innovation is significantly more complex than incremental innovation – generally predictable and well-known. Because of these differences of nature, incremental innovation tends to be favored during the innovation portfolio management processes, as companies prefer to focus their attention to current products and customers. However, the portfolio management practices indicated for managing radical innovation (i.e. non-traditional financial tools and strategic buckets) have not been successful in protecting radical innovation, and portfolios are becoming increasingly incremental. To understand this phenomenon, this thesis aims to investigate how firms protect and foster radical innovation during portfolio management processes, in order to guarantee that radical innovation is not harmed over time. Following an evolutive approach, this research has been based in six phases, producing two articles published in journals, two articles under review in journals, one article published in an international conference, one article that is a chapter in an online encyclopedia and an article still in progress. These texts were developed by conducting Eisenhardt-like multi-case studies and literature reviews, including systematic literature review. At its inception, this thesis focused on understanding the use of non-traditional financial valuation methods (specifically Real Options pricing) to overcome challenges imposed by uncertainty in radical innovation and assess the value of the projects, thus allowing companies to adequately compare radical and incremental innovation projects. It was identified that the Real Options pricing methods are not effective in accomplishing such task, and that firms still look for ways to valuate radical innovation. The research, then, observed that the problem is not the valuation method used, but the innovation management system that requires managers to seek legitimacy at different organizational levels. In its second stage, the research analyzed the use of Real Options mechanisms in different organizational levels and found that when firms cannot valuate radical innovation, they lack the multi-level organizational integration to deal with uncertainty in

different levels. Further, the research investigated how firms manage uncertainty in multi-organizational levels and identified the role of portfolio management in orchestrating this management. Literature reviews identified that existing knowledge regarding portfolio management follows micro- and macro-level approaches – and this thesis suggests that, to manage radical innovation, a multi-level organizational separation that connects both approaches is needed. Lastly, the study empirically ascertained that a strong multi-level separation for innovation portfolio management is needed, and that radical innovation requires a unique management system which includes environmental, strategic, portfolio, project and individual levels, thus forming an innovation portfolio management system that contains ambidextrous dynamic capability. This thesis contributes with literature on innovation portfolio management at the macro and micro-levels and presents management guidelines for practitioners.
Keywords: Portfolio management. Innovation portfolio management. Radical innovation. Multi-level analysis. Strategic buckets. Real options. Ambidexterity. Dynamic capabilities.

1 INTRODUCTION

This thesis investigates how to protect and foster radical innovation during portfolio management processes. To do so, an evolutive research agenda has been set. The initial stages of the research aimed to look at the problem linked to the valuation of innovation projects using financial methods. This took place because of the high uncertainty levels associated with radical innovation. The use of Real Options pricing methods was identified as a solution for valuating radical innovation projects. The research observed, however, that Real Options pricing was not effectively adapted to address the valuation problem of radical innovation, as uncertainty management in highly innovative projects is related to the problem of managing a portfolio with this type of project. The literature on portfolio management was then reviewed, focusing in identifying the theoretical concepts in which discussions on the subject were based. This supported the elaboration of a conceptual framework to link portfolio management of radical innovation and firm-performance. Such literature review also supported the elaboration of propositions to explain how radical innovation projects are managed within companies' portfolios. Finally, a comprehensive empirical investigation was conducted to focus on the organizational mechanisms through which businesses organize a multi-level approach to ambidextrously manage incremental and radical innovation at the same time. The theoretical findings of this stage were translated to practitioner's language, in an effort to expand the reach of the research's findings. This PhD thesis concludes that a strong multi-level organizational separation is necessary to foster radical innovation projects, covering not only the definition of resources for each type of project, but a complete organizational separation between radical and incremental projects, which addresses aspects from the environment, strategy, portfolio, project and individual levels.

The outcome of this research were seven papers – of which six have already been completed and one is still in progress.[1] This document, thus, integrates the findings and methodological aspects that are brought by the papers, establishing a holistic and integrated view for the different research phases and their outputs.

---

[1] Regarding the seven papers: one is published in conference annals, two are published in two different journals, two are under review in two different journals, one is published as a book chapter in an online encyclopedia and one is still in progress. Details of the papers and the outlets where they were published are present throughout this document.

1.1 GENERAL CONTEXT

Since Schumpeter (1942) consolidated the notion of *creative destruction* as the driver of economic development, innovation has become a central topic for those interested in how economics (in broader terms) and business (in a more specific sense) evolve. By this notion, the process of creative destruction consists on developing improvements to established products and processes. Thought innovation shifts industry paradigms. This process brings monopolist returns for the innovative firms (at least until other players copy the product/process or the introduction of the next innovation) and is the "essential fact about capitalism" (Schumpeter, 1942, p. 83), highlighting the dynamic nature of the economic system.

From a management point of view, research has been investigating the phenomenon of producing new products, services and business for a long time, intending to understand environmental, strategic, organizational and individual dynamics surrounding innovation management. A frequent topic on management research relates to how firms create, sustain and manage innovations with heightened levels of uncertainty (Bessant, Oberg, & Trifilova, 2014; Leifer et al., 2000; Stringer, 2000). There are many definitions and classifications for this type of innovation, such as radical (e.g., Paulson, Connor, & Robeson, 2007; Slater, Mohr, & Sengupta, 2014), breakthrough (e.g., O´Connor, Leifer, Paulson, & Peters, 2008), major (e.g., O'Connor, 2008), disruptive (e.g., Christensen, Bohmer, & Kenagy, 2000; King & Baatartogtokh, 2015), and strategic (O'Connor, Corbett, & Peters, 2018), among others. Despite of these classifications, the intrinsic uncertainty in developing innovative products brings challenges for companies' established management systems and imposes different paradigms in managing projects (De Meyer, Loch, & Pich, 2002; Huchzermeier & Loch, 2001; Leifer et al., 2000; O'Connor et al., 2018; O'Connor, Leifer, Paulson, & Peters, 2008; Rice, Connor, & Pierantozzi, 2008; Sommer & Loch, 2004)). Although they differ in terminology, all classifications have uncertainty as a key intrinsic characteristic. This work adopts the term *radical innovation (RI)* to refer to innovations with high levels of uncertainty, as opposed to incremental innovation, which can be defined as those that "exploit [firms'] existing assets and capabilities" (O'Reilly & Binns, 2019, p. 50).

Uncertainty is a key characteristic that differentiates radical innovation projects from the incremental ones (O'Connor, 2012a; Pich, Loch, & Meyer, 2002). In an effort to make research on innovation with high uncertainty more feasible, given the rarity of radical innovation,

O´Connor (2008) suggested that the concept of major innovation, which includes radical innovation and "really new innovation" (O'Connor, 2008). Major innovations can be defined as those that develop new technologies and market opportunities capable of significantly improving a company's capacities, albeit without the same extreme degree and varied dimensions of uncertainties than radical innovation. Innovation with heightened uncertainty frequently challenges firms' established management systems and capabilities, requiring specific management approaches in order to be conducted by incumbents (Christensen & Bower, 1996; O´Connor, 2008; Slater et al., 2014).

Developing radical innovation is important for firms, as it guarantees that the company is not missing out on the next technology or market "wave" (Tushman & Anderson, 1986). Radical innovation also helps companies in developing future competitive advantages and supporting organizational renew, which drives incumbents to improve their performance levels, for instance, by establishing new business platforms for growth (O´Connor et al., 2008; Slater et al., 2014). Because of radical innovation's potential to provide high and monopolist returns for a company, literature regarding the topic adopts a macro-level approach to the issue, in order to understand its relationship with firm performance. This is underlined by studies such as Eggers (2014), which focused on technology or industry evolution; Eggers & Park (2018), which focused on incumbents' adaptation and learning when facing technological change; and Eggers & Kaul (2017), which focused on implications of failure in further development. Literature also adopts a micro-level approach to look into how organizational aspects – such as functions (e.g., O'Connor, 2012; O'Connor et al., 2018) or capabilities (e.g., O´Connor et al., 2008) - are designed to deal with radical innovation. This research also identified discussions regarding the effect of uncertainty in portfolio management (De Meyer et al., 2002; Lenfle & Loch, 2010; Sommer & Loch, 2004) and management processes and systems (e.g., Cooper, 2013; Griffin, Price, Vojak, & Hoffman, 2014). This work dialogs with the abovementioned research approaches (both at the micro- and macro-level), sharing the same concern of contributing to deeper understanding how radical innovation is managed in incumbent firms.

1.2 RESEARCH PROBLEM

Considering the general context of the research on radical innovation and the management challenges associated to it, this work focuses on the portfolio management processes set to evaluate, prioritize and select radical innovation projects. The goal of this study is to better

understand how to design and organize resource allocation processes in radical innovation projects, in order to avoid undermining such projects during portfolio management decisions – particularly in comparison to incremental innovation projects.

Project Portfolio management (PPM), or Innovation Portfolio Management (IPM), when dealing with new product development or innovation projects, is a central activity in innovation management (Goffin & Mitchell, 2010). Research and practice have been interested in understanding how to simultaneously manage incremental and radical innovation projects in innovation portfolios, in order to design management systems and portfolio management processes that address integration issues caused by the different levels of uncertainty between incremental and radical innovation. The need of creating new approaches for radical innovation arises from the fact that radical innovation is harmed if evaluated through the same logic used to incremental innovation. This occurs as radical innovation is generally long-term, unpredictable and based on distinct technological, market capabilities, while incremental innovation is relatively short-term, predictable and based on established capabilities. In short, radical innovation is riskier than incremental innovation.

Financial resources would tend to shift towards incremental innovation over time, once firms are biased to favor their current products and customers (Christensen & Joseph, 1996; Christensen & Rosenbloom, 1995; Raisch & Birkinshaw, 2008). Incremental innovation projects represent safer and more comfortable choices for short-term outcomes. Meanwhile, radical innovation is considered as a bet for an unknown future. This mindset leads decision-makers to privilege the allocation of resources and attention on incremental innovation, damaging a company's future performance (Bagno, Salerno, & Dias, 2017; Colombo, von Krogh, Rossi-Lamastra, & Stephan, 2017; Stringer, 2000; Terwiesch & Ulrich, 2008).

To deal with this issue, research on innovation portfolio management has been traditionally focused on developing new processes and tools to guarantee that radical innovation is protected and receives sufficient resources. This effort could be divided in two groups: 1) the improvement of financial valuation techniques to properly identify the value of radical innovation projects, allowing the comparison of these projects with incremental projects; 2) practices and management frameworks (notably the strategic buckets approach) to protect resources for radical innovation at the process-level.

Regarding the first group, research has focused on adapting recognized financial models for a high uncertainty context. The most notable attempt to use financial models to address the value of uncertain projects is *Real Options pricing*. Originally developed to calculate financial options in stock markets, Real Options pricing was adapted, first for projects (e.g., in mining and petrochemical industries), and then to R&D and innovation contexts.[2] From the outset, the opportunity to value managerial flexibility (i.e. the possibility to change project directions at each stage as new information is obtained and uncertainty is mitigated) and increase project value, (McGrath, 1997; McGrath & Nerkar, 2004) made this financial approach attractive for innovation projects. Many models have been developed in this direction and research in the early 2000's indicated that this method was a form of solving the valuation problem for radical innovation (Huchzermeier & Loch, 2001; Santiago & Bifano, 2005; Santiago & Vakili, 2005).

In its turn, the second group – focused on developing practices and frameworks to protect resources for radical innovation during portfolio management processes – established the principles of segmenting and balancing portfolios in order to accomplish a task. Segmentation suggests that projects should be labeled according to their type (short/long-term, risky/less risky, radical/incremental, etc.) and compared to similar projects (Cooper, Edgett, & Kleinschmidt, 1997). Meanwhile, balancing indicates that each group of projects should be separated and have specific resources distributed between the projects of a specific type, in order to fix the amount of resources to that group, aiming to avoid that resources shift to projects of other types, for instance from radical to incremental innovation projects (Cooper, Edgett & Kleinschmidt, 2001; Cooper, Edgett, & Kleinschmidt, 1999; Terwiesch & Ulrich, 2008). This management approach covers segmentation and balancing is called *strategic buckets* (Chao & Kavadias, 2008; Kavadias & Chao, 2007). The separation of radical innovation projects in a specific bucket required that a pre-defined amount of financial resources was distributed within said bucket. It also required the implementation of specific evaluation criteria designed for radical innovation to address uncertainty-related specificities (e.g., lack of data, unpredictability or the impossibility to

---

[2] The original model to calculate the value of a financial option was developed by the Nobel Prize winners Black & Scholes (1973). The evolution towards traditional projects (e.g., petrochemical, mining – not R&D), called Real Options valuation or pricing, was initially proposed by Myers (1977) and consolidated during the 1980's, 1990's and the beginning of 2000's (e.g., Copeland & Tufano, 2004; Dixit & Pindyck, 1994, 1995; Trigeorgis, 1996).

calculate risk, return and apply NPV/ROI like analysis).[3] The implementation of these elements would guarantee that radical innovation projects are protected and receive the resources and attention necessary for their development. Strategic buckets is a top-down approach that seeks to guarantee that financial expenses reflect the business strategy, as each bucket represents a collection of new product development programs aligned with the innovation strategy (Kester, Hultink, & Lauche, 2009). This strategy aims to create well defined separations between programs, thus assuring the allocation of funds to projects that are not attractive if evaluated by the traditional valuation methods, supporting the destination of resources for radical innovation (Chao & Kavadias, 2008).

Despite of the use of the new valuation tools to address the challenges imposed by uncertainty (e.g., Real Options pricing) and the application of management approaches based on segmenting and balancing (strategic buckets), research has discussed the effectiveness of using such approaches – mainly to the end goals of protecting projects with heightened levels of uncertainty and fostering a favorable innovation environment. Hence, these solutions may not represent a "silver bullet" for the portfolio issues regarding radical innovation (Chao & Kavadias, 2008; Cooper, 2013). Moreover, literature alerts that the current portfolio management practices led to an unbalancing of the portfolios, which benefit more incremental initiatives and diminishes innovation disruptiveness (e.g., Chao & Kavadias, 2008; Cooper, 2013; Kester et al., 2009; Lerch & Spieth, 2013; Zschocke, Mantin, & Jewkes, 2014)

Cooper (2013), after analyzing fifteen years of application of the established portfolio management practices, asked: Where are all the breakthrough new projects? The author claims that, during the last years, innovation portfolios have ceased to be moderately balanced and have become extremely unbalanced, with much more smaller projects and less disruptive initiatives. Kester, Griffin, Hultink & Lauche (2011) objectively state that research on portfolio management leads to two systematic problems regarding the development of new products: i) the change towards more incremental projects, disturbing balance in the portfolios; and, ii) because of this change, the bias of the portfolios in reaching short-term revenue growth objectives. Moreover, research has found the influence of elements beyond the use of financial valuation tools and project and process-level management practices that influence the balance of portfolios

[3] Example of criteria developed for the evaluation, prioritization and selection of radical innovation projects in portfolio management are suggested by Paulson et al. (2007).

between radical and incremental innovation projects. To cite some as examples, Zschocke et al. (2014), analyzing the effect of market competition in portfolio management balance, indicate that the current practices do not protect the radical innovation in dynamic market competition and lead to increasingly incremental portfolios. Gutiérrez & Magnusson (2014) discuss the need of more theoretical developments about portfolio management for radical innovation, once this type of innovation requires different decision-making forms than those employed in traditional portfolio management. These conclusions are aligned with the request made by Chao & Kavadias (2008, p. 908):

> "Ultimately, the suggested portfolio balance remains a vague guide-line, which is resolved on a case-by-case basis. To the best of our knowledge, decisions regarding strategic buckets and the protection of resources have little or no theoretical foundation." (Chao & Kavadias, 2008, p. 908)

In addition, Kester et al. (2011) point towards a key theoretical gap in existing research regarding portfolio management of new product development projects:

> "… it will be especially interesting to managers to identify the mechanisms by which managers can achieve changes in the specific parts of the portfolio decision-making system to improve their portfolio decision effectiveness." (Kester et al., 2011, p. 659)

Portfolio management literature includes a key discussion on the reasons why propositions historically indicated to boost radical innovation by applying the established portfolio management processes, practices and tools. The discussion suggests that these mechanisms have not been effective for radical innovation and potentially generate more incremental portfolios. Spieth & Lerch (2014), for example, verify that, despite of the importance given by the literature to portfolio management, empirical evidence about usage, results and success factors related to portfolio management of radical innovation projects are still rare and insufficient.

In addition to the need of understanding the effects of the current portfolio management practices in radical innovation outputs, as discussed before, radical innovation literature indicates that this type of innovation would ask for novel organizational designs, strategic intents and capability building (O´Connor et al., 2008). O´Connor, (2008, p. 654) argues that to create dynamic capabilities in innovation with heightened uncertainty, a company "requires a specific, unique mechanism for considering and governing the portfolio of major innovation ventures". The author highlights that a complete management system for radical innovation should be set and separated from the management system for ongoing operations and incremental innovation. She suggests that companies employ an ambidextrous management approach, and comments:

"(…) but little theoretical work has been published to suggest how companies can actually be ambidextrous: excelling at current operations and continuous improvement while positioning themselves for future growth." (O´Connor 2008, p. 315). These suggestions indicate that broader organizational macro-level issues - beyond the analysis of portfolio management tools, practices and management frameworks - are needed to fully understand the problems relating to the management of radical innovation portfolios.

1.3 RESEARCH OBJECTIVES

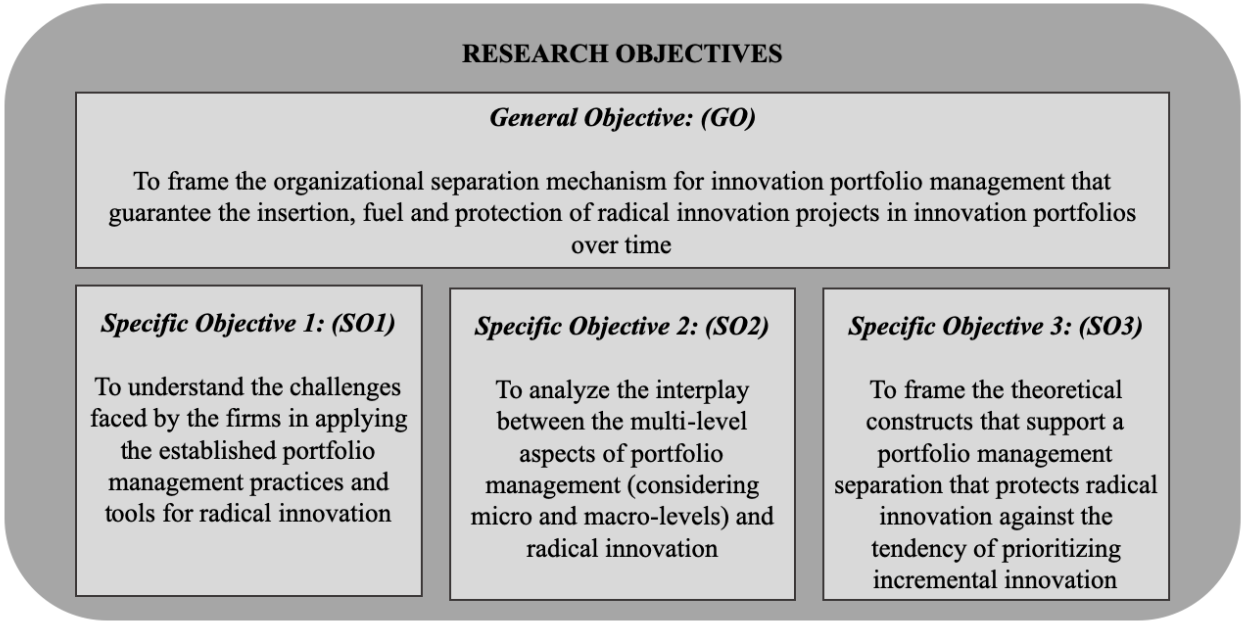
Intending to contribute with the understanding of the issues posted in this section, the research question that drives this thesis is: *how do firms design and organize the resource allocation processes in radical innovation projects in order to avoid undermining such projects during portfolio management when competing with incremental innovation projects?*

To do so, this thesis focuses on investigating both micro-level (process and project levels) and macro-level (organizational and strategic) issues that influence balancing portfolios towards radical or incremental innovation. The main objective is to open an argumentative path extending further from the principles that base the established management approaches to deal with radical innovation in portfolio management (particularly valuation, segmentation and balancing principles). Based on the connections between micro- and macro-level perspectives, the intention is to offer a comprehensive, multi-level perspective for innovation portfolio management research. Therefore, the general objective of this thesis (GO), derived from the research question, is to **frame the organizational separation mechanism for innovation portfolio management that guarantee the insertion, fuel and protection of radical innovation projects in innovation portfolios over time**.

The general objective (GO) is deployed into three specific objectives (SOs). Figure 1 illustrates the GO and the SOs.

a) SO1 - to understand the challenges faced by companies in applying the established portfolio management practices and tools for radical innovation.
b) SO2 - to analyze the relationship between multi-level aspects of portfolio management (considering micro and macro-levels) and radical innovation.
c) SO3 - to frame the theoretical concepts that support a portfolio management separation that protect radical innovation against the tendency of prioritizing incremental innovation.

Figure 1 – Research objectives: general and specific



Source: Figure developed by the author for this thesis

1.4 THESIS STRUCTURE

This is an article-based thesis format. It was divided into two parts: I – integrative thesis overview and II – thesis' papers, attached in the "Appendix". Part I is dedicated to present and discuss the integration of each article towards addressing the research objectives of the thesis. Following this lead, Part I details the general context of the research, research problem and justification, research objectives, thesis structure, research approach and methods, sections dedicated to explain and link each phase of the research and its conclusions, with research limitations and indications for further studies. The general structure of the thesis follows a traditional sequence of sections, in spite of being presented as an article-based format. It is important to highlight, as the thesis is composed by different articles, that the integrative part of the thesis recovers concepts and insights of the papers, once the main goal is to structure the argumentation present in the different pieces of research. .

Part II is composed by the papers themselves, the core of the research. Table 1 summarizes the high-level information of the papers (Ps). P#1 was published at the Journal of Engineering and Technology Management (Brasil, Salerno, & Gomes, 2018). P#2 was presented at the IRNOP (International Research Network on Organizing by Projects) Conference 2017, in

Boston, and selected to be published in a section dedicated to the conference at the journal Project Management Research and Practice (Brasil, Gomes, Salerno, & de Paula, 2017). P#3 was published at the Project Management Journal, part of the Special Issue "Exploratory Projects: From Strangeness to Theory" (Gomes, Brasil, Facin, de Paula, Gomes & Salerno, 2019). P#4 was published as a chapter of the Oxford Research Encyclopedia of Business and Management (Brasil & Eggers, 2019). P#5 is submitted to the Journal of Product Innovation Management (Brasil, Salerno, Eggers & Gomes). P#6 is being written and P#7 is submitted at the Research-Technology Management (Brasil, Salerno, Eggers & Gomes). The papers are appended at the end of this document.

Table 1 – Publications that base the thesis

Paper #	Journal / Conference	Title	Method	Objectives	Authors	Appendix
#1	Journal of Engineering and Technology Management	Valuation of innovation projects with high uncertainty: Reasons behind the search for real options	Multi-case studies	SO1, SO2	Brasil [a] Salerno [a] Gomes [b]	A
#2	IRNOP Conference 2017 and the journal Project Management Research and Practice	Multilevel approach for Real Options in the innovation management process: integrating project, portfolio and strategy	Multi-case studies	SO1, SO2	Brasil [a] Salerno [a] Gomes [b] de Paula [a]	B
#3	Project Management Journal	Proposing a Multilevel Approach for the Management of Uncertainties in Exploratory Projects	Multi-case studies	SO1, SO2 GO	Gomes [b] Brasil [a] Facin [a] de Paula [a] Gomes [b] Salerno [a]	C
#4	Oxford Research Encyclopedia of Business and Management	Product and Innovation Portfolio Management	Literature Review	SO2	Brasil [a] Eggers [c]	D
#5	Submitted to the Journal of Product Innovation Management	Innovation portfolio management as a dynamic capability: Linking micro and macro-level research through systematic literature review	Systematic Literature Review	SO2, SO3 GO	Brasil [a] Salerno [a] Eggers [c] Gomes [b]	E
#6	Being written	Portfolio management as a dynamic capability: protecting radical innovation to adapt and change	Multi-case studies	SO1, SO2, SO3 GO	Brasil [a] Salerno [a]	----
#7	Submitted to Research-Technology Management	Innovation portfolio ambidextrous management: guidelines to boost radical innovation	Multi-case studies (practitioners view)	SO1, SO2, SO3 GO	Brasil [a] Salerno [a] Eggers [c] Gomes [b]	F

Note: a – Department of Production Engineering (Poli-USP); b – Department of Business Administration (FEA-USP); c – Department of Management and Organizations (Stern School of Business, NYU)

Source: Table developed by the author for this thesis

2. RESEARCH APPROACH AND METHODS

To address the theoretical gaps highlighted in the previous sections, this research adopted an exploratory, inductive and post-positivist research approach, based on literature review and qualitative multi-case methods.[4] The articles composing the thesis correspond each of them to a different research phase. Therefore, the construction of the thesis has followed an evolutive approach, in order to accomplish its distinct objectives. In this sense, the output of a research phase indicated the paths to initiate the next phase.

As stated by Lerch & Spieth (2013), literature indicates that empirical evidences about the use, results, and main success factors related to portfolio management methods are still rare. The authors added that qualitative studies provide scholars with contextual factors surrounding innovation portfolio management and pointed towards the necessity of boosting the theoretical development of the field, as well as supporting new insights and practical implications and improvements of innovation portfolio management. This proposition follows the orientations of Eisenhardt (1989) and Yin (2006), who developed the well-known methodological approaches to build theory from qualitative multi-cases studies. Consequently, research has been applying case-studies to understand aspects related to portfolio management decision-making processes and governance. To cite some, Gutiérrez & Magnusson (2014) conducted interviews in three firms to investigate how innovation portfolio managers experiment and develop the legitimacy of their decisions. Kester et al. (2009) elaborated eleven case-studies to identify the different innovation portfolio management genres, according to the practices adopted. Kester et al. (2011) studied four companies to map the innovation portfolio management process. Lettice & Thomond (2008), in their turn, performed four in-depth case studies to comprehend how resource allocation occurs in radical innovation projects. Lerch & Spieth (2013) analyzed eleven firms to detail the dynamics of portfolio management for innovation projects.

Barczak, Griffin, & Kahn (2009) reinforce that, although benchmarking studies have identified which tools and approaches high performance firms in new product development have

---

[4] "[…] the Eisenhardt multiple case method is positivist in orientation [or more precisely, what Guba and Lincoln (1994) would label post-positivist]. It attempts to access ''factual'' data about what happened in a sample of relevant processes, and it aims to develop generalizable nomothetic causal laws about objectively observable phenomena in the real world." (Langley & Abdallah, 2011)

adopted, there is little content regarding the path through which these firms achieve success.[5] There is currently a need for more in-depth studies around how and why innovative firms were able to implement innovation portfolio management processes to support their performance (Barczak et al., 2009). This statement matches the request made by Chao & Kavadias (2008), who argue that the mechanisms to protect radical innovation during portfolio management processes still lack deeper theoretical development. For instance, one can cite, Laine, Korhonen, & Martinsuo (2016), who analyzed the impact of the management of new product development programs in generating ambiguities and uncertainties. Oliveira & Rozenfeld (2010), in turn, contributed to the discussion about the management of front-end activities in new product development, integrating technology, road-mapping and portfolio management.

Qualitative approaches have also been applied to research on radical innovation, based on multi-case methodological design. In this group, for instance, one could cite Leifer et al. (2000), O'Connor et al. (2008), O'Connor et al. (2018), Kelley, Connor, Neck, & Peters (2011), O´Connor (2008), O'Connor & McDermott (2004), Bagno et al. (2017), or Shaikh & O'Connor (2020). These authors have chosen a qualitative multi-case approach, arguing that the specific and direct observation of the managerial practices related to radical innovation is capable of clearing the main constructs and dynamics of the organizational structures. P#1, P#2, P#3, P#6, P#7 followed similar approaches. Note that P#7 is an article designed for practitioners. This means that it translates the main findings of this thesis into a language and structure friendly to managers. Also, it incorporates quotes and narratives from the case-studies developed in the previous phases of the research. This article was written in an effort to increase the relevance and impact of the research, once the topic is of interest for managers and companies.

Both P#4 and P#5 applied literature review methodologies to establish links between SO2 (to analyze the interplay between the multi-level aspects of portfolio management and radical innovation) and SO3 (to frame the theoretical constructs that support a portfolio management separation that protects radical innovation against the tendency of prioritizing incremental innovation). To achieve these objectives, a deeper understanding of the different research streams on portfolio management in general (P#4), and the theoretical foundations of innovation

[5] Specifically at the micro-level, focused on project and process aspects of portfolio management, research has been strongly driven by benchmarking studies (e.g., Cooper, Edgett, Scott, Kleinschmidt, 2001; Cooper, Edgett, & Kleinschmidt, 1999; Cooper, 2009; Cooper & Edgett, 2008; Cooper et al., 1997).

portfolio management (P#5) were necessary. P#5 also established the theoretical propositions and frameworks that were later used to guide the empirical research described in P#6 and P#7.

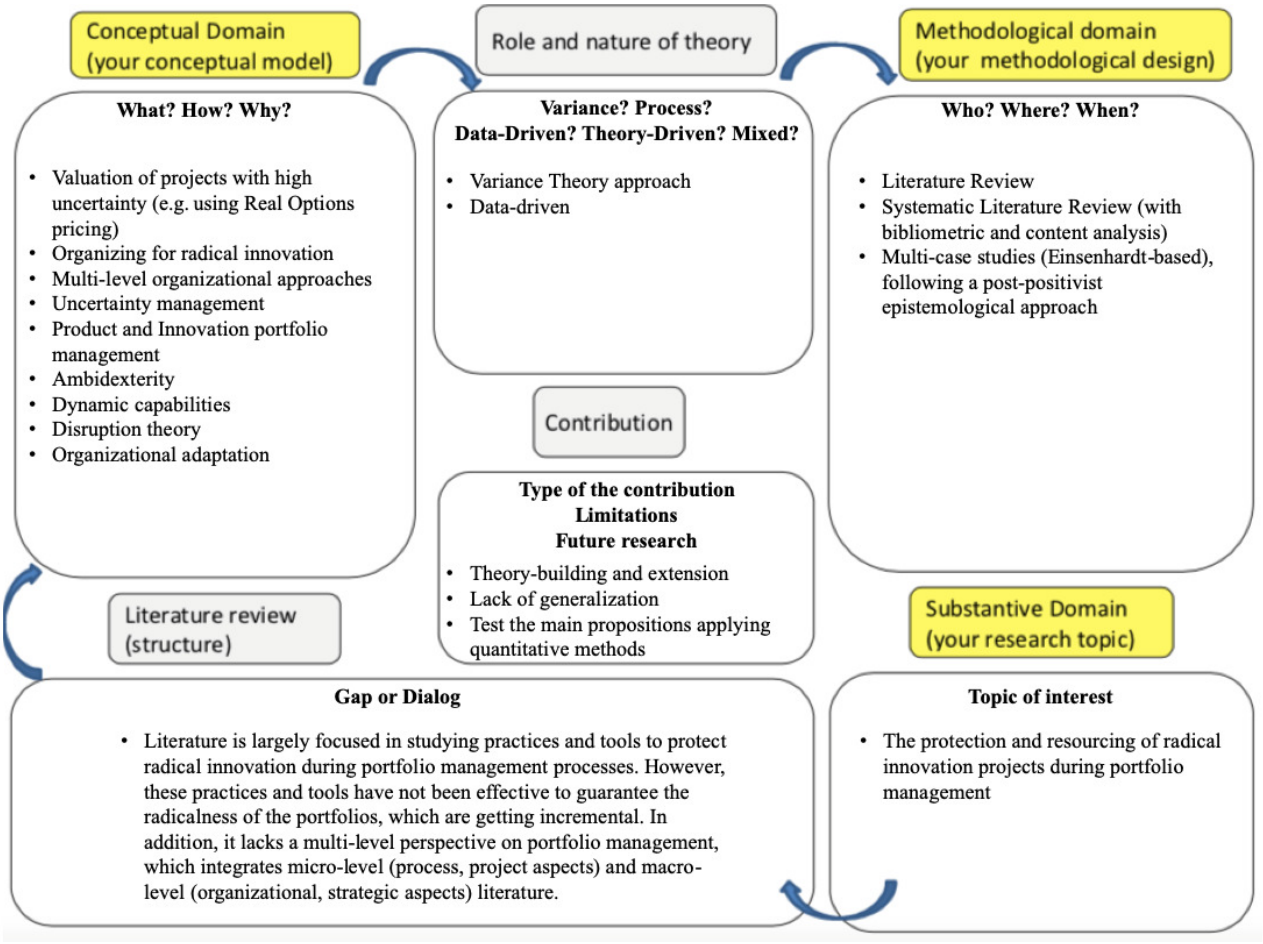
In addition, P#5 also applied bibliometric and content analysis to increase the legitimacy of the systematic literature review, thus enabling the identification of theoretical roots and clusters in innovation portfolio management research. Recently, similar approaches have been used in innovation research (e.g., Brones & Carvalho, 2015; Durisin, Calabretta, & Parmeggiani, 2010; Facin, Gomes, Spinola, & Salerno, 2016; Fleury, Stabile, & Carvalho, 2016; Gomes, Facin, Salerno, & Ikenami, 2016; Homrich, Galvão, Abadia, & Carvalho, 2018).

From the theoretical perspective, this thesis contributes to recent requests to bridge the link between micro- and macro-level aspects of organizations in strategy research. In this sense, Kouamé & Langley (2018) discuss this need at "Relating microprocesses to macro-outcomes in qualitative strategy process and practice research", published at the Strategic Management Journal. The authors demand research that links micro-level management processes and macro-level organizational outcomes. They also demand research that connects the strategy process from the strategy as practice perspective. By adopting a multi-level perspective, this thesis intends to dialog with scholars studying innovation portfolio management at the micro-level and those who apply a macro-level focus for the topic - for instance applying theoretical concepts as dynamic capabilities or organizational adaptation and learning. This macro-level perspective can be observed, for instance, at Klingebiel & Rammer (2014), Klingebiel & Adner, (2015), Klingebiel & Joseph (2015) and Eggers (2012).

In order to visualize the big picture of the research's methodological approach, Figure 2 illustrates the anatomy of the overall research, and Table 2 summarizes the research methods of the seven articles that compose this thesis.[6]

[6] The framework for the Anatomy of Qualitative Research was developed by Prof. Marlei Pozzebon (HEC-Montreal and EAESP-FGV) and presented during the course Doing and Publishing Qualitative Research, at EAESP-FGV, 2016.

Figure 2 – Research anatomy of the thesis



Source: Figure developed by the author for this thesis

Table 2 – Research method of each paper

Method	Research objective	Data sources	Selection criteria	Motivation/Justification
P#1: Multi-case studies	To understand the reasons behind the search of Real Options approaches to valuate radical innovation projects	Longitudinal data collection with interviews in 4 companies	Companies that explicitly have strategic intent to develop radical innovation	Although Real Options pricing is criticized by literature and practitioners, companies still look for methods to valuate radical innovation projects
P#2: Multi-case studies	To investigate how firms integrate Real Options approaches at the project, portfolio and strategy levels	Longitudinal data collection with interviews in 4 companies	Companies that explicitly have strategic intent to develop radical innovation	Real Options approaches differ between each other, being applied distinctly in each organizational level
P#3: Multi-case studies	To comprehend how firms manage uncertainties in exploratory projects	Data collection with interviews in 2 companies to analyze 6 exploratory projects	Projects that fill the theoretical definition of exploratory projects	Uncertainty challenges the management of highly innovative projects, imposing a multi-level management approach
P#4: Literature Review	To map the main streams of portfolio management literature (from the new product development and marketing perspectives)	127 articles	Search on the leading journals of management, business, innovation, industrial management, operations management, project management, technology management	Portfolio management literature mixes different theoretical streams and pursue different interpretations according to the organizational level they focus
P#5: Systematic Literature Review (Bibliometric and Content Analysis)	To identify the theoretical roots of innovation portfolio management and its intersection with the management of radical innovation	121 articles	Web of Science. Searched topic: "portfolio management". Refined results: "innovation" OR "disruptive" OR "substantive" OR "radical" OR "breakthrough". Document types: Article AND Review	The theoretical roots of innovation portfolio management literature may indicate an integrative view that supports the protection and fuels radical innovation projects during portfolio management processes
P#6: Multi-case studies (being written)	To identify the theoretical constructs of an ambidextrous portfolio management dynamic capability	Longitudinal data collection with interviews in 4 companies	Companies that explicitly have strategic intent to develop radical innovation	The architectural mechanisms of an ambidextrous portfolio management capability need to be understood to guarantee the protection of radical innovation projects and firms' adaptation
P#7: Multi-case studies (practitioners view)	To translate the theoretical concepts identified in managing portfolio management with radical innovation projects into practitioners' guidelines	Longitudinal data collection with interviews in 4 companies	Companies that explicitly have strategic intent to develop radical innovation	There is a lack of translation of the theoretical developments on innovation portfolio management aiming to indicate how to protect and fuel radical innovation for practitioners

Source: Table developed by the author for this thesis

2.1 THE EVOLUTIVE RESEARCH PROCESS

This thesis followed an evolutive process, meaning that the research problems were framed as the research evolved, considering a starting point. Different research phases formed the path through the final product. The results and findings of each research phase indicated next phase's research problem. Each research method was chosen aiming to address the research problem of that phase. Figure 3 summarizes the phases of the research process.

It is important to inform that this thesis is part of a broader research program conducted at the Laboratory of Innovation Management at the University of São Paulo (Laboratório de Gestão da Inovação – LGI). Since 2008, scholars at LGI follow companies based in Brazil (either Brazilian or global companies) that explicitly declare the strategic intent to develop radical innovation and structure their operations towards this goal. LGI scholars have their origins in studying organizational theories and such experience still influences the research on radical innovation as it provides an organizational lens for the topic. LGI is inspired by and linked to a similar research program coordinated by Prof. Gina O'Connor in the USA (formerly at Rensselaer Polytechnic School and nowadays at Babson College). Prof. O'Connor and colleagues have been following American companies performing radical innovation for more than 20 years.

Figure 3 – Research phases

		PHASE 1	PHASE 2	PHASE 3	PHASE 4		PHASE 5	PHASE 6
Research topics		Reasons to search for Real Options pricing methods to valuate radical innovation	Multi-level aspects in attempting to apply Real Options to valuate radical innovation	Multi-level uncertainty management of highly innovative projects	Theoretical streams and roots of (innovation) portfolio management		Principles of a multi-level separation for innovation portfolio management	Managerial aspects of the separation for portfolio management of radical innovation projects
Input for the next phase		Need of a multi-level approach	Need of a multi-level uncertainty mgmt	Need of a theoretical analysis of IPM	Need of a multi-level IPM separation		Need of a practitioners perspective	--------
Thesis objectives (General and Specific)	**GO:** To frame the organizational separation mechanism for innovation portfolio management that guarantee the insertion, fuel and protection of radical innovation projects in innovation portfolios over time					**P#5** Systematic Literature Review		
	SO1: To understand the challenges faced by the firms in applying the established portfolio management practices and tools for radical innovation	**P#1** Multi-case studies	**P#2** Multi-case studies	**P#3** Multi-case studies			**P#6** Multi-case studies	**P#7** Multi-case studies (practitioners view)
	SO2: To understand the challenges faced by the firms in applying the stablished portfolio management practices and tools for radical innovation				**P#4** Literature Review	**P#5** Systematic Literature Review		
	SO3: To frame the theoretical constructs that support a portfolio management separation that protects radical innovation against the tendency of prioritizing incremental innovation							

Source: Figure developed by the author for this thesis

The starting point for the research process of this thesis was the investigation of the reasons behind the search for non-traditional valuation methods (specifically the Real Options pricing) to valuate radical innovation projects. This topic, explored in P#1, emerged from the perception that companies still look for a way to valuate this type of project, even with literature indicating that the approach, initially taken as a solution for the lack of means of comparing such projects with incremental innovation projects (the latter capable of being adequately valuated by NPV as financial tools) during portfolio management decision-making process. While, for example, McGrath & Nerkar (2004), Huchzermeier & Loch (2001) and Santiago & Vakili (2005) defended the use of Real Options pricing for highly uncertain projects, Adner & Levinthal (2004) and Killen, Hunt, Kleinschmidt, & Hunt (2008) argue that these projects cannot be valuated, even with Real Options pricing methods. This occurs because of the lack of data associated to radical innovation projects, the mathematical complexity of the models, and the differences between financial options and projects.[7] Yet, literature changed the focus of the use of Real Options pricing towards Real Options Reasoning, transforming the approach not in a valuation tool anymore, but in a guide for firms' investment heuristics and reasoning (Barnett, 2008; Klingebiel & Adner, 2015). From the practice point of view, at the Laboratory of Innovation Management at the University of São Paulo (Laboratório de Gestão da Inovação – LGI), researchers had followed a group of companies, and perceived the dissatisfaction of the companies with the use of Real Options pricing and innovation portfolio management evaluation criteria in general.[8]

Moreover, a survey conducted with R&D managers from companies associated to AMCHAM-Campinas in 2016 - followed by a debate with the 15 companies at a meeting to discuss innovation portfolio management - indicated that the current portfolio management practices, especially those used to financially evaluate uncertain projects, were not satisfactory.[9,10] The managers also highlighted that the use of financial tools was harming the projects

---

[7] As opposed to financial options, for instance, projects cannot have their exercise price and time to exercise known during options pricing.

[8] A study that investigated the application of portfolio management practices for radical innovation projects was conducted by Silva (2016), at LGI, for her PhD thesis.

[9] AMCHAM-Campinas is the American Chamber of Commerce in the city of Campinas, State of São Paulo, Brazil.

[10] The survey and discussion were conducted when the research process indicated that Real Options pricing had not been effectively adopted by the companies, and the problem with valuating radical innovation projects persists. To explore such hypothesis, researchers used the event with relevant R&D managers to test the assumption.

evaluated during the portfolio management process. This led to the perception that the importance of calculating financial values for radical innovation, even with new and sophisticated methods (e.g., Real Options pricing) was overestimated and, in fact, it was not the silver bullet to assess the value of radical innovation projects and to potentialize their management in firms' portfolio management systems.

Meanwhile, firms still look for new approaches, as Real Options pricing, to valuate radical innovation projects. This indicates that, even with the failed experiences in solving the valuation problem by using new financial methods, there is some management discomfort in not having a financial value assigned to radical innovation projects. This led us to the first phase of this research, focused on investigating: *what are hidden reasons why firms search for Real Options approaches to valuate radical innovation?*

From the outset, P#1 intended to conduct in-depth case studies to understand why, even with the difficulties and barriers to apply financial methods for radical innovation, companies still search for new valuation tools to do so. As a result, P#1 indicated that established portfolio management processes are not suitable for evaluating radical innovation projects or the managers' performance, which causes managers to lose legitimacy, particularly when uncertainties and experimentation lead to failures or setbacks. The problem, hence, was not about project valuation.[11]

P#1's outcomes provoked the reflection about the financial role in driving companies' search for new tools, as Real Options pricing, to valuate radical innovation projects. At the end of the day, the topic being discussed is not finance or project value, but the relationship between project value, the way financial methods are legitimated within organizations and the general management systems used to allocate resources to innovation initiatives, including innovation strategy. Therefore, the consequent management approaches used to conduct innovation projects, make portfolio management decisions and frame innovation strategy lack a deeper understanding regarding the relationship with one another. This comes from the fact that the project, portfolio and strategy levels are naturally integrated when companies conduct certain activities, such as: using financial methods to evaluate processes by their estimated costs and potential revenues (project-level); setting portfolio management processes to allocate resources (portfolio-level);

---

11 The findings of each article are detailed in the next sections of this work.

and breaking the innovation strategy in buckets and defining the risk rate firms are willing to assess (strategy-level). However, this multi-level integration proposal is undermined by the fact that radical innovation does not enable the use of financial tools to valuate projects – mainly due to the heightened uncertainty associated with the projects.

Paper #2 was produced with the objective of identifying *how can the Real Options approach be integrated at the project, portfolio and strategy levels?* This was done in order to shed light on how the management practices and processes at different levels of the organizations are related between each other when valuating innovation projects. Real Options is used as the means of making the multi-level analysis possible. This phase was also based on multi-case studies, once a deeper exploration of the phenomenon was conducted.

An organizational multi-level perspective was applied as a focus to the investigation. This is derived from two perceptions. Firstly, the fact that literature on Real Options at the innovation context is split between those focusing on applying pricing methods at the project level; those focusing on developing optimization methods based on Real Options to perform portfolio analyses; those focusing in framing firms' strategies as sets of options that could be inserted in the Options logics – Real Options Reasoning. Secondly, the idea that different organizational levels pursue different mechanisms. Such differences should be aligned within each level and between the levels to support the valuation of innovation projects by Real Options approaches.

As a result, recommendations regarding how to deploy an options logic from strategy to project level were listed in P#2, considering portfolio management as the central mediator, guaranteeing the coherence in decision-making processes. Portfolio management, when employed with this objective, also addresses the need of assessment of the value of innovation projects and adequately translate strategic options into project options. Further, the role of uncertainty around innovation projects was identified as the frugal point in challenging the different organizational levels to adapt their management systems and mindsets in order to deal with unpredictable innovation projects.

Following the results obtained in P#2, it was noted that the role of uncertainty in driving organizational dynamics in managing innovation projects is more relevant than looking at the methods used to valuate the projects themselves. This is corroborated by the recognition of the contingencies brought by the different organizational levels as it supports the importance of

adopting a multi-level lens to investigate the issue. Thus, research moved to its third phase, producing P#3, focused on understanding: *how do firms manage uncertainties in exploratory projects?*

Exploratory projects were identified as the adequate object to support the investigation about the management of uncertainties across different levels within a company. Again, multi-case studies were applied to investigate the concepts behind the management of uncertainties in these projects.

An important outcome of P#3 was highlighting the role that portfolio management has in orchestrating the resource allocation in uncertain innovation projects, as well as the different management approaches to mitigate uncertainty at the multi organizational levels, as "the portfolio level is essential to increase the possibility of a firm benefiting from the resolution of uncertainties" (Gomes et al., 2019, p.14). This alerted for the need to better comprehend how innovation portfolio management literature guides the management of radical innovation projects, deals with uncertainty resolution and sustains radical innovation projects over time.

From this point, the fourth phase of the research was initiated. At this phase, the aim was to understand the literature on portfolio management and, then, its relationship with radical innovation. This phase produced P#4 and P#5. The first is an extensive literature review on portfolio management in a broad sense, dedicated to investigate not only innovation portfolio management (from the new product development and project management point of view), but product portfolio management (from the marketing point of view), as well. This is due to the fact that literature on innovation and product portfolio management are frequently mixed (specially at the strategic level). P#4 identified two main research streams on portfolio management, both on the innovation and on the product portfolio management sides. These are: the macro-level lens, focused on environmental, strategic, political and organizational issues around the resource allocation on innovation projects and the culling of products; and the micro-level lens, focused on project, process and individual issues. This work also indicated that innovation and product portfolio management are essentially a dynamic capability of a company, responsible for building firms' future competitive advantages and working as a key element for companies' adaptation to technological change and organizational renewal.

P#5, in its turn, extended these analyses by focusing on innovation portfolio management literature (mainly focusing in radical innovation) and applying systematic literature review -

bibliometric and content analysis. This article intended to integrate macro- and micro-level approaches on innovation portfolio management to characterize what would be an innovation portfolio management capability that was able to protect radical innovation projects - more fragile when compared with incremental innovation. This work resulted in an extension of the current state of the art on the topic related to how to deal with radical innovation projects in portfolio management decision-making processes. P#5, then, demonstrated that strategic buckets approach is not sufficient to guarantee the insertion and presence of radical innovation projects within a portfolio over time. By looking at the theoretical basis of innovation portfolio management literature, P#5 argues that radical innovation requires more than segmented and balanced portfolios (as suggested, for example, by Cooper et al., 1999 and Cooper et al., 1997) or strategic buckets to be protected. Many other micro- and macro-level aspects should be considered, in all organizational levels. Through the building of a multi-level framework for an innovation portfolio management dynamic capability focused on radical innovation, P#5 has linked portfolio management micro-aspects to macro-level organizational capabilities and, then, to company performance. P#5 suggests an organizational ambidextrous approach to protect radical innovation. In addition, the article has bridged different fields of management research, as strategy, project management and new product development.

As it defined an ambidextrous dynamic capability for the management of a portfolio of radical innovation, P#5 introduced the opportunity to investigate what would be the architecture of these organizational mechanisms by which this ambidextrous separation is operationalized. A theory building approach was then identified as capable to support this investigation.

At last, the fifth phase of the research was conducted and supports the writing of P#6 – which is still in process. Through the application of an Eisenhardt-based multi-case approach, this work aims to detail the theoretical concepts guiding a complete organizational separation for managing a portfolio of radical innovation. It considered that firms could either implement a weak separation, when radical innovation projects are not protected, or a strong separation, when a complete and ambidextrous multi-level separation is built to foster and protect radical innovation. This contributes to innovation portfolio management research both at the micro- and macro-levels. For micro-level research, P#6 indicates that the established parameters that guide portfolio management evaluation (i.e. maximization of returns, balancing, strategic fit) are not adequate when dealing with radical innovation and provides substitutes. Regarding macro-level

research, the study supports the understanding about how to operationalize ambidexterity and dynamic capabilities aiming to adapt to technological change and potentialize strategic flexibility.

Finally, considering the importance of theme and the findings of the research for managers, both to project management systems for radical innovation and to make decisions around this type of project, a practice-based text to orient practitioners was developed. Then, P#7 was put together, in order to summarize, in a non-academic language and structure, traps companies normally face when managing a portfolio of radical innovation projects, and general guidelines for overcoming these traps. More than that, it produced a management tool capable of being applied by managers to diagnose the status of the organizational separation in their firms (if it is weak, medium or strong), considering, again, a multi-level perspective (individual, project, organizational, strategic levels). This paper has an important role in translating some of the findings into practice and improving the relevance and impact of the research. The following sections aim to detail the findings of each research phase.

3. RESEARCH RESULTS

The results of the thesis are organized by research phase and the articles produced, with the objective of summarizing the main findings of each of them. Important to mention that the objective in this section is not to describe the articles in detail and briefly present the findings of each paper. The aim is to highlight the central logic of each article and, mainly, connect articles and research phases to form the overall PhD thesis and contributions.

3.1 PHASE 1: REASONS TO SEARCH FOR REAL OPTIONS PRICING METHODS TO VALUATE RADICAL INNOVATION

P#1 is the outcome of the first phase of this thesis. As already explained in the previous sections, this study was motived by the perception that companies are still trying to address the valuation problem (Goffin & Mitchell, 2010), despite of the indications in academic literature that applying non-traditional valuation methods for radical innovation is considered as flawed, as well as the fact that practitioners are not satisfied with the established valuation tools and evaluation criteria for radical innovation. . This reported that there is some unsolved issue behind the search for valuating radical innovation projects related to the management system designed to manage them.

Based on such perceptions, P#1 has investigated this inconsistency. In an effort to guide the inductive research - conducted through in-depth case studies in four companies with declared strategic intent to develop radical innovation - literature was reviewed in order to identify the arguments behind employing Real Options pricing to radical innovation. These reasons were: dealing with uncertainties and flexibility (e.g., Pich et al., 2002; Rice, Connor, & Pierantozzi, 2008; Schneider et al., 2008); valuating the radical innovation projects themselves (e.g., Huchzermeier & Loch, 2001), considering the increase in their competitiveness over incremental projects (e.g., Cooper et al., 1999) and improving in the technological negotiation positioning (e.g., Wang, Wang, & Wu, 2015); and legitimating decisions on the organizational and managerial system (e.g., Bunduchi, 2017; Gutiérrez & Magnusson, 2014; Mol & Birkinshaw, 2009; O'Connor, Leifer, Paulson, & Peters, 2008).

However, during the field research, the apparent reasons companies search for Real Options approaches to valuate radical innovation were identified, as well as the hidden reasons

behind the official rapport.[12] This supported the emergence of aspects related to the management system that guided the investigation, which supported the framing of two key concepts that , through their interrelationship, led to an explanation for the problem investigated.

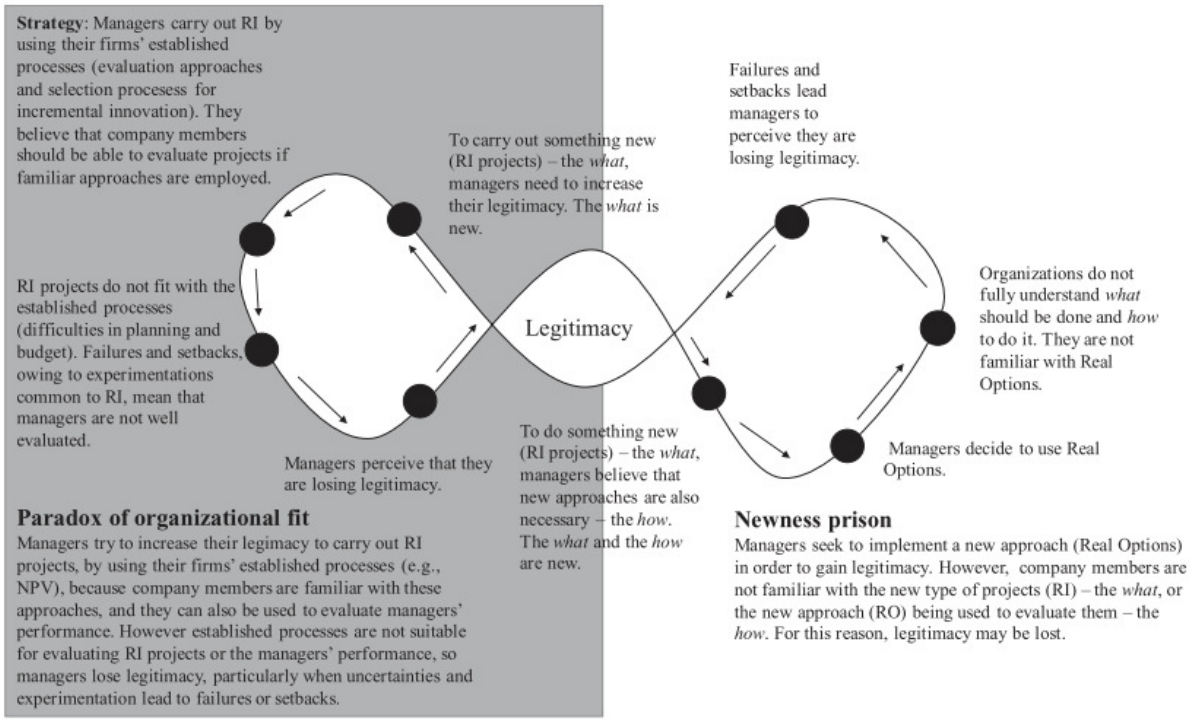
These concepts are "Newness Prison" and "Paradox of Organizational Fit". The "newness prison" occurs when managers seek to implement a new approach (Real Options pricing) in order to gain legitimacy. However, some company members are not familiar with the new type of projects (radical innovation, the "what"), or the new approach (Real Options pricing) being used to evaluate them (the how). For this reason, legitimacy may be lost. The "paradox of organizational fit", in its turn, appears when:

> "managers try to increase their legitimacy to carry out radical innovation projects, by using their companies' established processes (e.g., Stage-Gates, valuation by NPV/ROI), because managers in all organizational levels are familiar with these approaches, and they can also be used to evaluate managers' performance." (Brasil et al, 2018).

Figure 4, from P#1 (Brasil et al., 2018), synthetizes the searching process to valuate radical innovation projects.

[12] Details of the reasons provided by each company are described in detail in P#1 (Brasil et al, 2018).

Figure 4 - The "paradox of organizational fit" and the "newness prison"



Source: P#1 (Brasil et al., 2018)

To deal with the problems generated by the "Newness Prison" and the "Paradox of Organizational Fit", P#1 suggests that firms search for Real Options not only for its valuation mechanisms, but also to accomplish other objectives related to innovation management. Firstly, by searching for Real Options pricing, companies search for "RO (Real Options) Structuring". With their idea framed within the model, Real Options Structuring supports the identification of uncertainties and decision trees, helping decision-makers plan the idea by defining paths through which the project can evolve, discussing scope definition, phases, budget etc. Real Options pricing methods follow a logic that helps managers in dealing with uncertainty resolution through a learning perspective. Secondly, managers search for Real Options pricing methods because they allow the "RO Integration". In this sense, Real Options methods would frame the communication of the uncertainties to the organization, support the creation of a mindset for radical innovation, and establish a progressive resource allocation in projects, according to uncertainty resolution (in line with Klingebiel & Adner, 2015).

3.2 PHASE 2: MULTI-LEVEL ASPECTS IN THE ATTEMPT TO APPLY REAL OPTIONS TO VALUATE RADICAL INNOVATION

The findings of P#1 suggested that the search for calculating a value for radical innovation projects with Real Options pricing methods relates to multi-level organizational aspects beyond project-level valuation issues. Therefore, the second phase of the research sought to understand which issues are related to the valuation approaches in different organizational levels, as well as how are these levels integrated. As discussed before, the incapacity of using financial methods to assess the value of radical innovation not only harms the valuation *per se* but increases difficulties regarding the multi-level integration of the management of radical innovation projects.

P#2 (Brasil et al., 2017) went through the literature on Real Options in innovation context to understand how the approaches differ depending on the organizational level. This enabled the identification of three different theoretical streams on Real Options: at the strategic level; at the portfolio level; and at the project level. For each level, the logic, the source of managerial flexibility, and the mechanisms for managerial alignment about the method application were organized. An in-depth study was then conducted in four different companies, in order to identify how they link the use of Real Options within each level. The study also encompassed the management practices they adopt to align the application across the three organizational levels. Figure 5, from P#2, lists the practices identified.

The link among strategic, portfolio and project levels, according to P#2, is given by three aspects: managerial flexibility, managerial attention and deployment of options. Related to the first, three scenarios are described. It is argued that strategic planning can generate limited flexibility; or strategic planning generates managerial flexibility, but the portfolio constrains such flexibility (and vice versa); or the portfolio generates managerial flexibility, but the project management constrains such flexibility. Lastly, the third link that aligns the three organizational levels in applying Real Options in innovation context relates to the "ability of deploying the strategic action as an option (or a portfolio of options); further, each strategic option should be treated at the project level as a set of other options" (Brasil et al., 2017, p. 9).

Figure 5 – Processes related to each level of analysis

Level of Analysis	C1	C2	C3	C4
Strategic	Formal strategic planning, applying scenarios and roadmaps	Formal strategic planning, applying scenarios and roadmaps	Formal strategic planning applying SWOT analysis, Porter Five Forces.	Formal strategic planning
Portfolio	The firm has three portfolios: new products, new technologies and new process	Different portfolios for distinct innovation portfolios (e.g. technology, product, process)	The firm has two portfolios: new products and new process	The firm has one portfolio related to new product development
Project Management	The firm has two processes: new products and new technologies	Different innovation process for different types and degrees of innovation	Only the new product process is formalized	The firm has a well-established process for new product development

Source: P#2 (Brasil et al., 2017)[13]

3.3 PHASE 3: MULTI-LEVEL UNCERTAINTY MANAGEMENT OF HIGHLY INNOVATIVE PROJECTS

P#2 pointed towards two takeaways that inspired the third research phase. First, the idea that a multi-level approach is needed because the management practices and the whole management system should be thought through an integrative view, by which the different organizational levels are linked. Financial tools made the integration possible in incremental innovation or in projects other than radical innovation. But a multi-level integration for radical innovation remains to be built. Second, P#2 also confirmed that the main construct that drives not only the valuation problem around the management of radical innovation projects, but also the system to manage them, is uncertainty. Therefore, P#3 was written with the objective of investigating how firms manage uncertainty in exploratory projects, highly innovative, adopting a multi-level organizational lens.

[13] Companies studied in this research phase: C1 = Company 1; C2 = Company 2; C3 = Company 3; C4 = Company 4.

To do so, six projects, in two firms, were investigated in-depth, seeking to understand how firms manage uncertainties across the organizational levels in highly innovative projects, chosen for being the so-called “exploratory projects”. “Exploratory projects identity has been characterized as projects for which neither the goal nor the means to reach it can be clearly defined at the outset. They are frequently first-of-a-kind projects, exploring new technology, uses, business models, or strategic opportunities” (Lenfle, Midler, & Ha, 2019, p. 519). Therefore, “a key distinctive feature of exploratory projects is that such projects deal with a higher level of uncertainty in relation to more incremental innovation projects - situations in which managers act without clear understanding of the goals and the resources necessary to perform the projects” (Gomes et al., 2019, p. 1). This denomination, exploratory projects, is used in project management literature to refer to specific large scoped projects (e.g., Manhattan Project) and can be taken as a special case of radical innovation, maybe with even more unknowns-unknowns.

Based on the uncertainty management strategies at the network (given that the exploratory projects analyzed were conducted by a group of organizations – e.g., companies, universities, startups), organizational , portfolio and project level, P#3 introduced three categories of uncertainties: primitive, structural and elementary. These categories are conceptualized in the article as:

> “Primitive uncertainty is related to how far the exploration is from the core (e.g., business and competencies). It relies on general goals, purpose, the reasons why (e.g., why we should perform this exploratory project), and outcomes of an unknown situation (e.g., new technology, new market).” (Gomes et al., 2019, p. 10)
>
> “Structural uncertainty is related to the exploration breath, that is, to principles or functions, boundaries of the problem, options (e.g., different technological trajectories), or the scope of the unknown situation. We coded this type of uncertainty when managers refer to a lack of knowledge regarding the scope or boundaries of the problem (what we do not know or what we should know), principles or functions (what the functions are that define how this technology works), and roles (network).” (Gomes et al., 2019, p. 11)
>
> “While primitive uncertainties rely on fundamental knowledge gaps related to the what and why, that is, the goals and the purpose of the exploration (defining the exploration tolerance) and structural uncertainty refers mainly to boundaries, principles, functions, and options of the exploration (shaping the exploration breadth), elementary uncertainty

> refers to less aggregated uncertainties or more punctual ones." (Gomes et al., 2019, p. 11)

Figure 6 illustrates the Uncertainty Management House – which organizes the management approaches adopted at each level to deal with each type of uncertainty.

Figure 6 – The Uncertainty Management House

	Exploratory Projects		
	Primitive uncertainty	Structural uncertainty	Elementary uncertainties
	Primitive uncertainty relies on general goals, purpose, the reasons why, and outcomes of a given unknown situation.	Structural uncertainty relies on principles or functions, boundaries of the problem, or scope of a given unknown situation.	Elementary uncertainty relies on elementary aspects, or components of a given unknown situation.
Network Level	• The roles and goals are not clear • Governance mechanisms should encourage the experimentation and sharing of knowledge • Difficulties in evaluating the network outcomes and competencies	• The roles and goals are improved • Governance is more defined, orchestrating the uncertainty management and learning process • Dealing with the emergence of new information and uncertainties	• Governance is well defined, orchestrating the uncertainty management and learning process • Creating new ecosystems to address opportunities related to cope with elementary uncertainties
Organizational Level	• Network management • Resources allocated to pre-development • Protected space for experimentation • Learning exploration strategies	• Network management • Resources allocated to strategic experimentation • Protected space for experimentation • Incentives for experimentation • Learning exploration strategies	• Using knowledge transfer mechanisms from external actors to the firm • Appropriating knowledge from the mitigation of uncertainties • Incentives for exploiting the results of mitigating structural uncertainties
Portfolio Level	• Difficulties in comparing projects • Protected space for exploration projects • Proper process for selecting and evaluating	• Identifying synergies and interdependences among structural uncertainties • Creating projects to exploit the knowledge obtained from experimentation	• Creating new projects • Design routines to transform results from exploratory projects in other projects
Project Level	• Inductive experimentation by using imagination • Rapid prototyping • Flexible scope • Short feedback	• Deploying uncertainties • Charting the unknown • Uncertainty tree and mapping	• Traditional uncertainty management approaches

Source: P#3 (Gomes et al., 2019)

The central idea is that the goal of uncertainty management is reducing primitive uncertainty to structural uncertainty and then to elementary uncertainties. From this point, established uncertainty management approaches (e.g. the Learning Plan, by Rice et al., 2008) could be applied. To perform these reductions, P#3 argues that a multi-level uncertainty management is mandatory, focusing in holistically coordinating the uncertainty mitigation process. Additionally, P#3 identified that, by this uncertainty mitigation process, managers face the "Uncertainty Blindness", which "occurs when managers are not able to either define which uncertainties were mitigated (and the contributions to the firm) or why they should invest in reducing the additional ones" (Gomes et al., 2019, p. 13). To overcome this challenge, managers than, can employ the "intermediate anchorage", which is:

> (…) the use of intermediary artifacts (e.g., patents, reports, prototypes, secondary products, learnings) as a way of justifying the reasons why the organization should keep investing in mitigating uncertainties present in an exploratory project. Instead of thinking of overall results (which in turn could not be clear), managers make sense of intermediary artifacts that resulted or will result from uncertainty mitigation" (Gomes et al., 2019, p. 13-14)

However, P#3 alerts for the point that, by using an intermediate anchorage, companies and managers may lose the reference of the explorative objectives of the project itself, focusing on the artifacts created to anchor the main outcome of the project, for example a software developed during the project to support the overall project goal, but used internally into the company to justify the investments on the project (as it is difficult to materialize the results of an exploration project). Therefore, companies may expect that managers improve the software and continue to explore its applications. At the end, it is a mechanism used to reinforce the importance of the project during portfolio management processes and comparison against incremental and more tangible projects, in order to assess resources and attention from the company.

3.4 PHASE 4: THEORETICAL STREAMS AND ROOTS OF (INNOVATION) PORTFOLIO MANAGEMENT

During the conduction of the third phase of the research and the writing of P#3, it was clear that the influence of uncertainty in managing highly innovative projects permeates all organizational levels, and a holistic view of the management system is needed. Competition for available resources occurs at the portfolio management level, where decisions regarding investing or not in

a project (even without a clear objective or output) are made. As posted by P#3, “the management of uncertainties requires from portfolio management systems particular organizational and governance mechanisms” (Gomes et al., 2019, p. 3), as “portfolios are subject to uncertainty when project alternatives can still be identified and when managing uncertainty consists of making the optimal choice between possible decisions and probable states of nature” (Kokshagina, Le Masson, Weil, & Cogez, 2016, p. 272). This also corroborates the perceptions from P#1 (i.e. Brasil et al., 2018), that the valuation problem is generated by the form that the portfolio management system is designed, inducing firms to find a way to address financial values to radical innovation to make comparison with incremental innovation possible, supporting an apparent rational resource allocation – that is, an allocation legitimated by the traditional valuation tools, even if they are adequate. The dive into the literature - to review the concepts, theories and views about portfolio management - originated from the conclusion that portfolio management and its fundamentals was not adequately addressing the challenges brought by radical innovation.

The fourth phase of the research was based on the perception that portfolio management is the articulation engine of the system to manage radical innovation. The aim at this point was to theoretically understand how literature deals with the issues related to portfolio management, considering its different perspectives and, as a multi-level lens was guiding the overall research, how portfolio management is framed according to the distinct organizational levels. This research phase was split in two. The first has focused on understand portfolio management not only from the innovation (or new product development) point of view, but also employing a marketing perspective, as it drives the insertion or not of the products developed into the market. The second part of the fourth research phase was specifically focused on clearing the theoretical streams and roots of innovation portfolio management, and, additionally, to map and organize insights revealed by literature that could support the management of radical innovation.

3.4.1 Product and innovation portfolio management

The fourth phase of the research has initially focused on analyzing how research has studied the topic.[14] Following the review of 127 articles, published at top journals, this phase aimed to understand the different lens adopted to investigate the phenomenon of how firms form and make decisions related to their products and innovation projects portfolios, and guides research on the topic.

The literature analysis supported the framing of the research on portfolio management (product and innovation) in two lenses. First, the micro-level lens, which "deals with process aspects in managing decision-making for the product and innovation portfolios" (Brasil & Eggers, 2019, p. 5). Second, the macro-level lens, which "deals with the organizational, political, strategic, and environmental aspects of decision-making on product and innovation portfolios" (Brasil & Eggers, 2019, p. 13). This dialogs with the previous approaches of this PhD research, as, again, a multi-level perspective drives the search for investigating how firms manage radical innovation during their portfolio management processes and decision-making.

In reviewing the literature that applies a micro-level lens, fundamental principles were identified, both for product and innovation portfolio management. They come from the origins of portfolio management in finance (i.e. financial portfolio theory - Markowitz, 1952), where financial portfolios have their decisions driven by the relationships between risk and return. Therefore, product and innovation portfolio management have inherited these assumptions and have established their evaluative and decision-making mechanisms designed essentially to address three performance and success parameters:[15]

> "(a) strategic alignment, regarding to which extent the portfolio composition translates overall firm's strategic intents; (b) maximization of global portfolio value, an efficiency relation between resource input and output; and (c) balance: being the proportion in the split of resources according some given criteria, for instance, long- and short-term, high- and low-risk types of products or projects, among others."(Brasil & Eggers, 2019, p. 5)

The three parameters based different management frameworks both for product and innovation portfolio management. From an innovation point of view, literature on the subject has focused on drawing and evaluating portfolio management practices to assess innovation projects

[14] By defining the scope of the review as product and innovation portfolio management, P#4 excludes other objects of portfolio management literature, not related to the problem of the PhD research, as financial or alliance portfolio management.

[15] These parameters are cited, for instance, in Cooper, Edgett & Kleinschmidt (2001) and Kester, Hultink, & Griffin (2014).

through a dynamic decision-making process to evaluate, prioritize and select the projects to be resourced and supported. A micro-level innovation portfolio management framework is, for instance, strategic buckets. From the product side, literature has focused on producing management approaches to evaluate markets and products in order to decide about the insertion or culling of products from the current portfolio, as well as the influence of these decisions on other functions and processes of the firm (e.g., operations, supply chain and engineering). A micro-level product portfolio management framework is, for instance, product matrices (e.g., BCG or GE matrices).

Macro-level research on portfolio (product and innovation) management, instead, "links the strategic portfolio of the firm with investment policies, resource allocation regimes, technology, and market entry/exit timing, and their consequent influence on a firm's organizational capabilities" (Brasil & Eggers, 2019, p. 13). At this level, product and innovation portfolio management are mixed, and literature, specifically strategy literature, is interested in taking "a portfolio-based approach to firm performance, which allows for the intuition of innovation portfolios as the renewal stage for product portfolios—two phases of the same box" (Brasil & Eggers, 2019, p. 13). Macro-level literature works at the firm level, and more frequently has the dependent variable as firm performance – in opposition to micro-level literature, which aims to measure product or innovation performance.

Three main concepts were identified at the literature on portfolio management at the macro-level: a) entry and exit timing; b) portfolio breadth and depth; c) portfolio management resource allocation. The first relates to "analyzing the link between product strategies, innovation strategies, and industry evolution from birth to maturity" (Brasil & Eggers, 2019, p. 15). The second refers to how "portfolio breadth captures the range of products in a product line (or innovative projects in an innovation portfolio) that may target different groups of consumers and markets, while depth captures the number of offerings within each category" (Brasil & Eggers, 2019, p. 16). The third dedicates attention to the heart of portfolio management at the firm level, the form – or reasoning – by which firms organize their resource allocation (Real Options Reasoning is an example of it):

> "(…) the decision-making processes and reasoning which shape resource allocation are basic elements for portfolio management effectiveness and consequent innovation, and market and firm performance. More than defining the amount of resources to allocate to keep products in the portfolio or innovation projects in the pipeline, the form—regime

> or reasoning—through which these resources are allocated is important to understand portfolio management dynamics and outputs." (Brasil & Eggers, 2019, p. 17)

P#4 identified that portfolio management is a key organizational capability (a dynamic capability) to support firms' adaptation and response to technological and market change in dynamic environments, for instance, supporting or creating barriers to strategic flexibility. As the current product portfolio (embedded by the technological and market arenas dominated by the firm) and the future product portfolio (fueled by the current innovation portfolio) are the result of the ability of the firm to articulate the resource allocation processes, at the micro- and macro-levels, it defines how firms will manage and form their current and future competitive advantage, as well as leverage organizational renewal. This is aligned with literature interested in how firms adapt to technological change, which alerts that "strong commitments to existing technologies and the willingness to cannibalize existing products" may decrease "incentives to acquire new knowledge or assets (…) the ability to assimilate new knowledge or assets (…) the ability to reconfigure its business," and "make it less likely that a firm possesses knowledge or complementary assets relevant for a new technology" (Eggers & Park, 2018, p. 363).[16]

The paper also sheds light on the relationship between portfolio management and organizational ambidexterity (following the ambidexterity concept, for example, by Gibson & Birkinshaw, 2004). If firms must keep their competitive advantage by exploiting their current basis of resources (current products) and exploring the future basis of resources by developing new products, organizational mechanisms are needed to simultaneously manage both. It is still more complicated if radical innovation is considered. To develop radical innovation, firms need to design multi-level organizational decision-making processes to guarantee resources and attention.

3.4.2 Linking micro- and macro-level literature on innovation portfolio management to manage radical innovation

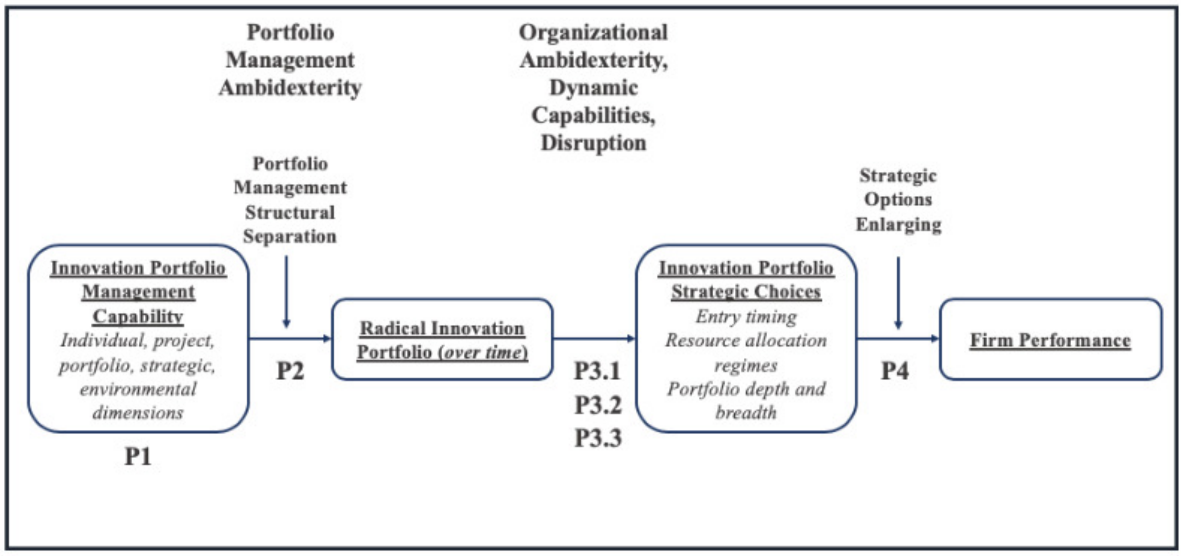
As P#4 indicated that portfolio management research is fragmented in micro- and macro-level lenses and that it is a dynamic capability that supports firm's performance, the second part of the fourth phase of this PhD research has focused on investigating the underlying principles of this capability linking both micro- and macro-level perspectives. In addition, P#4 has shown that micro- and macro-level literatures were not linked, blocking the development of a

[16] This compilation of citations was used in P#4 (Brasil & Eggers, 2019).

comprehensive and holistic view of innovation portfolio management, essential for improving the understanding of how to protect and develop radical innovation over time. This phase, adopting a systematic literature review (of 121 articles), and applying bibliometric and content analysis, produced P#5, which focused specifically in innovation portfolio management (not on product portfolio management) and with a special look at the what literature has developed around the management of radical innovation in this context.

The review also supported a coding-process of the articles driven by a multi-level perspective. The topics that research has dealt with could be grouped in those related to environmental, strategic, portfolio, project and individual levels. The multi-level analysis, supported by the evidence that literature addresses innovation portfolio management problems at the different organizational levels, not necessarily linked, has opened the opportunity to formulate what is an innovation portfolio management capability, as, by definition, a dynamic capability covers elements on all organizational levels. The research process also revealed innovation portfolio management has been built on macro-level theories – even when applied at the micro, project, process-level, as organizational ambidexterity (e.g., Benner & Tushman, 2003), dynamic capabilities (e.g., Eisenhardt & Martin, 2000) and disruption theory (e.g., Christensen & Bower, 1996). This supported the link between micro-level aspects of portfolio management and macro-level capabilities, as well as firm performance (addressing the asks by Kouamé & Langley, 2018). Also, propositions on how to articulate a multi-level innovation portfolio management capability to protect and foster radical innovation could be posted, along with the development of a model for innovation portfolio management capability and firm performance (Figure 7). The propositions developed by P#5 and listed on Figure 7 are synthetized on Table 3.

Figure 7 – Model for innovation portfolio management capability and firm performance



Source: P#5 (Brasil et al., *under review at the Journal of Product Innovation Management*)

One specific concept requires additional attention: the multi-level structural separation for innovation portfolio management. It relates to the proposition that, to protect and fuel radical innovation over time, a broader view is needed in comparison to the established approaches based on assessing the financial value of radical innovation (e.g., by applying Real Options pricing methods) or adopting strategic buckets. P#5 has revealed that aspects in different organizational levels influence the resource allocation in innovation projects. This means that the focus on solving the protection of radical innovation by developing new valuation tools or protecting radical innovation by strategic buckets are confined into part of the aspects located at the portfolio and project levels, neglecting the other aspects within these levels and at other organizational levels. The idea is that it is necessary to go beyond this view, and effectively set a multi-level organizational capability, able to build a strong separation between radical and incremental innovation projects. This not only aides resource allocation, but also guarantees that the processes, routines, heuristics and learning approaches at all the levels are aligned to accomplish radical innovation requirements. As stated in P#6:

> "such separation represents a broader view in comparison to those approaches which try to protect radical innovation from just project and processes perspectives (e.g., real options pricing or strategic buckets)" (Brasil et al., under review), and, "(…) following a multi-level perspective, we argue that to be effective in fueling and protecting radical innovation portfolios, innovation portfolio management architecture and decisions shall cover routines, processes and governance in all these levels. It means the radicalization

of portfolios structural separation, going far beyond the current bucketing approaches" (Brasil et al., under review).

Table 3 – Propositions developed by P#5

Proposition #	Proposition description
1	The management of portfolios with radical innovation projects based on strategic alignment, maximization of portfolio global value and balance (even when evaluation are not finance-based) is not sufficient to sustain radical innovation projects over time.
2	An effective protection of radical innovation depends on a deeper innovation portfolio management structural separation from incremental management systems, consider radical innovation separation at the individual project, portfolio, strategic and environmental levels.
3.1	An innovation portfolio management capability is ambidextrous when organizes radical innovation in a specific portfolio, with specific budget (and budgeting process), specific criteria and schedule, with a decision-making committee not involved in the decision-making of incremental projects, with separate and crafted resource allocation regimes, managed by people dedicated to radical innovation and from organizational higher levels, fueling and protecting radical innovation portfolios over time.
3.2	An innovation portfolio management capability is a dynamic capability when it extends firm's basis of resources, and this extension is based on radical innovation projects that are developed based on experimentation and learning.
3.3	An innovation portfolio management capability supports firms to behavior as incumbent and new venture at the same time by operationalizing different organizational spaces and management systems dedicated to radical and incremental innovation.
4	An innovation portfolio management capability based on a structural multi-level separation for radical innovation enlarges the number of strategic options and improves firm performance.

Source: Consolidated from P#5 (Brasil et al., *under review at the Journal of Product Innovation Management*)

3.5 PHASE 5: PRINCIPLES OF A MULTI-LEVEL SEPARATION FOR INNOVATION PORTFOLIO MANAGEMENT

The fifth phase of the research followed the production of P#4 and P#5, the two literature reviews on portfolio management and the consequent model for innovation portfolio management capability and firm performance.

At this moment, the research shifted its focus to the theoretically developed concept of multi-level structural separation for innovation portfolio management to protect and foster radical innovation over time. For that, case studies have been conducted in the four companies analyzed during this thesis' phases 1 and 2. Note that these companies have a declared strategic intent to develop radical innovation. Although research on the topic is completed, P#6 is still being produced. P#6 aims to develop the link between micro- and macro-level literature from a

macro-level strategy perspective. By investigating the principles of a multi-level separation for innovation portfolio management, P#6 intends to dialog with theories and scholars from this stream, focused, for instance, in investigating the operationalization of higher-level organizational concepts (e.g., dynamic capabilities, ambidexterity, organizational learning) and relating it to firm performance and firm response to technological change. As a result, the intention is to submit P#6 to a journal from the strategy field (e.g., the Strategic Management Journal).

Differently from the previous sections describing and linking P#1, P#2, P#3, P#4, P#5 – as well as the following section on P#7 - this section about P#6 is longer and more detailed than the others, as the complete paper is not appended. It is the opportunity to present the main ideas that will be further developed in article format. It is important to note that, in spite of being more detailed, this section is not an article, not applying the formal requirements it would demand.

3.5.1 The need of understanding the organizational mechanisms for protecting and fueling radical innovation for macro-level innovation portfolio management decision-making

Managing an innovation portfolio is a key task for managers (Cooper, Edgett, & Kleinschmidt, 2001), an important organizational decision-making process (Eggers, 2012), and affects firm's innovation and overall performance (Danneels, 2002; Klingebiel & Rammer, 2014). Radical innovation, in its turn, requires special management approaches, in order to receive resources and attention when competing with incremental innovation (e.g., Christensen & Joseph, 1996; O'Connor, 2012). In this sense, innovation portfolio management is decisive for adequately guaranteeing resources for radical innovation (Chao & Kavadias, 2008), given that this form of innovation is responsible for supporting firms' future competitive advantage and organizational renewal. Despite being investigated both from micro- and macro-level perspectives (Brasil & Eggers, 2019), research on innovation portfolio management still lacks an integrative theory covering the architecture of a higher-level capability dedicated to managing and protecting radical innovation during innovation portfolio management decision-making processes. Thus, the aim of P#6 is to answer the following research question: *What are organizational mechanisms of an innovation portfolio management dynamic capability to protect radical innovation and guarantee future strategic and competitive advantage?*

Broadly, innovation portfolio management is a set of micro- and macro-level processes that covers the usage of companies' resources (for instance, by funding incremental innovation).

These processes also allow the exploration of opportunities capable of supporting future strategic changes and organizational and competitive advantage renewal (for instance, by conducting radical innovation). This is done by effectively allocating and reallocating resources in portfolios (Klingebiel & Adner, 2015) in order to access, manage and reduce the intrinsic technological and market uncertainty in new product development projects (Cooper, Edgett, & Kleinschmidt, 1999; Klingebiel & Adner, 2015; Klingebiel & Rammer, 2014). The way firms structure their decision-making processes for allocating resources in innovation portfolios defines how committed they are to current technologies and their ability to adapt to technological changes (Eggers & Park, 2018). The structure of a company's decision-making process is also a mechanism of strategy operationalization (Cooper, Robert G.; Edgett, Scott J.; Kleinschmidt, 2001; R. G. Cooper et al., 1999; Kopmann, Kock, Killen, & Gemünden, 2017), and helps frame organizational capabilities, learning dynamics, strategic movements (Brown & Eisenhardt, 1997; Eggers, 2012; Helfat & Raubitschek, 2000). Lastly, such processes influence the ability and timing to enter new markets or technology areas (Klingebiel & Joseph, 2015; Lee, 2008; Suarez, Grodal, & Gotsopoulos, 2015).

There is a gap in incorporating micro-level project and process perspectives to better frame which organizational capabilities will support the exploration of new opportunities by radical innovation and the processes and routines capable of explaining the steps leading to the management of this type of innovation and strategic flexibility and adaptation. This occurs in spite of the importance given for innovation portfolio management by macro-level research, and ultimately affects business performance. It is known, for instance, that organizational forces move resources from radical to incremental projects, as established companies favor current products and customers (e.g., Christensen & Joseph, 1996; Tripsas & Gavetti, 2000). With this in mind, micro-level literature - looking into project, processes and individual aspects - has been interested in understanding how the management of portfolios carrying radical innovation differs from those with incremental innovation (Chandrasekaran, Linderman, & Schroeder, 2015; Chao, Kavadias, & Gaimon, 2009; Chao & Kavadias, 2008; Chao & Kavadias, 2013; Cooper.; Edgett.; Kleinschmidt, 2001; Cooper et al., 1999; Hutchison-Krupat & Kavadias, 2014), and discuss how to establish organizational mechanisms, systems and structures to protect and fuel radical

innovation over time (Colombo, von Krogh, Rossi-Lamastra, & Stephan, 2017; O'Connor, 2012; Slater, Mohr, & Sengupta, 2014).[17]

Nevertheless, data indicates that approaches based exclusively in micro-level management mechanisms and practices have also not been enough to protect and foster radical innovation, given that portfolios have become more incremental over time (Cooper, 2013; Kester, Griffin, Hultink, & Lauche, 2011; Kester, Hultink, & Griffin, 2014; Lerch & Spieth, 2013). This indicates the need of developing deeper relationships between micro-level issues and higher level capabilities (Killen, Jugdev, Drouin, & Petit, 2012; Söderlund & Tell, 2011), based on principles of organizational ambidexterity (e.g., Birkinshaw, Zimmermann, & Riasch, 2016; Tushman & O'Reilly, 1996) to effectively separate portfolio management for radical innovation and support firm performance.

The disconnection between micro project-level aspects of innovation portfolio management and the macro organizational-level represents a missed opportunity for strategy literature to connect resource allocation processes to innovation performance through the establishment of a broader organizational dynamic capability. Moreover, there is an opportunity to move from a generalist approach to investigating the effects of managing any type of innovation in business performance towards specific comprehension of how the micro-management of radical innovation shapes an innovation portfolio management capability that supports organizational renewal, by sustaining the need of a special care with radical innovation during the portfolio management process.

As it conducts the inductive theory-building research, P#6 aims to offer five major contributions. These are:

1. Through the application of a theory building approach, the work seeks to respond to the literature arguing that organizational mechanisms to balance resources towards incremental innovation efforts "have little or no theoretical foundation" (Chao & Kavadias, 2008, p. 908).
2. The article contributes to the literature on dynamic capabilities, as it offers operationalized aspects by which this strategic macro-level construct is framed. There

[17] Also some macro-level works (e.g., Criscuolo, Dahlander, Grohsjean, & Salter, 2017) have been alerting for the need of looking at portfolio management micro-level aspects for comprehending the differences in managing more innovative projects.

is an increasing interest in dynamic capabilities research to understand its mechanisms and boost innovation and adaptation (Helfat & Martin, 2015; Teece, Pisano, & Shuen, 1997). However, critics highlight problems with the vague aspects of the existing theoretical frameworks on the subject, as well as its lack of empirical support and operationalization of the concept of dynamic capabilities (Barreto, 2010; Wilden, Devinney, & Dowling, 2016; Winter, 2003). Comprehending innovation portfolio management as a capability allows companies to frame its organizational and management mechanisms for radical innovation.

3. When specifically treating innovation portfolio management for radical innovation, the paper aims to bridge organizational processes and companies' ability to adapt to technological and market disruption (Eggers & Park, 2018), as well as internal readiness to be strategically flexible and engage in technological or market arenas (Klingebiel & Joseph, 2015).
4. A deeper understanding about the reasoning shaping decision-making processes to allocate resources in radical and incremental innovation projects represents a contribution to the debate on how firms operationalize organizational ambidexterity to concomitantly explore their current resource basis and prepare for the future (Gibson & Birkinshaw, 2004; Iii, 2013; Lavie, Stettner, & Tushman, 2010). In this sense, Lavie et al. (2010), when reviewing literature about the management of exploration and exploitation of firm's basis of resources, highlight research gaps related to the understanding of multiple modes of balancing exploration and exploitation: the costs, challenges and trade-offs brought by balancing efforts; the relationship between exploration and exploitation in different levels; the links between balancing efforts and industry evolution. This also adds to the debate around establishing ambidextrous management systems and organizational designs to accommodate radical innovation (Colombo et al., 2017; O'Connor, 2012b; Slater et al., 2014).
5. P#6 has the potential to represent an effort towards the application of qualitative methodological approaches associating micro-level processes to macro-level outcomes in strategy qualitative research (Aguinis & Molina-Azorin, 2015; Felin, Foss, & Ployhart, 2015; Kouamé & Langley, 2018). As resource allocation processes

are key capabilities, the articulation of micro-level aspects with macro-level organizational capabilities follows a “Strategy-as-Practice” perspective and is relevant to explain firms’ strategic flexibility and competitive advantage (Chao et al., 2009; Klingebiel & Rammer, 2014).

3.5.2 Methodological approach for P#6

To investigate the *organizational mechanisms of an innovation portfolio management dynamic capability to protect radical innovation*, the research in which P#6 is supported followed Eisenhardt's (1989) guidelines for inductive multi-case and theory-building research. The research design was based on four cases, reaching Eisenhardt’s orientations of theoretical sampling (between four and ten cases), choosing companies where the phenomenon is transparently observable. This research approach is adequate due to the lack of theory about the protection of radical innovation during portfolio management processes (as stated by Chao & Kavadias, 2008) and its relationship with firm-level capabilities. Furthermore, a multi-case design offers more robust and generalizable theory than single cases (Eisenhardt & Graebner, 2007).

P#6 has adopted a theoretical sampling approach. To do so, it used “extreme cases” (Eisenhardt, 1989), following companies that have launched innovations based on new markets and technologies within the last five years and have also declared strategy to conduct innovation projects in new market and technological arenas, as well as are listed in innovation rankings.

This study is part a broader research program focused on longitudinally following the management of radical innovation in Brazilian companies and multi-nationals with representation in Brazil, conducted at the LGI. The broader research project has been conducted since 2008 and includes companies that declare to have strategic intent to pursue radical innovation. Analyzing such companies is crucial for this research, as it indicates concern of the company in design management systems to deal with that. The research therefore focused on the management system level, trying to comprehend routines, practices and processes applied in managing the portfolios. For this research phase specific data collection was conducted from the middle of 2015 until the end of 2018. Selected companies were interviewed in this process; the results are described on Table 4.

Table 4 – Cases and interviews by cases for P#6

Company	Characteristics	Research activities on Radical Innovation at LGI	On portfolio management
CH1	Chemical multinational company diversifying from commodities through radically innovative processes. The company has a well established, successful system for incremental innovation. It also has radical innovations, and is looking for a mechanism to deliver radical innovation systematically. Operations in the Americas and Europe.	Longitudinal study since 2008. Interviews with CEO, C-level, managers of the radical innovation unity, BUs leaders, technicians. **104 hours of interviews**	Workshop with leaders on valuation and portfolio management **(~30 people)** Focused interviews to capture barriers to radical innovation: **40 hours**
AP1	Auto parts multinational company with most business linked to internal combustion engines, searching for diversification of its products. The company has a well established, successful system for incremental innovation. It also has radical innovations, and is looking for a mechanism to deliver radical innovation systematically. Operations in the Americas, Europe, and Asia.	Longitudinal study since 2008. Interviews with VP, innovation leaders, global innovation manager, local innovation managers, technicians, PMO. Discussion workshops. **54 hours of interviews**	Focused interviews to capture barriers to radical innovation: **30 hours**
CO1	Cosmetics multinational company. The company has a well established, successful system for incremental innovation. It also has radical innovations, and is looking for a mechanism to deliver radical innovation systematically. Operations in the Americas and Europe.	Longitudinal study since 2009. Interviews with head of the Board, VP, Global Research & Product Development Director, innovation managers, portfolio governance manager, pipeline portfolio manager, responsible for open innovation, **42 hours of interviews**	Focused interviews on to capture barriers to radical innovation: **10 hours**
PH1	Pharmaceuticals company with national operations, with patents licensed worldwide. The company has a well established, successful system for incremental innovation. It also has radical innovations, and is looking for a mechanism to deliver radical innovation systematically. Operations in Brazil	Case studies in 2012 and 2018-2019. Interviews with radical innovation director and coordinator, R&D and innovation managers, senior scientist, HR manager, IP manager. 3 in site workshops to discuss innovation issues with radical innovation team (3h each). **20 hours of interviews**	Focused interviews to capture barriers to radical innovation: **15 hours**

Source: Table developed by the author for this thesis

As P#6 intends to understand the portfolio management decisions through the macro and micro-lens, a research protocol was formulated (with semi-structured script, based on open-

ended questions) covering issues regarding portfolio management at the strategic, organizational, project and individual levels. Then, interviews were conducted with selected individuals in each company – 60 to 120 minutes each. These individuals are directors, managers and leaders that somehow participate in the portfolio management process, not only as decision-makers, but also as responsible for projecting and evaluating the decision-making system. Further, in some companies, workshops were conducted with the participation of the research team and groups of informants of the companies. These workshops sought to validate hypothesis or allow a deeper analysis of companies' structure, strategy, portfolios. For that, as complement, companies' documents were accessed. The documents included organograms, process guidelines, project management systems, worksheets, project and portfolio data and indicators, strategy declarations, innovation committee reports and management protocols. The research was concerned with the triangulation of the data collection within each company, interviewing different players involved at the portfolio management process and cross-referencing the legitimacy of the information provided with other interviewees.

During the interviews, evidence surrounding the dynamics of portfolio management processes was gathered. Such evidence includes internal classifications applied for innovation projects, problems companies had in evaluating different problems, examples of specific cases when radical innovation represented a challenge for the portfolio management system. Also, hypothetical situations were presented to the interviewees, which were then asked to tell what would happen in that company. For instance, researchers asked: "After the exploratory phase of a radical innovation project, if you need to access a higher amount of investment, for example to build a pilot industrial plant to test hypothesis of the new chemical process under development, how would you convince the portfolio committee about this need?".

3.5.2.1 Research design and data analysis for P#6

As previously mentioned, the research that led to P#6 adopted an inductive research design not based on investigating the causes behind the variation of outcomes between different sampled cases (as in Martin & Eisenhardt, 2010). Differently, firms were chosen based on the variations on the "independent variables" (e.g., differences in innovation portfolio management architectures and practices), and then inductively formulated the outcomes. Similar works intending to link micro-level processes to strategy, macro-level outcomes have also adopted this strategy (e.g., Huy & Zott, 2019).

Following approaches used in previous studies on innovation portfolio management that applied qualitative Eisenhardt-based case studies (e.g., Klingebiel & Joseph, 2015), the data analysis fit with an open and non-theory driven coding process (following the coding process for Grounded Theory, proposed, among others, by Charmaz, 2006). This means that data analysis began by looking at the data to identify emerged concepts, essentially focusing on those relating to how managers decide during innovation portfolio management processes, how they deal with the uncertainties that radical innovation brings to decision-making, how they proceed to concomitantly and separately manage incremental and radical innovation, as well as how the rest of the firm responds to this context. As described before, little previous theoretical constructs and concepts informed this coding process, in order to make the emergence of concepts, constructs, patterns and relationships possible and not biased by established theories (follwing the Grounded Theory drivers by Miles, Huberman, & Saldana, 1994). Therefore, as concepts emerged, researchers tested contextual issues that influence the phenomenon, in an attempt to frame the relationship between concepts. The data collection and coding were conducted parallelly. This allowed that the testing of the codes developed during the next interviews, in order to refine and validate concepts. This interactive coding process - coupled with the recursive inputs given by the collected data to the codes, and vice versa - supported the formulation of the data structure (data structure as proposed by Gioia, Corley, & Hamilton, 2013). At this stage, researchers began to consult literature about the emerging concepts, in order to identify other possibly- related concepts related to them (e.g., precedents).

3.5.3 Initial research results for P#6

The central assumption that a complete multi-level and ambidextrous organizational separation is needed to protect and foster radical innovation supported the indication that some constructs characterize the degree of this separation. Therefore, by adopting extreme concepts, data has been indicating that firms pursue a *strong* or a *weak* separation for innovation portfolio management. On one hand, a strong innovation portfolio management separation is capable of covering aspects in all different multi organizational levels (i.e. environmental, strategic, portfolio, project and individual levels). A weak separation, on the other hand, lacks management approaches that consider radical innovation characteristics and specificities in some of the organizational levels. As discussed in P#5 , research has concluded that elements beyond project and portfolio management were covered by the established practices of valuating radical

innovation projects with financial methods that promise to address the challenges brought by uncertainty (e.g., Real Options pricing) or the use of strategic buckets to halt the escape of resources from radical innovation to incremental innovation, therefore influencing the dynamics of fueling innovation portfolios. The multi-level complete alignment of management approaches among different organizational levels would be needed to perennially protect and foster radical innovation over time – a strong separation.

The fifth phase of the research process of this PhD thesis has detected that four constructs (moderated by their levels in an organization) define a strong separation in innovation portfolio management processes:

1. The level of equity or fairness
2. The level of proximity to strategy
3. The level of openness for resourcing radical innovation
4. The level of economies of scale.

The next sub-sections intend to briefly explain these concepts.

3.5.3.1 The level of equity or fairness

The first construct, the level of equality, may defined as the level to which firms drive the innovation portfolio management decision-making by the principles of equity and fairness, not by equality. To explain these concepts, one can seek for established concepts in political science for an analogy. The prominent political scientist John Rawls, who developed a Theory of Justice for political liberalism, argues that a fair social system does not focus on providing opportunities equally for citizens, independent of their initial conditions (Rawls, 2009).[18] Instead, a fair social system is based on providing equal initial conditions, considering the differences each citizen has. For the author, when evaluating the needs of some social group, it would be necessary to observe their background and particularities – called "the original position". Fair is not treating everyone equally, applying the same rules and analysis to all. Adapting the evaluation systems according to the original position each group has would, therefore, be fair.

---

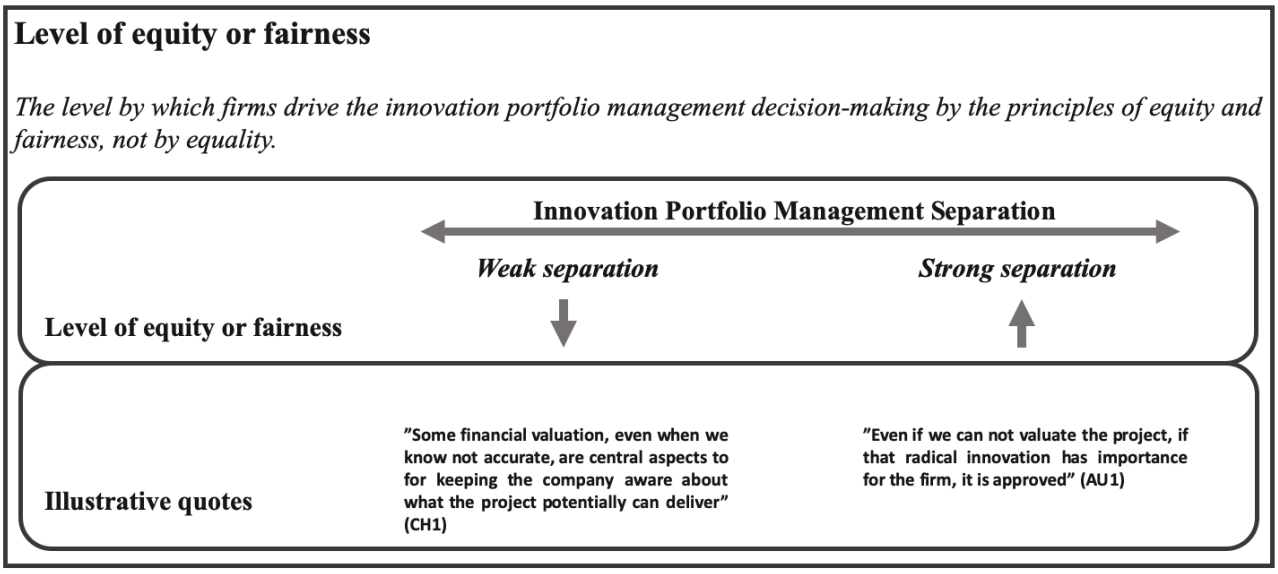
[18] John Rawls has developed his Theory of Justice for political liberalism in the 1960's and 1970's (for a revised version of the original book, see Rawls, 2009), building it upon other important theorists of the social contract, as Locke, Rousseau, and Kant. Many are the interpretations of the original theory, for example on Hittinger (1994) and Samar (1995).

A weak or strong separation for innovation portfolio management follows the same logic. A weak separation carries the principle that all innovation projects should be evaluated equally, with scandalized processes and reasoning. A strong separation, on the other hand, considers that radical innovation differs both in nature and importance. Following Rawls's ideas, different should be treated differently. From a practical point of view, this means that it is not sufficient to develop specific criteria for radical innovation in a specific bucket if the criteria (even when not financial) are embedded by the same assumptions of characterizing risk and return, or if the participants of the committees that evaluate incremental and radical innovation are the same. The origins of the resources are also relevant in this context. In CH1, for instance, an innovation manager argues:

> "We have resources for the radical innovation projects from our operational expenses (OPEX) buffer and we evaluate it against the similar uncertain projects within the same bucket, so, until we do not need a significative amount of investments, we can support it. However, when we need to build a pilot plant, which requires a higher budget, we need to ask for money in equal conditions for all of the company's projects in the investment committee, responsible for approving capital expenditure (CAPEX) for building new factories, implement another ERP or paint the headquarter".

A fair system would consider that radical innovation requires different project management systems, criteria, committees, agenda, decision-makers, resource funds and other elements. It is different and strategically more relevant, thus requiring a different and special attention from the firm. Figure 8 summarizes the idea of the level of equity and fairness and provides some illustrative quotes.

Figure 8 – Level of equity or fairness



Source: Figure developed by the author to be published in P#6 (Brasil, Salerno, in progress)

3.5.3.2 The level of proximity to strategy

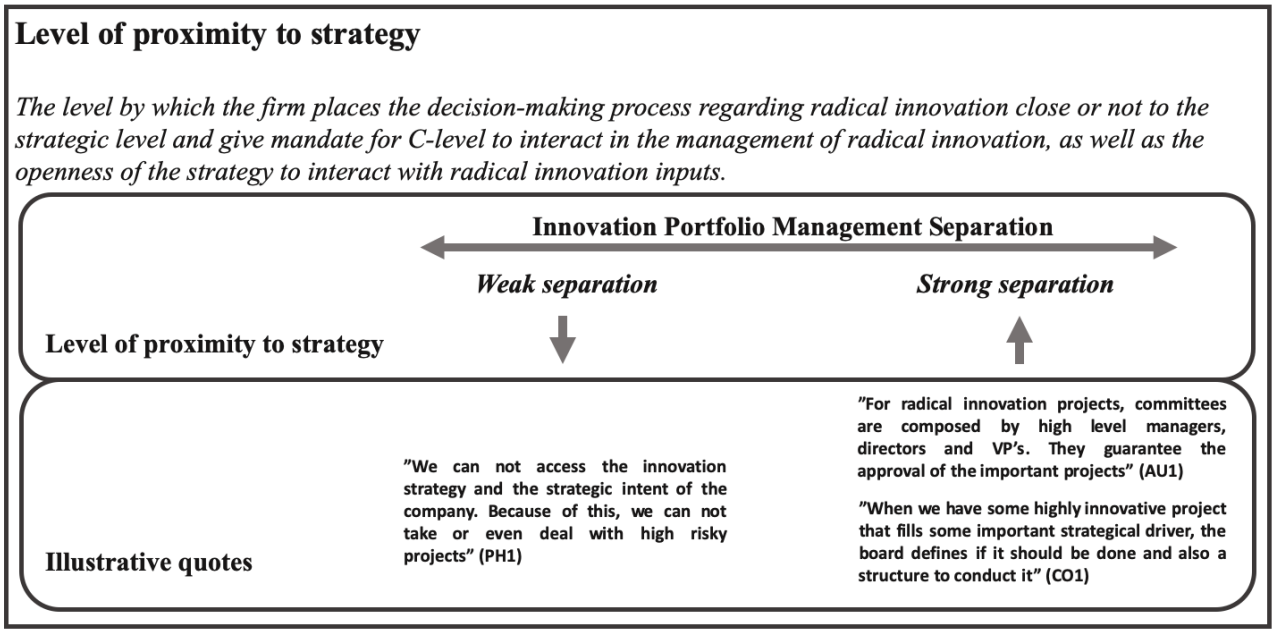
The second construct is the level of proximity to strategy. This construct can be defined as the proximity decision-making processes regarding radical innovation have to the strategic level. It also includes the level of interaction in the management of radical innovation, as well as the openness of the strategy to interact with radical innovation inputs.

Radical innovation comprises companies' future competitive advantages and organizational renewal (e.g., O´Connor et al., 2008). More than signaling its importance for the survival of a business, this means that top management, by the C-Level, should have it under its mandate. The strategic buckets approach was an attempt to delegate the strategy from the higher levels of the organization to the lower levels. Framing the innovation arenas to invest in, validating the criteria used to evaluate projects in each bucket and defining the percentage of resources to be allocated in each bucket allows top management to expect that the participants of innovation committees follow their drivers and operationalize strategy. However, radical innovation, as seen in this thesis, is not effectively protected exclusively by the application of this mechanism, losing resources and attention over time. It should be C-Level's responsibility to guarantee that projects have funds and conditions to be conducted – albeit with interventions when necessary.

Moreover, radical innovation incubates strategy. Although it may not necessarily accomplish the current declared strategy, radical innovation can reach strategic objectives not considered by the company, and not deployed in strategic buckets. Radical innovation does not necessarily address current strategic gaps, but it has the potential of creating new strategies. A specific analysis of each radical innovation project is required in order to verify if its results will fit future strategies for the business. AU1, for example, produces parts of combustion engines, a product that the C-Level assumes has no future (because of new electrical engines under development). Because of this, AU1's board defined that they should look for other opportunities based in the company's current capabilities (e.g., materials engineering), in any other technological or market domain, to build new ventures. This challenge cannot be addressed by delegating the decisions to the lower levels of the organization. Moreover, the C-Level executives are the only ones with understanding and power to correctly guide this process.

Another issue related to the need of radical innovation being close to the strategic level is the fact that, because of the uncertainties related to it, predictions may be not possible. Needs originating from the development of the project should be presented to C-Level executives. AU1, again, represents an example. To enable the development of radical innovations in other domains, the C-Level defined a team to conduct the selected projects (and is open to analyze other possible projects), with direct contact with the board. This was made in an effort to be informed about the needs of each project, allocating resources on demand, and unblocking any barriers the project face within the organization. The processes the project team follows are not the same of other innovation projects at the company, being crafted by the identified needs. Figure 9 summarizes the idea of the level of proximity to strategy and brings some illustrative quotes.

Figure 9 – Level of proximity to strategy



Source: Figure developed by the author to be published in P#6 (Brasil, Salerno, in progress)

3.5.3.3 The level of openness for resourcing radical innovation

The third construct developed is the level of openness for resourcing radical innovation. This can be defined as the level to which a company is open to allocate more resources to radical innovation once it has its uncertainties resolved during project evolution.

Strategic buckets approach is driven by the principle that the share of resources to be allocated in each bucket is pre-determined. Because of this, valuation methods are applied to quantify the amount of resources needed by a project, the associated expected return and base the distribution of resources between and within buckets. However, radical innovation cannot have its costs and returns entirely assessed at the beginning. Radical innovation projects follow a phased and cyclic perspective, and after experimentations and each learning loop, the next phase can be understood and planned.[19] If resources are fixed for a radical innovation bucket, evidence indicates that it may be misaligned with radical innovation needs, as the company does not visualize the future resource requirements. Therefore, the firm should be open to fund radical innovation, even if the need of resources was previously not identified. The firm would need to

[19] As proposed, for instance, by Rice et al. (2008), who developed a Learning Plan approach for managing radical innovation projects.

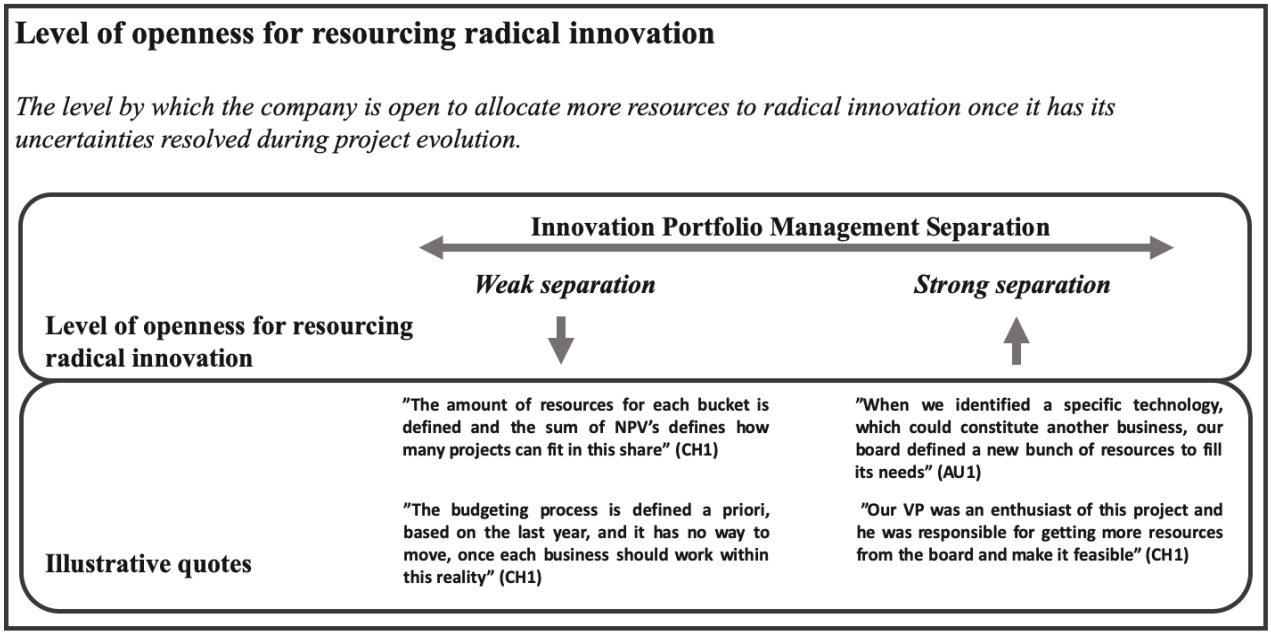
find resources for these projects independently of the previous definitions about the share dedicated to the bucket.

The construct of level of openness for resourcing radical innovation is complementary to the level of proximity to strategy. One of the main responsibilities of the C-Level is to evaluate, case-by-case, the needs of radical innovation, including the resources necessary. A high-level organizational source of budget for radical innovation supports the stability of the project. The quote by an Innovation Director of CO1 exemplifies:

> "When an innovation project is taken as strategic, the discussions about the resources it requires are made on the strategic committee, formed by the board members. If needed, board members decide to allocate more resources in it."

Note that this openness represents an advance in managing innovation portfolios for radical innovation when it is a one-way openness. This means that non-predicable resources are able to be allocated in radical innovation projects, but once resources are allocated in radical innovation projects, it represents a risk if they can be shifted to other types of projects, because, incremental innovation naturally tends to prevail in resource allocation against radical innovation (Cooper, 2013; Kester et al., 2011; Lerch & Spieth, 2013). Figure 10 summarizes the idea of the level of openness for resourcing radical innovation and provides some illustrative quotes.

Figure 10 – Level of openness for resourcing radical innovation



Source: Figure developed by the author to be published in P#6 (Brasil, Salerno, in progress)

3.5.3.4 The level of economies of scale

The fourth construct is the level of economies of scale. This construct can be defined as the level to which a company applies standardized decision-making processes for radical innovation in order to reduce related costs. A central driver in operations and process management is the standardization of process in order to reach economies of scale and enable an organization management. Moreover, the standardization of processes ensures the attendance of quality requirements, as it controls variations. However, the innovation context posts challenges to this principle. This thesis has indicated the need of specific procedures to manage radical innovation. As process management systems and information technology software to manage new product development projects adopts the standardization assumption to support the management practices, it may represent a barrier for radical innovation.

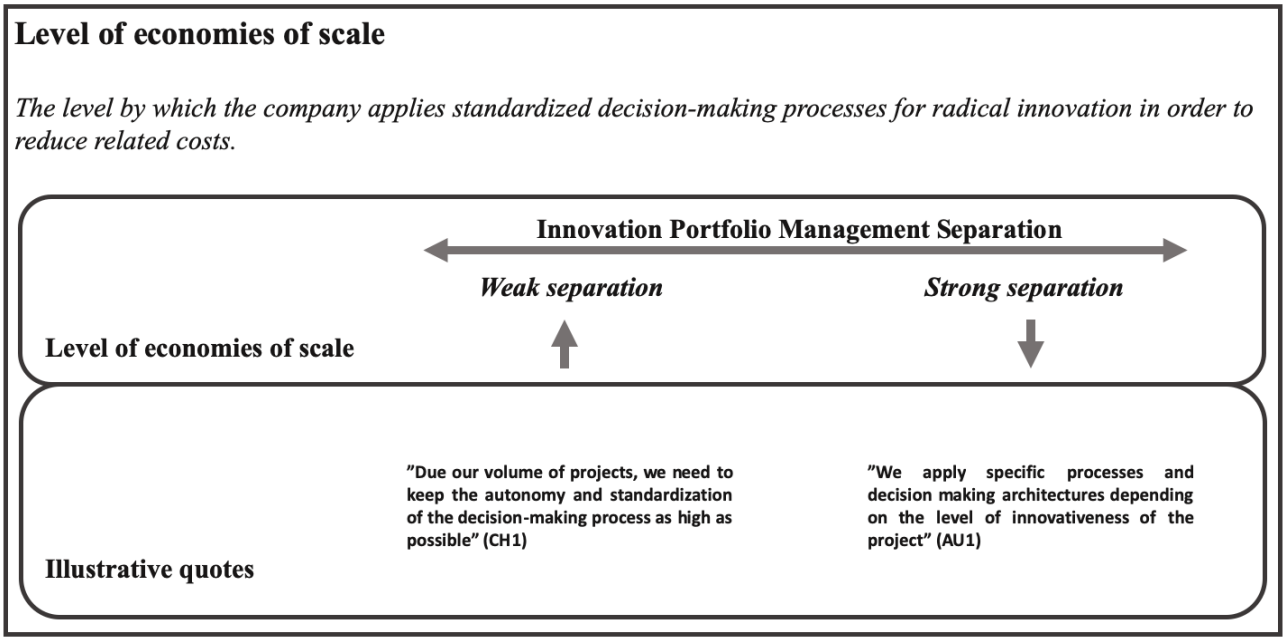
Identifying top-down approaches for innovation portfolio management, as strategic buckets, does not consider the previous three principles of innovation portfolio management separation (i.e. the level of equity or fairness, the level of proximity to strategy, the level of openness for resourcing radical innovation). In this sense, the principle of economies of scale synthesizes the ideas of building decision-making processes, resource allocation regimes, tools, project management approaches, funding sources, governance mechanisms and even appropriate

mindset to evaluate and conduct radical innovation. To properly conduct radical innovation, firms should accept that they may lose economies of scale in managing innovation projects. Nevertheless, to support the feasibility of a unique management for a radical innovation project, the volume of this type of project is not as high as the others. A firm intending to conduct radical innovation does not manage more than a few units of such projects or initiatives, what allows companies to handle each project through the principle of fairness, with the participation of the C-Level on their management and with special on-demand funding mechanisms. As a manager at AU1 affirmed:

> "After the identification of the next phase of the project, the board and project managers define how the next activities are going to be conducted, designed and the process' requirements"

Figure 11 summarizes the idea of the level of economies of scale and provides illustrative quotes.

Figure 11 – Level of economies of scale

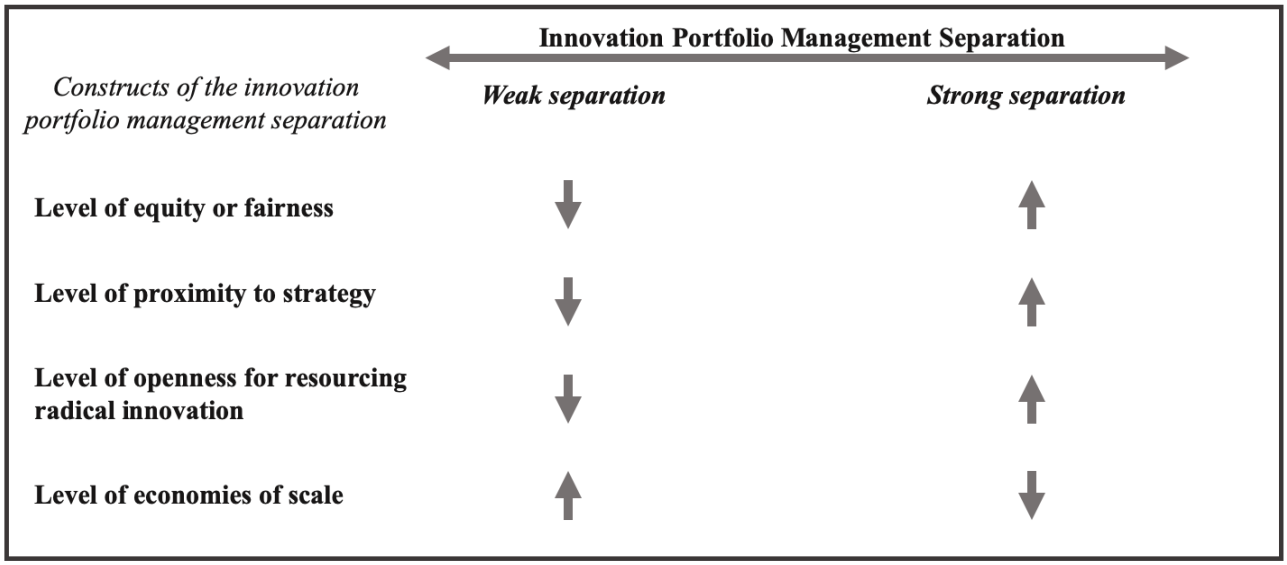


Source: Figure developed by the author to be published in P#6 (Brasil, Salerno, in progress)

3.5.3.5 The principles of innovation portfolio management separation and the macro-level strategy

The previous sections briefly presented the constructs of an innovation portfolio management separation that have been emerging from the inductive sixth phase of the research of this thesis. Figure 12 resumes the relationships of the constructs and a strong and weak innovation portfolio management separation.

Figure 12 – Constructs of the innovation portfolio management separation



Source: Figure developed by the author to be published in P#6 (Brasil, Salerno, in progress)

The constructs characterizing a portfolio management for radical innovation may supply information to research focused on macro-level analysis and interested in identifying the effects of micro-level processes in innovation and firm performance. The evaluation of how different levels of innovation portfolio management separation in firms' innovation or general performance is a potential link to be developed. This is aligned, for instance, with works that investigated the effect of resource allocation reasoning in innovation performance (e.g., Klingebiel & Adner, 2015). Also, it creates a pathway for companies to establish relationships between management practices that base such constructs and theorization of an ambidextrous capacity for innovation – which is aligned, for instance, with Chandrasekaran, Linderman, Sting, & Benner (2016), or O´Reilly, Harreld, & Tushman (2009). Moreover, the view of weak or strong separation can benefit the analysis on how firms adapt and change when facing technological changes (considering the recognized role of portfolio management in this context, as proposed by Eggers & Park, 2018). The proposed constructs also relate to macro-level studies investigating how the decision-making process for more innovative projects interacts with the organizational learning (as studied, for instance, by Criscuolo, Dahlander, Grohsjean, & Salter, 2017). Lastly, the characterization of such constructs supports the operationalization of an

innovation portfolio management dynamic capability, which is able to assure that radical innovation is protected and fostered, while firms undergo organizational renewal over time.

3.6 PHASE 6: MANAGERIAL ASPECTS OF THE SEPARATION FOR PORTFOLIO MANAGEMENT OF RADICAL INNOVATION PROJECTS

The fifth phase of the research, described above as guiding the findings of P#6, aims to inductively frame the key constructs that form a multi-level structural separation for innovation portfolio management. This means an advance in relation to the established approaches indicated to protect radical innovation during portfolio management processes, going beyond simply focusing on new methods to valuate radical innovation or applying strategic buckets to allocate resources. The outcomes of the research represent insightful guides for managers that have the mission to manage radical innovation or project management systems to deal with that. With this in mind, phase six of the research was dedicated to translating the main managerial findings of the thesis for managers.[20] This thread of thought led to P#7.

In this sense, P#7 has framed four traps in managing for radical innovation, and the development of portfolio management guidelines for radical innovation, based on three fundamental assumptions. The common traps managers face when managing portfolios with radical innovation problems are:

1. Treating innovation projects like financial assets, which relates to the limits in applying financial methods to evaluate radical innovation, because of uncertainty and the lack of data and the attempts of managers of forcing financial evaluations to make the evaluations friendly to the language the executives are normally familiarized with.
2. Adopting a “one size fits all” approach to portfolio management. This concerns attempts to gain scale by applying standardized processes to manage all projects they have. Although appealing, radical innovation requires specifically crafted management processes, because of its particularities.
3. Believing that separate systems solve everything, particularly the belief that separate resource allocation systems at the project level (i.e. strategic buckets) are sufficient to guarantee that resources are used in radical innovation over time. The multi-level perspective explored in this thesis has shown that other aspects - for example managers’

[20] Insights by other research conducted at the LGI and by its partners, in which the author of the thesis was participant, were also included in P#7.

background (at the individual level) - influence their decision on selecting or not a project. P#7 sets that if firms still use the same decision-making processes, decision-makers, organizational structures, governance mechanisms and project management processes, bucketing resources will not protect radical innovation projects from the resource shift to incremental projects.

4. A preference for omission errors. This trap is based on the preference firms have in investing in safer projects, due to the fact that they base their decisions by asking what happens if they invest in a project (how much does it return?) and not asking what happens if they do not invest in a project (*if we do not invest in this project, what opportunities do we lose?*).

To develop management guidelines to orient practitioners in avoiding these traps, P#7 listed three fundamental assumptions. The first is that managers should emphasize appropriate decision-making, or favor equity over equality. Thus, P#7 highlights:

> "Radical projects require to be differentiated from incremental projects. and radical projects need to be treated differently, with their own evaluation and management systems." (Brasil, et al., *under review*)

The second fundamental assumption argues that radical innovation is incubated by strategy. This means that the idea that bases the bucketing approaches (that innovation strategy could be broken and delegated to the lower levels of the organization by defining *a priori* the amount of resources to be allocated in each group of projects) does not fit radical innovation needs. C-level executives should be involved in the decisions around radical innovation projects. Firstly, because they have higher strategic relevance; secondly, because they inform strategy and give inputs for strategic change; thirdly, because projects need resources on demand – budget, for instance, cannot be asked at the beginning - and C-Level executives need to evaluate the next requirements of a project after each experimentation phase.

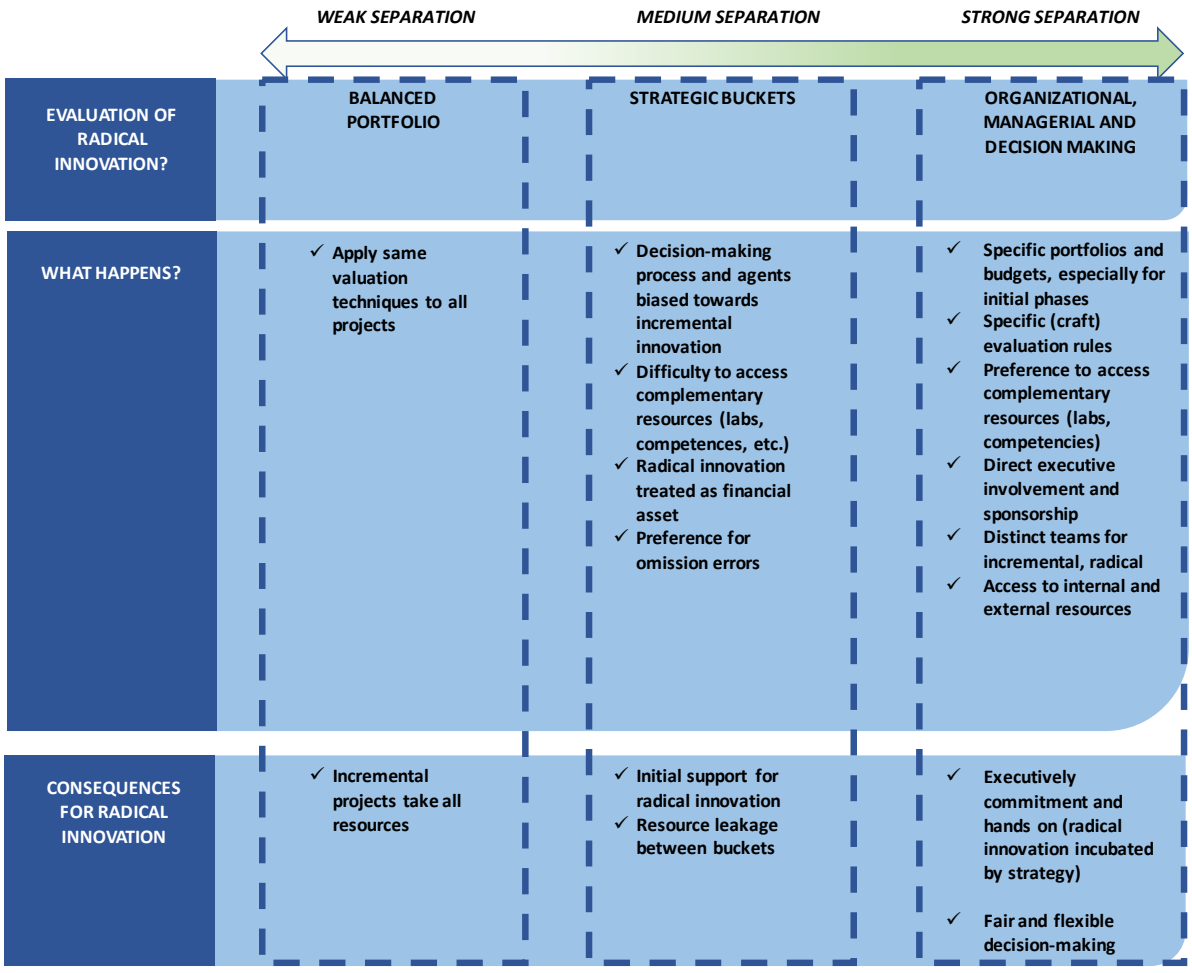
Finally, the third fundamental assumption that managers should pay attention to avoid the traps in managing radical innovation is the importance of a strong separation that preserves alignment and fit. Following the underlying principle of this PhD thesis, of managing portfolios through a multi-level and ambidextrous lens, in order to protect and foster radical innovation, P#7 defends:

> "Firms need to adopt an ambidextrous, strongly separated innovation management system to completely address the challenges in managing radical innovation. Portfolio management for radical innovation must separate financial resources for radical versus

> incremental projects, moving on to rethinking multiple structural and organizational decision-making processes – committee mandates, competence levels, sponsorship, knowledge integration, evaluators, budgeting processes, tools, and agendas. Successful radical portfolio systems offer *a strong and comprehensive separation* between project type*s, with multilevel integration and analysis*." (Brasil et al., *under review*)

These assumptions supported the framing of three degrees of portfolio management separation (Figure 8). By this view, a weak separation represents the segmentation of projects and balancing of resources within the same portfolio. A medium separation is the application of strategic buckets, with segmentation of projects, balancing of resources and different portfolios. A strong separation covers a complete organizational, managerial and decision-making separation. After this, P#7 has proposed the portfolio management guidelines for managing radical innovation, based on the principles of weak, medium and strong separation.

Figure 13 – Innovation portfolio management separation degrees



Source: P#7 (Brasil et al., *under review*)

Figure 14 – Portfolio Management Guidelines

PORTFOLIO MANAGEMENT GUIDELINES

Does executives demonstrate strategic intent to pursue radical innovation?	None	Discussed in planning process, but no specific mandate	Strategic planning identifies key targets for radical innovation efforts	
Are executives directly supervising radical projects?	No	Executives participate to show support or to understand process, but take no direct part	Executives actively participate in discussions and evaluations for radical projects	**STRATEGIC**
Do managers championing radical projects have access to executives?	No open access	Access is ad hoc, based on personal connections	Formal guidelines for how managers can access executives to understand strategic role of projects	
Are there separate budgets for radical and incremental projects?	Single portfolio	Buckets exist, but processes allow reallocation	Buckets with clear, formalized separation	
Does the same committee discuss both types of projects in the same meeting?	Single committee, single meeting	Different meetings, but nearly same participants and same agenda, process	Projects have completely independent agenda, participants and evaluation process	
How are large capital expenditures for radical innovation considered?	Similar to other expenses	Radical innovation has dedicated access to limited funds for testing, prototyping but follows generic process for larger investments	Formalized, independent process for discussing major budget allocations for radical projects	**ORGANIZATIONAL**
Who works on radical projects?	Same teams work on incremental and radical projects	Distinct teams, but shared space and resources	Distinct teams, locations, resources	
How do radical innovation teams access external and internal resources?	No clear access to resources	Access resources by bypassing formal processes	Formal process with executive involvement to evaluate need to access resources	
Are there different project management and evaluation processes for radical, incremental projects?	Standardized processes	Distinct processes (or one process but informal acceptance of violation), but standard format for all radical projects	Distinct processes with expectation of customization for each project (determined ex ante)	
What is basis for evaluation criteria for radical projects?	Financial	Mix of financial and non-financial	Strategic, learning, experimentation	**PROJECT**
Can radical projects shift technological and market domains?	No	Only by bypassing formal processes	Project charter allows for evaluation of need to change domains	

What is the nature of incentives for innovation managers?	Based on project success (favoring short term)	Managers face conflicting incentives	Clear rewards for leading important, strategic projects irrespective of outcomes	INDIVIDUAL
Do innovators managers act as entrepreneurs, employing a craft management approach?	Managers are risk averse	Champions act as entrepreneurs, but are not recognized by formal establishment	Managers feel empowered, with autonomy to take risks and uncertain tasks	
Is innovation manager authority based on financial metrics or strategic innovation?	Legitimation based on financial power	Formal legitimation of strategic needs, but processes default to financial	Using non-financial arguments to legitimate decisions is acceptable	
Do innovation managers have appropriate mental models to deal with radical projects?	Mental models revolve around current, mature technologies	Mental models recognize importance of radical innovation, but not means to achieve success	Mental models encompass experimentation, learning, deal with poor data and "unknowns-unknowns"	

Source: P#7 (Brasil et al., *under review*)

3.7 SUMMARY OF THE RESULTS IDENTIFIED BY THE THESIS

Table 5 was designed to summarize and compile the main contributions of each of the seven papers that compose this PhD thesis.

Table 5 – Main contributions of the seven papers that compose the PhD thesis

P# / Method	Main contributions
P#1 Multi-case studies	Framing of the reasons behind the search for Real Options pricing methods to valuate radical innovation. Developing of the concepts "the newness prison" and the "paradox of the organizational fit", which drives the search for legitimacy by managers. Suggestion of the reasons to search for Real Options for radical innovation: search for RO Structuring and RO Integration
P#2 Multi-case studies	Identification of the management practices that align the use of Real Options in different organizational levels (multi-level perspective) Linking between strategic, portfolio and project levels given by managerial flexibility, attention and the deployment of options.
P#3 Multi-case studies	Framing of the management of uncertainty in highly innovative projects in different organizational levels (multi-level perspective). Categorization of uncertainties in primitive, structural and elementary. Developing the concepts of uncertainty blindness and intermediate anchorage.
P#4 Literature Review	Identification of the main research streams in (product and innovation) portfolio management literature Framing of the micro- and macro-level literature on portfolio management Listing of the portfolio management frameworks at the micro-level. Listing of three main constructs of portfolio management literature at the macro-level: a) entry and exit timing; b) portfolio breadth and depth; c) portfolio management resource allocation.
P#5 Systematic Literature Review	Investigation of the theoretical roots of the innovation portfolio management literature. Linking the micro- and macro-level literature on innovation portfolio management by the formulation of an innovation portfolio management dynamic capability. Designing a model for innovation portfolio management capability and firm performance Listing propositions that support an innovation portfolio management ambidextrous separation for radical innovation.
P#6 Multi-case studies (being written)	Linking micro- and macro-level literature on innovation portfolio management with higher organizational concepts (e.g., dynamic capabilities, ambidexterity, organizational learning and adaptation). Introducing the constructs defining a strong or weak separation in innovation portfolio management to protect and fuel radical innovation: a) the level of equity or fairness; b) the level of proximity to strategy; c) the level of openness for resourcing radical innovation; d) the level of economies of scale.
P#7 Multi-case studies (practitioners view)	Translating the academic findings on portfolio management of radical innovation into practitioners language. Identification of four traps in managing radical innovation: a) treating innovation projects like financial assets; b) adopting a “one size fits all” approach to portfolio management; c) believing that separate systems solves everything; d) a preference for omission errors. Framing of three assumptions for portfolio management guidelines: a) emphasize appropriate decision-making, or favor equity over equality; b) radical innovation is incubated by strategy; c) the importance of strong separation that preserves alignment and fit. Defining what are the degrees of portfolio management separation: weak, medium, strong. Developing portfolio management guidelines.

4. CONCLUSIONS, IMPLICATIONS AND LIMITATIONS

This PhD thesis sought to investigate how to guarantee the protection and fostering of radical innovation projects during the portfolio management processes. Through the application of an evolutive research process, beginning with the investigation of the use of Real Options pricing methods to valuate radical innovation projects, until the framing of what would constitute an ambidextrous innovation portfolio management capability, this work adopted qualitative and inductive multi-case studies and literature review approaches to investigate how firms build architectural mechanisms to avoid that radical innovation is harmed during the competition for resources against incremental innovation projects.

The research demonstrated that a multi-level organizational approach is needed to address the challenges imposed by radical innovation to the established management system. Micro- and macro-level aspects of the decision-making processes related to portfolio management resource allocation shall be holistically orchestrated to guarantee that organizations build a strong structural separation that effectively protects and fosters radical innovation over time. The alignment within each organizational level and among levels is believed to be the key factor in not falling in the traps in managing radical innovation.

Established approaches for managing portfolios with radical innovation (e.g., Real Options pricing methods and strategic buckets) represent a necessary, but not sufficient step towards the protection of radical innovation. By simply focusing in improving these micro, project, process-level approaches, research has neglected the findings that indicate the influence of other aspects from organizational levels in provoking the shift of resources from radical innovation to incremental innovation, or the inability to manage the first, due to its intrinsic specificities, especially regarding heightened levels of uncertainty. Also, this work contributes to discussions around the adherence of the use of Real Options pricing for valuating radical innovation (e.g., Adner & Levinthal, 2004; Huchzermeier & Loch, 2001; McGrath & Nerkar, 2004); the effectiveness of the current portfolio management practices in supporting the development of breakthrough innovation (e.g., Chao & Kavadias, 2008; Cooper, 2013; Terwiesch & Ulrich, 2008); and portfolio management approaches to deal with radical innovation (e.g., Paulson et al., 2007); focused on developing ambidextrous perspectives to manage R&D projects (e.g., Chandrasekaran, Linderman, Sting, & Benner, 2016); or interested in manage uncertainties in highly innovative projects (e.g., Lenfle et al., 2019).

From the macro-level perspective, this work indicates that the existing literature has missed on the opportunity to look at micro-level portfolio management aspects to understand how innovation strategy is implemented, and how this implementation affects firm performance. It also reaffirms concepts discussed at the macro-level research - such as dynamic capabilities, ambidexterity, disruption theory and organizational adaption -, which may benefit from taking portfolio management processes as mechanisms to operationalize these principles, as well as characterizing portfolio management as a central capability to boost organizational renewal and handle strategic flexibility. The results of this thesis add to the discussion on how firms respond differently to technological change (e.g., Eggers & Park, 2018); or how the ambidexterity concept is considered into lower-level organizational processes to support the exploration of new business opportunities (e.g., O´Reilly, Harreld, & Tushman, 2009).

Literature on radical innovation, focused on investigating how management systems are designed to support this special case of innovation and to address its particularities through management practices, also receive inputs from this thesis, as theoretical concepts that base the structural separation proposed for managing portfolio with radical innovation inform the overall organizational design for this type of innovation (as discussed, for instance, by O'Connor, 2012 and O´Connor et al., 2008).

This thesis may guide research interested in specific topics within each organizational level cited. When studying, for instance, project management practices for radical innovation, or strategic resource allocation regimes, literature has the opportunity to anchor the findings in a broader multi-level perspective that this work has proposed, in order to check if the general alignment with the aspects located in other organizational levels is accomplished.

The contributions of the six completed papers separately are deeper discussed in the appendix sections (P#1, P#2, P#3, P#4, P#5, P#7) and the main finding of P#6, being written, is described at the previous sections of this thesis. The seven works, inserted into the general research process of this thesis, are capable of providing insights for innovation, portfolio management and strategy literature, especially regarding radical innovation.

4.1 IMPLICATIONS FOR THEORY AND FURTHER STUDIES

Each article comprised in this PhD thesis has its own indication of possible future studies, described at the appended sections of this document. The theoretical development and insights proposed open pathways for future research. First, following a post-positivist epistemological

approach, in which inductive or theoretical propositions should be quantitatively tested, propositions and concepts shall be assessed. In this sense, P#1, P#3, P#5 and P#6 offer opportunities for verifying the effects of the propositions they present in innovation or product performance (by, for instance, assessing patent generation). P#6, additionally, deserves the chance to verify how the theoretical constructs that fundament the structural multi-level ambidextrous separation interplay with firm performance. This matches the demands of Kouamé & Langley (2018), who affirm that Strategy-as-Practice macro-level research would benefit from the link with micro-level management processes, as those related to portfolio management. To do so, scholars could measure the performance outcomes of the firms which pursue the portfolio management architecture based on ambidextrous approaches.

P#2 and P#7, in their turn, support analysis of how firms and managers apply managerial practices to both align Real Options approaches (P#2) and the structural multi-level separation (P#7). Analysis of this implementation can lead to the development of new management frameworks and good practices (that can also be evaluated quantitatively) that inform about the issues related to how managers manage portfolio decision-making processes to deal with radical innovation.

Research can investigate how aspects in each organizational level (e.g., environmental, strategic, portfolio, project and individual) interplay with each other., mainly through the analysis of a specific aspect within an organizational level. This potentially includes, for instance, the relationship between how managers search for legitimacy in portfolio decisions - an individual-level aspect - and the dynamism of the competitive environment the firm is inserted in - an environmental/strategic aspect. This suggestion may break barriers between each organizational level and drive research to more holistic views of innovation portfolio management.

Another stream of research is deeper investigating the propositions of this thesis in specific sectors. Projects conducted at the pharmaceutical industry, for example, are significantly different than automobile or software industries in terms of nature, time-frame, competencies, costs and uncertainties. This can shed light on the discussions about the conceptualizations around what is a radical innovation project. The term can be more contextually understood to support more assertive empirical findings.

From the macro-level perspective, strategy, management and organizations literature may improve their understanding of how to operationally measure ambidexterity and dynamic capabilities. The dynamic capabilities concept, for instance, has received critics due to its vagueness and little empirical support (I. Barreto, 2010; Helfat & Peteraf, 2015; Wilden et al., 2016; Winter, 2003). Further, ambidexterity could have its application in process-level practices improved, in line with recent studies (e.g., Chandrasekaran et al., 2016). Both can benefit from looking at portfolio management literature and by the theoretical development of an ambidextrous innovation portfolio management dynamic capability. Moreover, the establishment of an innovation portfolio management capability that addresses the challenges posted by radical innovation can form a relevant construct to explain how firms adapt to technological change and learn over time.

4.2 LIMITATIONS OF THE RESEARCH

As any research work, this PhD thesis has limitations. The first relates to the literature review articles (P#4 and P#5). To review a feasible amount of publications, selection criteria were adopted and relevant works may have been excluded from the analysis. The second limitation refers to the empirical articles (P#1, P#2, P#3, P#6, P#7). The findings identified cannot be generalized, as the articles adopted inductive multi-case studies, following a post-positivist lens. More empirical studies, especially quantitative analyses are necessary to support generalized outcomes. Also, the companies chosen to be studied are part of a theoretical sample, filling some previous qualitative requirements: to have a declared strategic intent to develop radical innovation). This implies in a potential bias regarding the specific path-trajectory and context of these companies.

Finally, as an evolutive research work, conducted for six years, it is important to highlight the differences between the first and the last publication. As the research has evolved, the researcher has also accumulated new knowledge, had access to new literature and incorporated new insights, as well as improved his research abilities. This means that the last works contain both more robust theoretical basis and methods.

REFERENCES

Adner, R., & Levinthal, D. a. (2004). What Is Not a Real Option: Considering Boundaries for the Application of Real Options to Business Strategy. *The Academy of Management Review*, *29*(1), 74. https://doi.org/10.2307/20159010

Aguinis, H., & Molina-Azorin, J. F. (2015). Using multilevel modeling and mixed methods to make theoretical progress in microfoundations for strategy research. *Strategic Organization*, *13*(4), 353–364. https://doi.org/10.1177/1476127015594622

Bagno, R. B., Salerno, M. S., & Dias, A. V. C. (2017). Innovation as a new organizational function: evidence and characterization from large industrial companies in Brazil. *Production*, *27*(0), 1–13. https://doi.org/10.1590/0103-6513.207316

Barczak, G., Griffin, A., & Kahn, K. B. (2009). Perspective: Trends and drivers of success in NPD practices: Results of the 2003 PDMA best practices study. *Journal of Product Innovation Management*, *26*(1), 3–23. https://doi.org/10.1111/j.1540-5885.2009.00331.x

Barnett, M. L. (2008). An attention-based view of real options reasoning. *Academy of Management Review*, *33*(3), 606–628. https://doi.org/10.5465/AMR.2008.32465698

Barreto, I. (2010). Dynamic Capabilities: A Review of Past Research and an Agenda for the Future. *Journal of Management*, *36*(1), 256–280. https://doi.org/10.1177/0149206309350776

Benner, M. J., & Tushman, M. L. (2003). Exploitation, Exploration, and Process Management : The Productivity Dilemma. *The Academy of Management Review*, *28*(2), 238–256. https://doi.org/10.2307/30040711

Bessant, J., Oberg, C., & Trifilova, A. (2014). Framing problems in radical innovation. *Industrial Marketing Management*, *43*(8), 1284–1292. https://doi.org/10.1016/j.indmarman.2014.09.003

Birkinshaw, J., Zimmermann, A., & Riasch, S. (2016). How Do Firms Adapt to Discontinuous Change? *California Management Review*, *58*(4), 36–58. https://doi.org/10.1525/cmr.2016.58.4.36

Black, F., & Scholes, M. (1973). The Pricing of Options and Corporate Liabilities. *Journal of Political Economy*, *81*(3), 637–654.

Brasil, V. C., Gomes, L. A. V., Salerno, M. S., & de Paula, R. A. S. R. (2017). Multilevel approach for Real Options in the innovation management process : integrating project,

portfolio and strategy. In *International Research Network on Organizing by Projects (IRNOP)* (pp. 1–14).

Brasil, V. C., Salerno, M. S., & Gomes, L. A. de V. (2018). Valuation of innovation projects with high uncertainty: Reasons behind the search for real options. *Journal of Engineering and Technology Management*, *49*, 109–122. https://doi.org/10.1016/j.jengtecman.2018.08.001

Brasil, V. C., & Eggers, J. P. (2019). Product and Innovation Portfolio Management. In *Oxford Research Encyclopedia of Business and Management* (pp. 1–31). https://doi.org/10.1093/acrefore/9780190224851.013.28

Brones, F., & Carvalho, M. M. (2015). From 50 to 1: Integrating literature toward a systemic ecodesign model. *Journal of Cleaner Production*, *96*, 44–47. https://doi.org/10.1016/j.jclepro.2014.07.036

Bunduchi, R. (2017). Legitimacy-Seeking Mechanisms in Product Innovation: A Qualitative Study*. *Journal of Product Innovation Management*, *34*(3), 315–342. https://doi.org/10.1111/jpim.12354

Chandrasekaran, A., Linderman, K., Sting, F. J., & Benner, M. J. (2016). Managing R&D Project Shifts in High-Tech Organizations: A Multi-Method Study. *Production and Operations Management*, *25*(3), 390–416. https://doi.org/10.1111/poms.12410

Chao, R. O., & Kavadias, S. (2008). A theoretical framework for managing the new product development portfolio: When and how to use strategic buckets. *Management Science*, *54*(5), 907–921.

Chao, R. O., Kavadias, S., & Gaimon, C. (2009). Revenue Driven Resource Allocation: Funding Authority, Incentives, and New Product Development Portfolio Management. *Management Science*, *55*(9), 1556–1569. https://doi.org/10.1287/mnsc.1090.1046

Charmaz, K. (2006). Coding in Grounded Theory Practice. In SAGE (Ed.), *Constructing grounded theory: A practical guide through qualitative analysis* (pp. 42–70).

Christensen, C. M., & Rosenbloom, R. S. (1995). Explaining the attacker's advantage: Technological paradigms, organizational dynamics, and the value network. *Research Policy*, *24*, 233–257. https://doi.org/10.1108/S0742-3322(2013)0000030015

Christensen, C. M., & Bower, J. L. (1996). Customer Power, Strategic Investment, and the Failure of Leading Firms. *Strategic Management Journal*, *17*(3), 197–218.

Christensen, C., & Joseph, B. (1996). Customer Power, Strategic Investment, and the Failure of Leading Firms. *Strategic Management Journal*, *17*(3), 197–218.

Christensen, C. M., Bohmer, R., & Kenagy, J. (2000). Will Disruptive Innovation Cure Health Care ? *Harvard Business Review*, (October), 102–112. https://doi.org/10.1016/0002-9610(92)90118-B

Colombo, M. G., von Krogh, G., Rossi-Lamastra, C., & Stephan, P. E. (2017). Organizing for Radical Innovation: Exploring Novel Insights. *Journal of Product Innovation Management*, *34*(4), 394–405. https://doi.org/10.1111/jpim.12391

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

Cooper, Robert G., Edgett, S. J., & Kleinschmidt, E. J. (1999). New product portfolio management: practices and performance. *Journal of Product Innovation Management*, *16*(4), 333–351. https://doi.org/10.1016/S0737-6782(99)00005-3

Cooper, Robert G.; Edgett, Scott J.; Kleinschmidt, E. J. (2001). Portfolio Management for New Product Development: Results of an Industry Practices Study. *R&D Management*, *31*(4).

Cooper, Robert G, & Edgett, S. J. (2008). Maximizing Productivity Maximizing Productivity. *Research-Technology Management*, *51*(2), 47–58.

Cooper, Robert G. (2009). How companies are reinventing their idea-to-launch methodologies. *Research Technology Management*, *52*(2), 47–57. https://doi.org/10.1080/08956308.2009.11657558

Cooper, Robert G. (2013). Where Are All the Breakthrough New Products?: Using Portfolio Management to Boost Innovation. *Research-Technology Management*, *56*(5), 25–33. https://doi.org/10.5437/08956308X5605123

Copeland, T., & Tufano, P. (2004). A real-world way to manage real options. *Harvard Business Review*, *82*(3), 90–99, 128. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15029793

Criscuolo, P., Dahlander, L., Grohsjean, T., & Salter, A. (2017). Evaluating Novelty : The Role of Panels in the Selection of R&D Projects. *Academy of Management Journal*, *60*(2), 433–460.

Danneels, E. (2002). The dynamics of product innovation and firm competences. *Strategic Management Journal*, *23*(12), 1095–1121. https://doi.org/10.1002/smj.275

De Meyer, a., Loch, C. H., & Pich, M. T. (2002). Managing project uncertainty: from variation to chaos. *MIT Sloan Management Review*, *43*(2), 60–67. https://doi.org/10.1109/EMR.2002.1032403

Dixit, A. K., & Pindyck, R. S. (1994). *Investments under Uncertainty* (1ed ed.). Chichester, UK: Princeton University Press.

Dixit, A. K., & Pindyck, R. S. (1995). The Options Approach to Capital Investment. *Harvard Business Review*, *73*(3), 105–115. Retrieved from http://hbr.org/1995/05/the-options-approach-to-capital-investment/ar/2

Durisin, B., Calabretta, G., & Parmeggiani, V. (2010). The intellectual structure of product innovation research: A bibliometric study of the journal of product innovation management, 1984-2004. *Journal of Product Innovation Management*, *27*(3), 437–451. https://doi.org/10.1111/j.1540-5885.2010.00726.x

Eggers, J. P. (2012). All experience is not created equal: learning, adapting, and focusing in product portfolio management. *Strategic Management Journal*, *22*, 315–335. https://doi.org/10.1002/smj

Eggers, J. P. (2014). Competing technologies and industry evolution: the benefits of making mistakes in the flat panel display industry. *Strategic Management Journal*, *35*, 159–178. https://doi.org/10.1002/smj

Eggers, J. P., & Kaul, A. (2017). Motivation and ability? A behavioral perspective on the pursuit of radical invention in multi-technology incumbents. *Academy of Management Journal*, *ahead of p*.

Eggers, J. P., & Park, K. (2018). Incumbent Adaptation to Technological Change: The Past, Present, and Future of Research on Heterogeneous Incumbent Response. *Academy of Management Annals*, *12*(1), 357–389.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review*, *14*(4), 532–550.

Eisenhardt, K. M., & Martin, J. A. (2000). Dynamic capabilities: what are they? *Strategic Management Journal*, *21*, 1105–1121.

Facin, A. L. F., De Vasconcelos Gomes, L. A., De Mesquita Spinola, M., & Salerno, M. S. (2016). The Evolution of the Platform Concept: A Systematic Review. *IEEE Transactions on Engineering Management*, *63*(4), 475–488. https://doi.org/10.1109/TEM.2016.2593604

Felin, T., Foss, N. J., & Ployhart, R. E. (2015). The Microfoundations Movement in Strategy and Organization Theory. *The Academy of Management Annals*, *9*(1), 575–632. https://doi.org/10.1080/19416520.2015.1007651

Fleury, A. L., Stabile, H., & Carvalho, M. M. (2016). An Overview of the Literature on Design Thinking: Trends and Contributions. *International Journal of Engineering Education*, *32*(4), 1704–1718. Retrieved from http://www.ijee.ie/latestissues/Vol32-4/16_ijee3278ns.pdf

Gibson, C. B., & Birkinshaw, J. (2004). The antecedents, consequences, and mediating role of organizational ambidexterity. *The Academy of Management Journal*, *47*(2), 209–226. https://doi.org/10.2307/20159573

Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking Qualitative Rigor in Inductive Research: Notes on the Gioia Methodology. *Organizational Research Methods*, *16*(1), 15–31. https://doi.org/10.1177/1094428112452151

Goffin, K., & Mitchell, R. (2010). *Innovation management: strategy and implementation using the pentatlhon framework* (2ed ed.). Nova Iorque: Basingstoke (UK): Palgrave Macmillan.

Gomes, L. A. de V., Facin, A. L. F., Salerno, M. S., & Ikenami, R. K. (2016). Unpacking the innovation ecosystem construct: Evolution, gaps and trends. *Technological Forecasting and Social Change*. https://doi.org/http://dx.doi.org/10.1016/j.techfore.2016.11.009

Gomes, L. A. de V., Brasil, V. C., Facin, A. L. F., de Paula, R. A. S. R., Gomes, F. de V., & Salerno, M. S. (2019). Proposing a Multilevel Approach for the Management of Uncertainties in Exploratory Projects. *Project Management Journal*, *50*(5), 1–17. https://doi.org/10.1177/8756972819870064

Gomes, L. A. de V., Facin, A. L. F., & Hourneaux Junior, F. (2019). Building a bridge between performance management, radical innovation, and innovation networks: A systematic literature review. *Creativity and Innovation Management*, *28*(4), 536–549. https://doi.org/10.1111/caim.12348

Griffin, A., Price, R. L., Vojak, B. A., & Hoffman, N. (2014). Serial Innovators' processes: How they overcome barriers to creating radical innovations. *Industrial Marketing Management*, *43*(8), 1362–1371. https://doi.org/10.1016/j.indmarman.2014.08.010

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. Handbook of qualitative research, 2(163-194), 105.

Gutiérrez, E., & Magnusson, M. (2014). Dealing with legitimacy: A key challenge for Project Portfolio Management decision makers. *International Journal of Project Management*, *32*(1), 30–39. https://doi.org/10.1016/j.ijproman.2013.01.002

Helfat, C. E., & Peteraf, M. A. (2015). Managerial cognitive capabilities and the microfoundations of dynamic capabilities. *Strategic Management Journal*, *36*, 831–850. https://doi.org/10.1002/smj

Helfat, C. E., & Martin, J. A. (2015). Dynamic Managerial Capabilities. *Journal of Management*, *41*(5), 1281–1312. https://doi.org/10.1177/0149206314561301

Homrich, A. S., Galvão, G., Abadia, L. G., & Carvalho, M. M. (2018). The circular economy umbrella: Trends and gaps on integrating pathways. *Journal of Cleaner Production*, *175*, 525–543. https://doi.org/10.1016/j.jclepro.2017.11.064

Hutchison-Krupat, & Kavadias, S. (2014). Strategic Resource Allocation: Top-down, Bottom-up, and the Value of Strategic Buckets. *Management Science*, *61*(2), 391–412. https://doi.org/10.1287/xxxx.0000.0000

Huchzermeier, A., & 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.

Huy, Q., & Zott, C. (2019). Exploring the affective underpinnings of dynamic managerial capabilitie: How managers' emotion regulation behaviors mobilize resources for their firms. *Strategic Management Journal*, *40*, 28–54. https://doi.org/10.1002/smj.2971

Jugend, D., & da Silva, S. L. (2014). Product-portfolio management: A framework based on Methods, Organization, and Strategy. *Concurrent Engineering*, *22*(1), 17–28. https://doi.org/10.1177/1063293X13508660

Kavadias, S., & Chao, R. O. (2007). Resource allocation and new product development portfolio management. In *Handbook of New Product Development Management* (pp. 135–163).

Kelley, D. J., Connor, G. C., Neck, H., & Peters, L. (2011). Building an organizational capability for radical innovation: The direct managerial role. *Journal of Engineering and Technology Management - JET-M*, *28*(4), 249–267. https://doi.org/10.1016/j.jengtecman.2011.06.003

Kester, L., Hultink, E. J., & Lauche, K. (2009). Portfolio decision-making genres: a case study. *Journal of Engineering and Technology Management - JET-M*, *26*(4), 327–341. https://doi.org/10.1016/j.jengtecman.2009.10.006

Kester, L., Griffin, A., Hultink, E. J., & Lauche, K. (2011). Exploring portfolio decision-making

processes. *Journal of Product Innovation Management*, *28*(5), 641–661. https://doi.org/10.1111/j.1540-5885.2011.00832.x

Kester, L., Hultink, E. J., & Griffin, A. (2014). An empirical investigation of the antecedents and outcomes of NPD portfolio success. *Journal of Product Innovation Management*, *31*(6), 1199–1213. https://doi.org/10.1111/jpim.12183

Killen, C. P., Hunt, R. A., Kleinschmidt, E. J., & Hunt, R. a. (2008). Project portfolio management for product innovation. *International Journal of Quality & Reliability Management*, *25*(1), 24–38. https://doi.org/10.1108/02656710810843559

King, A. A., & Baatartogtokh, B. (2015). How Useful Is the Theory of Disruptive Innovation? *Harvard Business Review*, *57*(1), 44–56. https://doi.org/10.1287/mksc.ll00.0617

Klingebiel, R., & Rammer, C. (2014). Resource allocation strategy for innovation portfolio management. *Strategic Management Journal*, *35*, 246–268. https://doi.org/10.1002/smj

Klingebiel, R., & Adner, R. (2015). Real Options Logic Revisited: The Performance Effects of Alternative Resource Allocation Regimes. *Academy of Management Journal*, *58*(1), 221–241. https://doi.org/10.5465/amj.2012.0703

Klingebiel, R., & Joseph, J. (2015). Entry timing and innovation strategy in feature phones. *Strategic Management Journal*, *37*(6), 1002–1020. https://doi.org/10.1002/smj.2385

Kokshagina, O., Le Masson, P., Weil, B., & Cogez, P. (2016). Portfolio Management in Double Unknown Situations: Technological Platforms and the Role of Cross-Application Managers. *Creativity and Innovation Management*, *25*(2), 270–291. https://doi.org/10.1111/caim.12121

Kouamé, S., & Langley, A. (2018). Relating microprocesses to macro-outcomes in qualitative strategy process and practice research. *Strategic Management Journal*, *39*(3), 559–581. https://doi.org/10.1002/smj.2726

Laine, T., Korhonen, T., & Martinsuo, M. (2016). Managing program impacts in new product development: An exploratory case study on overcoming uncertainties. *International Journal of Project Management*, *34*(4), 717–733. https://doi.org/10.1016/j.ijproman.2016.02.011

Langley, a., & Abdallah, C. (2011). Templates and Turns in Qualtative Studies of Strategy and Management. *Research Methodology in Strategy and Management*, *6*(2011), 201–235. https://doi.org/10.1108/S1479-8387(2011)0000006007

Lavie, D., Stettner, U., & Tushman, M. L. (2010). Exploration and Exploitation Within and

Across Organizations. *Academy of Management Annals*, *4*(1), 109–155. https://doi.org/10.1080/19416521003691287

Leifer, R., Mcdermott, C. M., O'Connor, G. C., Peters, L. S., Rice, M. P., & Veryzer, R. W. (2000). *Radical innovation: How mature companies can outsmart upstarts* (1st ed.). Harvard Business Press.

Lenfle, S., & Loch, C. (2010). Lost Roots: How Project Management Came to Emphasize Control Over Flexibility and Novelty. *California Management Review*, *53*(1), 32–55.

Lenfle, S., Midler, C., & Ha, M. (2019). Exploratory Projects : From Strangeness to Theory. *Project Management Journal*, *50*(5), 519–523. https://doi.org/10.1177/8756972819871781

Lerch, M., & Spieth, P. (2013). Innovation project portfolio management: A qualitative analysis. *IEEE Transactions on Engineering Management*, *60*(1), 18–29. https://doi.org/10.1109/TEM.2012.2201723

Lettice, F., & Thomond, P. (2008). Allocating resources to disruptive innovation projects: challenging mental models and overcoming management resistance. *International Journal of Technology Management*, *44*(1/2), 143–159. https://doi.org/10.1504/ijtm.2008.020702

Martin, J. A., & Eisenhardt, K. M. (2010). Rewiring: Cross-business-unit collaborations in multibusiness organizations. *Academy of Management Journal*, *53*(2), 265–301. https://doi.org/10.5465/AMJ.2010.49388795

Markowitz, H. (1952). Portfolio Selection. *The Journal of Finance*, *7*(1), 77–91. https://doi.org/10.1111/j.1540-6261.1952.tb01525.x

McGrath, R. G. (1997). A Real Options Logic for Initiating Technology Positioning Investments. *The Academy of Management Review*, *22*(4), 974. https://doi.org/10.2307/259251

McGrath, R. G., & Nerkar, A. (2004). Real options reasoning and a new look at the R&D investment strategies of pharmaceutical firms. *Strategic Management Journal*, *25*(1), 1–21. https://doi.org/10.1002/smj.358

Meifort, A. (2015). Innovation Portfolio Management : A Synthesis and Research Agenda. *Creativity & Innovation Management*, *25*(2), 1–19.

Miles, M. B., Huberman, M. a, & Saldana, J. (1994). Drawing and Verying Conclusions. In *Qualitative Data Analysis: A Methods Sourcebook* (pp. 276–322). https://doi.org/January 11, 2016

Mol, M. J., & Birkinshaw, J. (2009). The sources of management innovation: When firms

introduce new management practices. *Journal of Business Research*, *62*(12), 1269–1280. https://doi.org/10.1016/j.jbusres.2009.01.001

Myers, S. C. (1977). Determinants of Corporate Borrowing. *Journal of Financial Economics*, *5*, 147–175.

O'Connor, G. C., & McDermott, C. M. (2004). The human side of radical innovation. *Journal of Engineering and Technology Management*, *21*(1–2), 11–30. https://doi.org/10.1016/j.jengtecman.2003.12.002

O'Connor, G. C. (2008). Major innovation as a dynamic capability: A systems approach. *Journal of Product Innovation Management*, *25*(4), 313–330. https://doi.org/10.1111/j.1540-5885.2008.00304.x

O´Connor, G. C., Leifer, R., Paulson, A. S., & Peters, L. S. (2008). *Grabbing lightning: bulding a capability for breakthrough innovation* (1 ed.). São Francisco, EUA: John Wiley & Sons, Inc.

O'Connor, G. C. (2012). Innovation: From process to function. *Journal of Product Innovation Management*, *29*(3), 361–363. https://doi.org/10.1111/j.1540-5885.2012.00909.x

O'Connor, G. C., Corbett, A. C., & Peters, L. S. (2018). *Beyond the Champion: Institutionalizing Innovation Through People*. Stanford, California: Stanford University Press.

O´Reilly, C. A., Harreld, B. J., & Tushman, M. L. (2009). Organizational ambidexterity: IBM and emerging business opportunities. *California Management Review*, *51*(4), 75–99.

O'Reilly, C. A., & Binns, J. M. (2019). The Three Stages of Disruptive Innovation: Idea Generation, Incubation, and Scaling. *California Management Review*, *61*(3), 49–71. https://doi.org/10.1177/0008125619841878

Oliveira, M. G., & Rozenfeld, H. (2010). Integrating technology roadmapping and portfolio management at the front-end of new product development. *Technological Forecasting and Social Change*, *77*(8), 1339–1354. https://doi.org/10.1016/j.techfore.2010.07.015

Paulson, A. S., Connor, G. C. O., & Robeson, D. (2007). Evaluating radical innovation portfolios. *Research-Technology Management*, *50*(5), 17–29.

Pich, M. T., Loch, C. H., & Meyer, A. De. (2002). On uncertainty , ambiguity , and complexity in project management. *Management Science*, *48*(8), 1008–1023.

Raisch, S., & Birkinshaw, J. (2008). Organizational Ambidexterity: Antecedents, Outcomes, and Moderators. *Journal of Management*, *34*(3), 375–409.

https://doi.org/10.1177/0149206308316058

Rice, M. P., Connor, G. C. O., & Pierantozzi, R. (2008). Implementing a Learning Plan to Counter Project Uncertainty. *MIT Sloan Management Review*, *49*(2), 54–62.

Santiago, L.P., & Bifano, T. G. (2005). Management of R&D Projects Under Uncertainty: A Multidimensional Approach to Managerial Flexibility. *IEEE Transactions on Engineering Management*, *52*(2), 269–280. https://doi.org/10.1109/TEM.2005.844465

Santiago, Leonardo P., & Vakili, P. (2005). On the Value of Flexibility in R&D Projects. *Management Science*, *51*(8), 1206–1218. https://doi.org/10.1287/mnsc.1050.0387

Schneider, M., Tejeda, M., Dondi, G., Herzog, F., Keel, S., & Geering, H. (2008). Making real options work for practitioners: A generic model for valuing R&D projects. *R and D Management*, *38*(1), 85–106. https://doi.org/10.1111/j.1467-9310.2007.00500.x

Schumpeter, J. A. (1942). *Capitalism, Socialism & Democracy*. (Harper & Brothers, Ed.), *Comparative Biochemistry and Physiology. Part C, Comparative* (1st ed.). New York, NY. https://doi.org/10.1016/0306-4492(75)90020-9

Shaikh, I. A., & O'Connor, G. C. (2020). Understanding the motivations of technology managers in radical innovation decisions in the mature R&D firm context: An Agency theory perspective. *Journal of Engineering and Technology Management - JET-M*, *55*(September 2018). https://doi.org/10.1016/j.jengtecman.2020.101553

Silva, D. O. Da. (2016). *Gestão de portfólio de projetos de inovação: análise das práticas adotadas por empresas industriais de grande porte*. Universidade de São Paulo.

Slater, S. F., Mohr, J. J., & Sengupta, S. (2014). Radical product innovation capability: Literature review, synthesis, and illustrative research propositions. *Journal of Product Innovation Management*, *31*(3), 552–566. https://doi.org/10.1111/jpim.12113

Söderlund, J., & Tell, F. (2011). Strategy and capabilities in the P-form corporation: Linking strategic direction with organizational capabilities. *Advances in Strategic Management*, *28*(2), 235–262. https://doi.org/10.1108/S0742-3322(2011)0000028013

Sommer, S. C., & Loch, C. H. (2004). Selectionism and Learning in Projects with Complexity and Unforeseeable Uncertainty. *Management Science*, *50*(10), 1334–1347. https://doi.org/10.1287/mnsc.1040.0274

Spieth, P., & Lerch, M. (2014). Augmenting innovation project portfolio management performance: the mediating effect of management perception and satisfaction. *R&D*

Management, *44*(5), 498–515. https://doi.org/10.1111/radm.12092

Stringer, R. (2000). How to Manage Radical Innovation. *California Management Review*, *42*(4), 70–88. https://doi.org/10.2307/41166054

Terwiesch, C., & Ulrich, K. (2008). Managing the opportunity portfolio. *Research-Technology Management*, *51*(5), 27–38. https://doi.org/10.1080/08956308.2008.11657523

Trigeorgis, L. (1996). *Real Options: Managerial Flexibility and Strategy in Resource Allocation* (1ed ed.). Cambridge, USA: MIT Press. Retrieved from http://books.google.com/books?id=Z8o20TmBiLcC&pgis=1

Tripsas, M., & Gavetti, G. (2000). Capabilities, Cognition, and Inertia: Evidence from Digital Imaging. *Strategic Management Journal*, *21*(10/11), 1147–1161. Retrieved from http://www.jstor.org/stable/3094431

Tushman, M. L., & Anderson, P. (1986). Technological Discontinuities and Organizational Environments. *Administrative Science Quarterly*, *31*(3), 439. https://doi.org/10.2307/2392832

Wang, J., Wang, C.-Y., & Wu, C.-Y. (2015). A real options framework for R&D planning in technology-based firms. *Journal of Engineering and Technology Management*, *35*, 93–114. https://doi.org/10.1016/j.jengtecman.2014.12.001

Wilden, R., Devinney, T. M., & Dowling, G. R. (2016). The Architecture of Dynamic Capability Research Identifying the Building Blocks of a Configurational Approach. *The Academy of Management Annals*, *10*(1), 997–1076. https://doi.org/10.1080/19416520.2016.1161966

Winter, S. G. (2003). Understanding dynamic capabilities. *Strategic Management Journal*, *24*(10), 991–995. https://doi.org/10.1002/smj.318

Yin, R. K. (2006). Case Study Reserach - Design and Methods. *Clinical Research*, *2*, 8–13. https://doi.org/10.1016/j.jada.2010.09.005

Zschocke, M. S., Mantin, B., & Jewkes, E. M. (2014). The effect of competition on R&D portfolio investments. *Production and Operations Management*, *23*(8), 1439–1449. https://doi.org/10.1111/j.1937-5956.2012.01376.x

APPENDEXES

APPENDIX A – Paper #1: Valuation of innovation projects with high uncertainty: Reasons behind the search for real options

Brasil, Vinicius Chagas, Salerno, M. S., & Gomes, L. A. de V. (2018). Valuation of innovation projects with high uncertainty: Reasons behind the search for real options. *Journal of Engineering and Technology Management*, *49*, 109–122.

DOI: https://doi.org/10.1016/j.jengtecman.2018.08.001

Download PDF Share Export

ELSEVIER

Journal of Engineering and Technology Management

Volume 49, July–September 2018, Pages 109-122

Valuation of innovation projects with high uncertainty: Reasons behind the search for real options

Vinicius Chagas Brasil [a], Mario Sergio Salerno [a], Leonardo Augusto de Vasconcelos Gomes [b]

Show more

https://doi.org/10.1016/j.jengtecman.2018.08.001 Get rights and content

Abstract

Real Options (RO) has been indicated to valuate projects with high uncertainty. However, literature points to challenges and asks for an organizational understanding of its use. So: Why do managers search for the RO approach to valuate radical innovation projects? Based on five in-depth case studies, we discuss hidden organizational and managerial issues related to the search for RO to valuate radical innovation. We argue that managers search for RO to cope with the "paradox of organizational fit", and later, to deal with the "newness prison", employing RO Structuring and RO Integration to allow exposure to radical innovation.

Previous article in issue Next article in issue

JEL classifications

M11 Production Management; O30 General; O31 Innovation and Invention: Processes and Incentives; O32 Management of Technological Innovation and R&D

Keywords

Innovation Management; Radical Innovation; Project Valuation; Uncertainty Management; Real Options

APPENDIX B – Paper #2: Multilevel approach for Real Options in the innovation management process: integrating project, portfolio and strategy

Brasil, Vinicius Chagas, Gomes, L. A. V., Salerno, M. S., & de Paula, R. A. S. R. (2017). Multilevel approach for Real Options in the innovation management process: integrating project, portfolio and strategy. In International Research Network on Organizing by Projects (IRNOP) (pp. 1–14).

DOI: https://doi.org/10.5130/pmrp.irnop2017.5680

International Research Network on Organizing by Projects (IRNOP) 2017

11-14 June 2017

Citation: Brasil, V. C., Gomes, L. A. V., Salerno, M. S. and de Paula, R. A. S. R. 2017. Multilevel approach for Real Options in the innovation management process: integrating project, portfolio and strategy. *International Research Network on Organizing by Projects (IRNOP) 2017*, UTS ePRESS, Sydney: NSW, pp. 1-14. https://doi.org/10.5130/pmrp.irnop2017.5680

Published by UTS ePRESS | http://pmrp.epress.lib.uts.edu.au

CONFERENCE PAPER

Multilevel approach for Real Options in the innovation management process: integrating project, portfolio and strategy

Vinicius Chagas Brasil[1]*, Leonardo Augusto Vasconcelos Gomes[2], Mario Sergio Salerno[3], Rafael Augusto Seixas Reis de Paula[4]

[1]Production Engineering Department. University of São Paulo, Brazil. viniciuscbrasil@usp.br
[2]Business Administration Department. University of São Paulo, Brazil. lavgomes@usp.br
[3]Production Engineering Department. University of São Paulo, Brazil. msalerno@usp.br
[4]Production Engineering Department. University of São Paulo, Brazil. rafaelaugustoseixas@usp.br

***Corresponding author:** Vinicius Chagas Brasil, University of São Paulo, Brazil. viniciuscbrasil@usp.br

Name: International Research Network on Organizing by Projects (IRNOP) 2017

Location: Boston University, United States

Dates: 11-14 June 2017

Host Organisation: Metropolitan College at Boston University

DOI: https://doi.org/10.5130/pmrp.irnop2017.5680
Published: 07/06/2018

Synopsis

The Real Options approach used by innovative firms has been largely studied considering three different levels: strategy level, innovation portfolio level and project level. The theoretical discussion, however, is still unclear about how to integrate these three levels. The main goal is to identify how it is possible to integrate the Real Options approach on project, portfolio and strategy levels.

Research design

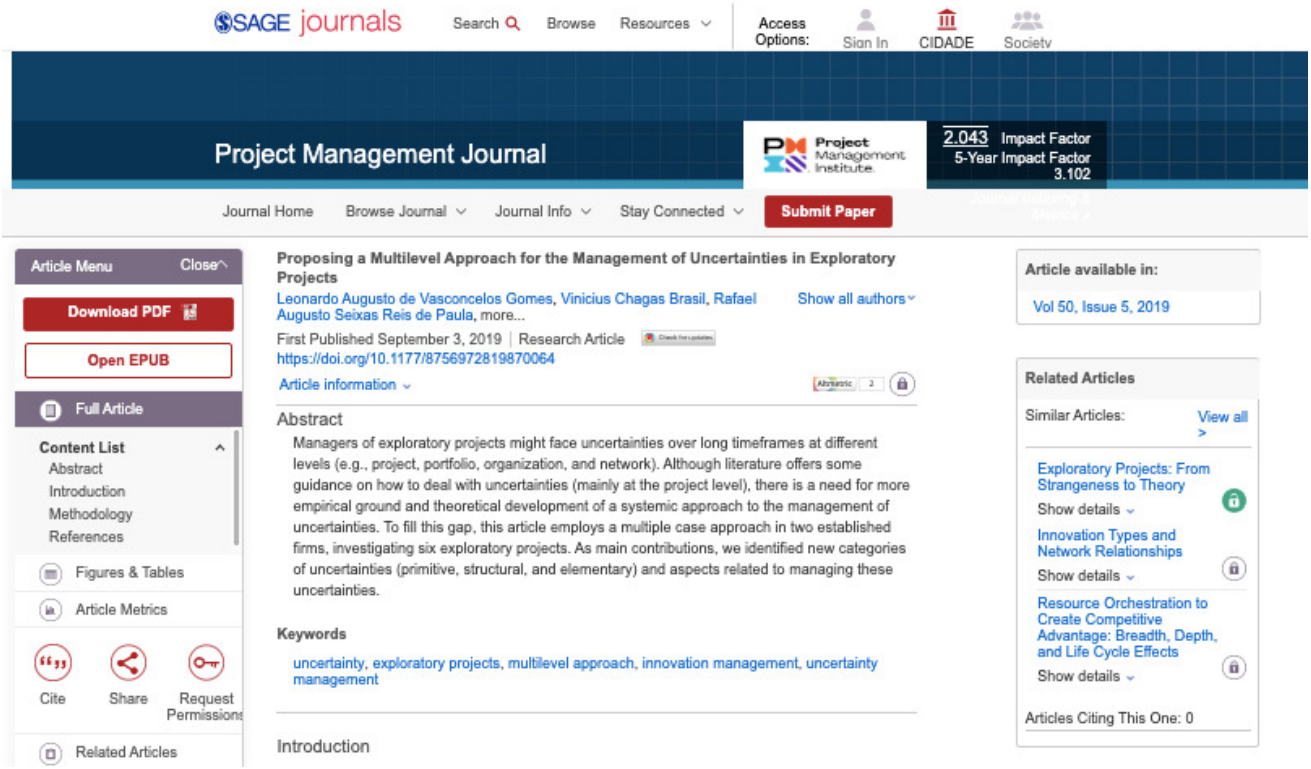
Based on four in-depth case studies and on grounded research in companies in Brazil, where we have longitudinally accompanied specific projects, we propose a discussion on the main

DECLARATION OF CONFLICTING INTEREST The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. **FUNDING** The author(s) received no financial support for the research, authorship, and/or publication of this article.

APPENDIX C – Paper #3: Proposing a multilevel approach for the management of uncertainties in exploratory projects

Gomes, L. A. de V., Brasil, V. C., Facin, A. L. F., de Paula, R. A. S. R., Gomes, F. de V., & Salerno, M. S. (2019). Proposing a Multilevel Approach for the Management of Uncertainties in Exploratory Projects. Project Management Journal, 50(5), 1–17.

DOI: https://doi.org/10.1177/8756972819870064

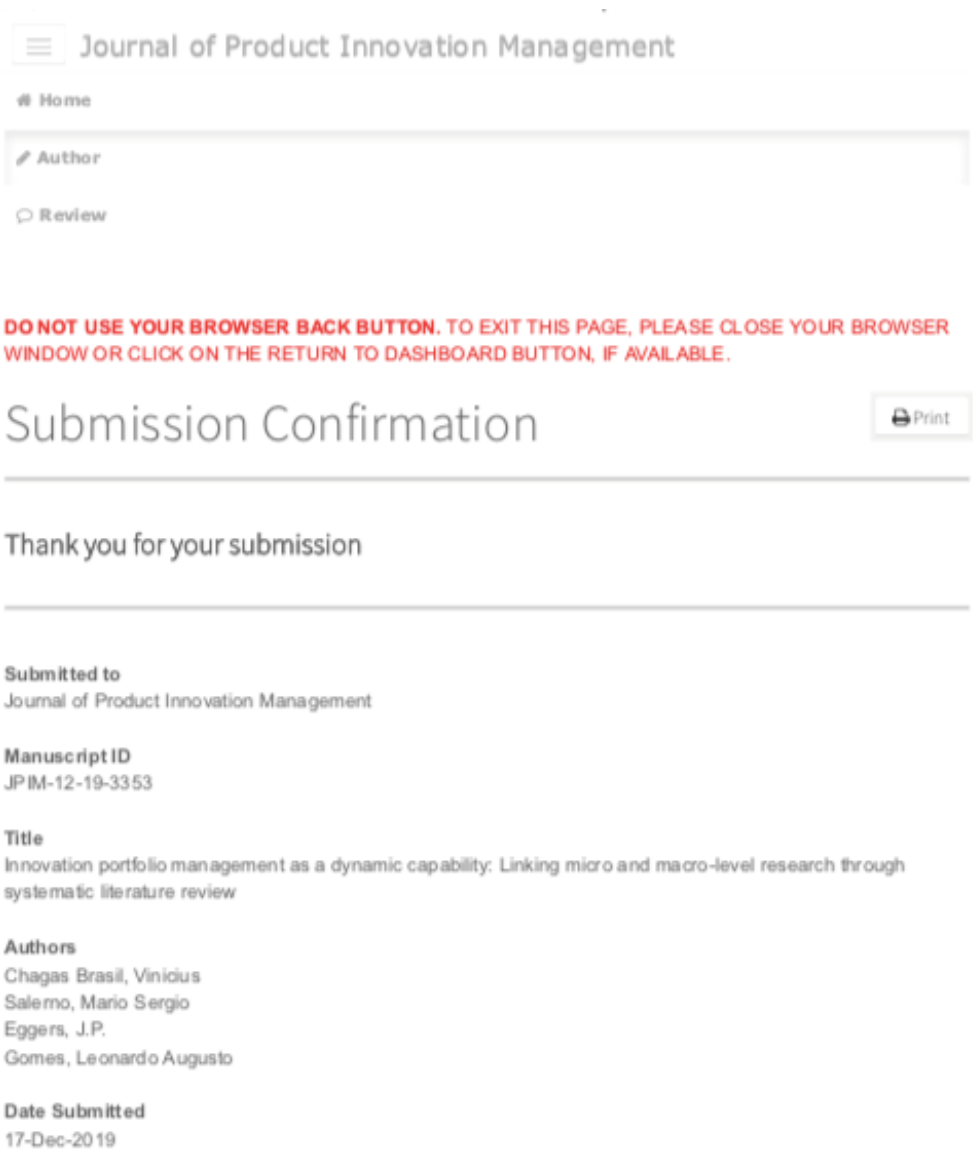


APPENDIX D – Paper #4: Product and Innovation Portfolio Management

Brasil, Vinícius Chagas, & Eggers, J. P. (2019). Product and Innovation Portfolio Management. In Oxford Research Encyclopedia of Business and Management (p. 1–31). DOI: https://doi.org/10.1093/acrefore/9780190224851.013.28

APPENDIX E – Paper #5: Innovation portfolio management as a dynamic capability: Linking micro- and macro-level research through systematic literature review

Brasil, Vinicius Chagas, Salerno, M. S., Eggers, J. P., & Gomes, L. A. de V. Under review at the Journal of Product Innovation Management.



Journal of Product Innovation Management

Home

Author

Review

DO NOT USE YOUR BROWSER BACK BUTTON. TO EXIT THIS PAGE, PLEASE CLOSE YOUR BROWSER WINDOW OR CLICK ON THE RETURN TO DASHBOARD BUTTON, IF AVAILABLE.

Submission Confirmation

Print

Thank you for your submission

Submitted to
Journal of Product Innovation Management

Manuscript ID
JPIM-12-19-3353

Title
Innovation portfolio management as a dynamic capability: Linking micro and macro-level research through systematic literature review

Authors
Chagas Brasil, Vinicius
Salerno, Mario Sergio
Eggers, J.P.
Gomes, Leonardo Augusto

Date Submitted
17-Dec-2019

Innovation portfolio management as a dynamic capability: Linking micro and macro-level research through systematic literature review

Abstract

A firm's innovation project portfolio must support current product lines (typically through incremental innovation) and build for the future (often through more radical innovation). As a result, the ability to manage the innovation portfolio has implications for both short and long-term performance. Despite the recognition of the differences between incremental and radical innovation, and substantial research focus on the enablers of radical innovation, the fragmented nature of the existing literatures on portfolio management creates many untapped opportunities. Specifically, research has focused on micro-level aspects related to project and process elements of portfolio management, or on macro-level aspects regarding environmental, political and organizational elements, but the two levels are largely disconnected. This lack of integration hampers both theoretical development and practical application of frameworks.

To integrate and systematize micro and macro levels, we performed a systematic literature review based on bibliometric and content analysis in order to identify research streams and theoretical perspectives. By analyzing 127 articles, we present descriptive statistics, citation, co-citation and bibliometric coupling networks. In sequence, we aggregate almost a hundred topics focused in IPM literature into 17 meso-groups and further on five levels of IPM approaches: individual, project, portfolio, strategic and environmental levels. This synthesis allows us to offer a multi-level theoretical framework defining IPM as a dynamic capability. We outline the development of IPM ambidextrous capacity (IPM structural separation), which consists of multilevel IPM separation to protect radical innovation. We argue that the IPM dynamic capability shapes radical innovation management performance and conclude with theoretical propositions to guide future research.

Key words: Portfolio management; Innovation management; Radical Innovation; Bibliometric analysis; Dynamic capabilities.

APPENDIX F – Paper #7: Innovation portfolio ambidextrous management: Guidelines to boost radical innovation

Brasil, Vinicius Chagas, Salerno, M. S., Eggers, J. P., & Gomes, L. A. de V.

Under review at Research-Technology Management.

Research-Technology Management

Innovation Portfolio Ambidextrous Management: Guidelines To Boost Radical Innovation

--Manuscript Draft--

Manuscript Number:	
Article Type:	Article
Full Title:	Innovation Portfolio Ambidextrous Management: Guidelines To Boost Radical Innovation
Short Title:	Innovation Portfolio Ambidextrous Management: Guidelines To Boost Radical Innovation
Manuscript Classifications:	Innovation Typology/Model; Organization and Culture; R&D Integration w/Business; Portfolio Management; Project Portfolio; Innovation Portfolio; Tools and Techniques; Portfolio Evaluation Tools
Keywords:	Radical Innovation Portfolio Management Innovation Portfolio Management Project Portfolio Management Innovation Innovation Management Multi-level analysis
Abstract:	Managing an innovation portfolio is crucial for firms looking to foster radical innovation. Radical innovation, however, imposes challenges for traditional portfolio management systems, given uncertainty and unfamiliarity with such operations. If not managed by systems and tools that consider the distinction between incremental and radical innovation, portfolio management decision-making processes will tend to favor incremental innovation. We argue that tools and methods to protect radical innovation do not comprehensively address the problem, which requires a broader, multi-level organizational approach. Following our experiences in three research programs focused on radical innovation, we propose a multi-level framework for innovation portfolios based on three designing and managerial mechanisms: portfolio management separation; portfolio management fit; and portfolio management alignment. We suggest guidelines for ambidextrous portfolio management capable of establishing a strong separation between incremental and radical projects, supporting a more fruitful management environment for radical innovation.
Corresponding Author:	Vinicius Brasil Universidade de Sao Paulo São Paulo, São Paulo BRAZIL
Corresponding Author E-Mail:	viniciuscbrasil@usp.br
Order of Authors:	Vinicius Brasil
	Mario Sergio Salerno
	J.P. Eggers
	Leonardo Augusto de Vasconcelos Gomes
Manuscript Region of Origin:	BRAZIL
Author Comments:	