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Instituto de Geociências

DIEGO RAFAEL DE MORAES SILVA

OBSTACLES TO INNOVATION IN BRAZIL: AN EMPIRICAL ANALYSIS BASED ON THE BRAZILIAN INNOVATION SURVEY (PINTEC)

OBSTÁCULOS À INOVAÇÃO NO BRASIL: UMA ANÁLISE EMPÍRICA BASEADA NA PESQUISA DE INOVAÇÃO (PINTEC)

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INSTITUTO DE GEOCIÊNCIAS

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Dedico esta tese a Deus, pelos dons da vida e do amor

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“Toda inovação é científica, tecnológica e social. Ela implica mudanças de hábito e uma nova forma de conviver. Portanto, é um processo coletivo que, de fato, é conduzido pela sociedade. A empresa tem um lugar especial, mas há um complexo de atores que gravita em torno dela. A melhor expressão que eu conheço para isso é de um etnólogo francês, Marcel Mauss, que diz que a inovação é um fato social ‘total’”

– Evando Mirra (2011)

“These phenomena [‘Total’ Social Facts] are at once legal, economic, religious, aesthetic, morphological and so on. They are legal in that they concern individual and collective rights, organized and diffuse morality; they may be entirely obligatory, or subject simply to praise or disapproval. They are at once political and domestic, being of interest both to classes and to clans and families. They are religious; they concern true religion, animism, magic and diffuse religion mentality. They are economic, for the notion of value, utility, interest, luxury, wealth, acquisition, accumulation, consumption and liberal and sumptuous expenditure are all present”

– Marcel Mauss ([1950] 1966)

“The entrepreneur must be someone special because he has to be able to break through the resistance to change that exists in any society. Most people are unable to do this; they can only handle what is familiar to them. The entrepreneur, on the other hand, has the strength and the courage to challenge the accepted ways of doing things and to sweep aside the forces of tradition […]. That there exist some similarities between Schumpeter’s heroic entrepreneur and Weber’s charismatic leader is obvious”

– Richard Swedberg (1991)

RESUMO

Esta tese de doutorado discute o papel dos obstáculos à inovação sobre a inovatividade das empresas no Brasil. Diante de um contexto de baixo desempenho inovador no país, apostamos na análise das barreiras à inovação como um caminho frutífero para entender alguns dos mecanismos que explicam as dificuldades de inovação no Brasil. Para isso, usamos os dados da sexta edição da Pesquisa de Inovação (PINTEC 2014) para realizar análises estatísticas e demonstrar a utilidade dos indicadores para políticas baseadas em evidências a fim de abordar alguns dos desafios do Brasil na busca pela inovação. Nosso estudo começa por uma minuciosa revisão da literatura teórica e histórica, abordando as origens dos estudos da inovação. Nós demonstramos que as barreiras à inovação estão intimamente relacionadas tanto ao desenvolvimento teórico do conceito de inovação quanto ao interesse direcionado pela política nos debates sobre inovação. A partir desta revisão, construímos um quadro conceitual geral que abrange as relações entre determinantes, obstáculos e políticas de inovação. Diferentemente da maioria dos estudos empíricos, conceituamos o papel dos obstáculos à inovação como moderador que intervém na relação entre determinantes e inovatividade, afetando a inovação apenas indiretamente. Da mesma forma, também nos distanciamos da literatura empírica existente à medida que concebemos o papel das políticas de inovação não como determinantes, mas como fatores que desempenham o papel de destravar o efeito benéfico dos determinantes pela erosão do efeito maléfico das barreiras. Posteriormente, adequamos esse quadro conceitual geral aos dados disponibilizados pela PINTEC 2014, chegando a um modelo conceitual operacional que infelizmente perde parte das variáveis identificadas na revisão de literatura devido à indisponibilidade de dados. Nosso desenho de pesquisa empírica compreende duas etapas metodológicas: i. a estimação de modelos econométricos, mais especificamente Modelos de Regressão Multinomial Logística, avaliando tanto a associação de determinantes à inovatividade da empresa, quanto a moderação de obstáculos sobre esta associação; ii. a aplicação de técnicas de pareamento, mais especificamente Pareamento por Escore de Propensão, avaliando o efeito potencial de políticas de inovação sobre a prevalência de barreiras à inovação entre empresas tratadas e não tratadas pelas políticas. Os resultados econométricos mostram que a maioria dos determinantes está positivamente associada à inovatividade das empresas, mas quando a moderação por obstáculos é introduzida, alguns deles são fortemente prejudicados. No que diz respeito às políticas de inovação, os resultados mostram que apenas algumas delas conseguiram diminuir a percepção das barreiras à inovação entre as empresas que recebem o tratamento. Entretanto, nossos resultados devem ser lidos com bastante cautela, uma vez que existem algumas limitações importantes em jogo devido principalmente ao fato de que usamos dados transversais para nossas análises. Apesar dessas limitações, que nos impedem de alegar causalidade em nossos resultados, o estudo aqui conduzido contribui para a literatura ao fornecer uma abordagem perspicaz para modelar as várias relações entre determinantes, obstáculos e políticas de inovação em diferentes contextos e também contribui para os debates sobre políticas de inovação no Brasil, fornecendo algumas recomendações baseadas em evidências para abordar as barreiras à inovação existentes no país.

Palavras-chave: Inovação tecnológica – pesquisa; Política de ciência e tecnologia; Sistema de inovação.

ABSTRACT

This doctoral thesis discusses the role of obstacles to innovation over company innovativeness in Brazil. Faced with a context of low innovation performance in the country, we bet on the analysis of innovation barriers as a fruitful path to understand some of the mechanisms that account for the innovation difficulties in Brazil. To do so, we relied on the data from the sixth edition of the Brazilian Innovation Survey (PINTEC 2014) to run statistical analyses while showcasing the potential usefulness of evidence-based policy advice for addressing some of the challenges of Brazil in the pursuit of innovation and, ultimately, socio-economic progress. Our study starts by a thorough review of the theoretical and historical literature addressing the origins of the innovation studies. We demonstrate that the innovation barriers are intimately related to both the theoretical development of the innovation concept and the policy-driven interest on innovation debates. From this literature review, we build a general conceptual framework encompassing the relationships between innovation determinants, obstacles and policies Differently from most empirical studies, we conceptualize the role of obstacles to innovation as a moderator intervening in the relationship between determinants and innovativeness, and hence affecting innovativeness only indirectly. Similarly, we also distance ourselves from the extant empirical literature as we conceptualize the role of innovation policies not as typical determinants of innovation, but as factors that play the role of unlocking the potential beneficial effect of determinants by eroding the malefic effect of barriers. Afterwards, we fit this general conceptual framework to the data available from PINTEC 2014, then achieving an operational conceptual model that unfortunately loses part of the variables identified in the literature review due to data unavailability. Our empirical research design comprehends two methodological steps: i. the estimation of econometric models, more specifically Multinomial Logistic Regression Models, assessing both the association of determinants to company innovativeness and the moderation of obstacles to innovation over this association; ii. the application of matching techniques, more specifically Propensity Score Matchings, assessing the potential effect of innovation policies over the prevalence of innovation barriers among treated and untreated companies. The econometric results show that most determinants are positively associated to company innovativeness, but when the moderation by obstacles to innovation is introduced some of them are strongly hindered. As regards the innovation policies, results show that just a few of them have been able to lower down the perception of innovation barriers among companies receiving the policy treatment. However, our results must be read with great caution, since there are some important limitations at play due mainly to the fact that we use cross-sectional data to run our analyses. Despite these limitations, that prevent us from claiming causality in our results, the study conducted herein contributes to the literature by providing an insightful approach to modelling the various relationships between innovation determinants, obstacles and policies at different contexts and also contributes to the innovation policy debates in Brazil by providing some evidence-based recommendations for addressing innovation barriers at play in the country.

Keywords: Technological innovation – research; Science and technology Policy; Innovation system.

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LIST OF ABBREVIATIONS

ANPEI	Associação Nacional de Pesquisa e Desenvolvimento das Empresas Inovadoras
ANT	Actor-Network Theory
ATE	Average Treatment Effect
ATET	Average Treatment Effect on the Treated
CAPES	Coordenação de Aperfeiçoamento de Pessoal de Nível Superior
CDM	Crépon-Duguet-Mairesse Model
CIS	Community Innovation Survey
CNAE	Classificação Nacional de Atividades Econômicas
CNPq	Conselho Nacional de Desenvolvimento Científico e Tecnológico
ECLAC	Economic Commission for Latin America and the Caribbean
EU	European Union
EUROSTAT	Statistical Office of the European Union
FINEP	Financiadora de Estudos e Projetos
FIT	Financement de l'Innovation Technologique
GDP	Gross Domestic Product
GERD	Gross Expenditure on Research and Development
IBGE	Instituto Brasileiro de Geografia e Estatística
IDB	Inter-American Development Bank
KIBS	Knowledge Intensive Business Services
LAC	Latin America and the Caribbean
MCA	Multiple Correspondence Analysis
MIP	Mannheim Innovation Panel
MLR	Multinomial Logistic Regression
NBER	National Bureau of Economic Research

NSF	National Science Foundation
OECD	Organization for Economic Co-operation and Development
OR	Odds Ratios
OSRD	Office of Scientific Research and Development
PBM	Plano Brasil Maior
PDP	Política de Desenvolvimento Produtivo
PIE	Programa Inova Empresa
PINTEC	Pesquisa de Inovação
PITCE	Política Industrial, Tecnológica e de Comércio Exterior
PSM	Propensity Score Matching
R&D	Research and Development
RICYT	Red de Indicadores de Ciencia y Tecnología
RRR	Relative-Risk Ratios
SciSIP	Science of Science and Innovation Policy
SCOT	Social Construction of Technology
SIAT	Survey of Innovation and Advanced Technology
SNA	System of National Accounts
SSRC	Social Science Research Council
S&T	Science and Technology
ST&I	Science, Technology and Innovation
STS	Science and Technology Studies
SYS	Stanford-Yale-Sussex Synthesis
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNU-MERIT	United Nations University – Maastricht Economic and Social Research Institute on Innovation and Technology

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Introduction

Context and motivation

Over the past couple of decades several countries in Latin America and the Caribbean (LAC) have made significant strides in developing policies to attract foreign investment (UNCTAD, 2017), reduce poverty and raise incomes (IDB, 2017). Nonetheless, scholars have found that:

> [D]espite success in macroeconomic stabilization and good progress in market-friendly structural reforms, the region has not achieved its expected high growth performance. While the accumulation of factors of production, both physical and human capital, has helped to narrow the income gap with the United States, productivity is low and its poor performance continues to be a drag to income convergence. (Crespi et al., 2014, Synopsis p.1)

Scholars have been asking what else the region could do in terms of productive development policies to spark productivity and growth. The same question underlines the basic motivation to this thesis. In contrast to Crespi et al. (2014) who focused on industrial policy across sectors, however, this study concentrates on technology and innovation strategies and policies. Specifically, we concentrate on private sector innovation capabilities and innovation propensity in the largest economy of Latin America: Brazil. Our attention falls primarily onto explaining innovation determinants across sectors and on deciphering the role of both financial and non-financial obstacles[1] in turning this propensity into innovative products (goods or services) and processes. Also, we seek to understand how effective various types of innovation policies have been in eroding these barriers to innovation in Brazil.

A recent report released by the World Bank argues that entrepreneurial activity in LAC suffers from an endemic innovation gap in comparison with more developed economies. Moreover, this gap extends well beyond the typical financial constraints, as the report says:

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[1] Obstacles have also been referred in the literature as barriers, constraints and inhibitors (Hadjimanolis, 2003), and although there may be subtle differences in the meaning of these terms, we use them interchangeably herein.

> Latin America and the Caribbean suffers from an innovation gap. On average, its entrepreneurs introduce new products less frequently, invest less in research and development, and hold fewer patents than entrepreneurs in other regions; moreover, their management practices are far from global best practices. A deficit in human capital for innovation, lack of competition, and inadequate intellectual property rights may explain the region's underperformance. (Lederman et al., 2014, p.61)

Barring a few top-performing firms, the innovations driving productivity growth in low- and middle-income economies differ from those in high-income ones. Most firms in the former economies engage in activities far from the technology frontier. They innovate by adopting and adapting products and processes already tested elsewhere (Grossman and Helpman 1991; Segerstrom 1991; Ayyagari et al, 2011). Cutting-edge innovation gradually becomes important as firms in a country close in to the world technology frontier (Acemoglu et al., 2006). LAC firms tend to score towards the lower end of the spectrum in product innovation. Firms in East Asia and Eastern Europe tend to introduce new products more frequently, conduct more research and development (R&D), and obtain foreign patents more often than LAC firms (Lederman et al, 2014). What accounts for such lackluster performance?

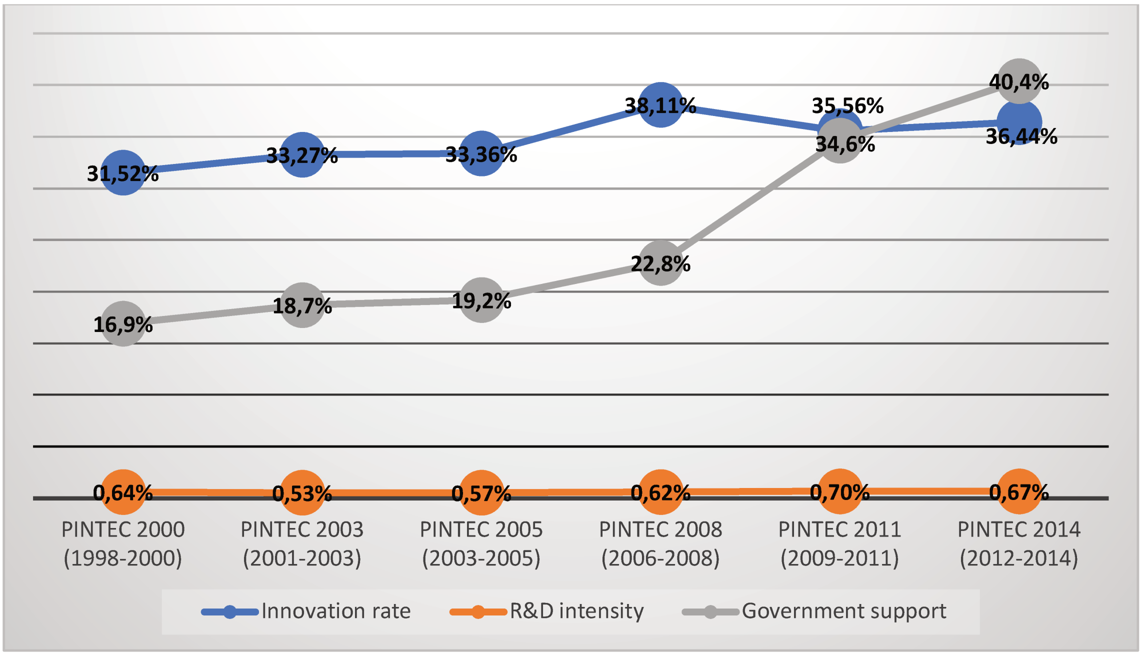
As regards the Brazilian case, the data from the sixth edition of the Brazilian Innovation Survey (*Pesquisa de Inovação* – PINTEC 2014) might be valuable in shedding light at some of these issues. This survey has been released in December 2016 by the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* – IBGE), providing detailed survey information on innovation output, R&D expenditure and personnel, sources of funding, sources of information, cooperative partnerships, innovation barriers, government support, among others. A striking conclusion that can be gleaned from the aggregate data is that the innovative performance in Brazil has been relatively stagnant in the last decade. Two indicators pointing out to this situation are shown in Figure 1: the innovation rate and the R&D intensity appear stabilized.

The innovation rate is calculated according to the proportion of firms that reported having introduced an innovation[2] in the period covered by the survey. In the last three

[2] The more general definition of the innovation rate considers the introduction of product or process innovation, regardless the novelty degree of such innovation (at the firm, country or world level).

editions of PINTEC, the innovation rate for the manufacturing sectors[3] in Brazil varied from 38.11% in the period 2006-2008, to 35.56% in 2009-2011, and then 36.44% in the last period 2012-2014. The R&D intensity from the Brazilian manufacturing sectors, calculated as the intramural R&D expenditure over the net sales revenue, had a similar behavior. It was 0.62% in PINTEC 2008, increasing to 0.70% in PINTEC 2011, but moving backwards again in PINTEC 2014 to 0.67%. However, the proportion of innovative firms using government support instruments has increased rapidly more recently indicating expanding role for public support. From 22.8% in the period 2006-2008, it now reached 40.4% in the last edition of PINTEC.

Figure 1 - Evolution of selected indicators of the Brazilian manufacturing sectors, 1998-2014 (%)



Source: Author's elaboration based on IBGE, 2002, 2005, 2007, 2010, 2013, 2016.

How does one make sense of this data? Which are the underlying forces behind such a counterintuitive scenario? Of course, it is very likely that there is a conjunctural aspect related to the global financial crisis in 2008 and the subsequent economic and political turmoil that took place in Brazil in the last few years. In this sense, the government support might probably be one of the factors explaining why the innovation

[3] Our comparisons rely only on the manufacturing sectors, as the survey universe has changed over the years with the inclusion of the electricity and gas sector and selected service sectors in the last editions.

indicators in the country are stabilized, and not free falling. Nevertheless, it seems to be undeniable that structural aspects also play a key role in this context, potentially preventing the efficacy of policy programs. But how to identify these aspects and address them with more targeted policies?

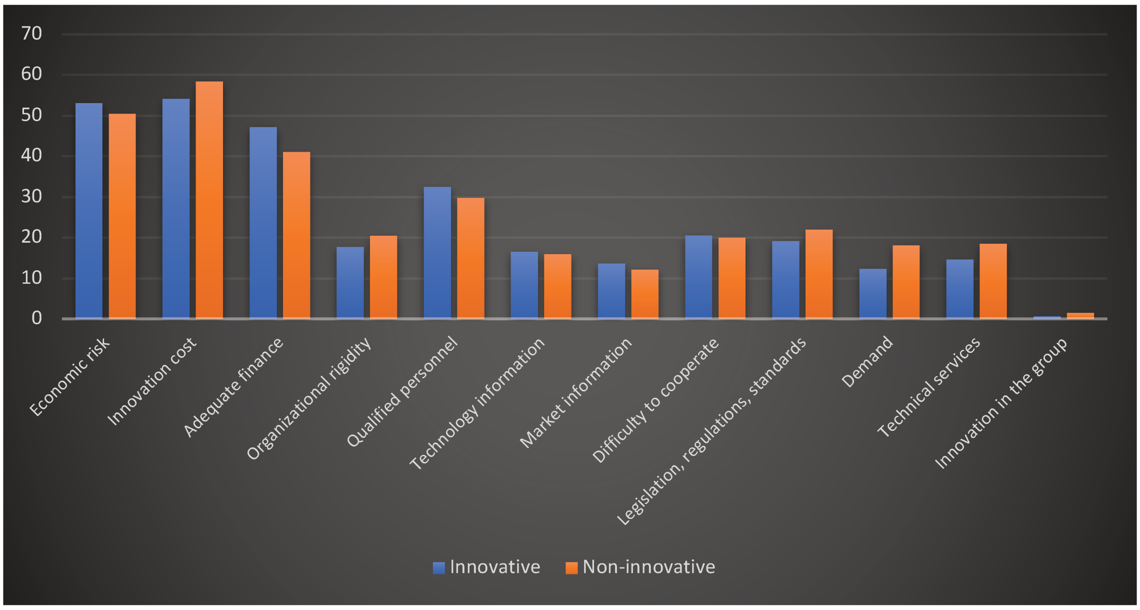
Since its first edition, the Oslo Manual, designed by the Organization for Economic Co-operation and Development (OECD) to provide guidelines for the innovation measurement, is emphatic about the importance to assess the obstacles to innovation for policy purposes (OECD, 1992). Indeed, the Oslo Manual highlights in its third edition that measuring the innovation barriers is especially relevant for developing countries, as doing so they might better understand and assist potentially innovative companies to overcome such obstacles (OECD, 2005). Thus, the assessment and understanding of innovation barriers appear as a fruitful path to tackle the paradoxical Brazilian context, rendering keen suggestions for changes on the current policy framework.

The first innovation survey to follow the Oslo Manual guidelines was prepared by the Statistical Office of the European Union (EUROSTAT) in the early 1990s and named Community Innovation Survey (CIS) (Smith, 2005). In Brazil, PINTEC is an innovation survey that since its beginnings in the early 2000s follows closely the guidelines of Oslo Manual as well, even though it has its own peculiarities, as a broader coverage of R&D information, for instance (Moraes Silva and Furtado, 2017). Therefore, as recommended by the Oslo Manual, PINTEC has a specific section dedicated to measure obstacles to innovation in the country, inquiring about the companies' perception of several factors as innovation barriers.

Although the innovation surveys provide a range of interesting data, and then one would expect that this data had a significant impact on designing and evaluating innovation policies worldwide, what some scholars have observed is that such surveys are systematically underused by policymaking both in Europe (Arundel, 2007) and Latin America (Baptista et al., 2010). In the specific case of PINTEC data on innovation barriers, they are mostly absent not only in the policymaking but also in the academic literature on innovation studies, with a few exceptions (e.g., Resende et al., 2014; Kannebley and Prince, 2015). That makes even timelier the use of PINTEC data to analyze the Brazilian innovation context in light of innovation barriers indicators.

A first glimpse of PINTEC aggregate data may provide interesting insights for various subjects (e.g., Moraes Silva et al., 2018), including innovation barriers, so that we must draw from it a big picture of the incidence of different obstacles to innovation across types of companies in the country. For instance, according to Figure 2, the degree of importance assigned to various factors hampering innovation is similar across innovative and non-innovative firms. Economic Risk, Innovation Cost and Adequate Finance Sources are perceived as the most important factors, while the Centralization of Innovation Elsewhere in the Group is perceived as the less important.

Figure 2 - Assignment of high importance to innovation barriers by Brazilian innovative and non-innovative firms, 2012-2014 (%)



Source: Author's elaboration based on IBGE, 2016.

The similarity among innovators and non-innovators in terms of perceived innovation barriers is inconsistent with recent findings pointing out to a distinction between revealed and deterring barriers to innovation (e.g., D'Este et al., 2012; Blanchard et al., 2013). Moreover, Figure 2 reiterates the more traditional perception of the dominant importance of financial obstacles over others, which also contradicts recent literature insisting that obstacles other than financial constraints (such as knowledge, network and organizational barriers, for instance) are very important as well (e.g., Coad et al., 2016; Pellegrino and Savona, 2017). These results invite for a closer look to PINTEC 2014 data, especially at the disaggregated level and through the application of econometrics.

Our research implements an in-depth analysis of PINTEC 2014 microdata in order to assess the effect of innovation barriers on firm innovativeness in Brazil, hypothesizing that obstacles to innovation play a moderation role over the relationship between determinants and innovativeness. The idea is to verify to which extent the various obstacles to innovation moderate the influence of several determinants of innovation (such as R&D, Size, Cooperation, and so on) over companies' innovativeness in recent years. Since companies rely on different determinants depending on their innovation strategy, we expect that the presence of innovation barriers might change companies' behavior, forcing them to adapt their strategies by resorting more (or less) to certain determinants than when obstacles are absent.

The bulk of the extant literature on obstacles to innovation has not considered whether and how firms change their strategy in response to perceived barriers (Antonioli et al., 2017; Moraes Silva et al., 2019), ultimately impacting their innovativeness. However, since several strategies may coexist within an industry with firms more or less willing to innovate (Blanchard et al., 2013), we sustain that analyzing the data at micro level from this perspective could render interesting results to figure out the unexpected aggregate results aforementioned and support some policy recommendations.

In addition, Pellegrino and Savona (2017) argue that one interesting area for future research would be assessing the differential effects of innovation barriers on the introduction of incremental and radical innovations. Indeed, the literature has pointed out that radical innovation barriers are a complex phenomenon per se on which the current theoretical and empirical understanding is limited (Sandberg and Aarikka-Stenroos 2014). The way we approach this issue herein is through the study of the effect of innovation barriers on the novelty level of firms' innovations. Firms that introduce an innovation with a higher novelty level (at world level, for example) would be expected to face more or different obstacles to innovation as certain problems are not effectively perceived until firms need to face them (Tourigny and Le, 2004). This expectation is also aligned with the recent literature findings on the different perceptions of obstacles according to the firms' engagement in innovation.

Finally, we also assess the extent to which the innovation policies in place in Brazil have been effective in putting innovation barriers down. As we saw in Figure 1, the basket of innovation policy programs in the country has expanded and diversified over the last years (De Negri and Rauen, 2018). Hence, understanding innovativeness in Brazil also demands taking the policy instruments into account. While it is important to theoretically conceive and empirically estimate the moderation role of the obstacles to innovation on the determinants that companies resort to innovate, it is also important to verify if the policy interventions have been successful in addressing the hindrances that companies face in the country. In the best scenario, there would be no obstacles and companies would be able to rely on the several determinants without any restriction. However, this idealized world is clearly utopian, as there will always be some level of constraints to the innovation activity in the various contexts, and the role of public policy is precisely to identify these barriers and tackle them as effectively as possible.

In short, this thesis seeks to analyze three distinct but connected relationships: i. The effect of determinants of innovation on companies' innovativeness in Brazil, which is a determination relationship; ii. The effect of obstacles to innovation on the determinants of innovation in Brazil, therefore moderating the previous determination relationship; iii. The effect of innovation policies on obstacles to innovation in Brazil, which can cancel the latter moderation relationship while unlocking the former determination relationship. As one can see, the ultimate goal of our analyses is to understand the innovativeness of Brazilian firms, but in order to achieve this understanding we will need to appraise a series of relationships between innovation determinants, obstacles and policies. One might also notice that each of these categories has a diverse nature to be taken into account, as when we talk about innovativeness we shall consider product and process innovation, as well as incremental and radical innovation, and when we talk about determinants, obstacles and policies we shall also consider their diversity (technological and social determinants, financial and non-financial obstacles, supply and demand policies, and so on and so forth).

All of this diversity will be considered in our econometric procedures to a certain extent. However, we ought to highlight that assuming such a complexity view on innovation must go hand-in-hand with a parsimonious and humble attitude towards our research goals. In this sense, we do not expect to be able to account herein for all the complexity that we observe in our theoretical framework, even because such a task would tend to infinite and likely generate analysis paralysis at the end. On the contrary, with this thesis we intend only to put a little brick on the broad wall of the innovation studies which embraces the complexity of the subject at the same time that accepts simplifications aiming to operationalize the research activity.

A final word of caution about our empirical setting is also necessary. As our database consists of cross-sectional data, we will not be able to claim causality in our analyses. Instead, we will only point out to statistically significant associations that might be suggestive for causal relationships, which ought to be more rigorously explored in other studies using panel data or experimental research, for instance. Although this represents an important limitation of our study, we still sustain that the empirical exercise carried out herein is of utmost relevance for understanding the state of innovation in Brazil, at least as a first step relying on an up-to-date and extensive database. Also, we truly expect that our results can shed some light to the main factors that enable and hamper the innovativeness in the country, as well as they can suggest which policies have been able to improve the current scenario and which ones should be strengthened to foster the national development.

Research questions and objectives

The study conducted herein is driven by two main research questions that complement and reinforce each other, which are the following:

1. To what extent the innovativeness of companies in Brazil has been affected by the moderation role of obstacles to innovation over determinants of innovation at play in recent years?
2. To what extent the Brazilian innovation policies have been effective in unlocking the potential of the determinants of innovation to convert into company innovativeness by eroding the innovation barriers at play in recent years?

In order to answer these questions, we will accomplish a set of objectives throughout this thesis that can be divided into general and specific ones. Thus, the main objectives of our research are the following:

- General Objectives:

i. Address market and systemic failures that may hinder innovation in Brazil;

ii. Deepen the theoretical understanding of the relationship between innovation determinants, obstacles and policies;

iii. Provide recommendation for policy domains that might reduce the efficacy of innovation barriers in hindering private sector innovation;

iv. Showcase the potential usefulness of evidence-based policy advice for addressing innovation challenges of the country in the pursuit of development;

- Specific Objectives:

i. Develop an overall theoretical model to assess the relationships between innovation determinants, obstacles and policies in the country;

ii. Assess the differential effects of determinants and obstacles over product and process innovativeness;

iii. Estimate the differential moderation role of obstacles to innovation over firm-specific and network-specific determinants of innovation;

iv. Appraise the particularities of financial and non-financial innovation barriers on the moderation relationships;

v. Evaluate the differential effects of a series of innovation policies for alleviating the obstacles to innovation at play in the country;

vi. Ascertain the existence of sectoral patterns of interaction driving the relationships between the various innovation determinants, obstacles and policies in the country;

Structure of the thesis

This thesis is divided into five chapters. Chapter 1 presents a thorough theoretical and historical discussion about the origins of the innovation studies and its implications for the study of obstacles to innovation. In order to understand the innovation barriers, we deemed that a detailed historical review on the general subject of the innovation concept and theory would be convenient. From our perspective, it would be impossible to have a clear understanding of the innovation barriers without knowing the nitty-gritty of the evolution of the innovation concept, encompassing its determinants, obstacles and policies. Hence the need of a such long chapter, which guides our discussion through different theoretical traditions in the social sciences with the aim of achieving a general conceptual framework that could help us to grasp the precise role of the obstacles to the innovation process.

Chapter 2 discusses the beginnings of the measurement of innovation barriers, as well as the linkage between the study of obstacles to innovation and a policy-driven approach towards science and technological progress. This chapter intends to show how the indicators to measure obstacles to innovation evolved hand-in-hand with the sophistication of the theoretical and conceptual understanding of innovation. At the same time, it also shows that the concern with innovation barriers was driven by a policy orientation since its early days, so that it is almost impossible to separate the two subjects. However, the chapter also touches upon the challenges of incorporating complex and up-to-date statistics into the innovation policy domain, especially within developing countries that have less tradition on evidence-based policymaking and struggle more often with policy discontinuity issues.

Chapter 3 presents our data source (sixth edition of the Brazilian Innovation Survey – PINTEC 2014) and the research design of our study. It starts by detailing the content of PINTEC 2014 database and the procedures we applied to select our relevant sample for the empirical exercises. At this point, we discuss the importance of working with a sample that filters out non-innovative companies unwilling to innovate from our study. Then it moves to the outline of the operational conceptual model and of the hypotheses that will be tested in this thesis, which basically fit the theoretical and conceptual review undertaken in Chapter 1 to the scope of PINTEC 2014 database. The construction of the variables to be used in the empirical analyses is discussed afterwards, paying special attention to the differentiation between independent variables (determinants of innovation), moderation variables (obstacles to innovation) and treatment variables (innovation policy instruments). To conclude, it explains the empirical methods that we will resort to in the statistical exercises: multinomial logistic regression models and propensity score matching techniques.

Chapter 4 presents both the descriptive statistics and the econometric results obtained in our empirical exercises. In the descriptive statistics, we show how our sample is composed in terms of companies' size strata, sectoral groups and innovativeness. The frequency statistics on the perception of obstacles to innovation are presented, as well as the mean values for the determinants of innovation under consideration in our study. Some tests for assessing the adequacy of the aggregated innovation barriers are also displayed. Lastly, frequency statistics on the use of innovation policy instruments are presented. As regards the econometrics, we present the results of the multinomial logistic regression models for product and process innovativeness separately. The models start by comprehending only the determinants of innovation as independent variables, and then adding one obstacle to innovation at a time to assess how each barrier moderate the relationship between determinants and innovativeness. Finally, we present the T-tests results of mean comparisons before and after the application of the technique of propensity score matchings to verify the effect of innovation policy programs on lowering down the perception of innovation barriers.

Chapter 5 discusses the main findings of the empirical analyses. The focus is in the statistically significant results that unveil the moderation role of the obstacles to innovation over determinants of innovation and, as a result, over companies' innovativeness in Brazil. We are mostly interested in assessing two types of moderation relationship: i. an activation effect – when obstacles to innovation lead to a statistically significant association between determinants and innovativeness that did not exist when the barriers were absent; ii. an inversion effect – when obstacles to innovation lead to a statistically significant association between determinants and innovativeness that is the opposite of the association found when the barriers were absent. Besides, we also take into consideration the main results on the treatment effect of innovation policy programs over the incidence of innovation barriers, paying special attention to the statistically significant T-tests results after the propensity score matching technique was applied to find proper control groups. The chapter closes with some broad theoretical and policy implications that could be drawn from our most consistent findings.

This doctoral thesis ends with some final remarks pointing out to the main achievements and limitations from our study. In terms of achievement, we stress that we managed to develop a powerful general conceptual framework to analyze the relationship between innovation determinants, obstacles and policies at different contexts. Notably, the understanding of the obstacles to innovation as moderators of the relationship between determinants and innovativeness is the main contribution of this thesis to the innovation studies in general, and to the analysis of the Brazilian case in particular. As regards the limitations, we highlight the methodological constraints of working with cross-sectional data and the consequent impossibility of claiming causality, as well as we emphasize the theoretical restrictions of addressing only companies willing to innovate in the analysis and just a minor set of innovation variables in our models, which are those variables typically regarding innovation as a market phenomenon. Despite these limitations, this thesis concludes with some auspicious remarks as regards a new trend in bringing together economic and social variables in the innovation measurements in the years to come, which will benefit a lot the study of obstacles to innovation.

Chapter 1 – The Role of the Obstacles to the Innovation Process

1.1. Innovation as a socio-economic phenomenon

1.1.1. The Schumpeterian legacy and the economics literature

More than a century ago, the Austrian economist Joseph A. Schumpeter ([1912] 1982) put forth in his book named *The Theory of Economic Development* that innovation is the fundamental phenomenon of economic development and is at the heart of the capitalist process. According to him, innovations are the cause to substantial changes taking place inside the economic system which shift it away from equilibrium position. Such position was defined by Schumpeter ([1912] 1982) in terms of a circular flow of economic life whose nature essentially passive and adaptive makes the system prone towards equilibrium. It does not mean that there are no changes occurring in the circular flow, but those are only continuous minor adjustments that can be analyzed through static lenses and usually emerge in response to factors external to the economic realm. The changes stemming from innovation, on the other hand, are discontinuous in their very nature, sometimes even "revolutionary", and arise from factors internal to the system, which ultimately lead to economic development and require dynamic theoretical apparatus to be analyzed.

Innovation was firstly defined by Schumpeter ([1912] 1982) as new business combinations which comprise five distinctive cases: I) Introduction of a new good into the market; II) Introduction of a new method into the productive process; III) Opening of a new market; IV) Conquest of a new source of supply of raw materials or half-manufactured goods; V) Carrying out of a new organization of any industry. The role of implementing innovations is played by entrepreneurs, which should not be confused with simple managers or businessmen insofar as the entrepreneurial function only refers to carrying out innovations, and not to professions or social classes. At this point, Schumpeter ([1912] 1982) also makes an important differentiation between innovation and invention arguing that it is not part of the entrepreneurial function to invent anything, since inventions are economically irrelevant before being put into practice. Of course, the entrepreneurial function could eventually be performed by managers or inventors, but not necessarily.

Years later, Schumpeter ([1939] 2017) would refine his theory elaborating an in-depth book called *Business Cycles*. In fact, this work was a sequel to his 1912[4] book on the theory of economic development, as in this early work he had laid down the basic theoretical tools to analyze innovation through a dynamic approach, and now, in his 1939 book, he would ambitiously apply it to explain the development of capitalism from its origins until that time (Swedberg, 1991). He argues in this book that three internal factors – changes in consumers' tastes, productive resources' growth, and innovation – interact and mutually condition each other in the process designated by him as "economic evolution". However, innovation alone must be considered as the outstanding fact in the economic history of capitalist society, since the changes in the economic process brought by innovation, together with their effects and the responses to them, constitute the core of economic evolution.

Schumpeter ([1939] 2017) also rephrases his definition of innovation in this new book. Although still comprehending the five cases aforementioned, now innovation is more rigorously defined in terms of setting up a new production function, which describes the way in which quantities of products vary if quantities of factors vary. This covers both the cases of new products, in which entirely new production functions are created, and the cases of introducing new methods of production, carrying out organizational changes, and so on, in which new production functions replace older ones. Once again, Schumpeter ([1939] 2017) conceives the economic system as constituted by a circular flow – or stationary flow – running through autonomous and adaptive change in a closed domain which merely reproduces itself at constant rates. This system is in a state of equilibrium[5] until entrepreneurs – usually manifested by the leadership of new men working on the construction of new plants or the foundation of new firms – introduce innovations into the system and shift it away from equilibrium generating economic evolution. In other words, according to Schumpeter's model, innovation carried out by entrepreneurs is the prime mover to business cycles – stages of prosperity, recession, depression and recovery – leading to economic evolution and development.

[4] According to Swedberg (1991), although it says on the title page of the book that it appeared in 1912, it was actually published in 1911.

[5] In this book, Schumpeter ([1939] 2017) uses "the concept of general or Walrasian equilibrium. It implies that every household and every firm in the domain is, taken by itself, in equilibrium." (Volume I, p. 42). Also, "our concept is akin to what Marshallian theory means by long-time equilibrium, if the conditions thus designated are satisfied for every individual element of the economic system." (Volume I, p. 45).

The emphasis on the entrepreneurs as individuals carrying out innovations to reap profits gave way to a new understanding in one of the last and most famous books by Schumpeter titled *Capitalism, Socialism and Democracy* from 1942. Some authors (e.g., Freeman et al., 1982; Coombs et al., 1987) even say that it is possible to distinguish between two models of the Schumpeterian analysis of innovation arising from his works: Schumpeter Mark I – based on his early works, especially *The Theory of Economic Development*, conceives the technological innovation as grounded on inventions exogenous to the economic system whose market potential is realized by individual entrepreneurs commonly starting new companies to achieve temporarily monopoly profits; Schumpeter Mark II – based on his late works, especially *Capitalism, Socialism and Democracy*, conceives the technological innovation as grounded mostly on endogenous scientific and technological activities conducted by large firms. Schumpeter ([1942] 2008) identified during the interwar period that large companies establishing R&D laboratories were becoming the main locus for innovation worldwide. In fact, he was so impressed by the intensity of how R&D activity was getting institutionalized within large companies that he foresaw the innovative entrepreneur as ultimately being superseded by a bureaucratized type of innovation (Freeman et al., 1982).

In his book from 1939 on business cycles, Schumpeter ([1939] 2017) had already noticed the existence of large companies fiercely pursuing innovation, but only as an incidental phenomenon. Notwithstanding, it made him stress that capitalism is a process subject to institutional change and therefore a variation of "trustified capitalism" could eventually replace the standard "competitive capitalism" with which economists were used to deal with (Schumpeter, [1939] 2017). Indeed, what he realized a few years later was that "trustified capitalism" had ceased to be an exception to become the rule, and innovation was getting more and more part of the routines within large firms. In fact, Schumpeter ([1942] 2008) argues that perfect competitive markets have actually never existed in a pure form in the real world, so the notion that a competitive firm would tend to maximize production in an equilibrated stationary economy is almost irrelevant to the work of empirical economists.

Nevertheless, perhaps the most important point that Schumpeter ([1942] 2008) makes in this book is that capitalism is an evolutionary process in which takes place "creative destruction" through the introduction of innovations that destroy the old economic structures while creating new ones. Put another way, the fundamental perspective to understand capitalism is not by means of studying the way the current economic structures are managed, but through analyzing how the capitalist process creates and destroys such structures. In order to do so, a new notion of competition is needful. Schumpeter ([1942] 2008) argues that the old notion of price competition must be replaced by an idea of innovation competition, which is the type of competition par excellence in capitalism. Such competition is much more efficient, since it does not only take effect when it is present, but also when constituting a constant menace. It implies that incumbent companies are constantly under threat that competitors introduce an improved product or process into the market and surmount them. In the long run, this competition would reduce the capacity of monopolistic practices to maintain privileged positions and would actually confer a positive effect to oligopolies inasmuch as some restrictive practices could contribute to ease temporary business difficulties due to cyclical circumstances typical within the creative destruction process.

Although the Schumpeterian legacy for studying innovation in economics is of utmost importance, the truth is that he himself has not properly provided a theory of innovation (Ruttan, 1959; Godin, 2008), but rather a theory of economic development and business cycles spurred by innovations at the heart of the capitalist process. In other words, he did not present arguments covering the three dimensions necessary to constitute a theory of innovation (Godin, 2010b): I) Sources; II) Diffusion; III) Impacts. In fact, Schumpeter focused much more in the third dimension, while only providing rudimentary analysis for the other two. In terms of sources of innovation, Schumpeter Mark I ([1912] 1982) vaguely argued that innovations are the result of the activities of the entrepreneurs driven by psychological motivations such as the desire to conquest or the joy of creating, while Schumpeter Mark II ([1942] 2008) identified the internalization of research activities in large companies as the main driver for innovation without going through the nitty-gritty of the process. In terms of diffusion of innovations, Schumpeter was rather concerned with “imitation” and followers among entrepreneurs, so that he jumped from innovations to their effect in the whole economy, especially related to the business cycles, without discussing the diffusion process in detail (Godin, 2012). Therefore, a comprehensive theory of innovation must to be found somewhere else.

Two American economic historians stood out in the early days of developing a theory of innovation in economics. The first of them was A. P. Usher ([1929] 1954), which in his book named *A History of Mechanical Inventions* provided a historical account for the sources of invention making use of elements from the Gestalt psychology to explain the rise of innovations. One important difference between Schumpeter’s and

Usher’s approaches is worth to mention: the latter did not establish a precise distinction between invention and innovation, both simply meaning the emergence of “new things” in the areas of science, technology, art, etc. (Ruttan, 1959). Within his so-called “cumulative synthesis approach”, Usher ([1929] 1954) argued that major inventions are visualized as emerging from the cumulative synthesis of relatively simple inventions. This process encompasses four steps: i. perception of the problem, ii. setting the stage, iii. the act of insight, and iv. critical revision. Such theorization opens room for the possibility of consciously trying to affect the speed or direction of innovations around the second and fourth steps in the process by means of bringing together the elements of a solution, through the creation of the appropriate research environment, for example (Ruttan, 1959).

The other economic historian who pioneered in providing a theory of innovation was W. Rupert Maclaurin (1950, 1953) whose understanding was more aligned with Schumpeter’s ideas. In fact, Maclaurin sought advice from Schumpeter to start a research program on innovation, receiving as response the recommendation to undertake historical analysis of industries and business (Godin, 2008). Nevertheless, he narrowed down the topic of interest to only technological innovation, something more restricted than the concept of innovation put forth by Schumpeter. According to him, Schumpeter did not devote enough attention to the role of science, even though fundamental research and its funding were decisive factors for technological innovations. He proposed to break down the process of technological innovation into sequential stages to comprehensively understand and measure it. The stages were: pure science, invention, innovation, finance, and diffusion. In fact, Maclaurin’s theory was the first full-length discussion and schematization of what came to be called later the science-push linear model of innovation (Godin, 2008).

The linear model became the paradigm for science and technology policy after World War II, establishing a direct and necessary relationship between pure science and technological innovation. The origins of this model are commonly attributed to Vannevar Bush, the director of the Office of Scientific Research and Development (OSRD) during the Roosevelt and Truman administrations. Bush headed the preparation of the report titled *Science: the endless frontier* (Bush, 1945) setting up an overview on how the United States could keep their investment in research after the end of the war. This report suggested that basic research should be carried out without practical considerations in order to be the precursor of technological progress, but actually there is nothing more than vague ideas endorsing the linear model in it (Stokes, [1997] 2005). Interestingly, Maclaurin served as secretary to the committee on Science and Public Welfare assisting the preparation of *Science: the endless frontier*, wherein such committee proposed a taxonomy of research composed of pure research, background research, applied research and development, arguing that the development of important industries depends primarily on a continuous and vigorous progress of pure science (Godin, 2008).

Both Usher and Maclaurin, however, have been scholars widely neglected in the economics literature on innovation. One possible explanation for that stems from the fact that both were addressing the subject of innovation through mostly descriptive and qualitative analysis, while formalization and mathematics were already the highest-valued methods of inquiry among economists at that time. In fact, around the 1950s, the systematic study of Economics of Technological Change started to emerge in the United States among neoclassical economists. It gave rise to the first economic tradition dedicated to study innovation, although it was only concerned with innovation as technical invention introduced in the industrial production, and therefore did not provide any account on the origins of innovation (Godin, 2010a). The emergence of such tradition can be traced back to two major conferences that took place around the same period: the conference on "Quantitative Description of Technological Change" organized by the Social Science Research Council (SSRC) at Princeton University in 1951; and the conference on "Rate and Direction of Inventive Activity" organized by the National Bureau of Economic Research (NBER) at University of Minnesota in 1960. Both conferences were not the cause of technological innovation studies among economists, but they contributed to the emergence of the field and witnessed to the ideas that economists brought to study the subject (Godin, 2010a).

The proposal for the 1951 Conference organized by the SSRC came from discussions at two of its committees: the Committee on Economic Growth and the Committee on the Social Implication of Technological Change. The main enthusiast for the conference was the chair of the first committee, the economist Simon Kuznets, who circulated a memorandum of suggested topics in 1949, gathering thirteen contributions to the conference from top-notch scholars, such as the economists Jacob Schmookler, Gerard Debreu, Wassily Leontief, the economic historian W. Rupert Maclaurin, and the sociologist S. Colum Gilfillan (Godin, 2010a). It is clear that there was some disciplinary diversity in this conference, although the economic perspective prevailed to some extent. Actually, at that time economists were trying to catch up with other social scientists in dealing with invention, innovation and technological change, and this conference witnessed such effort. There was a project to publish the proceedings as a book, but it was later abandoned because the papers were not sufficiently aligned (Godin, 2010a).

SSRC also collaborated with NBER in the organization of the second conference, although the latter institution was leading the entire process. Another crucial partner was the RAND Corporation, whose interest in technology for national defense made it prone to get involved with technological innovation studies. Discussions between these institutions started in 1958 as they felt the need to better understand factors affecting inventive activity from an economic point of view (Godin, 2010a). Differently from the previous conference, the second one had a huge focus on economics and hence less disciplinary diversity. Invention was an emerging new idea in economics[6], while some other social sciences were producing in-depth knowledge on this subject for quite a long time. However, economists restricted the discussion to technical inventions, as they were mostly interested in studying inventions designed for practical use in industrial production. This relates to both facts that technological innovations are more measurable and more aligned to the disciplinary interest of economists on efficiency issues (Godin, 2010a). In a nutshell, this conference witnessed a shift from historical approaches to invention among economists until then, especially economic historians, towards formal (or classical) approaches to invention, technological change and, ultimately, innovation.

The NBER Conference got its main impetus[7] from Robert Solow's paper published in 1957 showing that the majority of output growth in the United States between 1909-1949 was mostly not due to increases in capital or labor, but to an unexplained large residual that he simply called "technical change" as a shorthand expression for any kind of shift in the production function (Solow, 1957). One year earlier, Moses Abramovitz had presented similar findings for the period 1869-1953, pointing out that since there was almost no knowledge about the causes of productivity increase in the United States in that period, the magnitude of such large residual could be

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[6] Certainly, there existed some thoughts on this issue from the very first economists such as Adam Smith ([1776] 1985) and Karl Marx ([1867] 1983), and more recently from a few economists during the 1920s and 1930s, namely Pigou ([1920] 2013), Hicks ([1932] 1963), and Robinson (1938), but nothing compared to what the tradition on Economics of Technological Change was about to inaugurate.

[7] Other minor sources of interest for such conference included the awareness that the American national security depended on the output of military R&D effort, the changing way that economists were looking to competitive process, and the efforts within the NSF to collect statistical series on R&D (Nelson, 1962).

taken as a measure of our ignorance (Abramovitz, 1956). Put another way, the emerging research findings on productivity turned the attention of economists interested in economic growth towards the process of technological change (Nelson, 1962). Therefore, at that moment technical invention was becoming a valuable subject from the lens of growth accounting and a legitimate topic of research among mainstream economists.

Scholars gathered in the conference to discuss conducive factors to invention, especially basic research, industry structure and demand, and also to reframe some key economic concepts in light of the need to understand the use of technical inventions in production, such as the concepts of information, allocation, balance and efficiency. Among the participants were Simon Kuznets, Jacob Schmookler, Fritz Machlup, Edwin Mansfield, Zvi Griliches, Kenneth Arrow and Richard Nelson. Once again contrasting to the previous conference, the NBER conference proceedings were published as a book which would later be acknowledged as the most definitive compendium to confer a status of legitimate research field to the Economics of Technological Change (Godin, 2010a). Some particular topics that were addressed in the book would later become canonical in the field, such as the use of patents and R&D statistics to analyze inventive activity, the concept of parallel inventive efforts, the discussion on profits from inventions, the relevance of some non-market factors and policy for inventions. All of that under the umbrella of traditional tools of economics, dealing with either the supply factors which are allocated to inventive effort, the output of inventive effort or the input-output relationship (Nelson, 1962).

This tradition would become a few years later even more consolidated when a group titled “Inter-University Committee on the Microeconomics of Technological Change”, whose members included Griliches, Mansfield, Nelson and Schmookler, got a grant of $150,000 from the Ford Foundation to produce studies on technological change (Godin, 2010a). One of the main approaches pursued by this group focused on the contribution of technology to productivity and economic growth through the lens of econometrics and production functions. The central issues they wanted to address were automation and technological unemployment, which had been occupying economists for decades after the Great Depression, giving rise to theoretical classifications of technologies (capital-saving, labor-saving or neutral) and productivity analyses. Productivity represented technology’s use in production, while changes in labor productivity due to changes in factors of production were equated with technological changes. Interestingly, technological change would replace invention as the main category for this tradition in the decades to come – hence the tradition being known as Economics of Technological Change – especially because of the increasing focus on production function and its input-output framework (Godin 2010a).

As a matter of fact, Schumpeter ([1939] 2017) had pioneered in the definition of innovation as the creation of new production functions, as we already mentioned. Nonetheless, the neoclassical conception following the work of Solow (1957) confers a different focus to such definition, largely confining it to the creation of new techniques assumed to not affect the nature of the output, i.e., process innovations. There is no such limitation in the definition by Schumpeter ([1939] 2017), but it can be easily explained by the fact that it makes the theory much more suitable under the constrains imposed by the basic concept of production function and the assumptions of the neoclassical model on economics (Coombs et al., 1987; Rosegger, [1980] 1996). Therefore, process innovations, understood as changes in the input-output relations that result in lower unit costs for the unchanged output, became the main object of analysis for the blooming field of Economics of Technological Change.

This tradition has been very productive and remains alive and well nowadays (Godin, 2010a). Such as aforementioned, its origins are found among mainstream economists in the United States around the 1950s and 1960s, and it has adopted the existing framework of Neoclassical Economics, such as formal theory and quantitative methods, to obtain legitimacy in pursuing studies on technical progress. There was no interest in developing a theory of technological innovation as technology itself remained exogenous to the economic models.[8] The process of technological innovation was a sort of "black box" in such a way that, paraphrasing Joan Robinson, economists treated technical progress as if it was "given by God, scientists and engineers" (Dosi, [1984] 2006). Dissatisfactions with such understanding and the general lack of realism from neoclassical models gave rise to a second tradition of research in economics from the 1970s onwards – that would be known simply as Economics of Innovation – which is currently acknowledged as the most emblematic tradition in the innovation studies (Godin, 2012).

Two major works appeared in the late 1960s showing signs of transition from the first tradition to the second one. The first one was the book by Nelson, Peck and Kalachek

[8] This is something that has partially changed within mainstream economics after the works by Paul Romer (1986, 1990) on endogenous technological change and growth.

from 1967 titled *Technology, Economic Growth and Public Policy*, which summed up what had been learned from the analyses on technological change and provided perspectives on the process of technical invention and diffusion of technological innovations (Nelson et al., 1967). The second one was the book by Edwin Mansfield from 1968 titled *The Economics of Technological Change*, in which the author gathered the main findings from the studies on technological change, productivity, technological unemployment, management of R&D, diffusion of innovations, and also provided some remarks on public policy (Mansfield, 1968). Both books explicitly combined the tradition on technological change with some elements that would define the second tradition, such as policy orientation, product innovation, user experimentation, among other ideas that the British economist Christopher Freeman put forth to launch the new field on Economics of Innovation some years later (Godin, 2012).

One might consider that Freeman inaugurated this tradition with his 1974 book called *The Economics of Industrial Innovation*, which intended to analyze the professionalized industrial R&D system and its consequences over innovation, economic growth and social well-being. In the book, Freeman ([1974] 1982) combines historical and institutional approaches from economics, as well as considerations from management and evaluation perspectives, in order to provide an explanation of the innovation process and elicit some policy implications. If it is true that, on the one hand, he got some insights from the transition works by American economists affiliated to the first tradition, such as Nelson and Mansfield, it is also true that, on the other, he drew huge inspiration from a few European scholars unconnected to this tradition who had already started to open the "black box" to understand the different characteristics of successful and unsuccessful innovations, the adaptive strategy of firms towards changing environments, the distinction between research and development, the idea of innovation as commercialized invention (new product), the role of market uncertainty, the internal logic of the innovation process, and so on (e.g., Carter and Williams, 1957; Jewkes et al., 1958; Langrish et al., 1972).

Freeman's approach had two remarkable characteristics. Firstly, it focused on technological innovation as commercialization, while the previous tradition had focused on technical invention introduced in industrial production, namely technological change (Godin, 2012). In other words, the first tradition was more concerned with analyzing process innovation, while the second one was more concerned with analyzing product innovation. The focus on products led to examining firms as suppliers of technological inventions rather than as users or adopters, bringing light to aspects such as the process of inventing new products among firms, the drivers and barriers to introduce technological innovations into the market, the strategies of firms in pursuing product innovations, among others (Godin, 2012). One can clearly observe that while productivity was the main issue for the first tradition, market became the pivotal point for the tradition inaugurated by Freeman. Secondly, he brought to the field the national policy dimension, which is largely absent in the first tradition. While the neoclassical assumptions were very averse to government interference, that should be relegated to only specific cases of market failure, the neo-Schumpeterian approach developed by Freeman conceived a broad spectrum of policy interventions aiming to promote technological innovation and socio-economic development.[9]

Freeman (1974 [1982]) claimed that Schumpeter was the founding father of this new tradition and his works were due to experience a renaissance through the Economics of Innovation. However, such connection may be less straightforward than one would expect. Firstly, Schumpeter's definition of innovation was broader than Freeman's, as it was not only confined to technological and commercialized innovation, although he had sometimes conferred special attention to the introduction of new commodities when analyzing the process of creative destruction (Schumpeter, [1942] 2008). Secondly, it seems that Schumpeter himself was not so convinced that governments should play a very proactive role in fostering innovation and development, although he had praised the entrepreneurial state that emerged along the history of Germany (Schumpeter, [1939] 2017). In fact, the emphasis on Schumpeter's works as the building blocks for the second tradition seemed to be also motivated for the need of this tradition to get some legitimization from "big names" in the history of economics, since that, differently from the previous tradition that benefited from the well-developed conceptual framework from Neoclassical Economics, it did have to appeal to old authors to justify the new theorization (Godin, 2012). Therefore, Freeman among others elected Schumpeter as their symbolic father and authority to develop the field.

According to Godin (2012), there exists at least two strategies for inventing a new tradition: contrasting it to or ignoring the previous one. Freeman seemed to have chosen the second strategy as he hardly ever discusses the findings from the Economics of

[9] Such policy orientation would become even clearer after Freeman (1987) elaborated the concept of National Systems of Innovation, followed by further developments by Lundvall (1992) and Nelson (1993).

Technological Change, while Richard Nelson, another major precursor of the second tradition, opted for the first one. Actually, Nelson had also been involved in constructing the first tradition on technological change, but later he would start to fiercely criticize the assumptions of Neoclassical Economics and to propose a new evolutionary approach to analyze innovation and economic growth. In the mid-1970s, Nelson published in collaboration with Sidney Winter a couple of papers pointing out that neoclassical explanations had run into difficulties to grasp the basic characteristics of the technical change process and proposing a new and more useful theory grounded in the Schumpeterian idea that the capitalist process has an evolutionary nature[10] (Nelson and Winter, 1974; 1977). Some years later, they would deepen their ideas in one of the most influential books within the second tradition named *An Evolutionary Theory of Economic Change* in which they propose that firms operate in dynamic selection environments whose main transformative force is innovation (Nelson and Winter, [1982] 2005).

About the same time, another very important precursor of the second tradition produced an eloquent book on the subject. The economic historian Nathan Rosenberg published in 1976 the book *Perspectives on Technology* synthesizing his contributions on the history of technology that involve a rich dialogue with the Schumpeterian works (Rosenberg, 1976). He shows that technology has played a central role in the history of businesses and industries, usually referring to how unpredictability and interdependence are strongly connected to the sequential processes of problem solving in the economic realm (Rosenberg, [1982] 2006). Rosenberg's works were also relevant to acknowledge the importance of incremental improvements and the feedback loops in the innovation process, especially his work in collaboration with Stephen Kline proposing an interactive model of innovation in contrast to the science-push linear model which overemphasized the role of R&D inputs in the innovation process (Kline and Rosenberg, 1986).

The early works by Freeman, Nelson and Rosenberg have defined the second tradition on Economics of Innovation in such a way that some scholars have called them the SYS (Sussex-Yale-Stanford) synthesis, based on the locations where at the time these major contributors were based (Freeman at the University of Sussex, Nelson at the Yale University, and Rosenberg at the Stanford University) (Dosi et al., 2006). Unlike the first tradition, this second one did not insert itself into an existing conceptual framework, but

[10] Such notion can also be found in the pioneering works by Marx ([1867] 1983) and Veblen (1898).

developed its own contrasting with the previous tradition in at least four aspects (Godin, 2012): I) It is descriptive rather than econometrical, and historical/institutional in focus; II) It studies product innovation more than process innovation; III) It has a major concern with policy issues; IV) It pursues the development of a theory of innovation. Overall, what one can observe is a shift in this tradition towards a deeper approximation between economics and other social sciences such as history, management, and sociology, but still from a remarkably economic perspective.

1.1.2. More than economics: other social sciences' perspectives on innovation

Even though the pioneering role of Schumpeter in defining and studying innovation is undisputable, it is also widely acknowledged that he privileged the perspective from economics while neglecting potential contributions from other social sciences. The same holds for both economic traditions that emerged after his works, although to a lesser extent for the Economics of Innovation. Interestingly, Schumpeter himself had remarked several times in his writings the relevance of putting together the various social sciences to analyze the capitalist process. The opening line in *The Theory of Economic Development*, for example, says: "The social process is really one indivisible whole" (Schumpeter, [1912] 1982, p. 9). In fact, inspired by the German sociologist Max Weber,[11] Schumpeter had assumed as his major intellectual project to devise a way to encompass the whole economic phenomenon through economic theory and the adjoining social sciences (Swedberg, 1991). From his perspective, a broad-based social economics should comprehend economic theory, history, statistics and sociology. The first three disciplines were applied in *Business Cycles*, whose subtitle is precisely "A Theoretical, Historical and Statistical Analysis of the Capitalist Process". The last one was deeply used in *Capitalism, Socialism and Democracy*.

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[11] Schumpeter started to touch upon the notion of a broad social economics after Weber invited him to contribute with a chapter to his handbook in social economics (*Grundriss der Sozialökonomik*). This chapter provided the foundations to Schumpeter's book *Economic Doctrine and Method: An Historical Sketch* ([1914] 2012), about which Swedberg (1991) says "Each time an economist is discussed, Schumpeter pays special attention not only to his contribution to economic theory but also to his attempt to complement economic theory with a general analysis of society […]. It is true that in doing so, Schumpeter may have just been following the directions received from Weber; the book, after all, was to be part of a general work in 'social economics' and not in pure economic theory" (p. 41). Later, Schumpeter would borrow the term *"Sozialökonomik"* (social economics) from Weber and carry it as his own intellectual project.

In spite of Schumpeter's interest in the broad notion of social economics, his definition and application of the innovation concept was much narrower than one would expect. When Schumpeter circumscribed his definition of innovation to the setting up of new production functions, he clearly narrowed down the study of innovation to economics. Therefore, we must explore in other authors the contributions from more general social science perspectives to the understanding of innovation as a socio-economic phenomenon. The first author to mention is the French sociologist Gabriel Tarde, whose book from 1890 titled *The Laws of Imitation* consisted in one of the major precursors on the study of diffusion of innovations, as his main goal was to "learn why, given one hundred different innovations conceived at the same time – innovations in the form of words, in mythological ideas, in industrial processes, etc. – ten will spread abroad while ninety will be forgotten" (Tarde, [1890] 1903, p. 140). Here we can already notice that the definition of innovation provided by Tarde was much broader than the Schumpeterian one. In fact, innovations for him were conceived as inventions, new ideas, new expressions or discoveries taking place throughout the range of social phenomena, such as language, religion, industry, etc. In other words, to Tarde, the process of innovation diffusion lay at the very basic and fundamental explanation of human behavior change, and invention and imitation are the elementary social acts (Rogers, [1962] 1983).

Following Tarde's lead, several sociologists started to work on diffusion of innovations from the 1940s onwards. Ryan and Gross (1943) pioneered this type of study in the field of Rural Sociology by investigating the diffusion of hybrid seed corn among Iowa farmers, followed by Coleman et al. (1957) in the field of Medical Sociology studying the adoption of a new drug among Illinois physicians. Years later, Everett Rogers ([1962] 1983) published his influential book named *Diffusion of Innovations*, in which he consolidated this topic as a legitimate sociological one. Such as Tarde, Rogers used a very broad definition of innovation as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" ([1962] 1983, p. 11). In this sense, the perceived newness of the innovation is what matters, and not whether it is objectively new or not.[12] Contrary to the economics literature, Rogers ([1962] 1983) argued that an economic advantage is only one among several factors that can drive an individual or

[12] There is a wide understanding in sociology that perceptions matter a lot, which was particularly deepened by the intellectual production within the Chicago School of Sociology pointing out that "if men perceive situations as real, they are real in their consequences" (Thomas and Znaniecki, 1927, p. 81).

organization to adopt an innovation,[13] such as social prestige, collective pressure, compatibility with previous innovations and existing values, etc. Put another way, a mix of innovation and innovator characteristics should be taken into account to understand the different degrees of adoption among individuals or organizations.

A little bit earlier than diffusion studies, other sociologists started to develop theories focusing on technological inventions in order to address the broad issue of social change. The first of them was William F. Ogburn, which provided some important rudiments for the development of a theory of technological innovation even hardly ever using the term "innovation" in his works (Ogburn, 1928; 1937; 1947), followed closely by his colleague S. Collum Gilfillan and the development of a sociology of invention (Gilfillan, 1935; 1953). Both authors were concerned in showing how changes in the material life (technology, above all) appeared to be taking place faster than those in the non-material part of social life, so that the latter was compelled to adjust itself in a process involving some level of cultural lag (Godin, 2010b). The causes of cultural lags could be found in such social and psychological obstacles to adopt technological inventions as old customs, utility and easiness of prevailing cultural frameworks, group interests, etc.

In the next few decades, the sociological focus shifted towards concerns on the social nature of scientific knowledge and its consequences over technology. The book by Thomas Kuhn ([1962] 1975) titled *The Structure of Scientific Revolutions*, in which he argues that scientific revolutions are episodes of non-cumulative development wherein old paradigms are replaced by new ones, represented the turning point. It gave rise to the field of Science and Technology Studies (STS) which aims to unmask the external – or extra-scientific – social factors behind not just the processes of pursuing the scientific knowledge, but also the content of such knowledge and its materialization in artefacts and technologies (Martin et al., 2012). Spiegel-Rösing and Solla Price (1977) edited the first STS handbook in the 1970s titled *Science, Technology and Society: A Cross-Disciplinary*

[13] A controversy on the issue of profitability versus other factors in the diffusion process of hybrid seed corn among American farmers occurred around the 50s and 60s. The economist Zvi Griliches (1957, p. 522) claimed that "in the long run, and cross-sectionally, [sociological] variables tend to cancel themselves out, leaving the economic variables as the major determinants of the pattern of technological change". The sociologist Everett Rogers ([1962] 1983, p. 215) responded later saying that "Perhaps if Dr. Griliches had ever personally interviewed one of the Midwestern farmers whose adoption of hybrid corn he was trying to understand […], he would have understood that farmers are not 100 percent economic men".

Perspective, and since then an enormous body of research has been conducted in this field which is still very active nowadays.[14]

STS literature has left the topics of innovation and technological change largely outside its core interests. Indeed, there has been some attempts to approximate the approaches from STS and Economics of Innovation in recent decades (e.g., Coombs et al., 1992; Velho and Rauen, 2010), but such efforts have shown short breath. Actually, another field from sociology has presented more promising bridges with the Economics of Innovation for a comprehensive understanding of the innovation process. Here we refer to Economic Sociology[15], which through the foundations of influential contemporary works, such as the ones by Mark Granovetter (1985) and Ronald Burt (1992) on social network analyses, Peter Evans (1995) and Fred Block (1996) on the institutional nature of capitalism, and Pierre Bourdieu (2000) and Neil Fligstein (2001) on the cultural aspects of markets, has strengthen relations between economics and sociology as regards the construction of a theory of innovation. Nowadays, one can identify the emergence of a Sociology of Innovation from the intellectual production of sociologists working within Economic Sociology (e.g., Pinch and Swedberg, 2008; Block and Keller, 2011; Ramella, 2015).

Another branch from sociology that has been useful for the development of a theory of innovation is the Sociology of Organizations. The pioneering work by the sociologist Joan Woodward (1958) named *Management and Technology* analyzed the relationship between organizational structure and performance showing that the type of technology used by organizations had a significant influence on it. In the early 1960s, Burns and Stalker (1961) published their influential sociological book titled *The Management of Innovation* analyzing how technical innovation relates to distinct forms of organization and the different patterns of communication associated with those forms. Another important contribution for deepening this subject includes the book by the business historian Alfred Chandler (1962) on *Strategy and Structure* examining

[14] Among the main research programs within STS, we can mention the "Strong Program" of Sociology of Scientific Knowledge (e.g., Bloor, 1976), the Social Construction of Technology (SCOT) program (e.g., Bijker et al., 1987), and the Actor-Network Theory (ANT) program (e.g., Latour, 1987).

[15] We refer here mainly to what has been called "New Economic Sociology", which emerged in the 1980s stressing that the crucial economic phenomena and institutions must be analyzed with the help of sociology's theoretical apparatus (Swedberg, 2004).

organizational changes and innovation from the perspective of the emergence of the multidivisional firm in the early 20th Century.

Nevertheless, such organizational concerns would achieve full development only within another research field, the Management literature. Among the most influential early works in the field, one can identify the book by Cyert and March ([1963] 1992) named *A Behavioral Theory of the Firm* in which they develop the concept of "search" linked to "organizational learning" in companies, the paper by Utterback and Abernathy (1975) elaborating a dynamic model of innovation in which an initial phase of product innovation is followed by another one of process innovation, pointing out to the complementarity between both, and the book by Allen (1977) called *Managing the Flow of Technology* which deals with communication flows in R&D organizations and how particular organizational structures enhance productivity. Nowadays, some of the main scholars working on innovation studies belong to the management field, such as David Teece, Michael Porter, Clayton Christensen and Henry Chesbrough. In short, the Innovation Management literature has been very prolific and keen to demonstrate that innovation and technology strongly influence the organization structure and vice-versa.

In addition to sociology and management, other social sciences have also contributed to innovation studies over the decades, such as psychology and the study of motivations and creativity for the individual inventiveness (e.g., Rossman, 1931; MacKinnon, 1962), anthropology and the study of innovation as cultural change resulting from the contact between cultures (e.g., Smith et al., 1927; Barnett, 1953), history and the study of comparative technological development over time and countries (e.g., Landes, 1969; Mokyr, 1990), and geography and the study of technology clusters and the stickiness of innovation activities over certain territories (e.g., Storper and Walker, 1989; Saxenian, 1994). But the point we want to make is that, although economics is indisputably the main source contributing for the consolidation of innovation studies along the years, other social sciences have also been at play providing very important insights to understand determinants and obstacles to innovation in order to encompass a broad theory of innovation as a social-economic phenomenon.

1.2. What determines innovation?

1.2.1. Determinants within the Schumpeterian tradition and economics literature

Economists have been struggling to identify what determines the innovative performance of firms and countries for a long time. Inspired by the works from Schumpeter, scholars from both the first and the second tradition discussed in the previous section have conducted numerous empirical studies on the so-called Schumpeterian Hypotheses,[16] namely: I) There is a positive relationship between innovation and monopoly power with the concomitant above normal profits; II) Large firms are more than proportionately more innovative than small firms. According to Kamien and Schwarz (1982), these are two independent hypotheses because possession of monopoly power does not necessarily imply large size or vice-versa. Such hypotheses rest on two fundamental features of Schumpeter's theory: competition through innovation and uncertainty. As we already recalled, the competition through innovation is characterized by the fact that competition can emerge from anywhere, and potential known and unknown rivals present a major source of uncertainty for the incumbent firm. Since it takes more money and resources to engage in such uncertain enterprise as innovation, monopoly power and large size are allegedly advantageous for innovative activity as they can help to cope with uncertainties (Kamien and Schwarz, 1982).

Now let us consider each of these hypotheses in detail. Starting with the relationship between innovation and monopoly power, scholars have argued that there are two major sources of interaction between them (see Kamien and Schwarz, 1982; Cohen, 2010). The first is between innovation and the anticipation of monopoly power and concomitant monopoly profits, implying the ability to prevent or at least to retard imitation by means of intellectual property mechanisms or erection of other barriers to entry. This reasoning associates the incentive to innovate with the expectation of *ex post* market power tied to the innovation. The second is between innovation and the actual possession of monopoly power (i.e., *ex ante* market power), implying the possibility that the monopoly firm extends its power to new products through its command over channels

[16] It is controversial whether or not such hypotheses really stem from the writings by Schumpeter. Richard Nelson ([1996] 2006), for example, argued that attributing those hypotheses to Schumpeter is a misreading of his works. Overall, a literal reading of Schumpeter shows that he has only provided fragmentary ideas that could lead to these hypotheses, but not their fully developed forms.

of distribution, its unique identity, or even by simply discouraging the intrusion of rivals in the new product line considering the possibility of quick retaliation. Overall, the possession of monopoly power allegedly brings crucial advantages to firms in the innovation process, such as high capacity to finance innovation internally, to keep secret key information about the innovation being developed, and to hire the most innovative people. However, it may also bring some disadvantages, such as preference for additional leisure over additional profits, overconcern with protecting current monopoly position, slowness in replacing current product or process by superior ones, among others.

After Schumpeter's insights, several theoretical models have been built to address the relationship between innovation and monopoly power, which usually offer conflicting conclusions and depend on a range of assumptions regarding appropriability conditions, the type of innovation, the "radicality" of the innovation, the change in the intensity of rivalry associated with innovation, etc. (Cohen, 2010). Empirical studies following these models have rendered a decades-long accumulation of mixed results. In face of the theoretical indeterminacy and the empirical inconclusiveness on this issue, some authors have reached the conclusion that, although market concentration and R&D intensity may be correlated, monopoly power is not an independent important driver of innovation (Cohen and Levin, 1989; Sutton, 1998; Cohen, 2010). Indeed, as little support for the first Schumpeterian hypothesis has been found, perhaps a more realist way to hypothesize the relationship between market concentration and innovation could be to consider an intermediate market structure between monopoly and perfect competition as promoting the higher rate of innovative performance (Kamien and Schwartz, 1982).

Moving to the second Schumpeterian hypothesis, some authors have argued that, although Schumpeter's remarks did point out to the relevance of firm size, the work by the economist John Kenneth Galbraith ([1952] 2010) is the one to be more properly acknowledged as fully developing the claim that size, both in terms of cash flow and personnel, is positively associated with innovativeness (Kamien and Schwartz, 1982; Coombs et al., 1987). The reasoning behind this hypothesis can be summarized as the idea that, in the same way as the prospect of monopolistic position favors the riskiest innovations, bigness favors the most expensive ones (Nutter, 1956). Galbraith ([1952] 2010) had noticed that as innovative activities were getting more and more expensive, large firms were becoming increasingly advantageous in the pursuing of innovations. According to Cohen (2010), among the several justifications for a positive effect of firm size on innovativeness that have been suggested over the years, one can find:

- Capital market imperfections confer an advantage on large firms in securing finance for risky R&D and innovation projects since that size is correlated with the availability and stability of internally generated funds;
- There are scale economies in the R&D function itself, as large research departments offer more chances for interaction, are more able to exploit specialized equipment, and favor division of labor among researchers;
- The returns from R&D are higher where the innovator has a larger volume of sales over which to spread the fixed costs of innovation, implying a cost-spreading advantage for large firms;
- R&D is allegedly more productive in large firms as a result of complementarities between R&D and other nonmanufacturing activities that may be better developed within larger companies, such as marketing and financial planning departments;
- Large and diversified firms provide economies of scope and reduce the risk associated with the prospective returns to innovation, since large firms with name recognition may move more easily into new markets and multiproduct firms have a greater chance of capturing the returns from discovery.

At the same time, counterarguments stressing the negative effects of size on innovativeness have also been presented (see Scherer and Ross, 1990), such as the claim that as firms grow large the efficiency in R&D and innovation is undermined either through the loss of managerial capacity or the increase of excessive bureaucratic control. Put another way, as companies grow in size, the incentives of individual scientists and entrepreneurs working within them may be reduced as either their ability to capture the benefits from their efforts diminishes or their creativity is restricted by the hierarchical structure of large corporations (Sah and Stiglitz, 1986). Therefore, similarly to the case of the relationship between monopoly power and innovativeness, there is also a theoretical indeterminacy about the effect of size on firms' innovative performance. Empirical literature has produced a lot of evidences over the years to support or reject the second Schumpeterian hypothesis. Most findings present mixed results as well, so that the robust empirical pattern only shows that R&D increases monotonically and typically proportionately with firm size, the number of innovations tends to increase less than proportionately than firm size, and the share of R&D effort dedicated to more incremental and process innovation tends to increase with firm size (Cohen, 2010).

Although abundant, the empirical exercises to test the Schumpeterian hypotheses have faced severe difficulties over the years, most of them related to theoretical or methodological shortcomings. Among the main difficulties, we can mention: I) identifying an innovation; II) defining the inputs into the innovation process; III) measuring firm size; IV) measuring monopoly power; V) determining the direction of causality. Moreover, the interchangeable use of different innovative inputs (R&D intensity, for example) and innovative outputs (innovation counts, for example) as dependent variables, has made it more difficult to produce interpretable and solid findings. In fact, the choice of measures of inputs and outputs of innovation has usually been guided by data availability rather than conceptual framework, but theoretical shortcomings have also been at play. Overall, evaluation of the Schumpeterian hypotheses should take place within the context of more complete models of the determination of technological progress (Cohen, 2010). Therefore, other firm and market characteristics should be taken into account to properly appraise the influence of size and monopoly power on company's innovativeness.

Other two hypotheses have also emerged in the economics literature proposing to go beyond the Schumpeterian ones. These are the so-called science/technology-push and demand-pull hypotheses. Some authors have argued that the first hypothesis finds a natural place in Schumpeter's ideas too (see Coombs et al., 1987), but most authors have associated the claim that science and technology are the prime movers in the innovation process to later scholars, such as Maclaurin (1950, 1953) and the science-push linear model of innovation or Nelson (1959) and the economics of basic scientific research. On the other hand, the second hypothesis claiming that demand and market forces are at the forefront of the innovation process is indisputably associated with the works by Jacob Schmookler (1962, 1966) emphasizing the role of economic opportunity in innovation through the analysis of patents and investment statistics. We now discuss each of these hypotheses in detail.

As pointed out previously, although the science-push linear model of innovation has usually been associated with Vannevar Bush (1945) and the report *Science: the endless frontier*, its full development is only found in the works by Maclaurin (1950, 1953) in which he conceived linear stages from pure science to technological and economic progress through innovation. In fact, such model is behind the main reasonings from the science/technology-push approach claiming that the inputs to the scientific and technological activities, especially basic research, are the fundamental initiators of innovation. The paper by Nelson (1959), in its turn, provided the theoretical economic basis for considering scientific knowledge a durable (semi) public good, so the basic research producing such knowledge would naturally suffer from underinvestment as the social gains expected from it are higher than the private profits. These considerations, added to the fact that companies around the world were increasingly settling research departments from the 1950s onwards, led to the conclusion that the scientific activities, usually measured as R&D expenditure or personnel, provide the necessary push to innovation and economic progress.

One of the first criticisms towards this approach came precisely from the writings by Schmookler (1962, 1966) in which he defended the opposite approach, i.e., the demand-pull hypothesis. He argued that his position emphasizing the role of expected economic benefits fiercely contrasted to the one which views technological progress primarily as an automatic outgrowth of the state of knowledge (Schmookler, 1962). In other words, in the demand-pull hypothesis the innovation initiation is seen as coming first from marketing and production departments at the firms, and only later the response comes from the research departments (Kamien and Schwartz, 1982). Therefore, the main idea in such hypothesis is that inventions and, ultimately, innovations are responses to profit opportunities. However, Schmookler (1966) himself did not argue that demand forces were the only determinants of innovation, but, as he put too much emphasis on the demand factors to counterbalance the science/technology-push views, he became the main exponent of a demand-led theory of innovation.

Both science/technology-push and demand-pull hypotheses were intensively criticized from the 1970s onwards, especially by those economists that were starting the second tradition on Economics of Innovation. In addition to the criticisms by Schmookler, the science/technology-push approach was severely contested by Nathan Rosenberg ([1982] 2006) as well, who argued that science is endogenous to the economic life, so we can identify causal chains from economy to science and vice-versa. This mutual determination stems from two facts: I) Scientific research is an expensive activity and has gotten more and more so over the years; II) Scientific research can be directed to achieve economic rewards, and the history of technology has shown that this is more the rule than an exception. Therefore, there is no surprise that modern industrial societies have created a wide scientific and technological domain closely shaped by economic needs and incentives (Rosenberg, [1982] 2006).

Notwithstanding, the very same Rosenberg also fiercely criticized the demand-pull approach in a very eloquent paper co-authored with David Mowery (Mowery and Rosenberg, 1979) in which they undertake a critical review of several empirical papers claiming to have corroborated the demand-pull hypothesis. What these authors found was that the notion that demand and market forces drive the innovation process was not demonstrated by the empirical analyses, since the concept of demand often used was loosely defined in terms of general human "needs", while the precise economic concept of demand, expressed and mediated by the market, is something else. Mowery and Rosenberg (1979) concluded that both the scientific base and the market forces play a key and interactive role in the innovation process, so that neglecting one or the other would be a huge mistake.

In fact, the same conclusion was reached by Freeman ([1974] 1982) some years earlier in his classical book on industrial innovation, wherein he argued that innovation is essentially an interactive and bilateral activity which, on the one hand, involves recognizing some needs or, more precisely, potential markets for a new product or process, and, on the other, also involves exploiting the available knowledge bases or even exploring new scientific and technological avenues through original research. Therefore, the innovation process should actually be understood as a coupling process putting techno-scientific possibilities and market opportunities together. However, only adding techno-scientific inputs and demand variables to the traditional firm size and monopoly power ones does not seem to be enough to achieve a comprehensive model of determinants of companies' innovativeness. Further variables related, for example, to appropriability conditions, intra-organizational attributes, collaboration networks, among others, have proved to be very relevant in the studies promoted by economists of the second tradition, but their origins are typically found in other social science literatures.

1.2.2. Determinants beyond economics literature

An important gap to which most empirical scholars working in the Schumpeterian tradition and economists in general have paid little attention refers to the study of network externalities (Cohen, 2010). The furthest they have gone into this issue for a long time relates, on the one hand, to the economics of transaction costs and its core idea of a dichotomy between hierarchies and markets in setting up contracts involving different degrees of moral hazard and trust between the economic actors (e.g., Williamson, 1985), and, on the other, the dynamic increasing of returns resulting from network externalities in the cases where an early-established technology becomes dominant so that latter and superior alternatives cannot supersede it (e.g., Arthur, 1989). While mainstream economics has found itself in trouble to deal with networks without giving up notions such as information symmetry and the representative firm,[17] scholars from sociology (e.g., Granovetter, 1973; Coleman, 1988; Burt, 1992) and management (e.g., Kanter, 1989; Hamel et al., 1989; Mitchell and Singh, 1996) have not had such problems and long ago identified that the substructure of interrelationships can impact the innovativeness of firms and individuals by spreading information and ideas (Ahuja et al., 2008).

The types of networks in which the firm is embedded and its position in them affect the firms' behavior and performance as it confers "network resources" to firms, which have been called "social capital" at the individual level by some sociologists (Vonortas, 2009). Differently from human capital, social capital is a relational asset, and not an individual one. In fact, social capital is the contextual complement to human capital, since the returns to human capital attributes depend on the individual's location in the social sphere, and therefore the investments to build social capital are different from those intended to build human capital (Coleman, 1988). The same goes to companies and other organizations, but instead of human capital they possess internal (or firm-specific) resources, and instead of social capital we usually refer to network resources, comprehending the formal and informal inter-organizational networks in which firms are embedded and can be used by them for strategic conception and implementation (Vonortas, 2009).

Inter-organizational networks promote innovation by providing information and technical know-how and by favoring joint problem solving of utmost importance, since the current technological environment requires competences and knowledge from multiple bases, so it would be impossible to most firms keep in pace with technology evolution and pursue cutting-edge innovations by themselves (Ahuja et al., 2008). In addition, networks also foster innovativeness by facilitating increased specialization and division of labor among organizations (Powell et al., 1996). The impact of inter-firm

[17] The hegemonic neoclassical economics has traditionally adopted a narrow conceptualization of firms as identically endowed, abstract, instantaneously adaptive entities, and therefore the need of cooperative networks for innovation and their benefits just disappear from such framework (Ahuja et al., 2008).

collaboration networks on firms' innovativeness has been studied at various levels, differentiating networks with respect to their duration and stability, the different partners and technologies involved, the degree of hierarchy, control, and formality, and whether the collaborations were forged to accomplish a specific task or evolved out of pre-existing associations (Powell and Grodal, 2005). The overall empirical evidence has shown that such collaborative networks play an important role in supporting firms to reach a high variety of knowledge bases in order to innovate (Ahuja et al., 2008).

Notwithstanding, there is a fundamental trade-off between organizational stability and variety in network structure that must be considered. The emergent network properties are the outcome of the accumulation of network resources among partners, and such resources depend on the maintenance and strengthening of these relationships (Kogut, 2000). Such situation creates forces for the preservation of the existing network which result in a natural tendency to freeze the structure of interactions, generating then stable network patterns that resemble the characteristics of organizations pursuing specialization at the expense of variety (Vonortas, 2009). Therefore, to ensure efficiency, companies need to balance between the incentives to reduce operational costs through stable and long-term cooperative arrangements with high-density and strong ties, and the incentives to reap higher gains through unstable and short-term cooperative arrangements with low-density and weak ties.

A similar dilemma exists at the firm level as well. Cohen and Levinthal (1989) argued in a very famous paper that R&D efforts play a dual role in companies, not only generating new information but also enhancing the capacity to explore existing information through mechanisms of learning. Put another way, there would be an absorptive capacity effect implying that high level of prior knowledge internally accumulated is necessary to evaluate and explore external knowledge. However, an unbalanced focus on the accumulation of internal capacities could prove problematic, as there exists a conservative nature of learning in organizations which by mechanisms of self-reinforcement result in specialization that can be harmful in environments of constant change (Levinthal, 1996). This implies the risk of a "competence trap" for companies locked in a highly specialized technological path losing the ability to appraise external opportunities.

The solution to avoid the "competence trap" is provided by the strategy of developing multiple knowledge bases. March (1991) proposed that companies must find an appropriate balance in their innovation search strategies between knowledge exploitation of their current competencies and knowledge exploration of new opportunities with the aim to achieve successful innovation development. Empirical literature has shown that external knowledge exploration strategies not only involve networks and cooperative partnerships, but also accessing various external sources of information and purchasing external embodied knowledge (machinery and equipment, for example) and disembodied knowledge (extramural R&D and licensing, for example) (see Arora and Gambardella, 2010). In fact, such company behavior is in tune with complementary routines associated with successful innovation management under discontinuous conditions, which tend to be related to highly flexible behavior, tolerance for ambiguity, emphasis on fast learning, among other characteristics that make companies able to manage innovation in an "ambidextrous fashion" (Tidd et al., [1997] 2005).

Other highly relevant determinants of innovation, which are also associated with networks and knowledge transfer, comprehend those factors typically discussed within the geography literature, such as proximity, location, clusters and so on. For a long time, it has been known that innovative activity is not uniformly or randomly distributed across geographical areas, and this tendency towards spatial concentration has only increased over the years (Asheim and Gertler, 2005). The reasoning behind this context is simple: the contemporary innovation process largely involves tacit knowledge whose production occurs simultaneously with transmission by means of mechanisms of user-producer interaction mostly circumscribed in a spatial area. In fact, empirical studies have found that geographic proximity is one of the main mechanisms explaining the occurrence of knowledge spillovers (see Ahuja et al., 2008). These findings have led scholars to emphasize the existence of "sticky places" for innovative activities, which provide companies and other organizations with the proper environment to social interaction and knowledge transfer rendering economies of agglomeration and, ultimately, spurring an innovative virtuous cycle (Saxenian, 1994; Boroughs, 2015).

Nevertheless, scholars have identified that not only proximity, knowledge transfer and network interactions matter as determinants of innovation in a certain locality, but also the set of local institutions and cultural frameworks that can make the innovation process smoother. Cultural frameworks comprehend a complex array of dimensions such as fundamental values, norms, motivations, perceptions, etc., which are related to the skills, practical knowledge and routines employed in everyday life, including productive behavior (Fernández-Esquinas et al., 2017). In fact, some studies have found that culture is an important explanatory factor for innovation because values, informal norms and cognitive repertoires shape the capacity to act and interact of individuals and organizations (e.g., McLean, 2005; James, 2005; Cooke and Rehfeld, 2011). Therefore, understanding innovation as a socially embedded economic action shaped by cultural and symbolic forces implies recognizing that such tacit elements enter every stage of the innovation process (Fernández-Esquinas et al., 2017).

Among the institutions, perhaps the ones that have been the most analyzed and debated are those related to appropriability conditions, which usually refer to environmental factors that enable an innovator to capture profits of innovation by creating barriers to imitation (Ahuja et al., 2008). As a matter of fact, there are some firm-specific factors also associated to appropriability conditions, such as informal or strategical methods of intellectual property protection (industrial secrecy, complexity of design, time lead over competitors, etc.), but the most commonly studied factors are the environmental ones associated to formal methods of protection (patents, copyrights, trademarks, etc.). Thereafter, appropriability conditions are usually identified with legal regimes of intellectual property rights in countries or regions.

Interestingly, unlike the early debates over intellectual property institutions touching upon more philosophical, political and moral questions about “natural rights” of inventors that employed their creative efforts to produce inventions or “justice” on the distribution of benefits from inventions that to some extent built upon collective and social processes, the contemporary analysis has shifted to much more economic concerns, especially on the trade-off between allocative efficiency and dynamic efficiency (David, 1993). Based upon the seminal work by Arrow (1962), this trade-off rationale implies that, on the one hand, if we assume no future inventions, the efficiency of the economic system is maximized by spreading knowledge (allocative efficiency), but, on the other, if we assume there are still inventions to come, then some sort of monopoly power expectation must be created to incentivize the necessary efforts (dynamic efficiency) (Williams and Aridi, 2015). Thus, in purely economic terms, the regime of intellectual property rights of a particular country will usually try to find a balance between these two types of efficiencies providing inventors some temporary monopoly over their inventions in exchange for the public disclosure of the invention. However, although this is the most current view on the issue, it does not mean that the foundational moral and political concerns involving intellectual property rights lost their importance and legitimacy.

There are also some intra-organizational attributes of companies somehow neglected in mainstream economics that received much more attention from management scholars. Firstly, we must mention firm scope. Although this attribute had already been approached by some economists, such as Edith Penrose ([1959] 2006) who argued that companies having a broad product base are more capable to apply the knowledge resulting from their internal R&D and also are less vulnerable to external shocks due to their diversification, management scholars advanced such ideas by integrating them with the notion of knowledge transfer inside organizational boundaries and domains (Miller et al., 2007). Teece (1986) was especially keen to highlight the importance of the links across marketing, manufacturing, and R&D in conditioning innovative performance. In fact, empirical literature has found that innovations that result from interdivisional knowledge transfer impact future innovations more than those resulting from knowledge outsourced or created within a single division (Ahuja et al., 2008).

Secondly, there is also the influence of organizational structures. Some scholars have found that the introduction of new technology often presents complex opportunities and challenges for organizations, leading to changes in managerial practices and also to the emergence of new organizational forms, so that organizational and technological innovations are intertwined (Lam, 2005). Therefore, one might expect that the management cultures and procedures to handle the different innovative projects impact the outcomes achieved as well as are impacted by them. Two concurrent views on the nature of organizational adaptation and change have been at the forefront of this debate, the first one stressing that organizational evolution is closely linked to the cyclical pattern of technological change, while the second one argues that organizations are not passive to the environmental forces, but also shape them (Lam, 2005). The current understanding tends to acknowledge that these are actually two complementary forces, and not antagonistic ones.

Last but not least, there is also psychological and sociological elements related to the willingness of managers and innovators to invest in risky activities. On the one hand, studies have found that, due to corporate governance mechanisms, managers may be less willing to invest in innovation activities than owners or stockholders would want them to, and, on the other, scholars have also suggested that the individual characteristics of top managers influence the innovative behavior of firms to the extent that psychological and social biases drive their decision making (Ahuja et al., 2008). In fact, as Rogers ([1962] 1983) remarked years ago in an extensive literature review, among the main characteristics of the individuals that adopt an innovation earlier one can find: higher level of formal education and social status, greater empathy and ability to deal with abstractions, and a more favorable attitude toward change, risky activities and science. Overall, the most innovative individuals must congregate a range of characteristics balancing venturesomeness and social respect.

1.3. The various obstacles to innovation

1.3.1. Financial-related obstacles in the traditional economics literature

At first, the neoclassical perspective conceived that investment decisions in markets characterized by no taxes, no bankruptcy, and no asymmetric information are indifferent to capital structure, so the sources of financing do not matter in this frictionless world (see Modigliani and Miller, 1958; Hottenrott and Peters, 2012). However, after some addition of realism to neoclassical models, the economics literature started to pay special attention to financial constraints as factors hampering firms' investment in innovation. The building blocks for focusing on financial issues were provided by the previously discussed science/technology push hypothesis and especially the works by Nelson (1959) and Arrow (1962) identifying scientific and technological knowledge as a durable (semi) public good, implying that firms may be unable to exclude others from using the knowledge they create, which ultimately generates underinvestment in innovation (Álvarez and Crespi, 2015). In other words, there is a fundamental market failure in the research investment for innovation, since that the marginal value it creates to society exceeds the marginal value it creates to individuals paying for it, so the allocation of resources that maximizes private profits are not optimal (Nelson, 1959).

The broad social gains in the knowledge creation might be expected especially from basic research producing (semi) public goods-type of knowledge hardly ever totally appropriable. Therefore, basic research efforts are likely to generate substantial external economies so that private-profit opportunities alone are not expected to draw as large a quantity of resources into basic research as is socially desirable (Nelson, 1959). Overall, in a free market economy it is typically assumed that there would be underinvestment in invention and research (especially basic research) fundamentally because it is a risky enterprise in which the product can be appropriated only to a limited extent (Arrow, 1962). Such assumption was empirically tested and verified in the 1970s by Mansfield and his students at University of Pennsylvania, which showed that, for a sample of seventeen industrial innovations, the median social return was 56%, while the median private return was only 25% (Mansfield et al., 1977).

In addition to internal financial constraints, this market failure approach also extends to external financial constraints. The intangible assets produced (or utilized) by knowledge investments may be very difficult to use as collateral in negotiating external funding, since the banks prefer physical assets to secure loans and may be reluctant to lend when the project involves the accumulation of intangible assets partially embodied in the firm's personnel (Álvarez and Crespi, 2015). Put another way, once that entrepreneurs are usually not the same individuals as financers in a market-based economy,[18] there exists an information gap between "inventors" and "investors" arising from problems related to asymmetric information and moral hazard (Hall, 2010).

The problem is that generally the inventor has better information about the quality of the project and the expected amount of effort needed to undertake it than external investors, opening room for opportunistic behavior (Álvarez and Crespi, 2015). Therefore, investment in innovation may be particularly affected by financial obstacles since too many information asymmetries exist due to the high degree of complexity, specificity and uncertainty of innovation projects (Hottenrott and Peters, 2012). In fact, as Arrow (1962) once put it, the central economic fact about the research processes for invention is that they are devoted to the production of information which, by its very definition, must be a risky process in that the output (information obtained) can never be predicted perfectly from the inputs.

Although the rationale for financial constraints on innovation is very straightforward, the empirical literature has not been as conclusive as one might expect (e.g., Savignac, 2008). Most empirical studies until recently had tested the presence of financing constraints to innovation indirectly by assessing the sensitivity of R&D investments to changes in cash-flows, finding sometimes a significant positive effect, but not always (see Hall, 2010). After the innovation surveys appeared in the mid-1990s,

[18] Schumpeter ([1912] 1983) had already pointed out to a similar differentiation between the role of "entrepreneurs" carrying out new productive combinations and the role of "capitalists" providing the necessary funding for such enterprise. In fact, according to Schumpeter's view, the financial system should be directed to create credit only to innovation projects, since there is no need for borrowing money in the ordinary economic life within the stationary flow (Schumpeter, [1912] 1983).

some authors have tried a different research strategy by combining financial and survey data to look more closely at the relationship between innovativeness and financial obstacles through direct information on the perception of financial constraints by firms. Overall, studies have found that these obstacles significantly lower the likelihood of firms to engage in innovative activities, but their effect takes place especially among small firms and high-tech/knowledge-intensive sectors (Savignac, 2008; Canepa and Stoneman, 2008; Álvarez and Crespi, 2015).

Another set of obstacles to innovation that, although not strictly linked to financial constraints, has found place within the mainstream economics literature by somehow fitting to the neoclassical framework through the idea of consumer sovereignty refers to the so-called demand obstacles. The theoretical basis for these obstacles is found in the previously mentioned demand-pull hypothesis and the seminal ideas from Schmookler (1962, 1966) pointing out that the inventive activity and, ultimately, the introduction of innovations into the market are conditioned by the existence of (latent) demand and positive expectations of profitability (financial rewards) from returns to innovation. It means that, in the absence of these conditions, there would not be sufficient incentives to companies invest in innovation. Therefore, one can expect that demand obstacles be at play either in terms of lack of demand or market uncertainty by affecting the willingness of firms to engage in innovation, which has actually been confirmed by some empirical studies (e.g., García-Quevedo et al., 2017).

Finally, there is a last financial-related set of obstacles to consider within the traditional economics literature, namely the market obstacles. These obstacles represent competition issues, which can, on the one hand, be related to too monopolistic market structures erecting barriers to entry for new innovative players, and, on the other hand, concern too competitive market structure with low appropriability conditions and fast imitative behavior hampering the incentives to innovate. These might be considered somewhat financial-related obstacles because they involve both the varying capacity of firms to finance innovation activities under diverse market structures and the different expectations of reaping financial gains from innovation depending on the position of the firm in the market structure. In fact, the empirical literature has found that market barriers are as important hindrances for firms as the most traditional financial ones (Pellegrino and Savona, 2017). The theoretical ground for these obstacles is to be found in the Schumpeterian hypothesis on the relationship between market structure and innovation performance, so that market obstacles present ambiguity (both too monopolistic and too competitive market structures can harm innovation) as well as do so the empirical findings gathered to validate this hypothesis (see Kamien and Schwartz, 1982).

1.3.2. Non-financial obstacles in the broader social sciences' perspectives

A set of non-financial obstacles has received increasing attention more recently. These obstacles encompass elements originated in the social sciences' literature discussed previously, such as network, institutional and intra-organizational aspects, which were later also largely incorporated in the second tradition of the Economics of Innovation by Neo-Schumpeterian and Evolutionary economists. The understanding of the non-financial obstacles benefited especially from the emergence of the innovation surveys in the 1990s (notably the Community Innovation Survey in Europe) providing both a detailed description of the innovative activity/performance of firms and statistical information about the perception of numerous factors hampering innovativeness among companies (Blanchard et al., 2013). The study of non-financial obstacles has allowed to overcome the limitation inherent to the market failure approach typically found in mainstream economics in order to reach a more comprehensive systemic failure approach that has been developing by heterodox economists and other social scientists (e.g., Woolthuis et al., 2005; Bleda and del Río, 2013). Let us now discuss some of these obstacles in more detail.

Firstly, we consider the group of the so-called knowledge obstacles, which has probably been the most studied group after the financial-related one. These obstacles usually comprehend elements like scant qualified personnel and lack of information on markets and technologies. In other words, such obstacles represent a lack of internal knowledge competencies and consequently a low absorptive capacity to explore external knowledge. The theoretical roots for this consideration shall be found in the famous papers by Cohen and Levinthal (1989) and March (1991) on the necessity of firms to have a strong and diversified knowledge base in order to be able to draw the most from their innovative activities and also from the external pool of knowledge that can be used to generate innovations. Some of the studies within the recent empirical literature have found support for the claim that knowledge obstacles might play a significant role in diminishing the propensity of companies to innovate (e.g., Segarra-Blasco et al., 2008; Amara et al., 2016), while others have found no significant effect for knowledge obstacles (e.g., Pellegrino and Savona, 2017) and significance only among companies more engaged in innovative activities (e.g., D'Este et al., 2012).

Similarly, there is also a group of network obstacles that refers to constraints concerning the difficulty in finding partners and establishing cooperative agreements for knowledge creation and innovation. These obstacles typically involve factors such as scant possibilities of firms to engage in cooperative arrangements with other actors in the innovation system, or even the lack of adequate external techno-scientific services to support companies' innovative activities. The reason for that could be either a disintegrated innovation system or a more fundamental absence of key actors at play in the system. The literature on social network analysis provides the elementary conceptual and theoretical tools to understand both the needs and the difficulties involved in the cooperation for innovation (Powell and Grodal, 2005). In a nutshell, this literature has remarked that the benefits from networks stem from the combination of incentive structures from markets and control mechanisms from hierarchies, but it has also stressed that this combination is only possible when there is a certain level of integration, trust and mutual understanding between the actors balanced with a certain level of heterogeneity and diverse interests, which is usually difficult to reach (Vonortas, 2009). However, recent empirical studies have largely neglected network obstacles while favoring the analysis of other barriers such as financial and knowledge ones, when not incorporating network elements in the group of knowledge obstacles.

Organizational constraints have also been at the spotlight for a while, especially in the innovation management literature. In a very influential book, Kanter (1983) showed that overly "segmentalist" management is more likely to create barriers to innovation, while more "integrative" management is more likely to improve productivity and foster innovation. In general, organizational obstacles comprehend factors such as organizational rigidities, management centralization and difficulty to adapt to changes in the environment. Organizational studies have provided the theoretical basis for such claims by arguing that innovation relates to different forms of organizational structures, especially the ones more adaptive through organizational learning to the continuous changes taking place in the turbulent and uncertain technological realm (Lam, 2005). Indeed, empirical findings have pointed out that firms facing organizational rigidities are less likely to become innovative (Tourigny and Le, 2004).

Another group of obstacles that must be considered refers to the institutional obstacles. Roughly speaking, these obstacles encompass the diverse set of formal and informal institutions hampering the innovative activity within a particular innovation system. Therefore, institution is broadly defined here as "the rules of the game" guiding the behavior of individuals and organizations in a society, such as conceived by scholars from Institutional Economics and Economic Sociology (e.g., North, 1990; Evans, 1995). Although institutional obstacles may then be represented by soft and tacit elements such as vicious business practices, lack of social trust and inefficient bureaucratic patterns, these barriers are more commonly found in the tangible structure of the regulatory framework. That is why the literature addressing institutional obstacles usually do it through regulatory issues, such as the regime of intellectual property rights, the definition of industrial standards, the legislation for taxation and other regulations. In fact, findings have indicated that regulatory barriers play a substantial role in the technology innovation process (Engberg and Altmann, 2015).

Relatedly, one might also want to consider cultural barriers as a separate group of obstacles to innovation. This group comprises elements related to cultural values, social norms, cognitive repertoires and skills, social roles, among others, which potentially contribute to shape the innovative process (Fernández-Esquinas et al., 2017). In fact, some studies have found that numerous cultural barriers act to restrict the innovation performance of companies (e.g, Leal-Rodríguez et al., 2014; Kostis et al., 2018). Therefore, the analysis of cultural elements aiming to understand the innovativeness of companies is definitely worth to consider in a broad conceptual framework, although they have been largely absent in the empirical literature.

Finally, one last group of obstacles that deserves to be mentioned is the set of socio-psychological obstacles. The analysis of these obstacles shifts the focus from the organizations towards the individuals as the characteristics that matter now are the ones related to personal biases among innovators, managers and decision-makers heading organizations in the innovation system. As a matter of fact, Schumpeter ([1912] 1983) himself had already drawn attention to this issue when he argued that, while most individuals acting within the stationary flow of the economic life do so rationally and in a safe ground, the ones that have decided to innovate only can do so by "swimming against the tide" so that the stable environment and its routines that were before an aid become a barrier. The psychology (and sociology to a lesser extent) literature has developed further this idea especially through the innovation barrier concept of mental models as deeply ingrained assumptions and generalizations that influence how individuals understand the world and make decisions (Yannopoulos et al., 2011).

However, these socio-psychological obstacles to innovation have been largely neglected in the empirical literature, probably because of their focus in the individuals instead of organizations.

1.4. Building a general conceptual framework for innovation

1.4.1. The moderation role played by the obstacles to innovation

From the sketch on determinants and obstacles to innovation developed so far, one might notice a moderation relationship between the former and the latter. Such moderation implies that the obstacles to innovation do not affect directly the innovation output of companies, but instead they hamper the positive effect of the various determinants over companies' innovativeness. For instance, the traditional financial obstacles refer foremost to the difficulties to internally fund R&D and other innovation activities or to externally obtain such funding, so they are directed to hamper a determinant of innovation, and not the innovation as an output. Similarly, knowledge, network, demand, organizational or any other determinant of innovation also have their equivalent barriers. In this sense, we can say that determinants and obstacles to innovation are the two sides of the same coin in the sense that to each area of influence on innovation they are both present, one representing the enabling factors of the innovation process, while the other represents the inhibiting ones. Therefore, one might conceive that obstacles to innovation play a general moderation role impacting first of all the determinants of innovation and only ultimately (and indirectly) the innovative performance.

However, such understanding has not represented the standard practice in the empirical literature. In fact, most recent empirical studies include obstacle variables in their econometric models just as other independent variables typically representing the determinants of innovation (e.g., Savignac, 2008; Segarra-Blasco et al., 2008; Blanchard et al., 2013; Álvarez and Crespi, 2015; Amara et al., 2016; D'Este et al., 2016; Coad et al., 2016; Pellegrino and Savona, 2017), then they expect the obstacle variables to show negative coefficients while the determinant variables are expected to show positive ones. Many of these studies are inspired by the Crépon-Duguet-Mairesse (CDM) model establishing a three-step relationship between research, innovation and productivity: the research equation linking research to its determinants, the innovation equation connecting research to output measures, and the productivity equation relating innovation output to productivity (Crépon et al., 1998). Basically, the supplementary empirical procedure in these studies consists in introducing obstacles as additional explanatory variables in the second step of the CDM model (i.e., in the innovation production function), which is the focus for studying companies' innovativeness (see Savignac, 2008; Segarra-Blasco et al., 2008; Blanchard et al., 2013).

From the perspective provided by the literature review undertaken so far, such empirical procedure is misleading in at least two ways. Firstly, although one must recognize the importance of the CDM model for the advancement of measuring and understanding innovation, it is clearly at odds with the most up-to-date theoretical developments of the Economics of Innovation pursuing a broader theory of innovation that encompasses economic and non-economic variables. This can be observed by the simple fact that in the CDM model innovation is basically a function of research, which undoubtedly resembles a science-push linear understanding of the innovation process. In addition, one of the versions of the model measures innovation outputs in terms of the number of patents, which again points out to a linear reasoning and also imply some sort of sectoral bias, since some sectors rely more on formal methods of protection while others rely more on informal methods of protection. Overall, the CDM model is to some extent more in tune with a neoclassical approach to innovation (i.e., the Economics of Technological Change), while the various criticisms from heterodox economists and other social scientists have shown over the last decades that innovation requires a more diversified disciplinary approach to be properly understood.

Secondly, as we have already mentioned, it does not seem theoretically adequate to include obstacle variables in the empirical setting just as other explanatory variables, since they actually play a moderation role in the innovation process and not a determination one. In fact, a few recent empirical studies have stressed this issue by explicitly analyzing whether and how companies change their strategy (i.e., the composition and weight of each internal and external determinant employed by the company in pursuing innovation) in response to their perception of different obstacles (e.g., Antonioli et al., 2017; Kanama and Nishikawa, 2017; Moraes Silva et al., 2019). Relatedly, other recent studies have analyzed how the perception of innovation barriers varies according to the heterogeneity of modes of learning or innovation behavior of companies (e.g., Thomä, 2017; Roud, 2018). In short, this whole idea of obstacles to innovation as moderation variables indicates that the effects of certain determinants on company innovativeness change in the presence of certain obstacles, so their relative importance in the company strategy might increase or decrease depending on the moderation effect from the various barriers.

Another issue that we must consider herein refers to the fact that the vast array of determinants and obstacles presented so far should affect differently product and process innovation, as well as radical and incremental ones. Indeed, it has been hard to establish a comprehensive theory on the factors that determine the innovative performance of companies precisely because scholars have achieved heterogeneous results with different methodologies focusing variously on product or process innovations, and sometimes favoring incremental innovations, while other times favoring radical ones (Vega-Jurado et al., 2008). Similarly, the literature on obstacles to innovation has identified that the nature of innovation matters for analyzing the various barriers, especially when it comes to radical innovation barriers which are complex and multifaceted phenomena that shall be addressed with particular attention (Sandberg and Aarikka-Stenroos, 2014; D'Este et al., 2016; Pellegrino and Savona, 2017). Therefore, the moderation relationship between determinants and obstacles is expected to vary with the nature of the innovation under consideration. Hence, in the same way that the determinants of product and process innovation might be different, as well as the ones of incremental and radical innovation, the obstacles moderating the effect of determinants over innovativeness are also expected to differ according to distinct types of innovation.

1.4.2. Policy responses to unlock determinants of innovation

One last issue ought to be discussed in order to equip us with thorough elements to build a general conceptual framework for understanding innovation. This issue refers to the role played by the several policy interventions seeking to spur the innovation process in a country or region. In fact, evidences from various social sciences have been gathered for years showing that public intervention to support development and socio-economic progress has been used as a legitimate mean for quite a long time across several nations (e.g., Gerschenkron, 1962; Furtado, 1983; Evans, 1995; Amsden, [2001] 2009; Chang, [2002] 2003). As regards innovation policies in particular, some recent evidences have been keen to point out to the entrepreneurial role eventually played by governments in fostering innovation in the most risky and promising fields (e.g., Block and Keller, 2011; Mazzucato, 2013).

The empirical literature on obstacles to innovation has taken policy into account mostly as just other determinant of innovation, similarly to what has been done with the barrier variables as previously described. In other words, many of the recent empirical studies include policy variables in their econometric models as independent variables expecting that they show positive coefficients testifying for their determination over companies' innovativeness (e.g., Segarra-Blasco et al., 2008; Blanchard et al., 2013; García-Quevedo et al., 2016). However, the understanding that we draw from our literature review pointing out to a moderation relationship between determinants and obstacles is actually different. In our view, the policy instruments play the role of unlocking the positive effects of determinants hampered by obstacles to innovation. In other words, the policy instruments would act precisely over the moderation generated by the various obstacles to innovation preventing determinants to affect positively companies' innovativeness. Therefore, the *raison d'être* of policy intervention for innovation must be found in the mitigation of barriers hampering the effectiveness of the determinants of innovation.

Some examples might illustrate and make our argument clearer. The financial obstacles previously discussed, for instance, typically call for the government (or some other non-profit organization) to intervene in order to ensure the proper funding for research and invention, mainly via universities and public laboratories, as a matter of conscious innovation policy. Thus, some of the finance-related policy instruments aim to unlock the positive effects of research on innovativeness by alleviating the burden of financial barriers via public funding for R&D and innovation. The same holds, for example, for policy instruments aiming to strengthen networks or diffuse technology, which consist basically on responses to barriers preventing cooperation or technology acquisition to positively affect firms' innovativeness. Of course, in the same way as the nature of determinants and obstacles is diverse, the nature of policies also varies so that it can be related to financial issues, knowledge shortages or any other type of constraint that attracts public authorities' attention. Addressing this diversity of policy programs, Edler and Fagerberg (2017) provide an illustrative frame for taxonomy of innovation policy instruments relating them to their overall orientation and stated goals, which is replicated in Figure 3.

Figure 3 – Taxonomy of innovation policy instruments

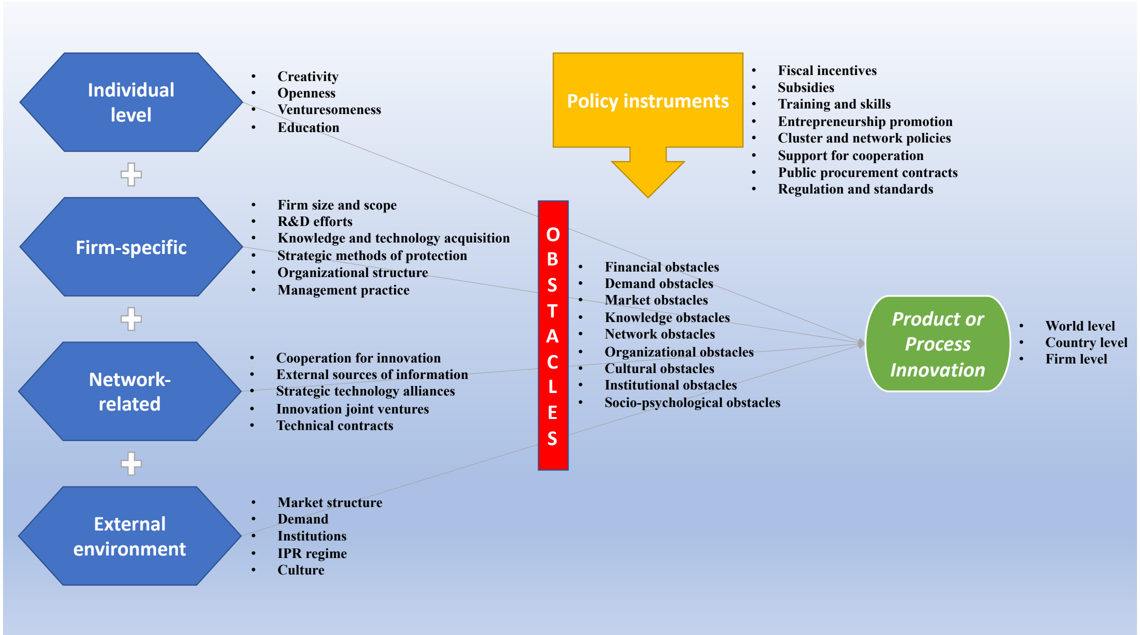
	Overall orientation		Goals						
Innovation policy instruments	Supply	Demand	Increase R&D	Skills	Access to expertise	Improve systemic capability, comple-mentarity	Enhance demand for inno-vation	Improve frame-work	Improve discourse
1 Fiscal incentives for R&D	●●●		●●●	●○○					
2 Direct support to firm R&D and innovation	●●●		●●●						
3 Policies for training and skills	●●●			●●●					
4 Entrepreneurship policy	●●●				●●●				
5 Technical services and advice	●●●				●●●				
6 Cluster policy	●●●					●●●			
7 Policies to support collaboration	●●●		●○○		●○○	●●●			
8 Innovation network policies	●●●					●●●			
9 Private demand for innovation		●●●					●●●		
10 Public procurement policies		●●●	●●○				●●●		
11 Pre-commercial procurement	●○○	●●●	●●○				●●●		
12 Innovation inducement prizes	●●○	●●○	●●○				●●○		
13 Standards	●●○	●●○					●○○	●●●	
14 Regulation	●●○	●●○					●○○	●●●	
15 Technology foresight	●●○	●●○							●●●

Notes: ●●● = major relevance, ●●○ = moderate relevance, and ●○○ = minor relevance to the overall orientation and stated innovation policy goals of the listed innovation policy instruments.

Source: Edler and Fagerberg, 2017.

A more detailed discussion on the policy nature of the debate as regards obstacles to innovation will be presented in the next chapter. For now, as we have gathered a comprehensive number of elements related to the innovation process, we are able to depict in Figure 4 a general conceptual framework that can be built from our literature review. We organize the various determinants in four broad sets (in blue) according to the level at which they are at play, from individual and firm-specific microlevels to network-related and external environment macrolevels. Some examples of the types of determinants to be found in each of these sets are provided. The arrows go from the determinants to the innovation outputs (in green), which can be product or process innovation at different novelty levels (new to the world, new to the country, new to the firm). The set of obstacles to innovation (in red), on the other hand, moderates this relationship by making the impact of some determinants on companies' innovativeness more or less effective. They can also be of various natures, such as financial, demand, knowledge, network, organizational, etc. Finally, the set of policy instruments (in yellow) emerges to tackle the obstacles at play in order to unlock the effectiveness of the hindered determinants of innovation. Some examples of policy instruments that might be used to spur innovation are also provided.

Figure 4 – General conceptual framework



Source: Author's elaboration.

Once again, we must stress that the examples of determinants, obstacles and policies that we gathered to elaborate our general conceptual framework are only illustrative, since it would be impossible to undertake an exhaustive survey that took into account the full diversity of these groups. Now we proceed to the next chapter with a twofold objective: first, discuss how the empirical literature focusing on obstacles to innovation has evolved over the years with a focus on its measurement interests and procedures; second, discuss the policy-driven nature of the debate on obstacles to innovation, especially as regards the creation of new indicators and the formation of a evidence-based policymaking movement in the innovation realm worldwide. Hopefully, these discussions will be helpful later on to both develop our econometric models and shed some light on our empirical results and policy recommendations.

Chapter 2 – Measurement and Policy Responses to Innovation Barriers

2.1. Early indicators and the rise of the Oslo Manual

As mentioned before, in the early days obstacles to innovation were indirectly measured as firms' R&D investment sensitivity to changes in cash-flows, market concentration or demand variation. This attitude towards measuring obstacles to innovation was aligned with mainstream economists' views which, on the one hand, focused on innovation aspects related to the neoclassical framework such as inventive activity, competition and demand, and on the other, valued more objective measures, even if indirect, rather than subjective or perceptional ones. This market failure approach to address obstacles to innovation has prevailed for a long time, as well as the innovation measurement by allegedly legitimate proxies such as R&D expenditures or patents, both very traditional indicators in tune with the linear rationale of the input-output framework typical within neoclassical economics. Hence, most empirical evidence for the presence of a wedge between internal and external finance, and the consequent underinvestment in innovation, uses R&D expenditure as a proxy for investment in innovation activities (Hall, 2010).

R&D data has been one of the few measures of innovation observed over long time periods at the firm level, at least since the publication in 1963 by the OECD of the document titled *Proposed Standard Practice for Surveys of Research and Experimental Development*, also known as Frascati Manual, which could partially justify the prominence of R&D indicators also in the analysis of obstacles to innovation.[19] Empirical literature within this branch has estimated R&D investment equations and tested whether liquidity constraints or excess sensitivity to cash-flow shocks are present and more pronounced than for ordinary investment (Hall, 2010). Among the main empirical evidences, one can find: large positive elasticity between R&D and cash-flow (Hall, 1992; Himmelberg and Petersen, 1994), significant positive relationship between both cash-flow and public-equity issuance and R&D investment especially among young high-tech

[19] The recognition of R&D, such as defined by the Frascati Manual, as an asset-creating activity in the 2008 System of National Accounts (SNA) from the United Nations (UN) demonstrates the high level of legitimacy that the R&D indicators have accumulated over the years, especially due to their alignment with traditional conceptual frameworks and mainstream economic indicators (Gault, 2013).

companies (Brown et al., 2009; Brown and Petersen, 2009), more sensitivity and responsiveness of R&D to cash-flow among companies operating in Anglo-Saxon economies than in Continental ones (Bhagat and Welch, 1995; Hall et al., 1999; Mulkay et al., 2001).

This situation of prominence of the R&D indicators and financial issues in the study of obstacles to innovation started to change in the early 1990s with the publication by the OECD of the document titled *Proposed Guidelines for Collecting and Interpreting Technological Innovation Data*, also known as Oslo Manual (OECD, 1992). With this manual, the OECD intended to lay down a conceptual framework for developing indicators in the areas of firms' objectives, sources of innovative ideas, factors that hamper innovation, engagement in R&D, costs of various innovation activities, among others (Hansen, 2001). The Oslo Manual drew inspiration from the intellectual production of the whole range of social scientists and heterodox economists working on alternative theoretical models to the then hegemonic linear model of innovation. According to Smith (2005), the works by Rosenberg are probably the main source of inspiration for the Oslo Manual in at least two ways: first, by challenging the notion of research-based discoveries as a necessary preliminary phase to innovation; second, by challenging the idea of separability between innovation and diffusion processes as they involve long and cumulative programs of post-commercialization improvements comprehending crucial incremental innovations.

More specifically, the work by Kline and Rosenberg (1986) proposing the so-called "chain-linked" model of innovation was of the utmost importance for the Oslo Manual conceptual foundation. This model stresses that innovation is not a sequential (or linear) process, but comprehends many interactions and feedback loops, as well as is a learning endeavor involving multiple inputs and not only the inventive (research-intensive) ones. Furthermore, this conception implies that, on the one hand, innovation is not just the creation of completely new products or processes, but also the introduction of relatively small changes, and, on the other, the innovation process should not be reduced to R&D efforts, but also comprehend other relevant non-R&D inputs, such as design activities, engineering developments and so on (Smith, 2005). Therefore, changes in the understanding of the innovation process over time have resulted in changes in the innovation indicators trying to keep pace with the broader definition and up-to-date theoretical foundations of innovation (Meissner et al., 2017; Gault, 2018).

The first edition of the Oslo Manual released in 1992 put forth a definition of innovation restricted to technological ones which only partially resembles the Schumpeterian ideas: “Technological innovations comprise new products and processes and significant technological changes of products and processes. An innovation has been implemented if it has been introduced on the market (product innovation) or used within a production process (process innovation)” (OECD, 1992, p. 28). Some years later, the OECD would update this definition in the third edition of the Oslo Manual (OECD, 2005) to better encompass the Schumpeterian ideas by including non-technological innovations, such as organizational and marketing ones. However, it is remarkable that, in addition to the Schumpeterian inspiration, one can find in the various editions of the Oslo Manual some ideas on innovation resembling the ones pioneered by sociologists such as Gabriel Tarde or Everett Rogers pointing out that innovation is a perceptional phenomenon more than a factual one.[20] This can be noticed by the notion within the Oslo Manual that the perception of innovations’ novelty might be related to different levels, so that the innovation may be new only for the firm introducing it, for the industry in the country in which the firm operates, or for the industry worldwide, which would be the most adequate level to address innovation in the Schumpeterian sense.

The indicators on obstacles to innovation proposed by the Oslo Manual also follow the perceptual approach. In its third edition, the manual lists several factors (far beyond financial issues) potentially hampering innovation to be surveyed in terms of their perceived importance among companies. The factors include economic ones, such as high costs or lack of demand, enterprise ones, such as lack of skilled personnel or knowledge, legal ones, such as regulations or tax rules, among others (OECD, 2005). Over the years, several countries have been engaging in the operationalization of the recommendations from the Oslo Manual through specific innovation surveys to measure the various facets of innovation among firms, including the obstacles to innovation. The pioneer and most relevant example is the CIS carried out by 27 member states of the European Union (EU) plus Norway and Iceland under the auspices of the EUROSTAT since 1993 aiming to

[20] In fact, although economists in general vastly prefer objective rather than subjective data, some of them have started to think differently in the last decades, especially within the branch of the Evolutionary Economics studying aspects of perception, mental models, learning processes, and their impacts on innovation and other economic issues (Hadjimanolis, 2003).

understand the extent and distribution of innovation activity in the region (Arundel and Smith, 2013).

By providing qualitative and quantitative data on innovation activities and on the successful introduction of different types of innovation into the market, the CIS and other innovation surveys worldwide have allowed a new wave of empirical studies on innovation and its determinants, effects and a variety of other topics (Mairesse and Mohnen, 2010). Since its very beginnings, the CIS has collected data on obstacles to innovation for several national realities, which made possible a revival in the empirical studies addressing the hindrance issues. In fact, the specific section dedicated to measure the perception of obstacles to innovation in the CIS and other similar surveys is the main data source for the current empirical literature on this subject, attesting how much this topic of research has largely benefited from the data coming from innovation surveys based on the Oslo Manual (Blanchard et al., 2013).

However, early on the use of innovation surveys for studying obstacles to innovation, some counterintuitive results were obtained. Analyzing data from the first edition of the CIS for Ireland, Denmark, Germany and Italy, Mohnen and Röller (2005) found that when firms report no obstacles their propensity to innovate is the lowest, suggesting an endogeneity problem as there may be reverse causality at play. Relying on data from the second edition of the CIS for Sweden, Lööf and Heshmati (2006) also obtained unexpected results pointing out to a positive association between the perception of some obstacles to innovation, such as problems with cooperation and lack of technology, and the innovative efforts among Swedish companies. Similar results had been reached years earlier by Baldwin and Lin (2002) studying not exactly obstacles to innovation, but impediments to technology adoption in Canada. These authors based their study in the Survey of Innovation and Advanced Technology (SIAT) of Statistics Canada, which actually appeared even before the Oslo Manual and the CIS. They found that the percentage of firms reporting impediments to technology adoption is markedly and consistently higher among technology users than non-users, and more frequent among innovating firms than non-innovating ones (Baldwin and Lin, 2002).

In view of such odd findings, Savignac (2008) came up with two possible explanations as sources of potential bias accounting for the positive correlation between innovation intensity and perception of obstacles: i. the decision to undertake innovative projects and the probability to face obstacles to innovation are likely to be both affected by common elements of unobservable heterogeneity; ii. the decision to engage in innovative activities and the perception of obstacles to innovation are simultaneously determined. Moreover, the author also discussed the possibility of a selection bias within innovation surveys which query indistinctly all firms (innovative and non-innovative) about the perception of obstacles to innovation. According to Savignac (2008), it would be better to ask only firms that “wished to innovate” about the potential obstacle they faced, since questioning non-innovative firms as well may have led to the overall odd results obtained simply because such firms have no interest in innovation and then find no obstacle in pursuing it.

As a strategy to work around this problem, Savignac (2008) proposes identifying a relevant sample of “potential innovators” among the companies surveyed, which encompasses the ones innovative plus the ones at least willing to innovate, in order to restrict the analysis of obstacles to innovation to this type of firm and possibly reduce the unobservable heterogeneity issues confounding the econometric estimations. In fact, after correcting for sample selection bias, the results obtained were largely the expected ones showing a negative correlation between innovation activity and perception of obstacles (Savignac, 2008), so the procedure of circumscribing the analysis to a relevant sample became a common practice in the empirical literature addressing innovation barriers. Let us know consider some of the main findings that such empirical analyses have rendered across different times and places.

Firstly, even the study of financial constraints to innovation was renewed after the publication of the Oslo Manual and the implementation of the CIS. Canepa and Stoneman (2008) used data from the second and third CIS conducted in the United Kingdom to explore whether financial factors constrain innovation, finding that such factors do impact upon innovative activity, especially among high-tech and small firms. Savignac (2008) showed that the likelihood that a firm will have innovative activities is significantly reduced by the existence of financial barriers using data from the FIT (*Financement de l’Innovation Technologique*) survey in France, whose methodological framework is the same as the well-known CIS’ one. Hottenrott and Peters (2012), using data from the German part of the CIS called Mannheim Innovation Panel (MIP), found that firms with higher innovative capability in general are more likely to have unexploited innovation projects independently of their financial background, but firms with high innovative capability and low levels of internal funds are especially more likely to be constrained than their liquid counterparts.

Soon after, scholars started to pay attention to non-financial obstacles to innovation as well, since the innovation surveys measure a series of potential financial and non-financial barriers as perceived by companies. According to Iammarino et al. (2009), most of these studies are situated in one of the two following strands: i. one line of research focuses on how the perception of different types of obstacles is affected by various firm and industry characteristics, including intensity/propensity to innovate; ii. the other line focuses instead on how the intensity/propensity to innovate is affected by perceived obstacles, controlling for other firm and industry characteristics. Therefore, the understanding of obstacles to innovation as dependent or independent variables has varied in the literature, and albeit the two approaches are related, they have required distinct econometric strategies. Even though our approach to obstacles to innovation is a different one, focusing on innovation barriers as moderation variables instead, it is worth to present some of the main studies and findings from both these strands.

Among the studies understanding the obstacles to innovation as independent variables in the econometric models, we can mention the following examples. Blanchard et al. (2013) analyzed the impact of financial and non-financial obstacles on the firms' propensity to innovate using data from the fourth wave of the CIS conducted in France, finding significantly negative estimates of the impact of the obstacles (both financial and non-financial) on the intensity of innovation among French firms. Expanding the analysis from innovation to productivity, Coad et al. (2016) estimated the effect of various barriers to innovation on firms' economic performance by using data from the CIS conducted in the United Kingdom. The authors identified that financial barriers negatively affect productivity across the whole productivity distribution, while knowledge barriers mostly affect high productivity firms. Relying on the same database from the CIS in the United Kingdom, Pellegrino and Savona (2017) also found similar results pointing out that not only financial barriers matter as hindrances to innovation, but also demand, market structure and regulation obstacles are responsible for reducing firms' propensity to innovate.

From the side of the studies addressing obstacles to innovation as dependent variables in the econometric models, one can also find interesting instances. Iammarino et al. (2009) analyzed data from the Italian CIS and observed that important differences in firms' perception of obstacles to innovation occur both across regional locations and types of firms, such as: firms located in the North and in the Center of Italy tend to less frequently perceive obstacles to innovation as relevant, and firms belonging to a corporate group (foreign or Italian) tend to perceive obstacles to innovation as relevant less than single domestic firms. Looking to data from the fourth CIS in the United Kingdom, D'Este et al. (2012) came up with an ingenious classification to investigate the relationship between firms' engagement in innovation and their assessment of the various obstacles. The authors distinguished between deterring barriers to innovation, which refer to obstacles that are seen as insurmountable by companies and prevent them from engaging in innovation in the first place, and revealed barriers to innovation, which refer to obstacles that emerge from the firms' awareness of the difficulties involved in innovation as a result of engagement in innovative activities.

Finally, there are also some recent studies being conducted within developing countries' context focusing on policy issues, such as the analysis by Resende et al. (2014) using the data on obstacles to innovation from PINTEC to study complementarities of innovation policies in Brazil, and the paper by Santiago et al. (2017) using data from the Mexican innovation survey to identify which companies' characteristics lead to the perception of which obstacles to innovation in Mexico and then draw some policy recommendations. In fact, the policy dimension of studying obstacles to innovation has been present very often in the empirical literature worldwide. Such dimension is particularly relevant for developing countries in need of understanding the main factors hampering the innovation performance in their specific contexts in order to elicit policy guidelines. Therefore, we move now to a more detailed consideration of the policy-driven nature of measuring obstacles to innovation.

2.2. The policy-driven nature of measuring obstacles to innovation

Policy concerns have been at the heart of the interests in measuring and understanding obstacles to innovation since the very beginning. As we mentioned before, the rationales of market failure were behind the conceptualization of the traditional financial, market and demand barriers to innovation within the mainstream economic framework. The sources and the effect of market failures for innovation are clearly defined in the neoclassical approach as: on the one hand, the effect of the existence of market failures is an underinvestment in R&D for the generation of new knowledge, and, on the other, their sources are explained by the (semi) public nature of knowledge understood as an economic good (Bleda and del Río, 2013). Therefore, the innovation activity grows costly, because of its indivisibility and the difficulty in appropriability, and grows risky, because of uncertainty in terms of both its final outcome and the level of demand resulting from the problem of price determination (Bach and Matt, 2005). Such as previously discussed, these elements contribute decisively to the emergence of financial, market and demand barriers to innovation, which require direct government intervention to be overcome.

Bach and Matt (2005) list the main policy principles and actions guiding government intervention within the neoclassical framework, namely: i. provide (or help to circulate) better information to reduce uncertainty and give the demand (supply) side better information on supply (demand); ii. substitute wholly or partially for the market either on the supply side (by carrying out innovative activity or contributing to the firms' investment in R&D by means of subsidies, tax breaks, grants, etc.), or on the demand side (by ordering innovative outputs to firms, or helping agents to buy such outputs), in order to reduce, or more evenly distribute, the uncertainty, risk and cost for innovative firms; iii. promote mechanisms or regulations to remove or diminish externalities or facilitate their internalization in the agent's optimizing calculations, mainly by providing a property right to innovator on his technology as a compensation for generating knowledge externalities. Such corrections to market failures allegedly lead the optimizing rationality of agents to allocate resources through market means in such a way that a "second-best" equilibrium can be reached (Bach and Matt, 2005). Hence, the aforementioned financial, market and demand barriers to innovation are only eroded by the policy action, which restores the optimal functioning of the market.

When the Oslo Manual appeared in the early 1990s, it also brought to the forefront the policy nature of measuring obstacles to innovation, but now understanding them beyond the traditional barriers to innovation found in the mainstream economics. In the first edition of the manual (OECD, 1992), it says: "Obstacles to innovation are significant for policy as well, since a good proportion of government measures are in one way or another aimed at overcoming them." (p. 23), and "Given that publicly funded R&D often accounts for a substantial proportion of total R&D in OECD economies, there is a clear need to understand its industrial effects more clearly. But R&D is only one element of public policy with effects on innovation performance. Other areas can also promote innovation performance, or restrict it. (…) These aspects of public policy can be examined via questions on firms' perceptions of obstacles to innovation." (p. 24). In its third edition (OECD, 2005), the Oslo Manual also emphasizes the importance of measuring and tackling obstacles to innovation in developing countries' contexts: "A key element in innovation policies in developing countries is to assist potentially innovative firms to overcome the obstacles that prevent them from being innovative and to convert their efforts into innovation." (p. 140).

As we already argued, the Oslo Manual drew a lot of inspiration from the second tradition of the Economics of Innovation and the adjacent social sciences such as sociology, management, history, among others. In particular, the third edition of the manual incorporated more explicitly the so-called innovation systems approach in a new chapter on linkages in the innovation process (Gault, 2013).[21] According to Smith (2000), the systems approach to innovation is founded on the idea that innovation carried out by firms cannot be understood purely in terms of independent decision-making at the company level, but involves complex interactions between a firm and its environment. Therefore, a key general premise of policy within the innovation systems framework is that the standard market failure rationale is not enough to promote the development and diffusion of innovations, requiring also that the government deals with "systemic failures"[22] involving problems rooted in the interactive behavior of the agents in the system and its institutions (Bleda and del Río, 2013).

Woolthuis et al. (2005) propose that the basic conceptual underpinnings of the innovation systems approach are: i. innovation does not take place in isolation, requiring interaction between the various actors in the system; ii. institutions (formal/hard and informal/soft) are crucial to economic behavior and performance, as they form the "rules of the game" reducing uncertainty in the system; iii. evolutionary processes play an important role by generating variety, selecting across such variety, and producing feedback from the selection process to variation creation. According to these scholars, in all these basic elements systemic imperfections may take place if the combination of mechanisms is not functioning efficiently, which then constitute the systemic failures.

[21] There are several specific branches within the innovation systems approach, among which the most well-known are the National Systems of Innovation (e.g., Lundvall, 1992), the Regional Innovation Systems (e.g., Braczyk et al., 1998), and the Sectoral Systems of Innovation (e.g., Malerba, 2004).

[22] Such as argued by Bach and Matt (2005), the term "failure" is adopted in this literature for the sake of simplicity, but may be misleading, since in the "market-oriented" framework there is always an implicit or explicit reference to an "optimal situation" that would be reached if all theoretical conditions were fulfilled, while within the alternative "systems-oriented" framework this reference to an optimal situation does not exist, and thus it is not exactly appropriate to consider "failures".

They can be listed in several groups, such as: infrastructural failures; transition failures; lock-in/path dependency failures; hard and soft institutional failures; strong and weak network failures; capability and learning failures; and still others (Smith, 2000; Woolthuis et al., 2005; Chaminade and Edquist, 2010).

Among the main basic policy principles that can be drawn from the innovation systems approach, one can mention the general need to help the development and orientation of the cognitive capacity of actors and to provide conditions conducive to the use of this capacity harmoniously (Bach and Matt, 2005). In terms of policy action, Wieczorek and Hekkert (2012) mention the following "systemic instruments" for innovation policy: i. stimulate and organize the participation of various actors; ii. create space for actors' capability development; iii. stimulate the occurrence of interaction among heterogeneous actors; iv. prevent ties that are either too strong or too weak; v. secure the presence of hard and soft institutions; vi. prevent institutions being too weak or too stringent; vii. stimulate the physical, financial and knowledge infrastructure; viii. ensure that the quality of the infrastructure is adequate. However, one might easily notice that the orientations from such approach are rather vague, which stems naturally from the fact that policy actions must be adapted to contexts defined according to geographic, industrial, sectoral, market, and institutional dimensions, so there are no "best-practices" for innovation policy in this perspective (Bach and Matt, 2005). Table 1 summarizes the main differences between the neoclassical and the innovation systems frameworks.

Table 1 - Differences between Neoclassical and Innovation Systems Frameworks

	Neoclassical Framework	*Innovation Systems Framework*
Underlying assumption	Equilibrium Perfect information	Non-equilibrium Asymmetric information
Focus	Allocation of resources for invention Individuals	Interactions in innovation processes Networks and framework conditions
Main policy	Science policy (research)	Innovation policy (technology/industry)
Main rationale	Market failure	Systemic (failure) problems
Government intervention	Provide public goods Mitigate externalities Reduce barriers to entry Eliminate inefficient market structure	Solve problems in the system Facilitate the creation of new systems Induce change in the supporting structure Facilitate transition and avoid lock-in

Main policy strengths	Clarity and simplicity Analysis based on long time series Science-based indicators	Context-specific Broad policies related to innovation Holistic conception of innovation
Main policy weaknesses	Linear model of innovation Framework conditions not considered	Difficult to implement in practice Lack of indicators for the analysis

Source: Adapted from Chaminade and Edquist (2010).

Adopting the innovation systems approach, the Oslo Manual brings to light several other obstacles to innovation, in addition to the traditional ones, that might be fundamental to tackle systemic failures and support the design of innovation policies. Obstacles such as knowledge, network, organizational and institutional barriers are now taken into account in the innovation surveys, and the literature using these data to discuss innovation policies has flourished in recent times. Relying on CIS data from various European countries, Galia and Legros (2004) and Mohnen and Röller (2005) found that there is a need to adopt a package of policies in order to help firms to engage in innovation activities, while a more targeted choice among policies is needed to encourage firms to persevere in their innovation efforts. Analyzing the complementarities between obstacles to innovation and policies, these studies departed from the idea that the scrutiny of such complex entities as organizational structures, institutions, and government policies provides a way to capture the intuitive ideas of synergies and systems effects (Mohnen and Röller, 2005).

As a matter of fact, recent papers have stressed the importance of innovation surveys and, especially, obstacles to innovation data in contributing to the design and implementation of evidence-based policy in the innovation domain (e.g., García-Quevedo et al., 2016; Coad et al., 2016; Pellegrino and Savona, 2017). One particular topic of research that emerged from this understanding concerns the increasing interest in innovation policies among developing countries as tools for catching-up (Chaminade et al., 2009). Some scholars have paid special attention to the analysis of the obstacles to innovation in the context of developing countries aiming to provide policy advice (e.g., Resende et al., 2014; Santiago et al., 2017), such as recommended in the third edition of the Oslo Manual. Comparative studies might be another interesting avenue for research, such as undertaken by Hölzl and Janger (2014) in investigating differences in the perception of barriers to innovation across countries characterized by diverse levels of development. These scholars found that knowledge barriers related to the availability of skilled labor, innovation partners and technological knowledge are more important for firms located in countries closer to the development frontier, while the opposite is true regarding the availability of external finance.

These and other findings could be very useful for evidence-based policymaking, particularly in developing countries, but the linkage between policy and innovation measurement has never been so simple. As showed in Table 1, the combination of the policy strengths of the neoclassical framework such as clarity, simplicity and the use of long time series of consolidated science-based indicators for the analyses, on the one hand, with the policy weaknesses of the innovation systems framework such as the difficulty to implement in practice the far vague recommendations stemming from the theoretical framework and the lack of consolidated indicators relying on the systemic model, on the other, make the incorporation of innovation surveys indicators (especially the ones based on the Oslo Manual) in policymaking especially problematic, as we shall discuss in the next section.

2.3. Problems of mismatching between innovation indicators and policymaking

In fact, as we discussed in the last section, innovation policy is partly influenced by the dialogue between policy and theory to the extent that the debate on the rationales for government intervention is inherently linked to the theoretical approach that one chooses to explain innovation and technological change (Chaminade and Edquist, 2010). In the same vein, there is also an essential complementarity between theory and measurement as, by and large, "getting the data right" requires "getting the theory right" and vice-versa (Hulten, 2007). According to Meissner et al. (2017), in recent decades there has been a gradual broadening of the concept of innovation and of the corresponding policy and measurement, whose key elements include: i. a concept spanning the whole chain of knowledge production from fundamental research to market launch; ii. a systemic understanding of innovation, in which innovation is seen as the result of the interaction of various actors; iii. a notion of innovation policy that is not restricted to promoting innovation as an end in itself, but that considers innovation as an important tool in overcoming social challenges; iv. a broad understanding of innovation policy extending beyond traditional science and technology policy to incorporate other relevant sectoral and social policies; v. greater attention paid to public sector and social innovation.

Nevertheless, some challenges have been presented to such theoretical evolution both in terms of empirical operationalization and policy implementation (Meissner et al., 2017). In the particular case of the relationship between measurement and policymaking, although it is widely agreed that one of the key aims of measuring innovation is to support policy design and evaluation, studies have found that the linkage between policy and statistics often involves highly complex mechanisms and the outcomes from such relationship have not been so virtuous and straightforward across countries as one would expect (Sloan, 2006). Researchers from the UNU-MERIT conducted one study in the early 2000s to assess to which extent the data from the CIS and similar surveys had been used to inform the innovation policy in several nations. In the period 2004-2006, they interviewed 67 members of the innovation policy community from different countries (55 from the European countries, and 12 from Canada, Japan, Australia and New Zealand) inquiring about their use of and need for innovation indicators. Surprisingly, they found that, despite the data availability from various waves of innovation surveys in these countries, policymakers still largely relied on the traditional patent and R&D indicators, while innovation indicators only played a minor role in the process of policy design and evaluation (Arundel, 2007).

These results led the researchers to coin the so-called "Oslo paradox", according to which one finds innovation surveys based on the guidelines from the Oslo Manual everywhere, but no substantial impact on the innovation policy among OECD countries. However, such phenomenon is not restricted to developed countries and innovation surveys based on the Oslo Manual, as a study conducted in Latin America showed years later. This study was sponsored by the Inter-American Development Bank (IDB) and aimed to identify whether innovation surveys were considered as relevant inputs to the policy community from Argentina, Chile, Colombia and Uruguay when designing and evaluating policies. After interviewing 36 members of the innovation policy community in these countries, the researchers verified that innovation surveys were not centrally considered as relevant inputs for policymaking in any of them (Baptista et al., 2010). Since the innovation surveys in most of these countries (the only exception is Chile) are not based on the Oslo Manual from the OECD, but in the regional version of it prepared by the *Red de Indicadores de Ciencia y Tecnología* (RICYT) and dubbed Bogota

Manual,[23] it is not appropriate to only talk about an "Oslo Paradox", but more broadly about a systematic underuse of innovation indicators worldwide.

This phenomenon seems to characterize not only the innovation field though, but the broader domain of science and technology (S&T) policy as a whole. Since the early 1990s, the literature on STS has identified the existence of a systematic underuse of S&T indicators on policymaking. The general diagnosis was that, despite decades of intense statistical production, the effective influence of these indicators on the policy cycle was still fairly low (Velho, 1992). In an extensive research conducted in the late 1980s on the design and use of S&T indicators in some developed countries, it was found that the assessment of S&T was mostly based upon peer review, and quantitative metrics were vastly disregarded (Nederhof and van Raan, 1989). According to Velho (1992), some of the most relevant reasons to explain this phenomenon are: i. the policymaking process involves not only policy, but also politics; ii. the indicators are necessarily grounded on theoretical models of measurement that sometimes are controversial; iii. the technical and methodological difficulties to measure the various phenomena persist despite the advances in the capability to collect and process information; iv. the creation and development of indicators usually happen oblivious to the needs of policymaking; v. indicators tend to be confined to specific boundaries, although social activities are usually intertwined.

Even though all these reasons play a key role for understanding the case of innovation indicators as well, the second one is particularly relevant for shedding light in the specific phenomenon of the underuse of innovation survey indicators. Scholars have argued that, while the shift away from the simplifying assumptions of the neoclassical account of technological change was a clear improvement stemming from the innovation systems approach and the consequent innovation surveys, such shift came at a heavy price as the problem of the choice of measures of innovation arose with the incorporation of historical specificity into the analysis (Scerri, 2006). In other words, the recent progress in the understanding of innovation systems, notably through the development of evolutionary approaches, showed that situations are always context-specific and path-

[23] RICYT released in 2001 the Bogota Manual, which is the result of collective efforts from Latin-American scholars to work around the difficulties to follow the Oslo Manual guidelines in less developed nations (RICYT, 2001). Later on, RICYT was invited to participate in the meetings to revise the second edition of the Oslo Manual, being in charge of preparing an annex proposal to the OECD's manual directed to the less developed country members and non-members of the organization (Lugones, 2006).

dependent, so there is no unequivocal interpretation of any indicator. Hence the complexity of innovation systems makes it tremendously difficult to understand the nature of the causal links between variables and draw general and straightforward conclusions to inform policymaking (Barré, 2005).

Arundel (2007) claims that, within the EU, one of the main reasons why the policy community strongly emphasizes R&D indicators over innovation survey indicators is the persisting power of the theoretical framework from the linear model of innovation on the policymaking reasoning. On the one hand, the continuing influence of the science-push model (and its neoclassical foundation in the background) has arguably hindered policy interest in a wider range of innovation indicators based on the systemic approach, and on the other, there is a clear dominance of supply-side R&D support programs in innovation policy across several countries (Arundel, 2007). The influence of neoclassical theory on politicians and policymakers remains strong as they generally assume a direct and positive relationship between GERD/GDP effort (gross expenditure on R&D – GERD – over the gross domestic product – GDP) and innovation system performance while ignoring other perhaps even more important factors, such as the relationship among the system's agents (Castro-Martínez et al., 2009).[24]

A comparison between the Frascati and Oslo manuals might enlighten the differences between R&D and innovation measurement and the implications for policy relevance of the indicators. While the Frascati Manual is arguably well standardized, as the definition of research used over the last five decades is similar from one edition to another, the Oslo Manual is more recent, and the definition of innovation is changing with every new edition (Godin, 2016). According to Godin (2016), both manuals offer distinct conceptual frameworks to guide measurement. The author argues that, in the Frascati Manual, one finds the stable and well-conventionalized (also neoclassical-related) linear input-output framework embodied in the institutional approach of the System of National Accounts (SNA) from the United Nations (UN). In the case of the Oslo Manual, on the other hand, one finds the unstable and still far from crystallized innovation systems approach underlying to the measurement enterprise. In other words, it seems that the linear model of innovation still remains influential in the political and administrative

[24] One clear example of this political bias is found in the early 2000s Lisbon Agenda from the EU which set as a target to increase the European R&D intensity to 3% of the GDP by 2010 hoping that such initiative would suffice to solve the EU's decline in competitiveness and innovation (Arundel, 2007).

circles largely due to its simplicity and stability in providing to decision makers a clear sense of orientation when it comes to thinking about allocation of funding for R&D activities (Godin, 2006).

In fact, some authors have argued that, while the really destructive critiques to the linear model of innovation implies the recognition of the systemic nature of innovation, they run the risk of leading to an alternative model where "everything depends on everything else" and yielding policy recommendations excessively vague and difficult to design, implement and evaluate, since that, on some occasions, a simplified representation of the innovation process which decomposes a complex system of interactions into linearly interconnected subsystems might not only be necessary but also desirable (Balconi et al., 2010). Therefore, it is not surprising that the simplicity of the linear model of innovation makes it attractive for policymakers negotiating or advocating changes to the allocation of public funds for R&D activities (Caracostas, 2007). Put another way, one might also speculate that the absence of an epistemological paradigm in the academic field of Innovation Studies could partially explain the underuse of innovation indicators based on the systems approach from the Oslo Manual, while the paradigmatic stability and clarity that the neoclassical framework confers to the R&D indicators stemming from the Frascati Manual legitimize and ensure their policy relevance.

As we could see from the discussion above, channeling useful data and analyses on the innovation process into policy design and evaluation is far from simple as various factors (institutional, historical, theoretical, methodological, etc.) combine to make it a complex and challenging process (Sloan, 2006). But this phenomenon is not limited to innovation survey indicators. Indeed, there is a huge literature pointing out that connecting research (and statistics) to policy is not a tricky undertaking only in innovation but in any policy domain, and research could indeed have a greater impact on policy than it has had to date. There is room for improvement for both policymakers, which could make more constructive use of research, and researchers, which could communicate their findings and data more effectively to inform policy (Crewe and Young, 2002). The willingness of practitioners and academics to reduce the gap between these two domains gave rise in the last decades to efforts to bridge research and policy by pursuing evidence-based policymaking (see Sanderson, 2002; Hansen and Rieper, 2009; Garcé, 2011).

Of course, the science, technology and innovation policy and academic fields are also taking part in this movement. One of the main initiatives in this sense is the so-called

Science of Science and Innovation Policy (SciSIP) in the United States, kicked off in 2005 by the President's Science Advisor, John Marburger, calling for the development of a new interdisciplinary field of quantitative science and innovation policy to better inform the American policymakers (Cozzens, 2010). Nevertheless, this is clearly not only an American enterprise, as one can identify an international community of practice emerging to advance the scientific basis of science, technology and innovation policy through the development of data collection, theoretical frameworks, models, tools and so on, in order to make future policy decisions based on empirically validated hypotheses and informed judgments (Fealing et al., 2011).

In Brazil, there have been some modest but important initiatives for the development of an evidence-based policymaking approach in the science and innovation policy domains as well (Velho, 2010). The analysis that we develop herein intends to contribute to this movement for evidence-based policymaking in the country, especially by showcasing how the data from PINTEC might be very helpful in addressing a typically policy relevant subject as obstacles to innovation. Therefore, in addition to the goal of deepen the understanding of the relationship between obstacles to innovation and firm innovativeness in Brazil, we also expect that our research proves useful for the development of evidence-based policies addressing some of the thorniest and long-standing challenges of the country in the pursuit of innovation and, ultimately, socio-economic progress. Beforehand, it is worthwhile though to provide a brief description of the recent Brazilian policy and measurement contexts in order to understand the interplay between these two domains in the country.

2.4. Brazil's policy and measurement contexts

According to Viotti (2008), we might conceive the evolution of the Brazilian policy and measurement efforts on science, technology and innovation (ST&I) as comprehending roughly three stages from the postwar onwards: 1st Stage (1950s-1970s) – characterized by the focus on state-led economic growth and extensive industrialization; 2nd Stage (1980s-1990s) – characterized by the focus on efficiency and liberalization of market forces; 3rd Stage (2000s-2010s) – characterized by the focus on new policy instruments for the scientific and technological progress within the private sector.

Although only the third and more recent stage is of interest for our purposes herein, we will also present some general characteristics about the first two stages in the next paragraphs in order to provide a big picture of the national context.

The first stage begins after the World War II, when the Brazilian development strategy started to fiercely focus on industrial policies with heavy state interference in the market as means to achieve economic growth (Suzigan and Furtado, 2006). During this period, the Brazilian state assumed the broad role of main economic actor by protecting the infant industry, supporting national and foreign private investments, and creating public companies in strategic sectors (Viotti, 2008). These years also witnessed the creation of various scientific and technological public institutions, such as the creation of both the Coordination for the Improvement of Higher Education Personnel (*Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* – CAPES) and the National Council for Scientific and Technological Development (*Conselho Nacional de Desenvolvimento Científico e Tecnológico* – CNPq)[25] in 1951 and the creation of the Funding Authority for Studies and Projects (*Financiadora de Estudos e Projetos* – FINEP) in 1967, which aimed to support and complement the import substitution industrialization process that was taking place in the country (Pacheco and Corder, 2010). The main theoretical framework guiding these policies was based on the structuralist approach developed within the Economic Commission for Latin America and the Caribbean (ECLAC) of the UN, whose leading scholars were Raúl Prebisch (1950) and Celso Furtado (1962) (Viotti, 2008). The industrialization process was meant to generate the transfer of modern technology, institutions and social relations to laggard nations, so the development process would be a consequence of the industrialization (Viotti, 2008).

In fact, the industrial policies from this period managed to achieve a fast-paced industrialization and economic growth that shifted the country's position in the international trade from a commodity supplier to a relevant manufacturing player (Suzigan and Furtado, 2006). However, this state-led development strategy, relying excessively on infant industry protectionism and the like, came with a high price and reached its limits at end of the 1970s as, on the one hand, subsequent macroeconomic and fiscal crises compromised the state capacity to pursue such expensive strategy, and, on the other, the knowledge and technology generation capability proved mostly developed

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[25] CNPq was originally named National Research Council (*Conselho Nacional de Pesquisa*). Although the original name changed in the 1970s, the acronym has remained the same.

only from the supply-side (state companies and public institutions) while the demand-side (private sector) remained dependent and fragile (Pacheco, 2007). Therefore, although in terms of economic growth the country really experienced an important advancement in this period, the socio-economic and technological development was much more elusive than that policy strategy could expect (Viotti, 2008).

In a nutshell, the limitation from these policies stemmed mostly from the fact that they were based on a linear understanding of innovation believing that the mere promotion of public R&D infrastructure and institutions would suffice to endogenize the process of technological change in the private sector. This represents the typical science-push linear model of innovation, positing that innovation depends on a necessary scientific base to be developed. In other words, the prevailing view at the time conceived the public sector as the provider of top-notch scientific and technological activities in the system, while the private sector was relegated to an inferior position of simple user or consumer of technologies in the system (Viotti, 2008). From this perspective, companies were just external agents in the innovation system, whereas public research institutions were the leading actors in the production and diffusion of new knowledge and technology. However, contrary to the expectations of the linear reasoning, the private companies barely benefited from the knowledge generated at public universities and research institutes as there was a remarkable dissociation between the public basic research efforts and the private companies' needs and capabilities (Arbix, 2010).

As regards the measurement initiatives during the first stage, this period was characterized by efforts to produce statistical information on S&T inputs, such as expenditure and human resources in research activities. In fact, already in the 1970s the Brazilian government was among the first to provide this information in response to a request from the United Nations Educational, Scientific and Cultural Organization (UNESCO) to compile data on scientific and technological activities worldwide (Velho, 2001). In the context of Big Science, policymakers around the world were more prone to foster science and technology since they realized their potential social and economic impact, moving from a previous broader understanding of "science as a progress engine" towards a new narrower understanding of "science as a solution to problems" (Velho, 2011). Evidently, there was also a marked linear rationale behind both understandings in tune with the prevailing development strategy in Brazil: investments in S&T activities, especially the ones undertaken at public research institutions, were the prime mover towards development and social well-being (Godin, 2005). Naturally, the indicators produced in Brazil at that time reflected this rationale and focused on measuring scientific publications, research expenditures and human resources, etc.

The rise of the second stage in the 1980s reversed this general public sector-centered approach towards its polar opposite: instead of pursuing an exacerbated state-led development strategy, the Brazilian economy should experience a strong liberalization shock (Viotti, 2008). During most of the 1980s and 1990s, the political agenda concerning the issues of technology and development in Brazil was dominated by the liberal view focusing on macroeconomic stability and institutional reforms (Erber, 2010). Basically, this view sustained that the process of opening the national market for the foreign investments would naturally unleash the technological and innovation development in the country. The role for the state action ought to be minimum in this view, only touching upon issues related to investment in infrastructure and training of human resources as an indirect way to support the creation of technological capabilities, which should be primarily driven by the private sector and the mechanisms of market competitiveness (Arbix, 2010).

Viotti (2008) argues that five main new elements of S&T policy arose at this second stage: i. Focus on the quality and efficiency of education, especially elementary school; ii. Reform of the intellectual property rights regime; iii. Focus on the use and diffusion of quality management practices; iv. Promotion of entrepreneurship, business incubators and technology parks; v. Introduction of innovation as a policy goal. Although these new elements started to address more sophisticated conceptions of innovation and technological change, one has to remember that they were still tied to the liberal perspective, which was markedly averse to policy action on the market. Indeed, the views from this period were closer to the tradition of the Economics of Technological Change than to the tradition of the Economics of Innovation. Therefore, despite of these new elements, the development strategy in the 1990s relied, generally speaking, on the following power structure: Regulatory state, foreign capital dominant on key technological sectors, restructured national private groups with limited financial capacity and weak productive synergies, especially as regards new technologies (Suzigan and Furtado, 2006).

Interestingly, such as the state-led approach in the previous stage, this market-oriented approach also built upon a linear reasoning on innovation, but here the linear model is represented by the demand-pull perspective positing that the competition forces are the prime mover of innovation. Hence, this time, the theoretical framework was based on the neoclassical economics, especially on the tradition of Economics of Technological Change and the work by scholars from the endogenous growth theory such as Romer (1990) and Grossman and Helpman (1991), sustaining that the public investment on basic research and human resources only would suffice to support the innovation process driven in an open economy primarily by market forces (Viotti, 2008). In other words, if innovation was considered a byproduct of state-led industrialization in the first stage, now it was considered a byproduct of market competitiveness, only requesting some minor state interventions to correct specific market failures. Yet, the reality proved once again more complex and trickier than any linear reasoning could expect, and the results achieved during the second stage were far from satisfactory, rendering only an impaired and dismantled system of support institutions for innovation, instead of reaching high levels of efficiency and technical progress (Arbix, 2010).

When it comes to the measurement initiatives, this second stage only experienced a minor reframing on the focus of the statistical production. Basically, it started to pay more attention to the private sector research activities. In the 1980s, the economic census carried out by the IBGE introduced questions regarding the companies' expenditure on R&D, patents and technology licensing (Moraes Silva and Furtado, 2017). Shortly after, the National Association for Research and Development of Innovative Companies (*Associação Nacional de Pesquisa e Desenvolvimento das Empresas Inovadoras* – ANPEI) began the execution of a R&D survey among its associates in the early 1990s (Erber, 2010). Both the economic census and the R&D survey addressed only inputs to the innovation process, and not the innovation itself (Moraes Silva and Furtado, 2017). Therefore, one can easily see that the linear rationale was still heavily present in the measurement initiatives of the second stage, although now comprehending also the inputs from the private sector and not only the ones from the public sector.

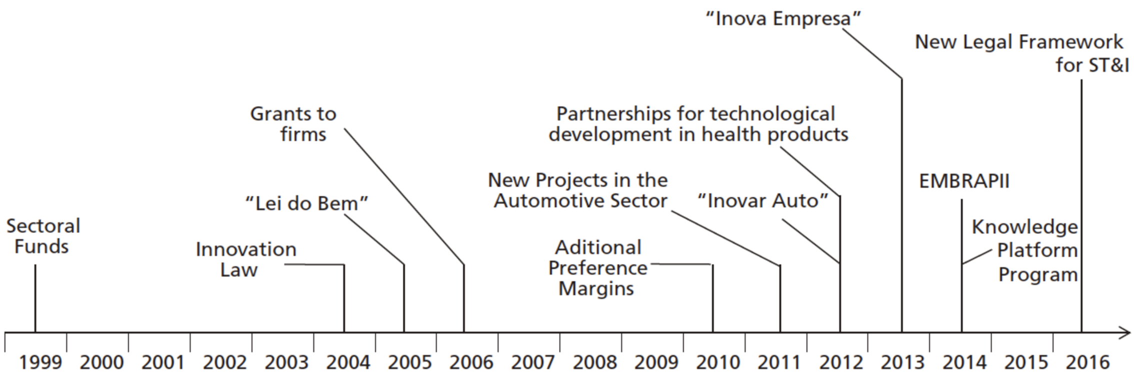
The third stage arises at the end of the 1990s and beginning of the 2000s with two invigorating changes in the S&T institutional landscape. Firstly, the creation of the so-called "Sectoral Funds" (*Fundos Setoriais*) in the late 1990s aiming to provide stability for the funding of S&T activities in key economic sectors of the country (Pacheco, 2007). In addition to improving the efficiency of the fundraising for the scientific and technological development in Brazil, the Sectoral Funds also inaugurated a new model of shared management which established that the guidelines, priorities, selection and approval of the funded projects were decided by a committee with representatives from various segments (Pachedo and Corder, 2010); Secondly, the implementation in the early

2000s of a new industrial policy in the country whose central core was the promotion of innovation at the private sector (Erber, 2010). This industrial policy was named Industrial, Technological and Foreign Trade Policy (*Política Industrial, Tecnológica e de Comércio Exterior* – PITCE), and it was inspired by the systemic approach to innovation in the social sciences, especially the tradition of the Economics of Innovation and the work by the evolutionary economists like Freeman (2008), emphasizing the need to articulate five elements (Arbix, 2010): i. adoption, imitation, improvement and development of new production techniques; ii. generation of new knowledge; iii. systems of economic and social innovation; iv. political and regulatory institutions; v. values and mores.

Other policies and laws followed after this turning point in the political environment towards innovation in Brazil. The so-called "Innovation Law" (*Lei da Inovação*, n. 10,973/04) was implemented in 2004 stipulating the rules for researchers from public institutions to participate in research projects with companies and the guidelines for the commercialization of intellectual property rights derived from these partnerships, as well as enabling the State to provide grants in order to subsidize R&D investments at private companies (De Negri and Rauen, 2018). Right after, a more modern scheme of tax incentives to encourage companies to invest in R&D was put in place with the implementation of the so-called Law of Good (*Lei do Bem*, n. 11,196/05) in 2005, which represented a significant improvement for business strategy as it put forth a specific tax deduction that could be automatically applied to R&D investments (De Negri and Rauen, 2018). Alongside these new laws and policies, the civil society also got more engaged in the discussions concerning science, technology and innovation, which can be exemplified by the reopening of the National Conferences on Science, Technology and Innovation (*Conferências Nacionais de Ciência, Tecnologia e Inovação*), whose first edition took place long ago in the 1980s, and did not include "innovation" in its title, while the second one occurred in 2001 bringing the innovation debate to light.

In the wake of this new stage, several other innovation-related laws and policies were implemented throughout the 2000s and 2010s, so one might easily argue that the Brazilian National System of Innovation was consolidated in this period (Arbix et al., 2017). Among the main recent instruments to support innovation, we can mention a few: the creation of the National Plan for Science, Technology and Innovation (*Plano Nacional de Ciência, Tecnologia e Inovação*) in 2008 aiming to articulate and coordinate the actions of the various political bodies related to ST&I in the country; the introduction of two new editions of industrial policies focusing on innovation, firstly in 2008 with the so-called Productive Development Policy (*Política de Desenvolvimento Produtivo* - PDP) and then in 2011 with the so-called Greater Brazil Plan (*Plano Brasil Maior* – PBM); the implementation of the first national program dedicated exclusively to foster technological innovation within private companies in 2013, the so-called Innovate Company Program (*Programa Inova Empresa* – PIE); the elaboration of an ambitious program designed to overcome societal problems through technology procurement in 2014, the so-called National Program of Knowledge Platforms (*Programa Nacional de Plataformas do Conhecimento*); and the implementation of the New Legal Framework for Innovation in 2016 (*Novo Marco Legal da Inovação*) aiming to reduce the bureaucratic burden and widen the legal flexibility to engage in innovation. In a synthesis exercise, De Negri and Rauen (2018) provide a timeline for the instruments that consolidated the National System of Innovation in Brazil in the last years, which comprehend some of those mentioned herein and some others, as can be seen in Figure 5.

Figure 5 – Chronology of Brazil's main ST&I policies and programs



Source: De Negri and Rauen (2018).

In short, all these efforts resulted in a fairly comprehensive framework of innovation policies, so the country relies nowadays on many instruments in use at developed countries, such as: i. Subsidized credit for innovation; ii. Tax incentives for R&D; iii. Grants for R&D projects; iv. Grants for university-industry collaboration; v. Public venture capital; vi. Public procurement for innovation; among others. However, it is still not clear to what extent these instruments have been truly effective. Some preliminary analyses show that, despite the efforts of the last decades, little has changed both in terms of innovativeness and R&D efforts in the country, as can be seen at Figure 1 presented in the introduction of this thesis. Maybe it is too soon to assess the results from these policies, but the general impression within the recent literature is that, although there has been an important increase in the public interventions to spur innovation in Brazil in the last years, the country has not reaped the expected benefits from these policies yet (De Negri and Rauen, 2018). In any case, the study developed herein intends to shed some light in this debate as well, so we can be surer about the consequences of the pro-innovation environment that arose in this new century.

Finally, as regards the measurement initiatives, this third stage brought the innovation indicators to the forefront of the statistical production. The main novelty in terms of measurement appearing in this period was the creation of PINTEC in the early 2000s by the IBGE (Erber, 2010). One of the most remarkable characteristics of PINTEC refers to the fact that this survey, differently from the previous data collections during the 1980s and 1990s, was based on the systemic approach advocated by the Oslo Manual from the OECD, thus repelling the conventional linear model of innovation on behalf of a more sophisticated understanding of the innovation process (Moraes Silva and Furtado, 2017). Therefore, the creation of PINTEC represented an important progress for the measurement of innovation in Brazil, especially because it enabled the production of indicators in tune with the up-to-date systemic view on innovation allowing both keener intellectual work and wiser policymaking addressing such a complex phenomenon. In closing, we provide in the Table 2 a synthesis of this brief overview on the three main stages of the innovation policy and measurement contexts in Brazil.

Table 2 – Main elements of each stage of the Brazilian policy and measurement contexts on science, technology and innovation

	1st Stage (1950s-1970s)	2nd Stage (1980s-1990s)	3rd Stage (2000s-2010s)
Development strategy	• Import substitution industrialization • Infant industry protection • State leadership • Public infrastructure and institutions for S&T	• Open and liberal economy • Macroeconomic stability • Efficiency and quality • Regulatory state	• Social policies for reducing inequality • Public-Private partnerships • State proactivity • Innovation policies
View on innovation	• Innovation as a byproduct of the state-led industrialization and economic growth	• Innovation as a byproduct of the market competition in an open economy	• Innovation as a result of both private and public initiatives and cooperation

Measurement initiatives	• Input indicators • S&T expenditure • S&T personnel • Focus on public efforts • Linear approach	• Input and some (minor) output indicators • R&D and Patents • Focus on private efforts • Linear approach	• Both input and output indicators • Both public and private efforts • Systemic approach

Source: Author's elaboration.

Before concluding this section, it is worthwhile to present some tentative thoughts about the likely end of the third stage in the late 2010s. As some scholars have pointed out, the Brazilian political system has yielded political parties unable to keep policies and programs for a long period, as the electoral cycles allied to predatory behavior of political actors lead to great instability and lack of long-run view in the conduct of public policies (Arbix et al., 2017). Such instability can be observed in some of the aforementioned innovation policy instruments. The two last industrial policies (PDP and PBM), for example, lost a lot of the focus on innovation that was present in the first one (PITCE) in favor of generous mechanisms of subsidies and protection to the traditional national industries in order to allegedly counterbalance the effects of the world financial crisis of 2007-2008 (Arbix et al., 2017). Similarly, the Knowledge Platform Program, for instance, was never fully implemented due to the political turmoil that has spread after the 2013 massive protests and demonstrations that took over the entire country (De Negri and Rauen, 2018). As regards the new federal administrations that came to power, firstly in mid 2016[26] and then in early 2019, both showed a more liberal inclination, arguing in favor of austerity measures and reduced policy intervention in the economy, which could have significant impacts on the innovation environment in Brazil. However, it is certainly too soon to have a clear understanding about the implications of this new liberal turnaround for the country's development strategies, although it seems clear enough that it might imply the end of the third stage discussed herein.

[26] The federal administration that came to power after the impeachment of President Rousseff in 2016 should not be strictly considered as a new administration, since it was part of the government elected in 2014. However, as the policy focus and political orientation of the federal administration changed dramatically after the impeachment, it is not totally inaccurate to consider it as a new administration.

Chapter 3 – Research Design

3.1. Data source and sample selection

PINTEC was first designed by the IBGE in the early 2000s aiming to provide a broad understanding of the innovation and R&D activities in the Brazilian economy and to support the actions and planning of the public and private actors (Moraes Silva and Furtado, 2017). Since its beginnings, PINTEC follows closely the guidelines of the Oslo Manual from the OECD, even though it has its own peculiarities, as a broader coverage of R&D information, for example. The survey has experienced some minor changes over the years mirroring the evolution of the Oslo Manual itself. In contrast to earlier editions, the last survey (sixth edition, PINTEC 2014) covers not only manufacturing sectors and technological innovations, but in tune with the third edition of the Oslo Manual it also covers some service sectors (notably the so-called Knowledge Intensive Business Services – KIBS) and non-technological innovations (organizational and marketing ones) (IBGE, 2016).

Our data source comes precisely from the last edition of PINTEC (PINTEC 2014), which comprises companies that have: i. active status in the Central Business Register held by IBGE; ii. main economic activity in extractive industry, manufacturing industry, electricity and gas, telecommunications, information technology services, architecture and engineering services, R&D services, data processing and web hosting, or editing, printing and music recording; iii. headquarters in Brazil; iv. 10 or more employees; v. business entity registration. The survey has two temporal references: i. most qualitative variables (dichotomous/binary, ordered categorical or unordered categorical variables) refer to the period 2012-2014; ii. quantitative variables (numerical discrete or continuous variables) and a few qualitative ones refer to 2014.

Moreover, the survey's sample design departs from the assumption that innovation is a rare phenomenon, so the sampling procedures need to ensure its representativeness. Therefore, PINTEC 2014 employed a stratified disproportional sampling procedure in which large companies (with more than 500 employees in manufacturing and more than 100 employees in services) were automatically included in the sample while the others were sampled according to their probability of being innovative (more likely innovative companies as identified in a screening process using government databases had higher weight in the sample selection). The final sample reached 17,171 firms[27], whose results were expanded to a universe of 132,529 firms by means of the Horvitz-Thompson estimator (IBGE, 2016). Table 3 presents the sectoral distribution of companies surveyed.

Table 3 - Distribution of companies surveyed by PINTEC 2014

Sector	**Total**
Extractive and manufacturing industries	**14,387**
Electricity and gas	**96**
Selected services	**2,688**
Total	**17,171**

Source: IBGE, 2016.

As mentioned before, PINTEC surveys a myriad of innovation-related elements that help to understand and monitor the state of companies' innovation in Brazil over the years. Companies are the unit of analysis from which information is obtained via questionnaire about their behavior, activities, incentives and other topics, what constitutes the "subject approach" (i.e., measuring innovation by inquiring innovating agents), in contrast to the "object approach" (i.e., measuring innovation by counting innovations themselves) (Archibugi and Sirilli, 2000). The rich thematic structure from PINTEC 2014 comprises several topics ranging from introduction of product or process innovation and R&D activities, to sources of information and cooperation for innovation, impacts and obstacles to innovation, among others. Each of these topics shall be presented more closely in the next paragraphs.

The survey starts asking basic characteristics of the companies, such as origin of controlling shareholder, belonging to a corporate group, scope of the company's main market. Afterwards, the survey queries about the introduction of new or substantially improved products (goods or services) into the market and/or new or substantially improved processes into the operational routine of companies. The innovative firms inform for both product and process innovation the novelty level of the innovation

[27] The effective number of firms that answered the survey altogether was smaller though (13,908 companies), corresponding to a response rate of around 80%.

introduced in terms of market scope (innovation at the firm, country or world level) and technical characteristics (improvement of a previous product/process or development of a brand new one), as well as they inform the main developer of the innovation (whether the company itself, other companies from the same corporate group, the company in cooperation with other organizations, or only other organizations). Lastly, since not every innovation effort is successful and there may be projects still in progress, the survey also asks about the existence of abandoned or ongoing innovation projects.

The survey then moves to the sections on innovation activities and funding. Measuring the allocation of resources to innovation activities reveals the innovative effort undertaken by companies in pursuing product and process innovation. PINTEC 2014 asks about the amount spent and relative importance (not important, low importance, medium importance, high importance) of eight categories of innovation activities, namely: i. intramural R&D activities; ii. extramural R&D acquisition; iii. external knowledge acquisition; iv. software acquisition; v. machinery and equipment acquisition; vi. training; vii. introduction of technological innovations into the market; viii. industrial project and other technical preparations for production and distribution. The survey also asks about the funding sources for these activities, but aggregating all non-intramural R&D activities into one single group and the intramural R&D activities into another which requires more detailed information.

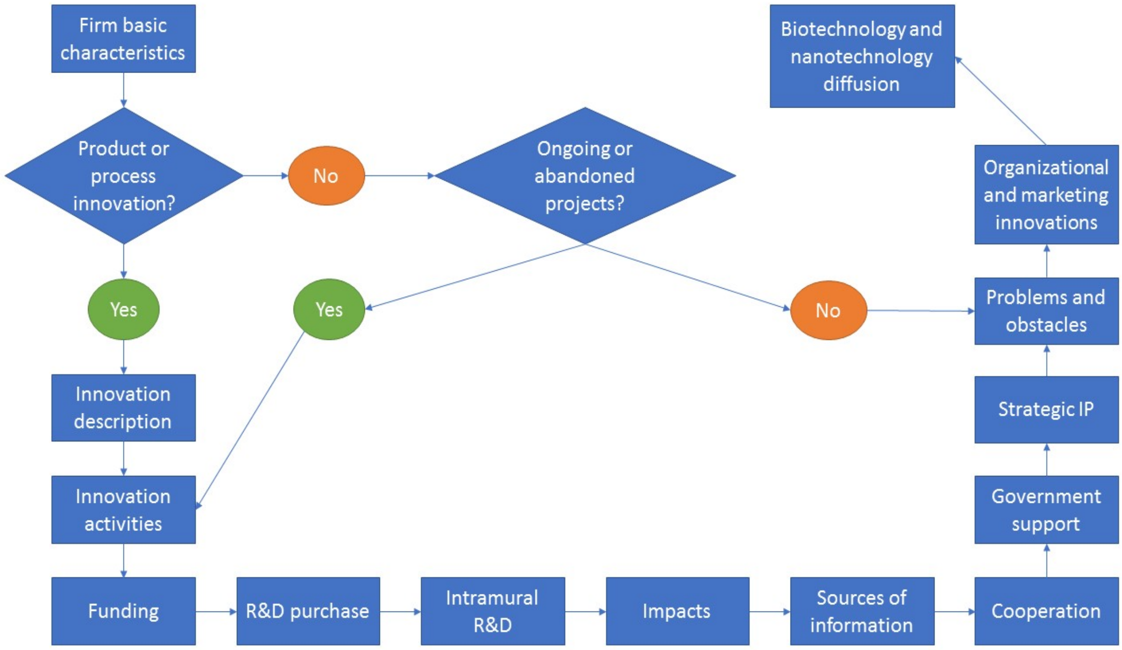
It is remarkable that PINTEC 2014 covers specially detailed information about R&D, something atypical among innovation surveys worldwide, but that can be partially explained by the fact that in Brazil there is no R&D survey, differently from most OECD countries, for example, so PINTEC was firstly designed to be a sort of hybrid of innovation and R&D surveys (Moraes Silva and Furtado, 2017). It has a specific section in the questionnaire dedicated to measure the percentage distribution of the amount spent on extramural R&D acquisition according to the type of organization providing the service, as well as a specific section dedicated to identify whether the intramural R&D activities were mostly continuous or occasional, the location of the R&D department, and the number of employees working on R&D by occupation, education, and type of employment (full- or partial-time).

The next section in the survey is dedicated to measure innovation impacts, which may reflect on the innovations percentage distribution on sales and exports or be associated to the product per se (improved quality, expanded scope of products, etc.), to the process per se (increased flexibility or productive capacity, reduced costs, etc.), to the market (kept or extended the market share, or opened up new markets, etc.), to the environment and sustainability, health and security, among others. The next two sections cover the topics concerning the relationship of the company with other organizations in the innovation system. Firstly, the survey queries about the sources of information that the company used to innovate; and secondly, it asks about partners in cooperative ventures for innovation. Both sections question about traditional potential sources/partners (such as suppliers, customers, competitors, consultants, universities, research institutes, among others) and their location, requiring companies to inform the relative importance of each one of them.

Moving to questions on the government support to innovation, PINTEC 2014 surveys information encompassing the use of policy instruments such as tax breaks, subsidies, public procurement, public funding and venture capital, etc. The survey also gathers information on the use of informal or strategic methods of intellectual property protection, such as complexity of product design, industrial secrecy, lead time over competitors and others. Finally, it moves to the section which matters the most for our purposes, the one on problems and obstacles to innovation. Both innovators and non-innovators answer this section. The innovators that faced problems during the innovation process, as well as the non-innovators that did not innovate because of obstacles they faced, inform the relative importance to a list of twelve potential factors hampering innovation: i. excessive economic risks, ii. high innovation costs, iii. lack of adequate funding sources, iv. organizational rigidities, v. lack of qualified personnel, vi. lack of information on technology, vii. lack of information on markets, viii. scant possibilities of cooperation, ix. difficulty to comply with standards, norms and regulations, x. lack of response from the consumers, xi. lack of adequate external technical services, xii. innovation activity centralized in another company from the same corporate group.

The survey ends asking whether companies had introduced organizational innovation (new management techniques, new methods of labor organization, etc.) and/or marketing innovation (significant changes in the marketing concepts or strategies, significant changes in the aesthetics or design of the products, etc.), and whether companies had used, produced or researched emergent technologies related to biotechnologies and/or nanotechnologies. Figure 6 summarizes the sixteen sections of the PINTEC 2014 questionnaire and their directional flow. It is important to notice that while a filter mechanism directs non-innovative companies (without ongoing or abandoned projects) to answer a more limited set of sections, both innovators and non-innovators answer the section on obstacles to innovation. This information is crucial in the design of the sample selection applied in our study.

Figure 6 – Thematic structure from PINTEC 2014

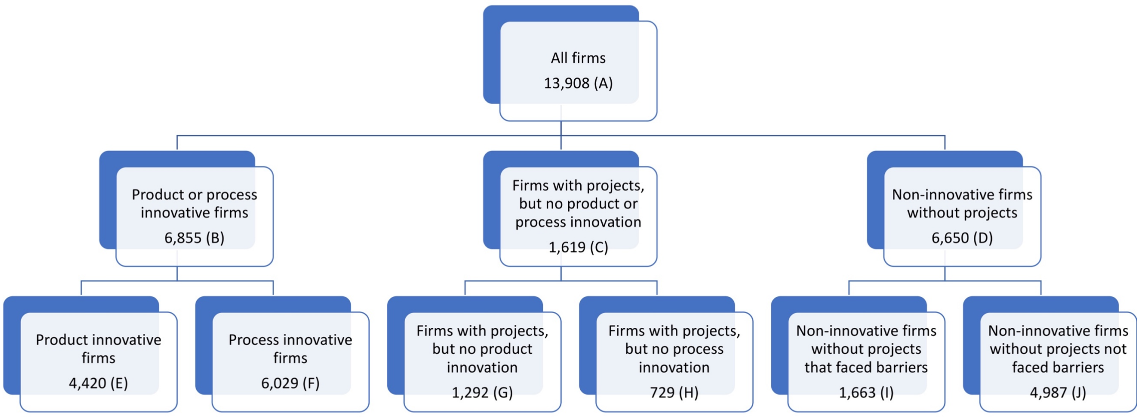


Source: IBGE, 2016.

Now let us turn to the details on sample composition for our study in Figure 7. Such as recommended by the recent literature (e.g., Blanchard et al., 2013; Coad et al., 2016; Pellegrino and Savona, 2017), we will not work with the full sample of PINTEC 2014, but rather with a "relevant sample" comprising only innovative companies (Group B) and potential innovators (Groups C and I) in order to filter out not innovation-oriented companies and avoid selection bias and endogeneity issues. The sample of potential innovators comprises companies that did not introduce product and/or process innovation, but had ongoing and/or abandoned innovation projects between 2012-2014 (Group C), plus companies that did not introduce innovation or had any project, but faced at least one very important obstacle to innovation between 2012-2014 (Group I).[28]

[28] To include this last group of companies (Group I) as potential innovators in our analysis, we needed to impute zero values for their responses to the variables referring to determinants of innovation, as they did not answer these questions in the survey.

Figure 7 – Sample composition



Obs.: The sum of B + C + D does not equal A because there is some overlapping between B and C as some firms reported innovation projects and did not innovate in product, but did so in process, and vice-versa. The same holds for E + F not equaling to B, and G + H not equaling to C, as some firms innovated in both product and process while others did not report projects and did not innovate in both product and process.
Source: Author's elaboration.

3.2. Conceptual model and hypotheses

In the Chapter 1, we drew from the literature review on determinants and obstacles to innovation a general conceptual framework (Figure 4) encompassing the moderation relationship between the main factors fostering and hampering the innovation process across different times and places and the role of public policies for unlocking the potential positive effect of hindered determinants on innovativeness. In this section, we present and discuss a reduced version of this general conceptual framework, which basically consists in an adaptation of the framework to the availability of information from our database (PINTEC 2014) in order to operationalize the empirical assessment of the hypotheses derived from the theoretical discussion. Hence, Figure 8 presents the operational conceptual model adapted to the data available in PINTEC 2014.[29]

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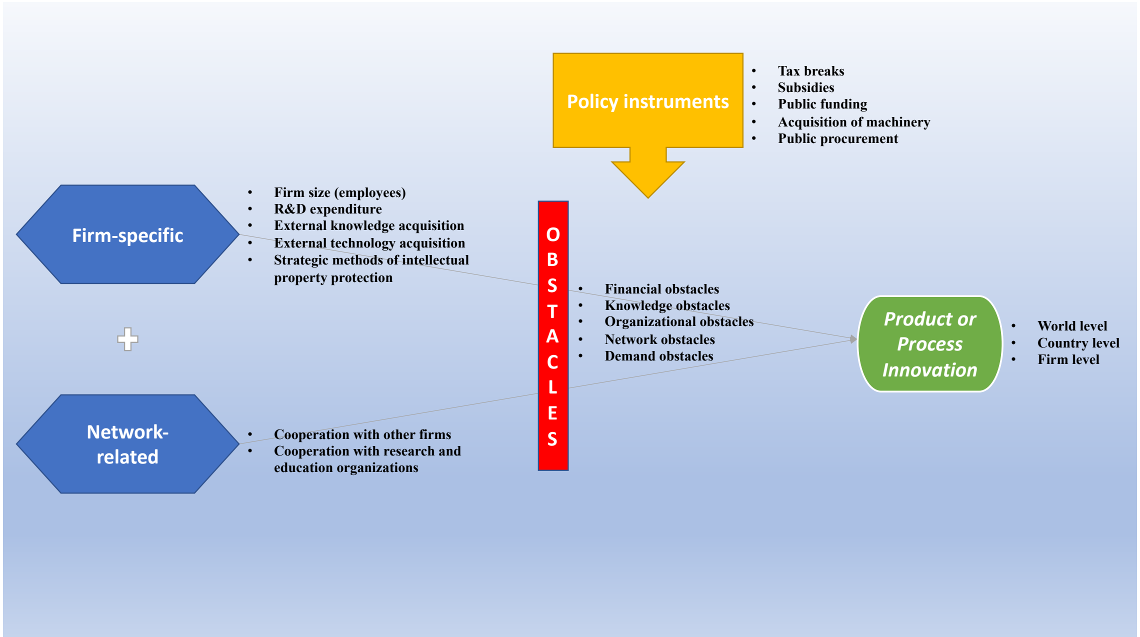
[29] To avoid multicollinearity issues, not all available data from PINTEC 2014 could be included in the model specification. For example, we opted to include R&D expenditure, but not R&D employees, as well as we decided to include cooperation for innovation, but not external sources of information.

Figure 8 – Operational conceptual model



Source: Author's elaboration.

Both sets of individual level and external environment determinants were completely left out of our operational conceptual model as PINTEC 2014 does not cover information regarding personal traits of potential innovators (researchers, managers, businessmen, etc.) or external environment conditions (demand, market structure, institutions, etc.) that could be used as proxies to socio-psychological and environment determinants of innovation. In compensation, several factors of the set of firm-specific determinants are comprised by the survey, so that only firm scope, organizational structure and managerial culture were left out of our model. As regards the set of network-related determinants, PINTEC 2014 does not cover strategic alliances, innovation joint ventures and the like, but it covers both cooperation for innovation and external sources of information. Regarding the set of obstacles to innovation, PINTEC 2014 covers most barriers identified in the theoretical discussion, the exception being market, institutional, cultural and socio-psychological ones. Finally, with respect to policy instruments, the survey covers a wide variety of different programs related to tax breaks, subsidies and scholarships, public procurement, funding for innovation projects, funding for the acquisition of machinery and equipment, among others.

As already discussed when presenting the general conceptual framework (Figure 4) in Chapter 1, the behavior within our operational conceptual model (Figure 8) goes in the following way: we assume that the set of determinants at the different levels (firm-specific and network-related) are positively associated with the innovation output (product or process innovation), which can take place at the firm, country or world level. However, the set of obstacles to innovation might interpose in this relationship moderating the effect of determinants over the innovation output. This moderation may manifest itself in at least two different ways: i. by generating a positive (negative) effect of a certain determinant that did not have a positive (negative) effect over the innovation output before the moderation, and ii. by inverting the positive (negative) effect that a certain determinant had over the innovation output before the moderation. From our perspective, the most interesting cases to identify and analyze in our study refer to the second one, when a determinant presents opposite effects before and after the moderation, as it shows a tremendous change in the behavior of the determinant due to the moderation introduced by the obstacle.

By and large, this moderation relationship means that, differently from most conceptualizations on obstacles to innovation, we conceive that the different barriers may positively affect certain determinants to the extent that, by affecting negatively others, they make that companies adapt their innovation strategy by relying more heavily on determinants with greater immunity to specific barriers. For example, when companies face knowledge barriers to innovation, they may start relying more on network determinants than firm-specific ones in order to access external expertise and presumably mitigate that particular obstacle. This implies an idea of heterogeneity of companies and their innovation strategies at different levels and contexts that to some extent responds to the existence and relevance of various obstacles to innovation.

Public policies enter the model precisely to tackle the issue of obstacles to innovation. The role of the government intervention via several policy instruments is to erode the innovation barriers and hence unlock the potential positive effects of determinants on companies' innovativeness. In other words, governments intervene in the innovation process by treating companies struggling with innovation barriers in order to eliminate such obstacles and unleash their innovative potential. Thus, innovation policies must exist only in contexts where there are obstacles to innovation at play. Otherwise, it would be meaningless to public authorities to intervene. Of course, here we rely on a broad understanding of such contexts demanding government intervention, encompassing not only the so-called "market failures" admitted by the neoclassical literature, but also the so-called "systemic failures" identified by the evolutionary approach.

From this discussion on the behavior of the different factors (variables) within our conceptual model, we can draw the following three general hypotheses to be tested in our empirical setting:

Hypothesis 1 (H1) – Determinants of innovation are positively associated with companies' innovativeness.

Hypothesis 2 (H2) – Obstacles to innovation moderate (positively and negatively) the association of determinants of innovation with companies' innovativeness.

Hypothesis 3 (H3) – Policy instruments erode obstacles to innovation by lowering companies' perception of innovation barriers.

One might notice that the first two hypotheses do not refer to the specifics of the companies' innovativeness (innovation output), namely: whether it is product or process innovation and its novelty level (firm, country or world level). The reason for this is that these hypotheses are just general ones, whose particularities will be tested empirically and discussed later on, but not presented as hypotheses per se. Besides, it is also remarkable that there is a great variety of determinants, obstacles and policies that will be considered in our analysis, but which is not explicit in our broad hypotheses. In fact, we left the specifics out of the elaboration of our hypotheses precisely because it would be unfeasible to hypothesize on all these particularities. Also, the role of our hypotheses is just to provide some broad guidance linking our theoretical discussions to the empirical exercises, so the details might be discussed afterwards even though there are not explicit hypotheses taking them directly into account.

3.3. Construction of variables

We start the discussion about the construction of the variables utilized in the empirical exercises by considering our two distinct dependent variables: Product innovativeness (PDIN) and Process innovativeness (PCIN). Both dependent variables are categorical ones with four categories each referring to the period 2012-2014. PDIN is 0 if the company did not introduce product innovation, but either had ongoing and/or abandoned innovation projects or assigned high importance to at least one obstacle to innovation; 1 if the company introduced product innovation at the firm level; 2 if the company introduced product innovation at the country level; and 3 if the company introduced product innovation at the world level. Similarly, PCIN is 0 if the company did not introduce process innovation, but either had ongoing and/or abandoned innovation projects or assigned high importance to at least one obstacle to innovation; 1 if the company introduced process innovation at the firm level; 2 if the company introduced process innovation at the country level; and 3 if the company introduced process innovation at the world level. As one might see, the baseline category (value 0) for both dependent variables refers to the companies defined as "potential innovators", those that did not innovate but at least tried or considered to do so, hence excluding non-innovators unwilling to innovate from our relevant sample.

Now as regards the independent variables, let us consider the construction of the variables related to firm-specific determinants of innovation. These are five variables: Firm Size (SIZE), R&D Expenditure (RDE), External Knowledge Acquisition (EKA), External Technology Acquisition (ETA), and Informal Methods of Intellectual Property Protection (IMIP). SIZE is a discrete numerical variable referring to the total number of employees working on the company at the end of 2014. RDE is a continuous variable referring to the total amount spent on intramural R&D in 2014. EKA is a continuous variable referring to the total amount spent on acquisition of extramural R&D and other external knowledges in 2014. ETA is a continuous variable referring to the total amount spent on acquisition of software, machinery and equipment in 2014.[30] IMIP is a dummy variable referring to whether companies have used informal methods of intellectual property protection such as complexity of product design, industrial secrecy, lead time over competitors and/or others in the period 2012-2014.

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[30] We applied a logarithmic transformation for our four discrete numerical and continuous independent variables (SIZE, RDE, EKA, ETA) in order to make their highly skewed distribution less skewed and have all variables in a similar scale when running the econometric models.

Moving now to the other group of independent variables, namely: network-related determinants of innovation. There are two variables in this group: Cooperation with Other Firms (COF) and Cooperation with Research and Education Organizations (CREO). COF is a dummy variable referring to whether companies have assigned high importance to cooperation partnerships for innovation with customers, suppliers, competitors, consultants and/or other companies from the same corporate group in the period 2012-2014. CREO is a dummy variable referring to whether companies have assigned high importance to cooperation partnerships for innovation with universities, research institutes, training and technical assistance centers and/or trials and essays institutions in the period 2012-2014.

Let us now consider the group of moderation variables referring to the obstacles to innovation, which is the focus of our study. There are five variables thematically aggregated in this group: Financial Obstacles to Innovation (FINOBS), Knowledge Obstacles to Innovation (KNOBS), Organizational Obstacles to Innovation (ORGOBS), Network Obstacles to Innovation (NETOBS), and Demand Obstacles to Innovation (DEMOBS), all of them taking into account the perception of innovation barriers in the period 2012-2014. FINOBS is a dummy variable referring to whether companies have assigned high importance to Excessive Economic Risk (RISK), High Cost to Innovate (COST) and/or Lack of Adequate Funding Source (FUND). KNOBS is a dummy variable referring to whether companies have assigned high importance to Lack of Qualified Personnel (STAFF), Lack of Information on Technology (INFOTECH) and/or Lack of Information on Markets (INFOMKT). ORGOBS is a dummy variable referring to whether companies have assigned high importance to Organizational Rigidities (RIGID), Innovation Activity Centralized in Another Company from the Same Corporate Group (CTGRP) and/or Difficulty to Comply with Standards, Norms and Regulations (STAND)[31]. NETOBS is a dummy variable referring to whether companies have assigned high importance to Scant Possibilities of Cooperating with Other Companies or Institutions (COOP) and/or Lack of Adequate External Technical Services (EXTECH).

[31] It could be argued that this specific barrier should be characterized as institutional or regulatory, but we decided to aggregate it into the group of organizational obstacles as studies have pointed out that it is important not to regard regulation as solely an external barrier, but rather to consider the organizational capacities and constraints to interpret and translate regulatory requirements (Engberg and Altmann, 2015).

DEMOBS is a dummy variable referring to whether companies have assigned high importance to Poor Response from Consumers to New Products (DEMAND).

Finally, regarding the group of policy programs, dubbed herein as "treatment variables", there are also five variables thematically aggregated in this group: Tax Breaks Programs (TBP), Economic Subsidies Programs (ESP), Public Funding Programs (PFP), Acquisition of Machinery Programs (AMP), and Public Procurement Programs (PPP), all of them taking into account the use of public instruments for innovation in the period 2012-2014. TBP is a dummy variable referring to whether companies have used tax breaks instruments for projects on R&D, technological innovation and/or information and communication technologies. ESP is a dummy variable referring to whether companies have used economic subsidies instruments for R&D projects and/or for scholarships and recruitment of researchers. PFP is a dummy variable referring to whether companies have used public funding instruments for R&D and innovation projects, cooperation with universities or research institutes, and/or venture capital. AMP is a dummy variable referring to whether companies have used financial instruments for the acquisition of machinery and equipment for innovation. PPP is a dummy variable referring to whether companies have used public procurement instruments for innovation.

Table 4 summarizes the variables presented above. It separates the set of dependent variables concerning companies' innovativeness, the set of independent variables concerning firm-specific determinants, the set of independent variables concerning network-related determinants, the set of moderation variables concerning obstacles to innovation which will be utilized to create the interaction terms to be used in the econometric regression models, and the set of treatment variables concerning public policies for innovation which will be used to test policy effectiveness in eroding barriers to innovation by means of matching techniques.

Table 4 - List of variables

	Variable	Definition	Nature
Dependent	Product innovativeness (PDIN)	Degree of novelty of the main product (if any) new or substantially improved implemented by the company between 2012-2014	Categorical
	Process innovativeness (PCIN)	Degree of novelty of the main process (if any) new or substantially improved implemented by the company between 2012-2014	Categorical
Independent - Firm	R&D expenditure (RDE)	Intramural R&D expenditure in 2014	Continuous
	External knowledge acquisition (EKA)	Expenditure for knowledge acquisition (extramural R&D and other external knowledges) in 2014	Continuous

	External technology acquisition (ETA)	Expenditure for technology acquisition (software, machinery and equipment) in 2014	Continuous
	Informal methods of intellectual property protection (IMIP)	Use of informal methods of intellectual property protection (complexity of product design, industrial secrecy, lead time over competitors, among others) between 2012-2014	Dummy
	Firm size (SIZE)	Number of employees at the end of 2014	Discrete
Independent - Network	Cooperation with other firms (COF)	Assignment of high importance to market partners of cooperation (other companies from the same corporate group, suppliers, customers, competitors, consultants) between 2012-2014	Dummy
	Cooperation with research and education organizations (CREO)	Assignment of high importance to research and education partners of cooperation (universities, research institutes, training and technical assistance centers, trials and essays institutions) between 2012-2014	Dummy
Moderation - Obstacles	Financial obstacles (FINOBS)	Assignment of high importance to financial factors hampering innovation (excessive economic risk, high cost to innovate, lack of adequate funding source) between 2012-2014	Dummy
	Knowledge obstacles (KNOBS)	Assignment of high importance to knowledge factors hampering innovation (lack of qualified personnel, lack of information on technology, lack of information on markets) between 2012-2014	Dummy
	Organizational obstacles (ORGOBS)	Assignment of high importance to organizational factors hampering innovation (organizational rigidities, difficulty to comply with standards, norms and regulations, innovation activity centralized in another company from the corporate group) between 2012-2014	Dummy
	Network obstacles (NETOBS)	Assignment of high importance to network factors hampering innovation (scant possibilities of cooperation, lack of adequate external technical services) between 2012-2014	Dummy
	Demand obstacles (DEMOBS)	Assignment of high importance to demand factors hampering innovation (poor or lack of consumer response to new products) between 2012-2014	Dummy
Treatment - Policy	Tax breaks programs (TBP)	Use of tax breaks instruments for projects on R&D, technological innovation and/or information and communication technologies between 2012-2014	Dummy
	Economic subsidies programs (ESP)	Use of economic subsidies instruments for R&D projects and/or for scholarships and recruitment of researchers between 2012-2014	Dummy
	Public funding programs (PFP)	Use of public funding instruments for R&D and innovation projects, cooperation with universities or research institutes, and/or venture capital between 2012-2014	Dummy
	Acquisition of machinery programs (AMP)	Use of financial instruments for the acquisition of machinery and equipment for innovation between 2012-2014	Dummy
	Public procurement programs (PPP)	Use of public procurement instruments for innovation between 2012-2014	Dummy

Source: Author's elaboration.

3.4. Econometric procedures

The econometric procedures applied herein involve a sort of two-stage modelling of our operational conceptual model (Figure 8). Firstly, we estimate by means of multinomial logistic regressions both the effect of determinants of innovation on companies' innovativeness and the moderation role of obstacles to innovation over determinants and, ultimately, over innovation output. Secondly, we assess the effect of policy instruments on lowering companies' perception of innovation barriers by means of propensity score matching techniques. Although these two stages are comprehended by one single conceptual model, they are related only on a loose sense, since they are not connected in a system of equations or the like. Therefore, these stages could actually be interpreted as independent methodological steps, but which will be useful to provide a comprehensive single analysis of the relationships envisaged in our operational conceptual model. The next subsections explain each stage in more detail.

3.4.1. Multinomial logistic regressions (MLR) with interaction terms

Since our dependent variables are unordered categorial ones with more than two categories, we ran multinomial logistic regression (MLR) models to estimate the effects of the determinants of innovation over companies' innovativeness and introduced interaction terms to assess the moderation role of the obstacles to innovation. This methodology is already traditional in the literature on the determinants of the innovation novelty (e.g., Amara and Landry, 2005; Vega-Jurado et al., 2008; Harirchi and Chaminade, 2014), and indeed is the most adequate when dealing with unordered categorial dependent variables with multiple options (Greene, 2012).[32] The mathematical specification of MLR estimation is given by:

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[32] A few studies in the literature have opted for the ordered logistic regression model instead (e.g., Protogerou et al., 2017), assuming that there is an underlying order in the innovativeness categories (innovation at the firm, country and world level) so the dependent variable represents a scale with a limited number of choices. Although we see the point of this reasoning, we sustain that the most adequate way to consider the innovativeness categories is as unordered ones, since scholars within the innovation studies have repeatedly argued that diffusion, incremental and radical innovation (concepts for which those categories are allegedly potential proxies) are fundamentally different phenomena, and not merely stages within a single scale (e.g., Rosenberg, [1982] 2006; Freeman et al., 1982; Katz, 1987).

$$Pij = \frac{e^{\beta_j X_i}}{1 + \sum_{j=0}^{3} e^{\beta_j X_i}}$$

This equation represents the probability that observation (firm) i will select alternative j (potential innovator, innovator at firm level, innovator at country level, innovator at world level), while X_i is the matrix of characteristics of the firm i and β_j is a vector of j parameters. Basically, this model is a generalization of the binary logistic regression model, since the binomial logit model is precisely a special case for $j = 0, 1$. In our case, the categories of response from the dependent variables are represented by $j = 0, 1, 2, 3$. To remove an indeterminacy in the model, we need to normalize to zero one set of coefficients to estimate multinomial logit models, so there are j - 1 sets of coefficients estimated. According to Greene (2012), this arises because the probabilities sum to one, so only j - 1 parameter vectors are needed to determine the j probabilities. This normalized coefficient refers to the baseline category in relation to which the other categories are contrasted in the estimation process. Our baseline category is the group of potential innovators ($j = 0$), so we will be examining how the predictor set affects the probability of (a) a company innovating at the firm level as opposed to being a potential innovator, (b) a company innovating at the country level as opposed to being a potential innovator, and (c) a company innovating at the world level as opposed to being a potential innovator. Therefore, the parameters estimated can be interpreted as follows:

$$\frac{P_{i1}}{P_{i0}} = \frac{e^{\beta_1 X_i}}{e^{\beta_0 X_i}} = e^{(\beta_1 - \beta_0)X_i} \quad \text{and} \quad \frac{P_{i2}}{P_{i0}} = \frac{e^{\beta_2 X_i}}{e^{\beta_0 X_i}} = e^{(\beta_2 - \beta_0)X_i} \quad \text{and} \quad \frac{P_{i3}}{P_{i0}} = \frac{e^{\beta_3 X_i}}{e^{\beta_0 X_i}} = e^{(\beta_3 - \beta_0)X_i}$$

or

$$\left(Ln\frac{P_{i1}}{P_{i0}}\right) = (\beta_1 - \beta_0)X_i \quad \text{and} \quad \left(Ln\frac{P_{i2}}{P_{i0}}\right) = (\beta_2 - \beta_0)X_i \quad \text{and} \quad \left(Ln\frac{P_{i3}}{P_{i0}}\right) = (\beta_3 - \beta_0)X_i$$

In short, the coefficients represent the marginal change in the logarithm of the odds of introducing product or process innovations new to the firm, to the country or to the world in contrast to the baseline category accounting for the potential innovators. Thus, the coefficient interpretation for an alternative j is the following: in comparison to the baseline category, an increase in the independent variable makes the selection of alternative *j* more or less likely. However, instead of reporting the coefficients themselves, we will report the so-called Relative-Risk Ratios (RRR)[33], which provide a more straightforward interpretation. Basically, the RRR of a coefficient indicates how the probability of the observation falling in the alternative category of the dependent variable compared to the probability of it falling in the baseline category changes with a marginal change in the independent variable under consideration. Put another way, the RRR is a ratio of two probabilities (falling in the alternative category/falling in the baseline category), so if RRR is greater than 1 then the probability of the observation falling in the alternative category relative to the probability of it falling in the baseline category increases as the independent variable increases, while if RRR is smaller than 1 then the probability of the observation falling in the alternative category relative to the probability of it falling in the baseline category decreases as the independent variable increases. All in all, if RRR > 1 the observation is more likely to be in the alternative category, and if RRR < 1 the observation is more likely to be in the baseline category.

As we said before, the variables on obstacles to innovation are used to construct interaction terms in order to assess the moderation effect of the barriers on the firms' innovativeness. The basic idea is to run econometric models containing only the variables from the two groups of determinants of innovation in our operational conceptual model and also econometric models including the interaction terms constructed from the variables on obstacles to innovation, multiplying these variables by the ones related to the determinants (e.g., RDE x FINOBS, CREO x KNOBS, etc.). This allows us to verify the distinction between "pure" and "conditional" effects of the various determinants on the innovativeness of the Brazilian companies. According to DeMaris (1991), the existence of first-order interaction implies that the relationship between a given predictor and the response is itself a function of another variable, commonly called a "moderator variable".[34]

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[33] RRR are similar to Odds Ratios (OR), which are the exponentiated regression coefficients typically used in binary logistic regressions to ease the interpretation. When it comes to multinomial logistic regression, the RRR is more commonly used, so the software STATA only applies this transformation. But again, RRR and OR are quite similar. The difference is that OR is a ratio of two odds (number of events/number of non-events) while RRR is a ratio of two probabilities (number of events/number of possible events).

[34] We adopt herein one of the most common frameworks used in the social sciences to conceptualize interaction effects which sets the distinction between: i. Dependent variable – an outcome variable that is thought to be determined by an independent variable; ii. Independent variable – a presumed cause of the dependent variable; iii. Moderator variable – a variable whose values influence on the effect of an independent variable on a dependent variable (Jaccard, 2001)

In linear regression, for example, the interpretation of interaction terms can be readily understood from the regression equation:

$$E(Y) = \alpha + \beta_1 X + \beta_2 Z + \beta_3 XZ$$

which can also be written as:

$$E(Y) = \alpha + \beta_2 Z + (\beta_1 + \beta_3 Z)X$$

In this case, X and Z interact in their effect on E(Y), so that a marginal increase in X changes E(Y) by ($\beta_1 + \beta_3$Z) units, a factor that is no longer a constant across levels of Z (which would be the case in an equation without the interaction term), but depends on the level of Z (DeMaris, 1991). In other words, we assume that these variables are involved only in an interaction with each other and not with other predictors, and further designate X as the focus variable and Z as the moderator variable. If Z is a continuous variable, β_3 represents the change in the impact of X on E(Y) for every unit increase in Z; if X is a dummy variable, then each unit increase in Z changes the difference in E(Y), between the groups coded 1 and 0 on X, by an increment of β_3; if both X and Z are dummies, then β_3 represents the change in the difference in E(Y) between those coded 1 and 0 on X, for those coded 1 versus 0 on Z. Likewise, first-order interactions can also be made intuitively meaningful in logit modeling by utilizing an odds-ratio or similar framework for their explication (DeMaris, 1991). Among the main distinct advantages of this approach, one might mention: i. it renders interpretations that are analogous to those for partial slopes in the interactive linear regression model; ii. it has great generality across virtually any type of logit model (multinomial, ordered, conditional, etc.); iii. it provides a precise quantitative interpretation for parameter estimates; iv. it depends only on the output from one run with standard log-linear software.

In our particular case, the interaction terms play the key purpose of assessing the moderation role of obstacles to innovation over the effect of determinants on companies' innovativeness in Brazil. Since our moderation variables are all dummies, the interpretation shall be as follows: the results of the interaction terms represent the change (in terms of RRR) in the effect of the independent variables (determinants) over the dependent variable (innovativeness) for the change in the moderation variable (obstacles) from 0 to 1. Put another way, the result (RRR) of the interaction term shows the effect of the determinants over the innovativeness when companies face innovation barriers. So, in the presence of the obstacle Z, the effect of the determinant X on the innovativeness Y is displayed by the result (RRR) from the interaction term XZ. It must be noticed that, in our case, the moderation variables will not be included in the model as regular predictors, but only through the interaction terms, since we have already discussed that obstacles to innovation do not affect innovation in itself, but only moderates the relationship between innovativeness and its determinants.[35]

In order to control for possible unobserved heterogeneity bias, we run the models for three different sectoral subsamples according to their technological intensity. Following the OECD classification for manufacturing sectors (OECD, 2011) and subsequent adaptations for non-manufacturing sectors (Cavalcante, 2014), we circumscribed one subsample of companies operating in the high and medium-high technology intensity sectors (labeled simply as "High-tech sectors"), one subsample of companies operating in the medium-low and low technology intensity sectors (labeled simply as "Low-tech sectors"), and finally one specific subsample of companies operating in the so-called Knowledge Intensive Business Services (labeled simply as "KIBS sectors"). Table 5 presents the sectors covered by the survey, their respective codes according to the National Classification of Economic Activity in Brazil (*Classificação Nacional de Atividades Econômicas* – CNAE), and their technology intensity classification. Besides, we also included dummy variables for each sector of economic activity (respective dummies for each subsample) controlling even more for sectoral heterogeneity by taking into account industry-fixed effects.

Nevertheless, the econometrical procedures carried on this thesis also present relevant limitations that must be highlighted. As we are dealing with cross-sectional data, we cannot claim causality in the relationships between independent and dependent variables, but only (weaker or stronger) statistically significant associations, since cross-sectional models are limited to one observation in time and are not able to control properly for much of the unobserved and time-invariant heterogeneity across firms. One possible alternative to work around this problem would be to use more than one edition of PINTEC

[35] Although the standard practice suggests including both components of the interaction term in the equation modelling, it is also possible to model interactions in ways that lead one to exclude one of the component parts of the interaction term (Jaccard, 2001).

as data source and run panel data analysis instead. However, this alternative also has its own shortcomings. On the one hand, companies surveyed in one edition of PINTEC are not the same as the companies surveyed in another, so it would be necessary to apply unbalanced panel data analysis rather than the preferable balanced one, which is somewhat worrisome as the survey' sample is skewed in favor of larger companies; on the other hand, not only PINTEC's sample coverage changes over time, but also its content scope, so that some important variables that we are addressing herein (IMIP and PPP, for example) only exist in the last edition of the survey (PINTEC 2014) and could not be scrutinized in a panel data analysis.

Despite these limitations, we sustain that the econometric estimations executed in our study should not be considered of lower value at least for two reasons. Firstly, because the use of econometrics herein has more the role of illustrating the empirical possibilities derived from our operational conceptual model than the role of identifying causal relationships in the strict sense. In fact, we believe that the main contribution of this thesis is to be found in the development of the general and operational conceptual models to understand the relationship between innovation determinants, obstacles and policies, and not in the empirical exercises as such. Secondly, one has to remember that some of the main contributions to the theoretical and empirical understandings of innovation were obtained through cross-sectional empirical settings as well, which is the case of the notorious CDM model, for instance. Therefore, one should not completely disregard the possibilities of advancing the innovation studies by using less sophisticated empirical settings and data sources.

Table 5 – Sectors, codes and technology intensity levels

Sectors	CNAE 2.0 (divisions and groups)	Technology intensity
Extractive Industries (Mining and quarrying)	**5, 6, 7, 8 e 9**	Low
Manufacturing Industries	**10 a 33**	
Manufacture of food products	10	Low
Manufacture of beverages	11	Low
Manufacture of tobacco products	12	Low
Manufacture of textiles	13	Low
Manufacture of wearing apparel	14	Low
Manufacture of leather and related products	15	Low
Manufacture of wood and of products of wood and cork, except furniture	16	Low
Manufacture of pulp, paper and paper products	17	Low
Manufacture of pulp	17.1	Low
Manufacture of paper and other articles of paper and paperboard	17 (excluding 17.1)	Low
Printing and reproduction of recorded media	18	Low
Manufacturing of coke, refined petroleum products, and biofuels	19	Medium-Low
Manufacture of coke and biofuels	19 (excluding 19.2)	Medium-Low
Manufacture of refined petroleum products	19.2	Medium-Low
Manufacture of chemicals and chemical products	20	Medium-High
Manufacture of inorganic chemical products	20.1	Medium-High
Manufacture of organic chemical products	20.2	Medium-High
Manufacture of resins, elastomers, artificial and synthetic fibers, pesticides and other agrochemical products, and household cleaning disinfectants	20.3 + 20.4 + 20.5	Medium-High
Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations, cleaning products, cosmetics and personal hygiene products	20.6	Medium-High
Manufacture of paints, varnishes and similar coatings, printing ink and mastics, and the like	20.7 + 20.9	Medium-High
Manufacture of pharmacochemical and pharmaceutical products	21	High
Manufacture of pharmacochemical products	21.1	High
Manufacture of pharmaceutical products	21.2	High
Manufacture of rubber and plastic products	22	Medium-Low
Manufacture of other non-metallic mineral products	23	Medium-Low
Manufacture of basic metals	24	Medium-Low
Manufacture of basic iron and steel products	24.1 + 24.2 + 24.3	Medium-Low
Manufacture of non-ferrous metals and casting	24.4 + 24.5	Medium-Low
Manufacture of fabricated metal products, except machinery and equipment	25	Medium-Low
Manufacture of computer, electronic and optical products	26	High
Manufacture of electronic components and boards	26.1	High
Manufacture of computers and peripheral equipment	26.2	High
Manufacture of communication equipment	26.3 + 26.4	High
Manufacture of irradiation, electromedical and electrotherapeutical equipment	26.6	High
Manufacture of other electronic and optical products	26.5 + 26.7 + 26.8	High
Manufacture of electrical equipment	27	Medium-High
Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus	27.1 + 27.3	Medium-High
Manufacture of domestic appliances	27.5	Medium-High
Manufacture of batteries, electric lighting equipment, and other electrical equipment	27.2 + 27.4 + 27.9	Medium-High
Manufacture of machinery and equipment	28	Medium-High
Manufacture of engines, pumps, compressors and other transmission equipment	28.1	Medium-High
Manufacture of farming machinery	28.3	Medium-High
Manufacture of machinery for mining, quarrying and construction	28.5	Medium-High
Manufacture of other machinery and equipment	28.2 + 28.4 + 28.6	Medium-High
Manufacture of motor vehicles, trailers and semi-trailers	29	Medium-High
Manufacture of motor vehicles	29.1 + 29.2	Medium-High
Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers	29.3 + 29.5	Medium-High
Manufacture of parts and accessories for motor vehicles	29.4	Medium-High
Manufacture of other transport equipment	30	Medium-High
Manufacture of furniture	31	Low
Other manufacturing	32	Low
Manufacture of medical and dental instruments and supplies, and of optical artifacts	32.5	Medium-High
Manufacture of other products	32 (excluding 32.5)	Low
Repair and installation of machinery and equipment	33	Medium-Low
Electricity and gas	35	Low
Selected services		
Editing, printing and music recording	58 + 59.2	KIBS
Telecommunications	61	KIBS
Computer programming, consultancy and related activities	62	KIBS
Software development on demand	62.01	KIBS
Customizable software development	62.02	KIBS
Non-customizable software development	62.03	KIBS
Other information technology services	62.04 + 62.09	KIBS
Data processing, hosting and related activities	63.1	KIBS
Architecture and engineering activities; technical testing and analysis	71	KIBS
Scientific research and development	72	KIBS

Source: Author's elaboration based on OECD (2011), Cavalcante (2014) and IBGE (2016).

3.4.2. Propensity score matching (PSM)

Matching techniques correspond to a group of methods that rely on a "selection on observables" assumption to identify the impact of policy programs with non-experimental samples. Such assumption (also known as "conditional independence assumption") imply that we can observe in our data all of the non-random factors that guide the outcome of interest and the program participation status, so we can control for their role in shaping the outcome and the remaining variation would then be driven by program participation and purely random oscillation (Lance et al., 2014). The basic idea of matching is to estimate what would have happened to someone under the counterfactual state (i.e., the alternative program participation status) by looking to what happened to someone just like them who actually experienced that counterfactual state. So, for instance, to estimate program impact for a program participant the matching approach forms an estimate of that participant's outcome in the absence of participation by using the outcome observed for a similar non-participant (Lance et al., 2014).

One of the main weaknesses of the matching relies on the burden of the "selection on observables" assumption, which basically means that one can only tell if an individual is like another in terms of characteristics that are observed. In other words, the matching estimates of the counterfactual outcome for each individual could not equal precisely the counterfactual outcome that that individual actually would have experienced, since with these techniques we can only find a similar individual in terms of the observable characteristics, while their similarity or dissimilarity in terms of the non-observable traits remains unknown. Therefore, matching estimators in general presume the absence of non-observable factors affecting the program participation status or the potential outcomes of interest.

Propensity score is a particular matching technique that estimate the counterfactual for each individual in a sample by matching them to an individual who experienced the counterfactual state and had a similar probability of program participation conditional on J observed characteristics, which mathematically can be written as:

$$\Pr(P = 1|x_1, x_2 \dots x_J)$$

This technique starts with the estimation of a Probit (or Logit) regression model whose dependent variable is a binary program participation status $P_{I=0,1}$ (in our case, the treatment variables on innovation policies) and the independent variables are those individual traits X_J which potentially vary between participants and non-participants and influence the outcome of interest Y (in our case, the obstacles to innovation). Therefore, the propensity score is the conditional (predicted) probability of participating in the program (receiving the treatment) given a set of pre-treatment characteristics. Put another way, this technique finds an individual experiencing the counterfactual outcome Y with a similar propensity score for each individual in the sample for whom an estimate of program impact needs to be formed (Lance et al., 2014). Within this framework, the counterfactual reasoning basically posits the comparison of the outcome of the treated observations with the outcome of the treated observations if they had not been treated by finding a close match using pre-treatment characteristics.

Propensity score matching allows us to find the treatment effects of a policy program on an outcome of interest. In order to identify the treatment effect, it is usually calculated an Average Treatment Effect (ATE) to assess the difference between the outcomes of treated and non-treated (or control) observations. When dealing with random experiments, a simple T-test between the outcomes for the treated and control groups can be applied to obtain the treatment effect. But, when dealing with observational studies, the use of ATE may be biased if treated and control observations are not similar. Thus, in this case, one needs to resort to Average Treatment Effect on the Treated (ATET), which calculates the difference between the outcomes of the treated observations and the outcomes of the treated observations if they had not been treated. As the second term is a counterfactual, one has to estimate it through a regression model and find close matches with the propensity scores (predicted probabilities) as a surrogate to the control groups from random experiments. Individuals with similar propensity scores are paired and the average treatment effect is then estimated by the differences in outcomes (Greene, 2012).

We can summarize the methodological procedures of the propensity score matching in the following step-by-step protocol (Avellar, 2009; Avellar and Botelho, 2016):

i. Compare using T-tests for the average outcomes of the treated and non-treated observations;

ii. Estimate a Probit regression model with the program participation status as dependent variable to obtain the propensity scores (predicted probabilities);
iii. Find a close match for each treated observation based on the propensity scores to create the fittest possible control group;
iv. After the matching, compare using T-tests the average outcomes of the treated and control observations;

Although its operationalization seems quite simple, the propensity score matching is actually a very tricky methodology and some of its caveats ought to be discussed. Firstly, albeit Probit regression models have been traditionally more used to obtain the propensity scores, one might also opt for using Logit regression models or any other binary model. There is no strong advantage to using Probit or Logit models (Heinrich et al., 2010), but this choice can render some minor differences in the results. Much more problematic is the challenge of specifying the model correctly by including all the relevant explanatory variables. While in practice many include everything for fear of omitting some important factor, others are more parsimonious and include only those controls that really do matter (Lance et al., 2014). A danger with the latter approach is that the model may fail to recognize some relevant variables, whereas a danger with the former is the possibility of including a bad control. Another question regarding the specification is how to handle continuous variables included as explanatory variables. Some suggest the inclusion of polynomial terms, while in practice these variables are often discretized by transforming them in dummy variables, for example, although there does not seem to be a widely accepted answer to this question (Lance et a., 2014).

As regards the matching methods, there are several of them available, such as: "Nearest Neighbor" matching – matches each individual for whom a program impact estimate must be formed with the individual with the closest propensity score value experiencing the counterfactual state; Caliper matching – finds matches within a certain distance from the propensity score value for the individual requiring a match; Kernel and local linear matching – uses weighted contributions from all individuals in the counterfactual state to form an estimate of the counterfactual outcome; among others. Besides, the considerations are not limited to the identification of matching methods, as, for instance, one must also decide whether to match with replacement (each control observation can be used as a match to several treated observations) or not (each control observations is used no more than once as a match for a treated observation). There is no consensus regarding best practices across these many possibilities, as, in general, the choice of matching method does not matter too much (Lance et al., 2014).

Let us consider now some of the main assumptions of propensity score matching. We have already discussed the first and most important one, which relates to the "Selection on Observables". But there are other two that are worth considering. Firstly, the so-called "balancing property" of the propensity score, which requires that for a given value of the propensity score, participants and non-participants should have similar distributions of background observable characteristics (Lance et al., 2014). Secondly, the so-called "common support condition", which requires that there is sufficient overlap in the characteristics of the treated and non-treated units to find adequate matches (Heinrich et al., 2010). When all these assumptions are satisfied, the treatment assignment is said to be strongly ignorable, and then one is allowed to proceed to the exercise of propensity score matching in order to find reliable results.

After this general discussion on the propensity score matching methodology, we are able to present how this technique is employed in our study. In order to obtain the propensity scores for each company on our sample, we ran Probit regression models whose mathematical specification is given by:

$$Prob(P = 1 \mid \boldsymbol{x}) = \int_{-\infty}^{x\prime\beta} \phi(t)dt = \boldsymbol{\Phi}(\mathbf{x}'\boldsymbol{\beta})$$

The set of parameters $\boldsymbol{\beta}$ reflects the impact of changes in **x** on the probability of P = 1, while the function Φ(t) is a commonly used notation for the standard normal distribution (Greene, 2012). Probit models are appropriate for handling dichotomous dependent variables like our own taking the values one and zero depending on whether companies have or not received the innovation policy treatment. Dependent variables are each of our five treatment variables presented in Table 4, while independent variables are the ones presented in Table 6, which comprehend a set of common companies' attributes correlated with participation on innovation policy programs in Brazil. We ran models to the three sectoral subsamples of Low-tech, High-tech and KIBS in order to assess to potential sectoral particularities. After obtaining the propensity scores, the matching method used was the "Nearest Neighbor" matching with replacement. In addition, we also added the command "common", which ensures the common support condition by dropping the percentage of the treatment observations at which the propensity score density of the control observations is the lowest, and ran tests to check the balancing property of the results. With the paired groups of treatment and control observations, we can then compare with T-tests their average of the outcomes of interest, which are the five moderation variables presented in Table 4 referring to the innovation barriers.

Table 6 – Explanatory variables for the propensity score matching

Variable	Definition	Nature
Innovativeness (INNO)	Introduction of product and/or process innovation at country and/or world level	Dummy
High expenditure on intramural R&D (HRD)	Expenditure on intramural R&D above the sample average	Dummy
Group affiliation (GRP)	Affiliation to a national or international corporate group	Dummy
Multinational enterprise (MNE)	Foreign controlling shareholder	Dummy
High net sales revenue (HNS)	Net sales revenue above the sample average	Dummy
Regional location on the south or southeast (RLS)	Company located on the south or southeast region of the country	Dummy

Source: Author's elaboration.

To conclude, a final word of caution is necessary to point out to the main limitation of the propensity score matching technique for our study. As our data is cross-sectional, it will not be possible to apply more sophisticated matching methods such as the differences-in-differences matching, which addresses unobserved heterogeneity by relying on panel data whose outcomes are available before and after the treatment occurs. Therefore, we must highlight that the analysis of our results for the propensity score matching will not allow us to claim causality, or program impact in the strong sense, but only to suggest potential effects of the innovation policies as regards the differences between the perception of innovation barriers by treated and non-treated companies. Of course, these suggestions are grounded on a high-quality and extensive database that constitutes the main data source for innovation in the country, but one must always bear in mind that the effects that we analyze in this study are only loosely connected to a causality framework as we do not consider data variation over time.

Chapter 4 – Empirical Findings

4.1. Descriptive statistics

We shall start the presentation of our empirical findings by the discussion of the main descriptive statistics to characterize our relevant sample. Table 7 shows the distribution of companies by size strata and sectoral technology intensity categories. From this data, we can observe that most companies from our total relevant sample (8,919 companies) operate at low-tech sectors (60.7%) and are medium-sized companies (44.4%). On the other hand, one can notice that the less represented companies are the ones operating in KIBS sectors (13.9%) and small-sized companies (24.3%). However, in general, we can say that we have a fairly balanced sample in terms of both size and sectors, as none of the intersections of these variables accounts for more than 30% of the whole relevant sample.

Table 7 - Distribution of companies from the relevant sample by size strata and sectoral technology intensity categories

	Low-tech sectors	High-tech sectors	KIBS sectors	Total
Small-sized companies (10-49 employees)	1,299 (14.5%)	453 (5.1%)	423 (4.7%)	2,175 (24.3%)
Medium-sized companies (50-249 employees)	2,417 (27.1%)	977 (10.9%)	567 (6.4%)	3,961 (44.4%)
Large-sized companies (+ 249 employees)	1,702 (19.1%)	834 (9.4%)	247 (2.8%)	2,783 (31.3%)
Total	5,418 (60.7%)	2,264 (25.4%)	1,237 (13.9%)	8,919 (100%)

Source: Author's elaboration.

Another way of characterizing our sample is by looking at the distribution of companies in terms of innovativeness. Table 8 does that by crossing the variables of product innovativeness and sectoral technology intensity categories. The data shows that from the total product innovativeness relevant sample (7,375 companies), most companies are potential product innovators (40.1%) and operate in the low-tech sectors (47.7%). Conversely, the less represented companies are the ones operating in the KIBS sectors (14.7%) and the world level product innovators (4.1%). But again, the data looks fairly balanced, as none of the intersections of these variables accounts for more than 30% of the whole relevant sample.

Table 8 - Distribution of companies from the relevant sample by product innovativeness and sectoral technology intensity categories

	Low-tech sectors	High-tech sectors	KIBS sectors	Total
Potential innovator PDIN = 0	1,959 (26.6%)	579 (7.8%)	417 (5.7%)	2,955 (40.1%)
Firm level innovator PDIN = 1	1,651 (22.4%)	828 (11.2%)	418 (5.7%)	2,897 (39.3%)
Country level innovator PDIN = 2	534 (7.2%)	485 (6.6%)	199 (2.7%)	1,218 (16.5%)
World level innovator PDIN = 3	110 (1.5%)	149 (2%)	46 (0.6%)	305 (4.1%)
Total	4,254 (47.7%)	2,041 (27.6%)	1,080 (14.7%)	7,375 (100%)

Source: Author's elaboration.

Similarly, Table 9 presents the data crossing the variables of product innovativeness and size strata. Medium-sized companies appear to be prevailing among the product innovativeness relevant sample as well (43.4%), while the small-sized companies are less present (23.7%). Once more, a very unbalanced distribution does not seem to be an important concern though.

Table 9 - Distribution of companies from the relevant sample by product innovativeness and size strata

	Small-sized companies (10-49 employees)	Medium-sized companies (50-249 employees)	Large-sized companies (+ 249 employees)	Total
Potential innovator PDIN = 0	963 (13.1%)	1,300 (17.6%)	692 (9.4%)	2,955 (40.1%)
Firm level innovator PDIN = 1	600 (8.1%)	1,295 (17.6%)	1,002 (13.6%)	2,897 (39.3%)
Country level innovator PDIN = 2	174 (2.3%)	492 (6.7%)	552 (7.5%)	1,218 (16.5%)
World level innovator PDIN = 3	16 (0.2%)	113 (1.5%)	176 (2.4%)	305 (4.1%)
Total	1,753 (23.7%)	3,200 (43.4%)	2,422 (32.9%)	7,375 (100%)

Source: Author's elaboration.

Now moving the focus to process innovativeness, Table 10 displays the data crossing the variables of process innovativeness and sectoral technology intensity categories. The most prevailing companies in the process innovativeness relevant sample (8,421 companies) are the ones operating in the low-tech sectors (61.3%) and firm level process innovators (60%). Conversely, the less prevailing firms are the ones operating in the KIBS sectors (13.8%) and world level process innovators (1.8%). One can notice that for process innovativeness the relevant sample is a little bit more unbalanced than for product innovativeness, as in the former the intersection of firm level innovators operating in low-tech sectors accounts for 37.4% of the relevant sample, which is more than one third of the sampled companies. However, we still sustain that this should not be taken as a big concern for our analyses because the number of companies being analyzed is quite high.

Table 10 - Distribution of companies from the relevant sample by process innovativeness and sectoral technology intensity categories

	Low-tech sectors	High-tech sectors	KIBS sectors	Total
Potential innovator PCIN = 0	1,506 (17.9%)	490 (5.8%)	396 (4.7%)	2,392 (28.4%)
Firm level innovator PCIN = 1	3,157 (37.4%)	1,276 (15.1%)	621 (7.5%)	5,054 (60%)
Country level innovator PCIN = 2	431 (5.1%)	281 (3.3%)	117 (1.4%)	829 (9.8%)
World level innovator PCIN = 3	70 (0.9%)	55 (0.7%)	21 (0.2%)	146 (1.8%)
Total	5,164 (61.3%)	2,102 (24.9%)	1,155 (13.8%)	8,421 (100%)

Source: Author’s elaboration.

Looking at the data crossing the variables of process innovativeness and size strata in Table 11, we can observe a similar pattern. In this case, medium-sized companies proved to be prevalent (44.2%), while small-sized companies are less represented (24.3%). Here, the intersection of medium-sized companies and firm level process innovators accounts for more than one fourth of the whole process innovativeness relevant sample (27.2%), which again raises a warning signal for the balance of the sample. But, also in this case, we need to keep in mind that the large relevant sample size greatly diminishes the concerns related to fairly unbalanced companies’ distribution, as we are analyzing almost nine thousand companies as a whole.

Table 11 - Distribution of companies from the relevant sample by process innovativeness and size strata

	Small-sized companies (10-49 employees)	Medium-sized companies (50-249 employees)	Large-sized companies (+ 249 employees)	Total
Potential innovator PCIN = 0	789 (9.4%)	1,067 (12.7%)	536 (6.3%)	2,392 (28.4%)
Firm level innovator PCIN = 1	1,144 (13.6%)	2,291 (27.2%)	1,619 (19.2%)	5,054 (60%)
Country level innovator PCIN = 2	98 (1.2%)	321 (3.8%)	410 (4.9%)	829 (9.9%)
World level innovator PCIN = 3	9 (0.1%)	46 (0.5%)	91 (1.1%)	146 (1.7%)
Total	2,040 (24.3%)	3,725 (44.2%)	2,656 (31.5%)	8,421 (100%)

Source: Author's elaboration.

Table 12 displays the mean values of the set of independent variables (determinants of innovation) that will be used in the econometric exercises to figure out the main determinants of product and process innovativeness among companies in Brazil in recent years. As the econometric exercises will take into account sectoral particularities, the mean values presented are also specified according to the sectoral groups in which the firms operate.

The first independent variable, Research and Development Expenditures (RDE), in general, tends to increase with both the technological intensity of sectors and the product and process innovativeness of companies. The only exceptions are country level product innovators and world level process innovators, for which the mean values of RDE decrease with the technology intensity of sectors. Both the second independent variable, External Knowledge Acquisition (EKA), and the third independent variable, External Technology Acquisition (ETA), tend to increase with product and process innovativeness by and large, but they are more evenly distributed among the sectoral groups. The fourth independent variable, Number of Employees (SIZE), also tends to increase with product and process innovativeness, although in terms of sectoral groups its mean values for low-tech sectors are more pronounced. Similarly, the mean values of the three last independent variables, Informal Methods of Intellectual Property Protection (IMIP), Cooperation with Other Firms (COF), and Cooperation with Research and Education Organizations (CREO), tend to increase with the product and process innovativeness at large, although in sectoral terms they are in general more pronounced for high-tech sectors.

Table 12 - Mean values of the independent variables by product innovativeness, process innovativeness and sectoral technology intensity categories

	Potential product innovator (PDIN = 0)			Firm level product innovator (PDIN = 1)			Country level product innovator (PDIN = 2)			World level product innovator (PDIN = 3)		
	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors
RDE*	270,844	584,560	245,535	574,964	5,348,589	3,212,764	8,047,015	7,254,024	4,302,212	8,650,771	19,046,485	66,885,010
EKA*	333,778	269,980	17,701	165,559	2,313,756	264,261	1,719,398	1,554,898	13,096,420	4,006,352	12,898,814	58,225
ETA*	1,268,955	525,271	129,022	2,519,246	1,591,557	3,570,630	5,674,355	3,043,524	33,961,530	4,474,326	5,180,859	542,798
SIZE	290	236	165	476	554	307	1,218	565	738	1,806	1,239	713
IMIP	0.13	0.25	0.11	0.43	0.51	0.33	0.63	0.67	0.56	0.71	0.80	0.65
COF	0.06	0.07	0.06	0.19	0.27	0.23	0.36	0.35	0.37	0.43	0.55	0.36
CREO	0.02	0.06	0.03	0.08	0.17	0.09	0.18	0.22	0.16	0.25	0.34	0.10
	Potential process innovator (PCIN = 0)			Firm level process innovator (PCIN = 1)			Country level process innovator (PCIN = 2)			World level process innovator (PCIN = 3)		
	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors
RDE*	140,547	1,419,200	1,009,434	493,301	4,707,836	6,450,003	3,693,163	12,261,140	5,746,505	48,427,651	18,037,325	5,827,548
EKA*	210,520	519,476	6,451,843	160,730	1,030,292	218,774	573,078	10,506,659	227,794	18,687,897	6,023,574	17,978
ETA*	177,496	67,286	14,641,480	2,347,465	1,383,669	2,914,685	6,319,845	6,269,838	6,932,730	16,416,530	8,924,123	446,079
SIZE	264	245	262	387	487	297	1,544	838	472	3,061	1,363	1,097
IMIP	0.10	0.23	0.10	0.35	0.54	0.35	0.58	0.72	0.53	0.62	0.87	0.61
COF	0.03	0.08	0.06	0.16	0.29	0.23	0.35	0.42	0.35	0.50	0.43	0.38
CREO	0.01	0.06	0.02	0.07	0.17	0.11	0.17	0.32	0.13	0.30	0.22	0.09

* The continuous variables RDE, EKA and ETA present monetary values on the base of Brazilian *Reais* – BRL (R$).
Source: Author's elaboration.

Table 13 presents the means, standard deviations and correlation matrix of the independent variables for the whole relevant sample. As the standard deviations are quite high, they suggest that there must be some outliers in the sample. This shall be taken into account as an extra cautionary point for our analyses, although it does not constitute a big concern due to the fact that the econometric exercises will be applied only to the sectoral groups, which are more homogeneous. On the other hand, as the correlation matrix does not display any correlation higher than 0.6, we do not need to be concerned with problems related to multicollinearity issues in our empirical setting.

Table 13 - Means, standard deviations and correlation matrix (*n* = 8,919)

	Mean	Std. Dev.	1	2	3	4	5	6	7
1. RDE*	2,425,988	41,056,860	1						
2. EKA*	1,120,227	36,942,620	0.28	1					
3. ETA*	2,740,533	49,130,450	0.02	0.40	1				
4. SIZE	472	1,980	0.38	0.18	0.20	1			
5. IMIP	0.34	0.47	0.05	0.03	0.03	0.08	1		
6. COF	0.17	0.37	0.09	0.05	0.06	0.14	0.22	1	
7. CREO	0.08	0.27	0.09	0.08	0.07	0.11	0.15	0.53	1

* The continuous variables RDE, EKA and ETA present monetary values on the base of Brazilian *Reais* – BRL (R$).
Source: Author's elaboration.

For the purposes of our study, even more important than looking at the descriptive statistics related to the independent variables, we shall pay special attention to the descriptive statistics concerning the moderation variables, which are the ones addressing the obstacles to innovation. Due to the relevance of these variables, we will present in the next few tables the frequency statistics of the disaggregated innovation barriers instead of the aggregated variables that will be applied in the econometrics, so one can tease out the prevalence of each barrier according to size strata, sectoral groups and company innovativeness. Beforehand, however, we shall display some statistics that might be helpful to check whether the aggregations that we use in econometrics are adequate or not. First of all, a correlation matrix comprehending every innovation barrier is presented in Table 14. The most correlated barriers are the financial-related ones (Excessive

Economic Risk – RISK; High Cost to Innovate – COST; and Lack of Adequate Funding Source – FUND), followed by the knowledge-related ones (Lack of qualified personnel – STAFF; Lack of information on technology – INFOTECH; and Lack of Information on Markets – INFOMKT). The other innovation barriers did not present any correlation coefficient higher than 0.3 between them. This indicates that only two of our aggregate obstacles to innovation (Financial Obstacles to Innovation – FINOBS; and Knowledge Obstacles to Innovation – KNOBS) are to some extent backed by the statistical variation of the specific barriers that compose them.

Table 14 - Innovation barriers correlation matrix (*n* = 8,919)

	1	2	3	4	5	6	7	8	9	10	11	12
1. RISK	1											
2. COST	0.57	1										
3. FUND	0.41	0.45	1									
4. STAFF	0.20	0.25	0.20	1								
5. INFOTECH	0.17	0.19	0.17	0.39	1							
6. INFOMKT	0.17	0.19	0.17	0.22	0.40	1						
7. RIGID	0.19	0.21	0.18	0.24	0.20	0.18	1					
8. CTGRP	0.03	0.04	0.00	0.02	0.00	0.02	0.07	1				
9. STAND	0.22	0.24	0.21	0.25	0.24	0.21	0.20	0.00	1			
10. COOP	0.22	0.22	0.26	0.25	0.25	0.27	0.19	0.03	0.26	1		
11. EXTECH	0.18	0.21	0.22	0.35	0.29	0.24	0.19	0.02	0.25	0.29	1	
12. DEMAND	0.22	0.19	0.18	0.17	0.15	0.21	0.16	0.04	0.16	0.21	0.26	1

Source: Author's elaboration.

Table 15 presents the results of a multiple correspondence analysis (MCA) that we ran to verify in more detail whether there would be more "natural" (statistical) aggregations different from the thematic aggregations that we applied for grouping the specific barriers into five variables. Once again, the variation of the financial-related obstacles to innovation are prevailing and account for most variance in Dimension 1, which in itself accounts for more than 90% of the total variance. Some of the knowledge-related obstacles to innovation, such as STAFF and INFOTECH, also show relevance to both statistical variations of Dimensions 1 and 2, but the overall picture that these results provide indicates that there is no statistical foundation to ground most aggregations that we made, except for the FINOBS and KNOBS, or even others that we did not anticipate. For this reason, our thematical aggregations seem quite reasonable to pursue as they are at least conceptually accurate, even though some of them lack the support from statistical variation.

Table 15 - Contribution (%) to dimension *i*'s variance (*n* = 8,919)

Obstacles	Dimension 1	Dimension 2
RISK	**10.6**	**23.9**
COST	**11.8**	**21.5**
FUND	9.9	**15.9**
STAFF	**10.1**	6.7
INFOTECH	9.6	**14.5**
INFOMKT	8.2	9.0
RIGID	6.3	0.4
CTGRP	0.1	0.1
STAND	8.2	0.7
COOP	9.4	1.4
EXTECH	9.6	6.0
DEMAND	6.0	0.1
Variance (%)	91.27	1.49
Cumulative variance (%)	91.27	92.76

Source: Author's elaboration.

Nevertheless, one last statistical test should also be applied to assess the consistency of the aggregate obstacles to innovation as we organize them for our econometric exercise. Table 16 presents the results of Cronbach's Alpha tests to check the internal reliability of the aggregate obstacles to innovation. For these tests, we had to use not the dummy variables of the specific innovation barriers, but the multi-item versions of these variables ranging from not important, low importance, medium importance and high importance. Also, as the Demand Obstacles to Innovation (DEMOBS) are not an aggregate variable, but consist of only one specific innovation barrier, they were not included in this analysis. The interpretation for this test is quite straightforward: the closer to 1 are the Cronbach's Alpha coefficients, the higher the internal reliability of the variables on obstacles to innovation. One can easily see that both FINOBS and KNOBS present very high coefficients, while Network Obstacles to Innovation (NETOBS) show a coefficient fairly high and Organizational Obstacles to Innovation (ORGOBS) display a coefficient fairly low, as the typical threshold for an acceptable Cronbach's Alpha is usually 0.7 or something not much smaller than that.

These results tell us that in general we can trust our aggregations to examine empirically the obstacles to innovation in Brazil, although some caution must be held for the analysis on the particular case of ORGOBS.

Table 16 - Internal reliability coefficients (Cronbach's Alpha) for the composite moderation variables (obstacles to innovation) (*n* = 8,919)

Aggregate Obstacles to Innovation	Specific Innovation Barriers	Cronbach's Alpha
Financial Obstacles (FINOBS)	• Excessive economic risk • High cost to innovate • Lack of adequate funding source	0.8964
Knowledge Obstacles (KNOBS)	• Lack of qualified personnel • Lack of information on technology • Lack of information on markets	0.8617
Organizational Obstacles (ORGOBS)	• Organizational rigidities • Difficulty to comply with standards, norms and regulations • Innovation activity centralized in another company from the same corporate group	0.5577
Network Obstacles (NETOBS)	• Scant possibilities of cooperation • Lack of adequate external technical services	0.7398

Source: Author's elaboration.

Moving now to the presentation of the frequency statistics of the specific barriers to innovation (which compose the aggregate obstacles to innovation), Table 17 starts by displaying the number of companies assigning high relevance to innovation barriers according to the size strata. The most prevailing innovation barriers are by far the financial-related obstacles of Excessive Economic Risk (RISK) and High Cost to Innovate (COST), which were identified as highly relevant by almost one third of each size strata. On the other hand, the less prevailing innovation barrier is the organizational-related obstacle of Innovation Activity Centralized in Another Company from the Same Corporate Group (CTGRP), which is barely mentioned as highly relevant by companies, regardless of size strata. In general, one can also notice that innovation barriers are more present within small-sized companies and less present within large-sized companies, so there seems to be a trend of decreasing the perception of innovation barriers as companies grow larger.

Table 17 – Companies assigning high relevance to innovation barriers by size strata (*n* = 8,919)

	Small-sized companies (10-49 employees)	Medium-sized companies (50-249 employees)	Large-sized companies (+ 249 employees)
RISK	770 (35.4%)	1,208 (30.4%)	813 (29.2%)
COST	822 (37.7%)	1,336 (33.7%)	883 (31.7%)
FUND	612 (28.1%)	920 (23.2%)	529 (19%)
STAFF	470 (21.6%)	584 (14.7%)	259 (9.3%)
INFOTECH	210 (9.6%)	276 (6.9%)	142 (5.1%)
INFOMKT	160 (7.3%)	235 (5.9%)	140 (5%)
RIGID	236 (10.8%)	324 (8.1%)	206 (7.4%)
CTGRP	16 (0.7%)	65 (1.6%)	91 (3.2%)
STAND	274 (12.5%)	408 (10.3%)	228 (8.1%)
COOP	282 (12.9%)	368 (9.2%)	170 (6.1%)
EXTECH	230 (10.5%)	307 (7.7%)	147 (5.2%)
DEMAND	196 (9%)	277 (6.9%)	182 (6.5%)
Companies by size strata	2,175 (100%)	3,961 (100%)	2,783 (100%)

Source: Author's elaboration.

Table 18 shows the number of companies assigning high relevance to innovation barriers according to technology intensity sectoral groups. Once more, the prevalence of the financial-related obstacles to innovation of Excessive Economic Risk (RISK) and High Cost to Innovate (COST) is remarkable, as well as the littleness of the organizational-related obstacle to innovation of Innovation Activity Centralized in Another Company from the Same Corporate Group (CTGRP), across all sectoral groups. But this time, there does not seem to be a clear pattern of trend in the perception of innovation barriers as the technology intensity of the sectoral groups change from Low-tech sectors to High-tech sectors, for example, or as the sectoral nature change from manufacturing sectors (Low-tech and High-tech sectors) to KIBS sectors. Actually, the perception of innovation barriers appears to be evenly distributed across the different sectoral groups, so it is hard to tell if there is any sectoral particularity related to the obstacles to innovation looking just at the descriptive statistics.

Table 18 – Companies assigning high relevance to innovation barriers by sectoral technology intensity categories (*n* = 8,919)

	Low-tech sectors	High-tech sectors	KIBS sectors
RISK	1,686 (31.1%)	725 (32%)	380 (30.7%)
COST	1,780 (32.8%)	800 (35.3%)	461 (37.2%)
FUND	1,225 (22.6%)	530 (23.4%)	306 (24.7%)
STAFF	836 (15.4%)	270 (11.9%)	207 (16.7%)
INFOTECH	406 (7.5%)	156 (6.9%)	66 (5.3%)
INFOMKT	318 (5.9%)	142 (6.3%)	75 (6%)
RIGID	470 (8.7%)	184 (8.1%)	112 (9%)
CTGRP	76 (1.4%)	61 (2.7%)	35 (2.8%)
STAND	554 (10.2%)	274 (12.1%)	82 (6.6%)
COOP	507 (9.4%)	188 (8.3%)	125 (10.1%)
EXTECH	420 (7.7%)	175 (7.7%)	89 (7.1%)
DEMAND	405 (7.5%)	143 (6.3%)	107 (8.6%)
Companies by sectoral groups	5,418 (100%)	2,264 (100%)	1,237 (100%)

Source: Author's elaboration.

Table 19 presents the number of companies assigning high relevance to innovation barriers by product innovativeness categories. Again, Excessive Economic Risk (RISK) and High Cost to Innovate (COST) have proved to be highly pervasive across all categories, while the presence of Innovation Activity Centralized in Another Company from the Same Corporate Group (CTGRP) appeared to be thin. However, something interesting is that the category of potential innovator shows a rather high concentration of companies assigning high relevance to innovation barriers. In fact, in the case of RISK and COST innovation barriers, the proportion of companies perceiving them among potential product innovators almost reached 50%, which means that roughly one out of two potential product innovators have faced very relevant financial-related obstacles to innovation. Nevertheless, there does not seem to be a clear trend of decreasing the innovation barriers as companies advance in the product innovativeness categories, since the world level product innovators are not usually the ones which have proportionally assigned less relevance to the various innovation barriers considered herein.

Table 19 – Companies assigning high relevance to innovation barriers by product innovativeness categories (*n* = 7,375)

	Potential innovator	Firm level innovator	Country level innovator	World level innovator
RISK	1,347 (45.5%)	747 (25.7%)	343 (28.1%)	98 (32.1%)
COST	1,461 (49.4%)	793 (27.3%)	389 (31.9%)	116 (38%)
FUND	983 (33.2%)	543 (18.7%)	249 (20.4%)	62 (20.3%)
STAFF	611 (20.6%)	363 (12.5%)	143 (11.7%)	36 (11.8%)
INFOTECH	280 (9.4%)	175 (6%)	88 (7.2%)	25 (8.1%)
INFOMKT	214 (7.2%)	171 (5.9%)	79 (6.4%)	25 (8.1%)
RIGID	369 (12.4%)	220 (7.5%)	85 (6.9%)	24 (7.8%)
CTGRP	92 (3.1%)	39 (1.3%)	26 (2.1%)	9 (2.9%)
STAND	433 (14.6%)	246 (8.4%)	116 (9.5%)	34 (11.1%)
COOP	407 (13.7%)	215 (7.4%)	92 (7.5%)	19 (6.2%)
EXTECH	312 (10.5%)	183 (6.3%)	86 (7%)	24 (7.8%)
DEMAND	329 (11.1%)	170 (5.8%)	75 (6.1%)	30 (9.8%)
Companies by product innovativeness	2,955 (100%)	2,897 (100%)	1,218 (100%)	305 (100%)

Source: Author's elaboration.

Table 20 presents the number of companies assigning high relevance to innovation barriers by process innovativeness categories. The prevalence of Excessive Economic Risk (RISK) and High Cost to Innovate (COST) is over again striking, especially when it comes to the category of potential innovators. Indeed, the concentration of companies assigning high relevance to the various innovation barriers is remarkable for the potential process innovators, even more than it was for the potential product innovators. In the particular case of COST, more than half of the potential process innovators assigned high relevance to it. As usual, the less perceived innovation barrier is Innovation Activity Centralized in Another Company from the Same Corporate Group (CTGRP) across all process innovativeness categories, but world level innovator. Differently to what was observed for product innovativeness categories, there seems to be some trend of decreasing the innovation barriers as companies advance in the process innovativeness categories, since the world level process innovators are the ones which typically have assigned less relevance to the various innovation barriers as a percentage.

Table 20 – Companies assigning high relevance to innovation barriers by process innovativeness categories (*n* = 8,421)

	Potential innovator	Firm level innovator	Country level innovator	World level innovator
RISK	1,146 (47.9%)	1,279 (25.3%)	234 (28.2%)	35 (23.9%)
COST	1,273 (53.2%)	1,373 (27.1%)	258 (31.1%)	42 (28.7%)
FUND	814 (34%)	956 (18.9%)	180 (21.7%)	30 (20.5%)
STAFF	498 (20.8%)	655 (12.9%)	105 (12.6%)	14 (9.5%)
INFOTECH	223 (9.3%)	310 (6.1%)	62 (7.4%)	7 (4.7%)
INFOMKT	183 (7.6%)	281 (5.5%)	48 (5.7%)	6 (4.1%)
RIGID	325 (13.5%)	345 (6.8%)	56 (6.7%)	7 (4.7%)
CTGRP	84 (3.5%)	51 (1%)	23 (2.7%)	5 (3.4%)
STAND	360 (15%)	425 (8.4%)	81 (9.7%)	11 (7.5%)
COOP	337 (14%)	381 (7.5%)	74 (8.9%)	4 (2.7%)
EXTECH	262 (10.9%)	326 (6.4%)	64 (7.7%)	5 (3.4%)
DEMAND	290 (12.1%)	283 (5.5%)	58 (6.9%)	6 (4.1%)
Companies by process innovativeness	2,392 (100%)	5,054 (100%)	829 (100%)	146 (100%)

Source: Author's elaboration.

In addition to the independent and moderation variables, our study also comprehends the assessment of treatment variables concerning innovation policies through propensity score matching (PSM) techniques. Therefore, we must characterize the relevant sample in terms of descriptive statistics on the various treatment variables as well. Table 21 displays the number of companies participating in innovation policy programs by sectoral technology intensity categories. From this data, we can observe that different programs prevail in different sectoral groups. Among firms operating in Low-tech sectors, the Acquisition of Machinery Programs (AMP) are the most used policy instruments, while firms operating in High-tech and KIBS sectors resorted more to the Tax Break Programs (TBP). On the other hand, the less used policy instruments across all sectoral groups are the Public Procurement Programs (PPP), which suggests that demand-side innovation policies are not widespread in the country yet.

Table 21 – Companies participating in innovation policy programs by sectoral technology intensity categories (*n* = 8,919)

	Low-tech sectors	High-tech sectors	KIBS sectors
Tax breaks programs (TBP)	396 (7.3%)	552 (24.3%)	185 (14.9%)
Economic subsidies programs (ESP)	84 (1.5%)	119 (5.2%)	46 (3.7%)
Public funding programs (PFP)	233 (4.3%)	242 (10.6%)	124 (10%)
Acquisition of machinery programs (AMP)	1,140 (21%)	367 (16.2%)	104 (8.4%)
Public procurement programs (PPP)	47 (0.8%)	37 (1.6%)	41 (3.3%)
Companies by sectoral groups	5,418 (100%)	2,264 (100%)	1,237 (100%)

Source: Author's elaboration.

Table 22 shows the number of companies participating in innovation policy programs by size strata. We can notice that for small-sized and medium-sized companies the most used policy instruments are the Acquisition of Machinery Programs (AMP), while for the large-sized companies the Tax Breaks Programs (TBP) prevail. Conversely, the Public Procurement Programs (PPP) appear again as the least used policy instruments, but this time we can observe more clearly that the Economic Subsidies Programs (ESP) are also policy instruments little used by companies across all size strata. In general, this data shows us that TBP and AMP are the predominant innovation policy instruments in the country, which might be symptomatic of both a lack of diversity in the policy options and a lack of more mission-oriented and long-run policy strategies.

Table 22 – Companies participating in innovation policy programs by size strata (*n* = 8,919)

	Small-sized companies (10-49 employees)	Medium-sized companies (50-249 employees)	Large-sized companies (+ 249 employees)
Tax breaks programs (TBP)	54 (2.4%)	321 (8.1%)	758 (27.2%)
Economic subsidies programs (ESP)	27 (1.2%)	79 (1.9%)	143 (5.1%)
Public funding programs (PFP)	77 (3.5%)	205 (5.1%)	317 (11.4%)
Acquisition of machinery programs (AMP)	408 (18.7%)	754 (19%)	449 (16.1%)
Public procurement programs (PPP)	29 (1.3%)	59 (1.4%)	37 (1.3%)
Companies by size strata	2,175 (100%)	3,961 (100%)	2,783 (100%)

Source: Author's elaboration.

Table 23 presents the number of companies assigning high relevance to the obstacles to innovation according to the use of innovation policy instruments (participation in innovation policy programs) and the technology intensity sectoral groups. This data also shows us the percentages (or averages) of companies assigning high relevance to each obstacle to innovation among those that participated (Treatment variable = 1) and those that did not participate (Treatment variable = 0) in a specific policy program. Therefore, we can assess in this table the so-called Average Treatment Effect (ATE) of each policy instrument for the distinct sectoral groups by just comparing the mean differences among those that received and those that did not received the treatment (those that used/ those that did not use the policy instruments). As we discussed in the previous chapter, such comparison is not an adequate exercise due to the fact that the companies that received the treatment are likely very different from the ones that did not receive the treatment, so there is no control group in a rigorous sense. This is why we will need to resort to matching techniques to perform a more accurate comparison. However, it could be interesting to take a first look at these descriptive statistics in order to identify some trends that ought to be verified in a more consistent way afterwards.

Tax Breaks Programs (TBP) seem to be effective in lowering the perception of obstacles to innovation across all sectoral groups, except for Knowledge Obstacles to Innovation (KNOBS) among companies operating in KIBS sectors. Economic Subsidies Programs (ESP), on the other hand, does not seem to be effective in eroding the obstacles to innovation, except for Organizational Obstacles to Innovation (ORGOBS) among companies operating in KIBS sectors. The same also holds true for the Public Funding Programs (PFP), which seem to be quite ineffective in addressing obstacles to innovation. Acquisition of Machinery Programs (AMP) appear to be effective in lowering the perception of innovation barriers only among companies operating in low-tech sectors. Finally, Public Procurement Programs (PPP) also seem to be ineffective in eroding obstacles to innovation across all sectoral groups. This data is interesting to provide a first glimpse at the distribution of companies assigning high relevance to innovation barriers among those that used and those that did not use policy instruments, but, as we already mentioned, relying only on it could be misleading due to the lack of comparability between these companies. Hence, in the next chapter we will apply propensity score matching (PSM) techniques to achieve more reliable results on the potential effects of these policies over obstacles to innovation faced by companies in Brazil.

Table 23 – Companies assigning high relevance to obstacles to innovation by the use of innovation policy instruments and sectoral technology intensity categories

	Tax breaks programs (TBP = 0)			Economic subsidies programs (ESP = 0)			Public funding programs (PFP = 0)			Acquisition of machinery programs (AMP = 0)			Public procurement programs (PPP = 0)		
	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors
FINOBS	2,232 (44.4%)	835 (48.7%)	512 (48.6%)	2,346 (43.9%)	994 (46.3%)	576 (48.3%)	2,276 (43.8%)	948 (46.8%)	535 (48%)	1,972 (46%)	885 (46.6%)	544 (48%)	2,374 (44.2%)	1,047 (47%)	580 (48.4%)
KNOBS	1,011 (20.1%)	331 (19.3%)	212 (20.1%)	1,051 (19.7%)	380 (17.7%)	245 (20.5%)	1,011 (19.4%)	360 (17.8%)	223 (20%)	842 (19.6%)	331 (17.4%)	226 (19.9%)	1,056 (19.6%)	394 (17.6%)	245 (20.4%)
ORGOBS	854 (17%)	347 (20.2%)	182 (17.3%)	900 (16.8%)	410 (19.1%)	199 (16.7%)	874 (16.8%)	378 (18.6%)	186 (16.7%)	759 (17.7%)	354 (18.6%)	186 (16.4%)	913 (16.9%)	422 (18.9%)	196 (16.3%)
NETOBS	718 (14.2%)	257 (15%)	157 (14.9%)	742 (13.9%)	290 (13.5%)	172 (14.4%)	727 (14%)	277 (13.6%)	159 (14.2%)	602 (14%)	251 (13.2%)	160 (14.1%)	752 (14%)	296 (13.2%)	169 (14.1%)
DEMOBS	314 (7.4%)	113 (6.6%)	91 (8.6%)	394 (7.3%)	138 (6.4%)	102 (8.5%)	388 (7.4%)	122 (6%)	96 (8.6%)	338 (7.9%)	119 (6.2%)	100 (8.8%)	403 (7.5%)	139 (6.2%)	102 (8.5%)

	Tax breaks programs (TBP = 1)			Economic subsidies programs (ESP = 1)			Public funding programs (PFP = 1)			Acquisition of machinery programs (AMP = 1)			Public procurement programs (PPP = 1)		
	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors
FINOBS	157 (39.6%)	229 (41.4%)	89 (48.1%)	43 (51.1%)	70 (58.8%)	25 (54.3%)	113 (48.4%)	116 (47.9%)	66 (53.2%)	417 (36.5%)	179 (48.7%)	57 (54.8%)	15 (31.9%)	17 (45.9%)	21 (51.2%)
KNOBS	61 (15.4%)	72 (13%)	46 (24.8%)	20 (23.8%)	23 (19.3%)	13 (28.2%)	61 (26.1%)	43 (17.7%)	35 (28.2%)	229 (20%)	72 (19.6%)	32 (30.7%)	15 (31.9%)	9 (24.3%)	13 (31.7%)
ORGOBS	69 (17.4%)	86 (15.5%)	21 (11.3%)	23 (27.3%)	23 (19.3%)	4 (8.6%)	49 (21%)	55 (22.7%)	17 (13.7%)	164 (14.3%)	79 (21.5%)	17 (16.3%)	10 (21.2%)	11 (29.7%)	7 (17%)
NETOBS	41 (10.3%)	48 (8.6%)	21 (11.3%)	17 (20.2%)	15 (12.6%)	6 (13%)	32 (13.7%)	28 (11.5%)	19 (15.3%)	157 (13.7%)	54 (14.7%)	18 (17.3%)	7 (14.8%)	9 (24.3%)	9 (21.9%)
DEMOBS	31 (7.8%)	30 (5.4%)	16 (8.6%)	11 (13%)	5 (4.2%)	5 (10.8%)	17 (7.2%)	21 (8.6%)	11 (8.8%)	67 (5.8%)	24 (6.5%)	7 (6.7%)	2 (4.2%)	4 (10.8%)	5 (12.1%)

Source: Author's elaboration.

4.2. Econometric results

4.2.1. Multinomial Logistic Regression (MLR) models – product innovativeness

Let us start the presentation of the econometric results by discussing the findings as regards product innovativeness of companies. Table 24 displays the results (Relative Risk Ratios – RRR) of the MLR models considering only the set of the determinants of product innovation, defined hereafter as "pure models". One has to remember that the baseline category herein refers to the potential product innovators (PDIN = 0), so the results indicate how likely it is that a given company be an innovator at certain novelty level (firm, country or world level) in comparison to how likely it is that this company be a potential innovator if there is an increase of one unit in a particular independent variable under consideration. Since the RRR is a ratio of two probabilities, results smaller than 1 indicate that it is more likely that a company be a potential innovator as the independent variable increases, while results greater than 1 indicate that it is more likely that a company be an innovator as the independent variable increases. Therefore, for purposes of language economy, when the results are smaller than 1 we interpret them just as a negative sign, whereas when the results are greater than 1 we interpret them just as a positive sign. Lastly, we must also mention that sectoral dummies are included in all models as well to take into account industry fixed-effects, but they are omitted from the tables in order to ease the analysis.

The findings from Table 24 testify to a large extent that all determinants under consideration are relevant to product innovativeness. RDE is highly statistically significant and positive across all sectoral groups and novelty levels, although it is especially important within sectors of higher technology intensity and in the determination of product innovativeness of higher novelty levels. EKA is only statistically significant and positive among companies operating in KIBS sectors for firm and country level product innovators. ETA is highly statistically significant and positive across almost all sectoral groups and novelty levels, except world level product innovators operating in High-tech sectors. IMIP is also highly statistically significant and positive across all sectoral groups and novelty levels, but especially for world level product innovators. SIZE is statistically significant and positive across all sectoral groups, but only for product innovations of higher novelty level. COF follows the same pattern as RDE, ETA and IMIP, and is highly statistically significant and positive across all sectoral groups and novelty levels. CREO is the only independent variable that presented unexpected results as it is statistically significant and positive only for country and world level product innovators operating in Low-tech sectors, while it is also statistically significant but negative for all product innovativeness levels among companies operating in High-tech sectors and for world level product innovators operating in KIBS sectors. Pseudo R^2 values are close to 0.2, which is quite reasonable for MLR models.

Table 24 - Regression results for product innovativeness by sectoral technology intensity groups

	Low-tech sectors			High-tech sectors			KIBS sectors		
Product innovation	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator
lnRDE	1.130***	1.274***	1.286***	1.235***	1.339***	1.434***	1.288***	1.371***	1.424***
	(0.0218)	(0.0299)	(0.0493)	(0.0289)	(0.0356)	(0.0566)	(0.0415)	(0.0519)	(0.0849)
lnEKA	1.004	1.011	1.007	1.038	1.012	1.010	1.193***	1.198***	1.072
	(0.0269)	(0.0322)	(0.0474)	(0.0345)	(0.0366)	(0.0446)	(0.0664)	(0.0729)	(0.0969)
lnETA	1.218***	1.195***	1.221***	1.117***	1.129***	1.053	1.244***	1.243***	1.143**
	(0.0158)	(0.0218)	(0.0379)	(0.0235)	(0.0272)	(0.0343)	(0.0425)	(0.0510)	(0.0715)
IMIP	3.224***	5.548***	6.754***	2.028***	3.516***	7.537***	1.885***	4.366***	6.380***
	(0.299)	(0.693)	(1.573)	(0.269)	(0.542)	(1.984)	(0.399)	(1.048)	(2.397)
lnSIZE	1.003	1.144***	1.391***	1.035	1.030	1.347***	1.047	1.082	1.302*
	(0.0324)	(0.0567)	(0.127)	(0.0535)	(0.0641)	(0.125)	(0.0715)	(0.0938)	(0.176)
COF	2.127***	3.278***	2.967***	2.406***	3.357***	3.920***	2.033**	3.059***	3.141**
	(0.313)	(0.578)	(0.828)	(0.511)	(0.763)	(1.121)	(0.632)	(1.035)	(1.458)
CREO	1.295	1.642*	2.187**	0.491**	0.510**	0.444**	0.553	0.641	0.255**
	(0.295)	(0.422)	(0.786)	(0.140)	(0.153)	(0.163)	(0.234)	(0.290)	(0.175)
Constant	0.0276***	0.00232***	0.000120***	0.526*	0.0959***	0.00281***	0.0985***	0.00609***	0.00292***
	(0.0137)	(0.00134)	(0.000107)	(0.196)	(0.0448)	(0.00221)	(0.0769)	(0.00601)	(0.00333)
Observations	4,254	4,254	4,254	2,041	2,041	2,041	1,080	1,080	1,080
Pseudo R^2	0.195	0.195	0.195	0.152	0.152	0.152	0.207	0.207	0.207

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses; Results for sectoral dummies are omitted.
Source: Author's elaboration.

Table 25 presents the results of the MLR models for product innovativeness with moderation from financial obstacles to innovation. The moderation relationship is assessed by the interaction terms combining the determinants of innovation and the FINOBS variable. The interpretation of the interaction terms seems complicated, but it is actually quite straightforward: if the result (RRR) is greater than 1, the probability of a company being an innovator at a certain level (firm, country or world level) is higher than the probability of it being a potential innovator if there is an increase of one unit of a given determinant while the company faces obstacles to innovation. Conversely, if the result is smaller than 1, the probability of a company being an innovator is lower than the probability of it being a potential innovator if there is an increase of one unit of a given determinant while the company faces obstacles to innovation. In other words, the interaction terms show how likely it is that a company innovates by relying on a given determinant at the same time that it perceives innovation barriers. Therefore, with the interaction terms we can verify which determinants are hampered by obstacles to innovation and which ones are actually triggered by these barriers as companies adapt their innovation strategies. Lastly, we must mention that, in addition to the results from sectoral dummies, the results from the determinants without moderation are also omitted from the tables with the interaction terms for the sake of smoothing the analysis.

The findings from Table 25 show that to a large extent most determinants lose part of their association to product innovativeness when companies face financial obstacles to innovation. RDE is less statistically significant when companies face financial barriers, but it still displays some statistically significant and positive results, especially among Low-tech sectors and for product innovations of lower novelty levels. EKA loses its statistically significant association among companies operating in KIBS sectors when companies perceive financial obstacles to innovation, but it also starts showing a statistically significant and positive result for country level product innovators operating in low-tech sectors. ETA loses part of its statistical significance as companies face financial barriers, but it also begins to exhibit a statistically significant and positive result for world level product innovators operating in High-tech sectors. IMIP and COF present results similar to the ones from RDE, with an overall loss of statistically significant association to product innovativeness when companies are facing financial obstacles to innovation, although there are still some significant and positive results. SIZE is the independent variable that suffered the most radical sign changes with the introduction of moderation by financial obstacles to innovation. While it presented some statistically significant and positive results in the pure models, now it displays several results that are statistically significant but negative. CREO loses most of its statistical significance when companies face financial barriers, but it also begins to exhibit a statistically significant and positive result for firm level product innovators operating in Low-tech sectors. Pseudo R^2 values improved with the inclusion of the interaction terms, which indicates that adding the financial obstacles to innovation to the models contributed to a better goodness of fit.

Table 25 - Regression results for product innovativeness (with financial obstacles moderation) by sectoral technology intensity groups

	Low-tech sectors			High-tech sectors			KIBS sectors		
Product innovation	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator
RDExFINOBS	1.175***	1.106**	1.186**	1.103**	1.120**	0.999	1.139**	1.062	1.074
	(0.0452)	(0.0508)	(0.0895)	(0.0516)	(0.0597)	(0.0780)	(0.0713)	(0.0780)	(0.122)
EKAxFINOBS	1.047	1.142**	1.087	1.101	1.040	1.033	1.067	1.087	0.953
	(0.0552)	(0.0702)	(0.0985)	(0.0738)	(0.0754)	(0.0904)	(0.119)	(0.133)	(0.173)
ETAxFINOBS	1.122***	1.118***	1.092	1.133***	1.158***	1.135*	1.089	1.082	1.033
	(0.0299)	(0.0413)	(0.0688)	(0.0489)	(0.0573)	(0.0752)	(0.0751)	(0.0894)	(0.137)
IMIPxFINOBS	2.049***	1.436	2.283*	1.531	2.269***	3.801**	0.684	0.843	0.598
	(0.390)	(0.363)	(1.058)	(0.417)	(0.714)	(1.991)	(0.295)	(0.405)	(0.439)
SIZExFINOBS	0.706***	0.745***	0.655***	0.703***	0.690***	0.751***	0.735***	0.769***	0.935
	(0.0173)	(0.0318)	(0.0609)	(0.0291)	(0.0394)	(0.0797)	(0.0400)	(0.0642)	(0.137)
COFxFINOBS	1.234	1.662	2.933*	1.346	0.831	0.667	1.973	1.797	13.08**
	(0.368)	(0.591)	(1.683)	(0.587)	(0.387)	(0.387)	(1.236)	(1.226)	(13.61)
CREOxFINOBS	2.243*	1.631	2.413	0.478	0.450	0.759	3.617	3.887	0.0617*
	(0.979)	(0.800)	(1.727)	(0.276)	(0.275)	(0.563)	(3.152)	(3.605)	(0.0968)
Constant	0.0269***	0.00221***	9.89e-05***	0.579	0.0983***	0.00240***	0.0852***	0.00562***	0.00292***
	(0.0132)	(0.00127)	(8.95e-05)	(0.222)	(0.0468)	(0.00193)	(0.0688)	(0.00564)	(0.00349)
Observations	4,254	4,254	4,254	2,041	2,041	2,041	1,080	1,080	1,080
Pseudo R^2	0.224	0.224	0.224	0.175	0.175	0.175	0.232	0.232	0.232

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses; Results for determinants without moderation and for sectoral dummies are omitted.
Source: Author's elaboration.

The findings from Table 26 show that the various determinants lose a lot of their statistically significant and positive association to product innovativeness when companies are facing knowledge obstacles to innovation. RDE is statistically significant and positive only for world level product innovators operating in Low-tech sectors when companies face knowledge barriers. EKA, on the one hand, starts to display statistically significant and positive results for firm and country level product innovators among Low-tech companies in the presence of knowledge obstacles to innovation, while ETA, on the other, experience a sign change within country level product innovators operating in KIBS sectors, whose result remains statistically significant, but becomes negative when companies face knowledge barriers. All results from IMIP and CREO lose their statistical significance when companies face knowledge obstacles to innovation. Once again, SIZE experiences a radical sign change when companies face knowledge obstacles to innovation as several results remain statistically significant, but become negative, especially among companies operating in Low-tech sectors and product innovations of higher novelty levels. The same happens to COF in the particular case of world level product innovators operating in High-tech sectors, which remains statistically significant, but becomes negative as companies face knowledge obstacles to innovation. Pseudo R^2

values also increased by including the interaction terms with knowledge barriers in the models, which indicates a better goodness of fit.

Table 26 - Regression results for product innovativeness (with knowledge obstacles moderation) by sectoral technology intensity groups

	Low-tech sectors			High-tech sectors			KIBS sectors		
Product innovation	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator
RDExKNOBS	1.015	1.069	1.194*	1.106	1.062	1.014	1.010	0.985	0.922
	(0.0507)	(0.0641)	(0.125)	(0.0682)	(0.0758)	(0.100)	(0.0771)	(0.0890)	(0.128)
EKAxKNOBS	1.191**	1.230**	1.092	0.984	1.016	1.122	1.569**	1.586**	1.285
	(0.0826)	(0.0998)	(0.138)	(0.0896)	(0.0999)	(0.128)	(0.320)	(0.337)	(0.362)
ETAxKNOBS	0.987	0.968	1.113	1.044	1.118*	1.093	0.902	0.839*	0.963
	(0.0321)	(0.0461)	(0.0985)	(0.0590)	(0.0749)	(0.0940)	(0.0718)	(0.0813)	(0.148)
IMIPxKNOBS	1.088	0.823	1.339	1.271	1.194	2.336	1.055	1.216	2.134
	(0.254)	(0.268)	(0.851)	(0.419)	(0.482)	(1.641)	(0.564)	(0.718)	(1.908)
SIZExKNOBS	0.870***	0.862**	0.674***	0.843***	0.802***	0.866	0.999	1.039	1.006
	(0.0264)	(0.0499)	(0.0980)	(0.0454)	(0.0643)	(0.124)	(0.0634)	(0.100)	(0.184)
COFxKNOBS	1.669	2.811**	2.375	0.649	0.443	0.197**	0.856	1.337	1.523
	(0.673)	(1.342)	(1.896)	(0.337)	(0.258)	(0.149)	(0.731)	(1.220)	(1.911)
CREOxKNOBS	2.174	2.592	3.166	0.688	1.247	0.960	1.193	0.920	1.264
	(1.254)	(1.664)	(2.974)	(0.462)	(0.898)	(0.881)	(1.311)	(1.075)	(2.220)
Constant	0.0304***	0.00226***	0.000124***	0.574	0.111***	0.00296***	0.101***	0.00623***	0.00298***
	(0.0152)	(0.00133)	(0.000112)	(0.216)	(0.0524)	(0.00235)	(0.0805)	(0.00622)	(0.00346)
Observations	4,254	4,254	4,254	2,041	2,041	2,041	1,080	1,080	1,080
Pseudo R^2	0.202	0.202	0.202	0.159	0.159	0.159	0.212	0.212	0.212

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses; Results for determinants without moderation and for sectoral dummies are omitted.
Source: Author's elaboration.

Table 27 presents findings for the models comprehending the interaction terms on organizational obstacles to innovation. Once more, one can see that most determinants lose their statistical significance also in the presence of organizational obstacles moderation. RDE, ETA and IMIP still present some positive and statistically significant results when companies face organizational obstacles to innovation, but nothing compared to the pure models. EKA starts to display statistically significant and negative results for country level product innovators at both Low-tech and High-tech sectors when companies perceive organizational barriers. SIZE experiences again a substantial sign change and starts to display several statistically significant and negative results when companies face organizational obstacles to innovation. COF also experiences a sign change for the specific case of world level product innovators operating in High-tech sectors when companies perceive organizational barriers, which remains statistically significant, but becomes negative. The same happens for CREO in the case of country level product innovators operating in Low-tech sectors, which was statistically significant and positive in the pure models, but now it is statistically significant and negative with the introduction of organizational obstacles. This variable also experiences a sign change in the opposite way in the cases of country and world level product innovators operating in High-tech sectors, which were statistically significant and negative in the pure models, but now they are statistically significant and positive in the presence of organizational barriers. Pseudo R^2 values increased accordingly with the introduction of the interaction terms, indicating an improvement in the goodness of fit.

Table 27 - Regression results for product innovativeness (with organizational obstacles moderation) by sectoral technology intensity groups

	Low-tech sectors			High-tech sectors			KIBS sectors		
Product innovation	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator
RDExORGOBS	1.128**	1.072	1.272**	1.053	1.101	0.921	1.160	1.176	1.087
	(0.0591)	(0.0678)	(0.142)	(0.0608)	(0.0738)	(0.0859)	(0.113)	(0.130)	(0.168)
EKAxORGOBS	0.971	0.856*	0.869	0.884	0.806**	0.842	1.075	0.970	1.001
	(0.0632)	(0.0684)	(0.102)	(0.0732)	(0.0732)	(0.0929)	(0.153)	(0.160)	(0.267)
ETAxORGOBS	1.032	1.128**	1.016	1.111*	1.040	1.078	1.171*	1.120	1.199
	(0.0365)	(0.0557)	(0.0862)	(0.0621)	(0.0678)	(0.0959)	(0.108)	(0.130)	(0.224)
IMIPxORGOBS	2.287***	1.367	2.321	1.340	1.609	1.404	0.581	0.532	0.925
	(0.588)	(0.469)	(1.556)	(0.451)	(0.631)	(0.892)	(0.363)	(0.383)	(0.992)
SIZExORGOBS	0.800***	0.809***	0.666***	0.828***	0.847**	1.023	0.786***	0.838*	0.923
	(0.0267)	(0.0497)	(0.101)	(0.0426)	(0.0613)	(0.125)	(0.0550)	(0.0881)	(0.156)
COFxORGOBS	2.504**	5.911***	10.22***	0.596	0.434	0.203**	0.749	0.795	0.285
	(1.056)	(2.878)	(8.076)	(0.291)	(0.232)	(0.151)	(0.612)	(0.734)	(0.431)
CREOxORGOBS	0.352*	0.186***	0.265	2.206	4.665**	7.716**	4.136	3.021	2.78e-06
	(0.194)	(0.114)	(0.233)	(1.469)	(3.309)	(7.064)	(4.925)	(3.885)	(0.00237)
Constant	0.0272***	0.00254***	0.000109***	0.536*	0.0972***	0.00295***	0.0853***	0.00586***	0.00222***
	(0.0135)	(0.00146)	(9.88e-05)	(0.201)	(0.0457)	(0.00233)	(0.0685)	(0.00588)	(0.00262)
Observations	4,254	4,254	4,254	2,041	2,041	2,041	1,080	1,080	1,080
Pseudo R^2	0.205	0.205	0.205	0.159	0.159	0.159	0.216	0.216	0.216

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses; Results for determinants without moderation and for sectoral dummies are omitted.
Source: Author's elaboration.

Table 28 presents findings for the models comprehending the interaction terms as regards network obstacles to innovation. We can observe again an overall reduction of the statistical significance of the results from the various independent variables. RDE, ETA and CREO lose all their statistically significant results when companies face network barriers. EKA starts to show statistically significant and positive results for the cases of firm and country level product innovators operating in Low-tech sectors in the presence of network obstacles to innovation. IMIP loses most of its statistical significance as companies struggle with network issues, except for firm and country level product innovators operating in KIBS sectors. SIZE displays over again several statistically significant and negative results when companies face network barriers. COF experiences a radical sign change for product innovators at all novelty levels operating in High-tech sectors when companies perceive network obstacles to innovation, as they start displaying statistically significant and negative results, whilst they displayed statistically significant and positive results in the pure models. Pseudo R^2 values increased just as expected, indicating again a better goodness of fit for the models with the interaction terms on network obstacles to innovation.

Table 28 - Regression results for product innovativeness (with network obstacles moderation) by sectoral technology intensity groups

	Low-tech sectors			High-tech sectors			KIBS sectors		
Product innovation	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator
RDExNETOBS	1.054	1.050	1.210	1.067	1.146	1.086	1.050	1.051	1.129
	(0.0623)	(0.0711)	(0.143)	(0.0753)	(0.0986)	(0.129)	(0.103)	(0.122)	(0.231)
EKAxNETOBS	1.217***	1.200**	1.178	0.942	1.016	0.840	1.201	1.025	0.923
	(0.0914)	(0.106)	(0.157)	(0.0917)	(0.110)	(0.122)	(0.231)	(0.221)	(0.335)
ETAxNETOBS	1.005	0.937	1.045	1.028	1.059	0.998	1.012	0.847	1.151
	(0.0401)	(0.0509)	(0.107)	(0.0654)	(0.0843)	(0.108)	(0.102)	(0.106)	(0.257)
IMIPxNETOBS	1.161	0.770	1.683	1.235	0.743	3.302	3.615*	11.64***	8.292
	(0.312)	(0.274)	(1.213)	(0.457)	(0.350)	(2.929)	(2.546)	(8.955)	(11.06)
SIZExNETOBS	0.810***	0.930	0.700**	0.904*	0.839*	0.845	0.781***	0.842	0.617
	(0.0309)	(0.0577)	(0.122)	(0.0520)	(0.0769)	(0.158)	(0.0701)	(0.112)	(0.205)
COFxNETOBS	2.175	3.852**	3.360	0.219**	0.112***	0.154**	2.575	4.928	8.385
	(1.113)	(2.200)	(2.913)	(0.133)	(0.0834)	(0.143)	(2.625)	(5.412)	(12.38)
CREOxNETOBS	0.863	0.552	0.432	2.219	2.358	1.876	0.591	0.301	6.04e-08
	(0.612)	(0.423)	(0.473)	(1.797)	(2.185)	(2.196)	(0.742)	(0.403)	(0.000104)
Constant	0.0325***	0.00244***	0.000137***	0.590	0.118***	0.00291***	0.0929***	0.00545***	0.00316***
	(0.0161)	(0.00142)	(0.000123)	(0.221)	(0.0558)	(0.00230)	(0.0727)	(0.00536)	(0.00363)
Observations	4,254	4,254	4,254	2,041	2,041	2,041	1,080	1,080	1,080
Pseudo R^2	0.202	0.202	0.202	0.158	0.158	0.158	0.218	0.218	0.218

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses; Results for determinants without moderation and for sectoral dummies are omitted.
Source: Author's elaboration.

Table 29 presents findings for the models comprehending the interaction terms that concern demand obstacles to innovation. Similar to the previous models, there is an overall reduction of the statistical significance of the various results. RDE and IMIP lose most of their statistical significance as companies face demand obstacles to innovation, retaining statistically significant and positive results only for world level product innovators operating in Low-tech sectors, and also world level product innovators operating in High-tech sectors exclusively for IMIP. EKA begins to exhibit statistically significant and positive results in the cases of both firm and country level product innovators operating in Low-tech sectors when companies face demand barriers. EKA and CREO lose all of their statistical significance in the presence of demand obstacles to innovation. Repeating the pattern identified in all previous moderation models, SIZE experiences a radical sign change and starts to display several statistically significant and negative results as companies perceive demand barriers. COF also experiences a sign change in the specific case of world level product innovators operating in KIBS sectors in the presence of demand barriers, as it displays now a statistically significant and negative result. Pseudo R^2 values increased with the introduction of the interaction terms, indicating that the moderation by demand obstacles to innovation improves the goodness of fit of our models.

Table 29 - Regression results for product innovativeness (with demand obstacles moderation) by sectoral technology intensity groups

	Low-tech sectors			High-tech sectors			KIBS sectors		
Product innovation	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator
RDExDEMOBS	0.996	1.050	1.289*	0.860	0.890	0.903	0.985	0.991	1.027
	(0.0758)	(0.0977)	(0.190)	(0.0820)	(0.0983)	(0.143)	(0.116)	(0.144)	(0.209)
EKAxDEMOBS	1.257**	1.342**	0.967	0.905	0.946	1.180	1.154	1.267	1.336
	(0.142)	(0.173)	(0.176)	(0.130)	(0.142)	(0.209)	(0.357)	(0.457)	(0.764)
ETAxDEMOBS	1.078	0.946	0.943	1.153	1.067	1.111	0.977	0.926	1.065
	(0.0580)	(0.0732)	(0.108)	(0.106)	(0.118)	(0.159)	(0.113)	(0.146)	(0.242)
IMIPxDEMOBS	1.123	1.731	5.170*	1.933	1.958	10.04**	3.415	4.620	0.962
	(0.449)	(0.892)	(4.468)	(1.055)	(1.253)	(11.11)	(3.134)	(4.874)	(1.435)
SIZExDEMOBS	0.813***	0.820**	0.706*	0.798***	0.841	0.706	0.951	0.901	1.137
	(0.0399)	(0.0725)	(0.135)	(0.0690)	(0.100)	(0.164)	(0.0774)	(0.136)	(0.242)
COFxDEMOBS	15.89***	13.95**	13.28**	2.038	0.452	0.0645*	0.725	0.484	3.92e-08
	(15.33)	(14.56)	(16.43)	(1.918)	(0.512)	(0.103)	(0.961)	(0.747)	(9.61e-05)
CREOxDEMOBS	0.152	0.314	0.607	0.183	0.701	1.735	6.236	6.773	6.68e-06
	(0.176)	(0.382)	(0.847)	(0.208)	(0.886)	(2.920)	(10.26)	(12.52)	(0.0211)
Constant	0.0283***	0.00235***	0.000122***	0.512*	0.0928***	0.00238***	0.0990***	0.00603***	0.00283***
	(0.0140)	(0.00136)	(0.000110)	(0.192)	(0.0435)	(0.00189)	(0.0785)	(0.00601)	(0.00332)
Observations	4,254	4,254	4,254	2,041	2,041	2,041	1,080	1,080	1,080
Pseudo R^2	0.201	0.201	0.201	0.162	0.162	0.162	0.211	0.211	0.211

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses; Results for determinants without moderation and for sectoral dummies are omitted.
Source: Author's elaboration.

4.2.2. Multinomial Logistic Regression (MLR) models – process innovativeness

Now moving to the process innovativeness findings from the MLR models, one has to keep in mind once again that the baseline category herein refers to the potential process innovators (PCIN = 0) and that the results are given in terms of Relative Risk Ratios (RRR). The way of interpreting the results is the same as that for product innovativeness: results smaller than 1 indicate that it is more likely that a company be a potential innovator as the independent variable increases, while results greater than 1 indicate that it is more likely that a company be an innovator as the independent variable increases. Similarly, in the case of the models assessing the moderation relationships, the interaction terms show how likely it is that a company innovates by relying on a given determinant at the same time that it faces obstacles to innovation. The interaction terms will allow us to verify which determinants are hampered by obstacles to innovation and which ones are actually triggered by these barriers as companies adapt their innovation strategies. Sectoral dummies are also included in the models for process innovativeness to address industry fixed-effects, but they are omitted from the tables to ease the analysis. In the particular case of the tables in which interaction terms are included, the results for determinants without moderation are also omitted to favor a more straightforward interpretation. Again, for purposes of language economy, when the results are smaller than 1 we will interpret them just as a negative sign, whereas when the results are greater than 1 we will interpret them just as a positive sign.

Table 30 presents the findings for the process innovativeness MLR models comprehending only the determinants of innovation, which we refer as “pure models”. As expected, most determinants seem to really matter for the process innovativeness of companies, regardless of the sectoral groups in which they operate. RDE is highly statistically significant and positive across all sectoral groups and novelty levels, although it tends to be more pronounced for process innovations of higher novelty levels. EKA is statistically significant and positive only among companies operating in High-tech sectors at all novelty levels, and also among companies operating in KIBS sectors for firm level process innovators. ETA is highly statistically significant and positive across all sectoral groups and novelty levels as well, although it tends to be more pronounced among companies operating in Low-tech sectors. IMIP is also highly statistically significant and positive across all sectoral groups and novelty levels, but especially for world level process innovators. SIZE is statistically significant and positive only for country and world level innovators operating in Low-tech and High-tech sectors. COF is statistically significant and positive across all sectoral groups and novelty levels, except firm level innovators operating in KIBS sectors. CREO displays the most surprising results, as it not only shows almost no statistically significant result, but also the only significant result it presents is negative, referring to firm level process innovators operating in High-tech sectors. Pseudo R^2 values revolve around 0.2, which is quite satisfactory for MLR models.

Table 30 - Regression results for process innovativeness by sectoral technology intensity groups

	Low-tech sectors			High-tech sectors			KIBS sectors		
Process innovation	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator
lnRDE	1.095***	1.251***	1.284***	1.081***	1.153***	1.195***	1.171***	1.240***	1.388***
	(0.0269)	(0.0367)	(0.0651)	(0.0271)	(0.0368)	(0.0660)	(0.0362)	(0.0524)	(0.115)
lnEKA	0.969	1.003	1.068	1.091**	1.122**	1.110*	1.132**	1.078	0.896
	(0.0346)	(0.0412)	(0.0611)	(0.0433)	(0.0502)	(0.0665)	(0.0598)	(0.0704)	(0.122)
lnETA	1.814***	1.819***	1.806***	1.538***	1.599***	1.569***	1.536***	1.521***	1.442***
	(0.0386)	(0.0483)	(0.0765)	(0.0457)	(0.0563)	(0.0811)	(0.0592)	(0.0755)	(0.119)
IMIP	3.105***	5.013***	4.538***	2.555***	5.052***	8.978***	2.223***	4.191***	5.586***
	(0.346)	(0.754)	(1.296)	(0.370)	(1.000)	(3.764)	(0.465)	(1.144)	(2.901)
lnSIZE	0.981	1.157***	1.450***	1.080	1.208**	1.547***	0.922	1.051	1.169
	(0.0327)	(0.0628)	(0.164)	(0.0600)	(0.0937)	(0.209)	(0.0590)	(0.102)	(0.216)
COF	2.695***	4.098***	5.102***	2.689***	2.950***	3.859***	1.542	2.769***	2.769*
	(0.513)	(0.924)	(1.816)	(0.612)	(0.795)	(1.529)	(0.457)	(0.999)	(1.683)
CREO	1.627	1.719	1.741	0.549*	0.673	0.467	1.463	0.841	0.348
	(0.488)	(0.580)	(0.806)	(0.173)	(0.240)	(0.231)	(0.648)	(0.447)	(0.337)
Constant	0.306***	0.0129***	0.000486***	0.375**	0.0190***	1.33e-10	0.185**	0.0142***	0.00174***
	(0.134)	(0.00735)	(0.000447)	(0.152)	(0.0106)	(1.90e-07)	(0.146)	(0.0140)	(0.00254)
Observations	5,164	5,164	5,164	2,102	2,102	2,102	1,155	1,155	1,155
Pseudo R^2	0.288	0.288	0.288	0.214	0.214	0.214	0.207	0.207	0.207

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses; Results for sectoral dummies are omitted.
Source: Author's elaboration.

Table 31 presents the findings for the models comprehending the introduction of interaction terms as regards financial obstacles to innovation. Most determinants lose a good part of their statistical significance as a consequence of the moderation. RDE is not statistically significant anymore among companies operating in KIBS sectors at all novelty levels and companies operating in High-tech sectors for world level process innovators when firms face financial barriers. EKA ceases to be statistically significant among companies operating in High-tech sectors at all novelty levels as firms perceive financial obstacles to innovation, but, on the other hand, it starts to display statistically significant and positive results for country level process innovators operating in Low-tech and KIBS sectors. ETA is not statistically significant anymore among companies operating in High-tech and KIBS sectors at all novelty levels when financial barriers are an issue, as well as IMIP is not statistically significant anymore among companies operating in KIBS sectors at all novelty levels and for world level process innovators operating in Low-tech sectors. SIZE experiences a radical sign change with the introduction of interaction terms to address financial obstacles to innovation, as it displays now several statistically significant and negative results across all sectoral groups and novelty levels, except world level process innovators operating in KIBS sectors. COF loses almost all statistical significance when companies are facing financial barriers, except for country level process innovators operating in High-tech sectors. CREO does not present any statistically significant result with the moderation by financial obstacles to innovation, either positive or negative. Pseudo R^2 values increased with the introduction of the interaction terms, indicating a better goodness of fit for the models comprehending the moderation role of financial barriers.

Table 31 - Regression results for process innovativeness (with financial obstacles moderation) by sectoral technology intensity groups

	Low-tech sectors			High-tech sectors			KIBS sectors		
Process innovation	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator
RDExFINOBS	1.191***	1.150**	1.318**	1.151***	1.134**	1.046	1.038	0.988	1.139
	(0.0582)	(0.0663)	(0.143)	(0.0572)	(0.0718)	(0.115)	(0.0621)	(0.0786)	(0.185)
EKAxFINOBS	1.118	1.216**	1.115	1.095	1.103	1.071	1.332**	1.375**	1.586
	(0.0787)	(0.0976)	(0.126)	(0.0898)	(0.101)	(0.130)	(0.156)	(0.192)	(0.470)
ETAxFINOBS	1.199***	1.234***	1.281***	1.064	1.070	1.115	1.130	1.133	0.970
	(0.0514)	(0.0655)	(0.111)	(0.0625)	(0.0749)	(0.119)	(0.0870)	(0.114)	(0.170)
IMIPxFINOBS	2.124***	1.886**	1.650	1.968**	2.818***	4.399*	1.149	1.566	0.372
	(0.488)	(0.577)	(0.993)	(0.579)	(1.120)	(3.711)	(0.488)	(0.856)	(0.379)
SIZExFINOBS	0.672***	0.694***	0.559***	0.712***	0.672***	0.683**	0.706***	0.703***	0.724
	(0.0157)	(0.0338)	(0.0718)	(0.0294)	(0.0498)	(0.115)	(0.0359)	(0.0668)	(0.167)
COFxFINOBS	1.496	1.033	0.980	1.805	2.760*	1.530	2.275	2.409	4.145
	(0.587)	(0.479)	(0.763)	(0.830)	(1.503)	(1.229)	(1.368)	(1.765)	(5.159)
CREOxFINOBS	1.604	1.092	3.061	0.743	0.764	0.477	3.656	4.956	3.661
	(0.943)	(0.719)	(2.871)	(0.472)	(0.549)	(0.478)	(3.287)	(5.345)	(6.985)
Constant	0.277***	0.0118***	0.000511***	0.403**	0.0197***	2.71e-10	0.216*	0.0165***	0.00216***
	(0.124)	(0.00691)	(0.000476)	(0.169)	(0.0112)	(2.59e-07)	(0.176)	(0.0165)	(0.00315)
Observations	5,164	5,164	5,164	2,102	2,102	2,102	1,155	1,155	1,155
Pseudo R^2	0.326	0.326	0.326	0.235	0.235	0.235	0.239	0.239	0.239

*** $p<0.01$, ** $p<0.05$, * $p<0.1$; Standard errors in parentheses; Results for determinants without moderation and for sectoral dummies are omitted.
Source: Author's elaboration.

Table 32 presents the findings for the models introducing interaction terms that concern knowledge obstacles to innovation. Again, most determinants lose to a large extent their statistical significance after the moderation. RDE only retains statistically significant and positive results for world level process innovators operating in Low-tech sectors and firm level process innovators operating in KIBS sectors when companies face knowledge barriers. EKA loses its statistically significant and positive results among companies operating in High-tech sectors at all novelty levels and firm level innovators operating in KIBS as firms perceive knowledge obstacles to innovation, but it also obtains statistically significant and positive results for firm and country level innovators operating in Low-tech sectors. ETA and COF lose all their statistical significance with the introduction of the moderation by knowledge barriers. IMIP only retains statistically significant and positive results for firm level process innovators operating in Low-tech sectors and country level process innovators operating in High-tech sectors as companies face knowledge obstacles to innovation. In the presence of knowledge barriers, SIZE experiences once more substantial sign change and presents several statistically significant and negative results across all sectoral groups. CREO begins to exhibit statistically significant and positive results for firm and country level process innovators operating in Low-tech sectors when companies face knowledge obstacles to innovation. As expected, Pseudo R^2 values increased with the inclusion of the knowledge barriers moderation, improving the goodness of fit of our models.

Table 32 - Regression results for process innovativeness (with knowledge obstacles moderation) by sectoral technology intensity groups

	Low-tech sectors			High-tech sectors			KIBS sectors		
Process innovation	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator
RDExKNOBS	0.975	0.962	1.529*	1.074	1.026	0.871	1.145*	1.002	0.935
	(0.0633)	(0.0737)	(0.372)	(0.0747)	(0.0909)	(0.124)	(0.0870)	(0.0979)	(0.209)
EKAxKNOBS	1.264**	1.340***	1.075	0.989	1.001	1.039	1.103	1.166	1.365
	(0.127)	(0.150)	(0.208)	(0.117)	(0.132)	(0.181)	(0.174)	(0.211)	(0.559)
ETAxKNOBS	1.070	1.079	1.132	1.127	1.136	1.138	0.969	0.882	0.558
	(0.0557)	(0.0719)	(0.161)	(0.0904)	(0.111)	(0.165)	(0.0900)	(0.103)	(0.234)
IMIPxKNOBS	2.119**	1.426	0.554	1.410	2.671*	2.040	0.674	0.645	0.343
	(0.645)	(0.575)	(0.540)	(0.528)	(1.463)	(2.210)	(0.347)	(0.415)	(0.508)
SIZExKNOBS	0.820***	0.844***	0.534**	0.792***	0.741***	0.920	0.875**	1.094	1.173
	(0.0242)	(0.0553)	(0.157)	(0.0452)	(0.0831)	(0.204)	(0.0559)	(0.112)	(0.284)
COFxKNOBS	0.669	0.814	1.069	1.798	2.127	1.670	2.442	2.770	9.502
	(0.334)	(0.489)	(1.307)	(1.132)	(1.584)	(1.894)	(2.363)	(3.000)	(18.78)
CREOxKNOBS	7.413**	6.677*	4.763	1.552	0.950	0.932	3.335	1.910	2.26e-06
	(6.809)	(6.654)	(7.294)	(1.332)	(0.935)	(1.320)	(4.448)	(2.927)	(0.00320)
Constant	0.381**	0.0152***	0.000616***	0.433**	0.0208***	3.14e-10	0.245*	0.0165***	0.00199***
	(0.170)	(0.00884)	(0.000577)	(0.179)	(0.0118)	(3.08e-07)	(0.194)	(0.0165)	(0.00290)
Observations	5,164	5,164	5,164	2,102	2,102	2,102	1,155	1,155	1,155
Pseudo R^2	0.296	0.296	0.296	0.221	0.221	0.221	0.217	0.217	0.217

*** $p<0.01$, ** $p<0.05$, * $p<0.1$; Standard errors in parentheses; Results for determinants without moderation and for sectoral dummies are omitted.
Source: Author's elaboration.

Table 33 presents the findings for the models including the interaction terms on organizational obstacles to innovation. There is an overall loss of statistical significance of the results as a consequence. RDE only keeps a statistically significant and positive result for world level process innovators operating in Low-tech sectors as companies perceive organizational barriers. EKA experiences a sign change for world level process innovators operating in High-tech sectors when there are organizational issues at play, as in the pure model it was statistically significant and positive and now it becomes statistically significant and negative. ETA also experiences a sign change when companies face organizational obstacles to innovation, as country level process innovators operating in KIBS becomes statistically significant and negative. IMIP and

CREO do not have any statistically significant result when firms perceive organizational barriers. SIZE displays again several statistically significant and negative results in the presence of organizational obstacles to innovation. COF loses most statistically significant results as companies perceive organizational barriers, but it also obtains a statistically significant and positive result for firm level process innovators operating in KIBS sectors. Pseudo R^2 values increased just as expected, attesting a better goodness of fit for our models with the inclusion of the interaction terms on organizational obstacles to innovation.

Table 33 - Regression results for process innovativeness (with organizational obstacles moderation) by sectoral technology intensity groups

	Low-tech sectors			High-tech sectors			KIBS sectors		
Process innovation	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator
RDExORGOBS	1.106	1.134	1.299*	1.082	1.033	1.031	0.915	1.032	0.0715
	(0.0754)	(0.0903)	(0.203)	(0.0662)	(0.0789)	(0.160)	(0.0742)	(0.105)	(18.76)
EKAxORGOBS	1.038	1.031	0.919	0.944	0.868	0.671*	1.091	1.131	0.00830
	(0.0923)	(0.105)	(0.134)	(0.0950)	(0.0972)	(0.151)	(0.152)	(0.197)	(6.070)
ETAxORGOBS	1.047	1.050	0.952	1.028	1.006	1.188	0.866	0.785*	0.00678
	(0.0580)	(0.0730)	(0.105)	(0.0749)	(0.0872)	(0.203)	(0.0760)	(0.101)	(3.215)
IMIPxORGOBS	1.624	1.438	0.946	1.783	1.584	2.539	1.326	1.527	1.85e-06
	(0.505)	(0.599)	(0.749)	(0.646)	(0.762)	(3.202)	(0.763)	(1.136)	(0.00380)
SIZExORGOBS	0.792***	0.812***	0.711*	0.790***	0.925	0.710	0.798***	0.913	1.091
	(0.0244)	(0.0558)	(0.127)	(0.0412)	(0.0815)	(0.182)	(0.0507)	(0.101)	(0.253)
COFxORGOBS	1.351	0.972	2.249	1.021	0.713	0.251	3.903*	0.666	1.02e-06
	(0.652)	(0.577)	(2.363)	(0.570)	(0.476)	(0.384)	(3.019)	(0.718)	(0.00629)
CREOxORGOBS	0.666	0.501	2.713	1.689	2.262	12.46	1.932	0.535	8.944e+06
	(0.471)	(0.407)	(3.118)	(1.325)	(2.012)	(20.77)	(2.178)	(0.850)	(5.977e+10)
Constant	0.325**	0.0134***	0.000453***	0.381**	0.0192***	1.53e-10	0.209**	0.0145***	0.00194***
	(0.144)	(0.00775)	(0.000432)	(0.156)	(0.0108)	(2.11e-07)	(0.166)	(0.0143)	(0.00297)
Observations	5,164	5,164	5,164	2,102	2,102	2,102	1,155	1,155	1,155
Pseudo R^2	0.297	0.297	0.297	0.223	0.223	0.223	0.228	0.228	0.228

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses; Results for determinants without moderation and for sectoral dummies are omitted.
Source: Author's elaboration.

Table 34 presents the findings for the models with interaction terms on network obstacles to innovation. Determinants heavily lose statistical significance after moderation. RDE and CREO do not show any statistically significant result when companies perceive network barriers. EKA loses all its statistically significant results identified in the pure models, but, on the other hand, it begins to exhibit a statistically significant and positive result for country level process innovators operating in KIBS sectors as companies face network obstacles to innovation. ETA and IMIP lose most of their statistically significant and positive results when companies perceive network barriers. In the presence of network obstacles to innovation, SIZE displays several statistically significant and negative results over again. COF loses most of its statistically significant and positive results identified in the pure models, but it also starts to display a statistically significant and positive result for firm level process innovators operating in KIBS when companies face network issues. Pseudo R^2 values increased accordingly, manifesting a better goodness of fit for the models that comprehend interaction terms on network obstacles to innovation.

Table 34 - Regression results for process innovativeness (with network obstacles moderation) by sectoral technology intensity groups

	Low-tech sectors			High-tech sectors			KIBS sectors		
Process innovation	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator
RDExNETOBS	1.009	1.058	1.455	1.064	1.019	1.002	0.953	0.977	0.0118
	(0.0776)	(0.0930)	(0.419)	(0.0840)	(0.104)	(0.218)	(0.0957)	(0.125)	(36.26)
EKAxNETOBS	1.145	1.041	1.076	0.875	0.987	0.805	1.441	1.595*	3.696e+10
	(0.122)	(0.128)	(0.245)	(0.109)	(0.138)	(0.282)	(0.353)	(0.431)	(6.111e+13)
ETAxNETOBS	1.081	1.161*	1.195	1.095	1.008	0.973	1.183	1.332*	2.32e-05
	(0.0671)	(0.0936)	(0.272)	(0.0920)	(0.109)	(0.233)	(0.147)	(0.213)	(0.0395)
IMIPxNETOBS	1.823*	1.609	0.642	0.812	2.050	5.998	1.579	5.375**	5.723e+23
	(0.610)	(0.716)	(0.799)	(0.335)	(1.327)	(12.07)	(0.966)	(4.344)	(8.081e+27)
SIZExNETOBS	0.811***	0.804***	0.544	0.839***	0.763**	0.720	0.790***	0.608***	4.66e-19
	(0.0278)	(0.0651)	(0.213)	(0.0509)	(0.102)	(0.315)	(0.0649)	(0.109)	(1.27e-15)
COFxNETOBS	1.126	0.917	0.149	1.389	1.221	1.48e-06	12.09*	60.15***	1.852e+38
	(0.621)	(0.618)	(0.303)	(1.032)	(1.079)	(0.00139)	(15.73)	(86.71)	(1.345e+42)
CREOxNETOBS	1.391	1.227	2.832	4.727	5.146	5.59e-05	0.374	0.0906	5.76e-22
	(1.405)	(1.367)	(6.209)	(5.944)	(7.011)	(0.0589)	(0.527)	(0.147)	(5.03e-18)
Constant	0.366**	0.0148***	0.000598***	0.411**	0.0205***	5.34e-10	0.183**	0.0149***	0.00176***
	(0.162)	(0.00851)	(0.000552)	(0.168)	(0.0115)	(4.12e-07)	(0.145)	(0.0147)	(0.00259)
Observations	5,164	5,164	5,164	2,102	2,102	2,102	1,155	1,155	1,155
Pseudo R^2	0.294	0.294	0.294	0.221	0.221	0.221	0.228	0.228	0.228

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses; Results for determinants without moderation and for sectoral dummies are omitted.
Source: Author's elaboration.

Table 35 presents the findings for the models including interaction terms on demand obstacles to innovation. Again, there is a general loss of statistical significance after moderation. RDE, EKA and CREO lose all their statistically significant results identified in the pure models when companies perceive demand barriers. ETA, IMIP and COF lose most of their statistically significant and positive results identified in the pure models as companies face demand obstacles to innovation. Just as in the previous models, in the presence of demand barriers, SIZE experiences a radical sign change and starts to display several statistically significant and negative results. Pseudo R^2 values increased just as expected, indicating the improvement of the models' goodness of fit with the introduction of the interaction terms on demand obstacles to innovation.

Table 35 - Regression results for process innovativeness (with demand obstacles moderation) by sectoral technology intensity groups

	Low-tech sectors			High-tech sectors			KIBS sectors		
Process innovation	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator	Firm level Innovator	Country level innovator	World level innovator
RDExDEMOBS	0.968	1.069	1.396	1.078	1.005	1.591	0.982	0.883	0.0303
	(0.0901)	(0.117)	(0.469)	(0.131)	(0.150)	(0.912)	(0.112)	(0.150)	(86.77)
EKAxDEMOBS	1.032	0.914	1.107	1.022	1.179	0.0105	6.487e+31	1.087e+32	1.105e+27
	(0.150)	(0.160)	(0.296)	(0.181)	(0.238)	(3.727)	(3.533e+35)	(5.922e+35)	(5.215e+31)
ETAxDEMOBS	1.148	1.102	1.282	1.164	1.341	2.177	1.071	1.538*	0.000214
	(0.100)	(0.118)	(0.270)	(0.176)	(0.247)	(1.848)	(0.163)	(0.354)	(1.233)
IMIPxDEMOBS	2.202*	1.029	0.461	2.698	11.61**	0.155	2.172	6.290	4.30e-08
	(1.043)	(0.648)	(0.626)	(1.717)	(11.43)	(0.436)	(1.753)	(7.607)	(0.000766)
SIZExDEMOBS	0.746***	0.796**	0.519*	0.784***	0.554***	0.282	0.814**	0.519**	1.289
	(0.0366)	(0.0797)	(0.205)	(0.0683)	(0.115)	(0.409)	(0.0745)	(0.140)	(0.306)
COFxDEMOBS	6.671**	5.684*	10.41	3.231e+06	2.053e+06	1.016	0.188	0.194	1.917e+11
	(5.849)	(5.763)	(17.48)	(2.663e+09)	(1.692e+09)	(2,404)	(0.294)	(0.354)	(3.160e+16)
CREOxDEMOBS	894,320	1.993e+06	109,347	1.42e-08	2.47e-08	0.472	10.60	19.13	8.30e-13
	(6.308e+08)	(1.405e+09)	(7.712e+07)	(1.17e-05)	(2.04e-05)	(1,116)	(20.25)	(43.55)	(1.43e-07)
Constant	0.325**	0.0133***	0.000470***	0.355**	0.0174***	2.22e-10	0.191**	0.0123***	0.00157***
	(0.143)	(0.00766)	(0.000436)	(0.145)	(0.00974)	(2.53e-07)	(0.150)	(0.0125)	(0.00242)
Observations	5,164	5,164	5,164	2,102	2,102	2,102	1,155	1,155	1,155
Pseudo R^2	0.295	0.295	0.295	0.224	0.224	0.224	0.222	0.222	0.222

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses; Results for determinants without moderation and for sectoral dummies are omitted.
Source: Author's elaboration.

4.2.3. Propensity Score Matching (PSM) results

Let us now consider the PSM results. As previously discussed, in order to apply the PSM technique, one needs to first run Probit models to obtain the propensity scores. In these models, the dependent variables are the policy instruments, while the independent variable are factors allegedly associated with the propensity of companies in participating in innovation policy programs. For the Brazilian context, we chose the following factors: innovativeness (INNO), high R&D expenditure (HRD), corporate group affiliation (GRP), foreign controlling shareholder (MNE), high net sales revenue (HNS), and location in the south or southeast (RLS). Table 36 presents the results for each policy instrument. Although the chosen factors were highly statistically significant for explaining participation in programs as Tax Breaks, Economic Subsidies and Public Funding, they were just lowly statistically significant for explaining participation in programs as Acquisition of Machinery and Public Procurement. Besides, they seem to be more relevant to manufacturing than to service sectors, which indicates a sectoral particularity as regards the firms' characteristics explaining participation in innovation policy programs in Brazil. Nevertheless, for the purposes of our goal of providing a first look to PINTEC 2014 microdata in order to verify the potential treatment effects of innovation policies over obstacles to innovation, these models seem good enough.

Table 37 presents the results of T-tests for the comparison of the percentages of treated and untreated companies facing financial obstacles to innovation before and after matching, according to technology intensity sectoral groups. One has to remember that, as the variables on obstacles to innovation are dummies, these percentages represent the average number of companies facing barriers among those that received and those that did not receive the treatment. In other words, we can estimate the Average Treatment Effect on the Treated (ATET) as the difference between the percentages of treated and untreated companies facing barriers after matching and compare this estimation to the Average Treatment Effect (ATE), which is simply the difference between the percentages of treated and untreated companies facing barriers before matching. To be precise, as the PSM technique manages to find untreated companies similar to the treated ones, it would be actually more accurate to call these as "control companies" in order to distinguish them from the untreated companies being compared to the treated ones before matching. This is exactly what we do in the presentation of the results in the next few tables.

PSM results for the perception of financial obstacles to innovation after matching are the following. Companies participating in Tax Breaks Programs (TBP) perceive fewer financial barriers if they are operating in Low-tech or High-tech sectors after matching, but more if they are operating in KIBS sectors, although there were no statistically significant results for the T-tests. Companies participating in Economic Subsidies Programs (ESP) face fewer financial obstacles to innovation when operating in KIBS sectors after matching, but more when operating in Low-tech and High-tech sectors, although again there were no statistically significant results for the T-tests. Companies participating in Public Funding Programs (PFP) face fewer financial barriers when operating in Low-tech and KIBS sectors after matching, but more when operating in High-tech sectors, although no statistically significant T-tests results are displayed. Companies participating in Acquisition of Machinery Programs (AMP) perceive fewer financial obstacles to innovation across all sectoral groups after matching, and in the case of companies operating in Low-tech sectors the T-test result was statistically significant. Likewise, companies participating in Public Procurement Programs (PPP) face fewer financial barriers across all sectoral groups after matching, and there is also a statistically significant T-tests result for companies operating in Low-tech sectors.

Table 36 - Probit models estimation for the propensity score matchings

	Tax breaks programs			Economic subsidies programs			Public funding programs			Acquisition of machinery programs			Public procurement programs		
	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors	Low-tech sectors	High-tech sectors	KIBS sectors
INNO	0.641***	0.379***	0.716***	0.458***	0.585***	0.495***	0.404***	0.450***	0.342***	0.026	0.165**	0.135	0.019	0.521***	0.340**
	(0.064)	(0.066)	(0.100)	(0.104)	(0.103)	(0.148)	(0.074)	(0.080)	(0.111)	(0.053)	(0.069)	(0.120)	(0.147)	(0.146)	(0.153)
HRD	0.937***	1.137***	1.036***	0.700***	0.870***	0.700***	0.825***	0.795***	0.881***	-0.088	0.111	0.042	0.425**	0.289	0.320
	(0.100)	(0.089)	(0.137)	(0.142)	(0.119)	(0.189)	(0.113)	(0.100)	(0.144)	(0.115)	(0.104)	(0.183)	(0.221)	(0.193)	(0.218)
GRP	0.247***	0.343***	0.485***	0.318***	0.505***	-0.028	0.256***	0.327***	0.029	0.053	0.184**	0.081	0.101	-0.027	0.162
	(0.076)	(0.094)	(0.122)	(0.114)	(0.123)	(0.193)	(0.082)	(0.105)	(0.141)	(0.057)	(0.95)	(0.141)	(0.147)	(0.199)	(0.186)
MNE	0.036	-0.216*	-0.318	-0.418**	-0.733***	0.000	-0.726***	-0.846***	-0.330	-0.831***	-0.601***	-0.588*	-0.473	-0.817**	-0.405
	(0.128)	(0.123)	(0.219)	(0.210)	(0.174)	(0.000)	(0.183)	(0.153)	(0.272)	(0.166)	(0.140)	(0.338)	(0.391)	(0.400)	(0.427)
HNS	0.852***	0.619***	0.259	0.415***	0.077	-0.033	0.412***	0.344***	0.077	-0.183**	-0.181*	-0.118	0.121	0.051	-0.531
	(0.075)	(0.087)	(0.196)	(0.127)	(0.126)	(0.317)	(0.093)	(0.102)	(0.217)	(0.075)	(0.104)	(0.276)	(0.180)	(0.197)	(0.437)
RLS	0.055	0.194**	0.155	- 0.103	-0.055	-0.297*	-0.166**	-0.136	-0.211*	-0.075*	0.044	-0.049	-0.238**	-0.234	-0.298*
	(0.074)	(0.090)	(0.132)	(0.114)	(0.138)	(0.166)	(0.076)	(0.101)	(0.124)	(0.047)	(0.086)	(0.128)	(0.120)	(0.173)	(0.164)
Constant	-2.018***	-1.413***	-1.683***	-2.464***	-2.187***	-1.813***	-1.879***	-1.580***	-1.351***	-0.718***	-1.503***	-1.366***	-2.259***	-2.198***	-1.751***
	(0.072)	(0.087)	(0.125)	(0.110)	(0.139)	(0.148)	(0.071)	(0.096)	(0.111)	(0.043)	(0.810)	(0.115)	(0.106)	(0.162)	(0.144)
Observations	5,418	2,264	1,237	5,418	2,264	1,171	5,418	2,264	1,237	5,418	2,264	1,237	5,418	2,264	1,237
Pseudo R^2	0.248	0.211	0.182	0.155	0.175	0.086	0.119	0.138	0.081	0.009	0.014	0.007	0.021	0.069	0.035

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses.
Source: Author's elaboration.

Table 37 - T-tests for the comparison of the percentages of treated and untreated companies facing financial obstacles to innovation before and after the matching, by technology intensity sectoral groups

	Low-tech sectors								High-tech sectors								KIBS sectors							
	Before matching				After matching				Before matching				After matching				Before matching				After matching			
	Treated	Untreated	ATE	T-test	Treated	Control	ATET	T-test	Treated	Untreated	ATE	T-test	Treated	Control	ATET	T-test	Treated	Untreated	ATE	T-test	Treated	Control	ATET	T-test
TBP	39.6%	44.4%	-4.8%	-1.85*	39.6%	56%	-16.4%	-1.33	41.4%	48.7%	-7.3%	-2.99***	41.4%	46.9%	-5.5%	-0.41	48.1%	48.6%	-0.5%	-0.14	48.6%	47.4%	1.2%	0.07
ESP	51.1%	43.9%	7.2%	1.32	51.1%	46.4%	4.7%	0.36	58.8%	46.3%	12.5%	2.66***	58.8%	42%	16.2%	1.25	54.3%	49%	5.3%	0.71	54.3%	58.6%	-4.3%	-0.22
PFP	48.4%	43.8%	4.6%	1.38	48.4%	54.9%	-6.5%	-0.43	47.9%	46.8%	1.1%	0.31	47.9%	40%	7.9%	0.61	53.2%	48%	5.2%	1.09	53.6%	65%	-11.4%	-0.62
AMP	36.5%	46%	-9.5%	-5.77***	36.5%	88.1%	-51.6%	-1.79*	48.7%	46.6%	2.1%	0.75	48.7%	58%	-9.3%	-0.45	54.8%	48%	6.8%	1.33	54.8%	70.1%	-15.3%	-0.62
PPP	31.9%	44.2%	-12.3%	-1.69*	31.9%	74.4%	-42.5%	-1.68*	45.9%	47%	-1.1%	-0.13	45.9%	48.6%	-2.7%	-0.14	51.2%	48.4%	2.8%	0.34	51.2%	68.2%	-17%	-0.83

*** p<0.01, ** p<0.05, * p<0.1.
Source: Author's elaboration.

Table 38 presents the results for the T-tests comparing the percentages of treated and untreated companies facing knowledge obstacles to innovation before and after matching, according to technology intensity sectoral group. Companies participating in Tax Breaks Programs (TBP) face fewer knowledge barriers after matching only if they are operating in KIBS sectors, but more when operating in Low-tech or High-tech sectors, although no statistically significant result for the T-tests was found. The very same pattern repeats for companies participating in all the other policy instruments, i.e., Economic Subsidies Programs (ESP), Public Funding Programs (PFP), Acquisition of Machinery Programs (AMP) and Public Procurement Programs, all of which also perceive fewer knowledge obstacles to innovation after matching only when operating in KIBS sectors, but more in Low-tech or High-tech sectors, albeit there was no statistically significant T-tests results as well.

Table 39 presents the results for the T-tests comparing the percentages of treated and untreated companies facing organizational obstacles to innovation before and after matching, according to technology intensity sectoral groups. Companies participating in Tax Breaks Programs (TBP) face fewer organizational barriers after matching when operating in High-tech and KIBS sectors, although the T-tests results for these were not statistically significant. Companies participating in Economic Subsidies Programs (ESP) perceive fewer organizational obstacles to innovation after matching when operating in High-tech and KIBS sectors, but the only statistically significant result for the T-tests was for companies operating in Low-tech sectors, whose participants of the ESP face more organizational barriers than the control group after matching. Both companies participating in Public Funding Programs (PFP) and in Acquisition of Machinery Programs (AMP) perceive fewer organizational obstacles to innovation only when operating in KIBS sectors, but no statistically significant result for the T-tests is displayed. Companies participating in Public Procurement Programs (PPP) face fewer organizational barriers only when operating in KIBS sectors after matching, but the only statistically significant result for the T-tests after matching was for companies operating in Low-tech sectors, whose participants of the PPP perceive more organizational obstacles to innovation than the control group after matching.

Table 38 - T-tests for the comparison of the percentages of treated and untreated companies facing knowledge obstacles to innovation before and after the matching, by technology intensity sectoral groups

	Low-tech sectors								High-tech sectors								KIBS sectors							
	Before matching				After matching				Before matching				After matching				Before matching				After matching			
	Treated	Untreated	ATE	T-test	Treated	Control	ATET	T-test	Treated	Untreated	ATE	T-test	Treated	Control	ATET	T-test	Treated	Untreated	ATE	T-test	Treated	Control	ATET	T-test
TBP	15.4%	20.1%	-4.7%	-2.27**	15.4%	13.1%	2.2%	0.26	13%	19.3%	-6.3%	-3.37***	13%	9.7%	3.3%	0.36	24.8%	20.1%	4.7%	1.46	24%	35.7%	-11.7%	-0.85
ESP	23.8%	19.7%	4.1%	0.94	23.8%	13%	10.8%	1.02	19.3%	17.7%	1.6%	0.45	19.3%	15.9%	3.4%	0.33	28.2%	20.8%	7.4%	1.21	28.2%	47.8%	-19.6%	-1.11
PFP	26.1%	19.4%	6.7%	2.51**	26.1%	15%	11.1%	1.07	17.7%	17.8%	-0.1%	-0.01	17.7%	15.2%	2.5%	0.28	28.2%	20%	8.2%	2.13**	28.4%	39%	-10.6%	-0.78
AMP	20%	19.6%	0.4%	0.31	20%	15.2%	4.8%	0.34	19.6%	17.4%	2.2%	0.99	19.6%	11.7%	7.9%	0.54	30.7%	19.9%	10.8%	2.60***	30.7%	65.3%	-34.6%	-1.52
PPP	31.9%	19.6%	12.3%	2.10**	31.9%	29.7%	2.2%	0.12	24.3%	17.6%	6.7%	1.05	24.3%	16.2%	8.1%	0.48	31.7%	20.4%	11.3%	1.74*	31.7%	60.9%	-29.2%	-1.50

*** p<0.01, ** p<0.05, * p<0.1.
Source: Author's elaboration.

Table 39 - T-tests for the comparison of the percentages of treated and untreated companies facing organizational obstacles to innovation before and after the matching, by technology intensity sectoral groups

	Low-tech sectors								High-tech sectors								KIBS sectors							
	Before matching				After matching				Before matching				After matching				Before matching				After matching			
	Treated	Untreated	ATE	T-test	Treated	Control	ATET	T-test	Treated	Untreated	ATE	T-test	Treated	Control	ATET	T-test	Treated	Untreated	ATE	T-test	Treated	Control	ATET	T-test
TBP	17.4%	17%	0.4%	0.21	17.4%	7.8%	9.6%	1.18	15.5%	20.2%	-4.7%	-2.44**	15.5%	23.5%	-8%	-0.73	11.3%	17.3%	-6%	-2.02**	10.6%	13.4%	-2.8%	-0.21
ESP	27.3%	16.8%	10.5%	2.54**	27.3%	2.3%	25%	2.94***	19.3%	19.1%	0.2%	0.06	19.3%	21.8%	-2.5%	-0.21	8.6%	16%	-7.4%	-1.34	8.6%	23.9%	-15.3%	-1.14
PFP	21%	16.8%	4.2%	1.66*	21%	2.5%	18.5%	1.63	22.7%	18.6%	4.1%	1.51	22.7%	11.9%	10.8%	1.19	13.7%	16.7%	-3%	-0.86	13.8%	30.8%	-17%	-1.16
AMP	14.3%	17.7%	-3.4%	-2.68***	14.3%	0.7%	13.6%	0.81	21.5%	18.6%	2.9%	1.28	21.5%	16.6%	4.9%	0.29	16.3%	16.4%	-0.1%	-0.02	16.3%	50%	-33.7%	-1.49
PPP	21.2%	16.9%	4.3%	0.78	21.2%	0	21.2%	3.53***	29.7%	18.9%	10.8%	1.65*	29.7%	27%	2.7%	0.15	17%	16.3%	0.7%	0.12	17%	31.7%	-14.7%	-0.94

*** p<0.01, ** p<0.05, * p<0.1.
Source: Author's elaboration.

Table 40 presents the results for the T-tests comparing the percentages of treated and untreated companies facing network obstacles to innovation, according to technology intensity sectoral groups. Companies participating in Tax Breaks Programs (TBP) face fewer network barriers after matching only when operating in High-tech sectors, albeit no statistically significant result for the T-tests was found. Companies participating in Economic Subsidies Programs (ESP) perceive more network obstacles to innovation after matching regardless of the sectoral group they belong to, with statistically significant T-tests results for companies operating in Low-tech and KIBS sectors. Companies participating in Public Funding Programs (PFP) perceive more network barriers after matching when operating in Low-tech and KIBS sectors, but with statistically significant T-test result only for the latter, and an equal perception of these barriers as compared to the control group when operating in High-tech sectors. Both companies participating in Acquisition of Machinery Programs (AMP) and in Public Procurement Programs (PPP) face fewer network obstacles to innovation after matching only when operating in Low-tech sectors, while they face more of these obstacles as compared to the control groups when operating in High-tech and KIBS sectors, with statistically significant T-tests results for the latter.

Table 41 displays the results for the T-tests comparing the percentages of treated and untreated companies facing demand obstacles to innovation, according to technology intensity sectoral groups. Companies participating in Tax Breaks Programs (TBP) face fewer demand barriers after matching when operating in High-tech sectors, but they face more of these barriers when operating in KIBS sectors and the same amount as compared to the control group when operating in Low-tech sectors, although none of these differences is statistically significant. Companies participating in Economic Subsidies Programs (ESP) face more demand obstacles to innovation after matching across all sectoral groups, albeit there was no statistically significant T-test result. Companies participating in Public Funding Programs (PFP) face fewer demand barriers after matching across all sectoral groups, but none of the mean differences was statistically significant either. Companies participating in Acquisition of Machinery Programs (AMP) face fewer demand obstacles to innovation after matching when operating in Low-tech and High-tech sectors, although there was no statistically significant result for the T-tests. Companies participating in Public Procurement Programs (PPP) perceive fewer demand barriers after matching only when operating in Low-tech sectors, but with statistically significant T-test result for this sectoral group.

Table 40 - T-tests for the comparison of the percentages of treated and untreated companies facing network obstacles to innovation before and after the matching, by technology intensity sectoral groups

	Low-tech sectors								High-tech sectors								KIBS sectors							
	Before matching				After matching				Before matching				After matching				Before matching				After matching			
	Treated	Untreated	ATE	T-test	Treated	Control	ATET	T-test	Treated	Untreated	ATE	T-test	Treated	Control	ATET	T-test	Treated	Untreated	ATE	T-test	Treated	Control	ATET	T-test
TBP	10.3%	14.2%	-3.9%	-2.18**	10.3%	6.5%	3.8%	0.64	8.6%	15%	-6.4%	-3.79***	8.6%	10.1%	-1.5%	-0.16	11.3%	14.9%	-3.6%	-1.28	11.7%	0.5%	11.2%	1.60
ESP	20.2%	13.9%	6.3%	1.66*	20.2%	7.1%	13.1%	1.96**	12.6%	13.5%	-0.9%	-0.28	12.6%	2.5%	10.1%	1.44	13%	14.8%	-1.8%	-0.34	13%	0	13%	2.60***
PFP	13.7%	14%	-0.3%	-0.12	13.7%	9.4%	4.3%	0.56	11.5%	13.6%	-2.1%	-0.92	11.5%	11.5%	0	0	15.3%	14.2%	1.1%	0.31	15.4%	0	15.4%	4.72***
AMP	13.7%	14%	-0.3%	-0.26	13.7%	15.2%	-1.5%	-0.11	14.7%	13.2%	1.5%	0.76	14.7%	10.3%	4.4%	0.56	17.3%	14.1%	3.2%	0.89	17.3%	0	17.3%	4.64***
PPP	14.8%	14%	0.8%	0.18	14.8%	25.5%	-10.7%	-0.80	24.3%	13.2%	11.1%	1.95*	24.3%	10.8%	13.5%	1.11	21.9%	14.1%	7.8%	1.40	21.9%	0	21.9%	3.35***

*** p<0.01, ** p<0.05, * p<0.1.
Source: Author's elaboration.

Table 41 - T-tests for the comparison of the percentages of treated and untreated companies facing demand obstacles to innovation before and after the matching, by technology intensity sectoral groups

	Low-tech sectors								High-tech sectors								KIBS sectors							
	Before matching				After matching				Before matching				After matching				Before matching				After matching			
	Treated	Untreated	ATE	T-test	Treated	Control	ATET	T-test	Treated	Untreated	ATE	T-test	Treated	Control	ATET	T-test	Treated	Untreated	ATE	T-test	Treated	Control	ATET	T-test
TBP	7.8%	7.4%	0.4%	0.28	7.8%	7.8%	0	0	5.4%	6.6%	-1.2%	-0.98	5.4%	7.4%	-2%	-0.22	8.6%	8.7%	-0.1%	-0.01	8.9%	2.2%	6.7%	0.72
ESP	13%	7.3%	5.7%	1.97**	13%	7.1%	5.9%	0.95	4.2%	6.4%	-2.2%	-0.97	4.2%	3.3%	0.9%	0.13	10.8%	8.4%	2.4%	0.57	10.8%	2.1%	8.7%	0.84
PFP	7.2%	7.4%	-0.2%	-0.11	7.2%	10.3%	-3.1%	-0.33	8.6%	6%	2.6%	1.60	8.6%	13.6%	-5%	-0.48	8.8%	8.6%	0.2%	0.09	8.9%	10.5%	-1.6%	-0.15
AMP	5.8%	7.9%	-2.1%	-2.31**	5.8%	15.2%	-9.4%	-0.67	6.5%	6.2%	0.3%	0.19	6.5%	10.6%	-4.1%	-0.39	6.7%	8.8%	-2.1%	-0.73	6.7%	4.8%	1.9%	0.11
PPP	4.2%	7.5%	-3.3%	-0.84	4.2%	25.5%	-21.3%	-1.69*	10.8%	6.2%	4.6%	1.13	10.8%	10.8%	0	0	12.1%	8.5%	3.6%	0.82	12.1%	7.3%	4.8%	0.32

*** p<0.01, ** p<0.05, * p<0.1.
Source: Author's elaboration.

Chapter 5 – The Moderation Role of Obstacles to Innovation in Brazil

5.1. Discussion of the empirical results

In this section, we endeavor to synthesize the main findings observed in the previous chapter. Since we presented many empirical results across several tables on the MLR models, we shall strive now to pinpoint the major statistical findings and connect them to the PSM results in order to extract a big picture from our empirical exercises. From now on, we will only be concerned with the statistically significant results that showed up in our econometric models and statistical tests. At first, the idea is to compare the statistically significant econometric results obtained in the "pure models" to the ones obtained in the "moderation models" containing the interaction terms on obstacles to innovation, thereby assessing the potential moderation effect of the obstacles to innovation over the determinants of innovation in Brazil. Afterwards, we will compare the statistically significant results from the T-tests obtained before the application of the PSM and after the matching, thereby assessing the potential unlock effect of the policy instruments over the obstacles to innovation. With these comparisons, we expect to shed some light on the main innovation issues at play in the Brazilian context.

Let us start with the presentation of Figure 9, which synthesize the statistically significant results from the MLR models for product and process innovativeness by presenting them in a more visual way. At this figure, one can see the sign (positive or negative, in terms of RRR) of the results from the whole MLR models as regards product and process innovativeness at the Firm (F), Country (C) and World (W) levels according to the sectoral technology intensity groups (Low-tech, High-tech and KIBS). The colored highlights were introduced to identify two situations in the "moderation models": firstly, the yellow highlights point out to results that became statistically significant after moderation; secondly, the red highlights point out to the statistically significant results that presented the opposite sign to the statistically significant results that had been identified in the pure models. Put another way, the yellow highlights represent an activation effect of determinants of innovation by the moderation role of the innovation barriers, while the red highlights represent an inversion effect of the direction of determinants of innovation by the moderation role of the innovation barriers.

Figure 9 - Synthesis of the statistically significant results from the MLR models for product and process innovativeness

Product innovativeness models

	Pure models									Financial obstacles									Knowledge obstacles									Organizational obstacles									Network obstacles									Demand obstacles								
	Low			High			KIBS			Low			High			KIBS			Low			High			KIBS			Low			High			KIBS			Low			High			KIBS			Low			High			KIBS		
	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W
RDE	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+					+							+		+																		+						
EKA							+	+			+								+	+					+	+			-			-					+	+								+	+							
ETA	+	+	+	+	+		+	+	+	+	+		+	+	+								+			-			+		+			+																				
IMIP	+	+	+	+	+	+	+	+	+	+		+		+	+													+															+	+				+			+			
SIZE		+	+			+			+	-	-	-	-	-	-	-	-		-	-	-	-	-					-	-	-	-	-		-	-		-		-	-	-		-			-	-	-	-					
COF	+	+	+	+	+	+	+	+	+									+		+				-				+	+	+			-					+		-	-	-				+	+	+			-			
CREO		+	+	-	-	-			-	+								-										-	-			+	+																					

Process innovativeness models

	Pure models									Financial obstacles									Knowledge obstacles									Organizational obstacles									Network obstacles									Demand obstacles								
	Low			High			KIBS			Low			High			KIBS			Low			High			KIBS			Low			High			KIBS			Low			High			KIBS			Low			High			KIBS		
	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W	F	C	W
RDE	+	+	+	+	+	+	+	+	+	+	+	+	+	+							+				+					+																								
EKA				+	+	+	+				+					+	+		+	+													-											+										
ETA	+	+	+	+	+	+	+	+	+	+	+	+																							-			+						+									+	
IMIP	+	+	+	+	+	+	+	+	+	+	+		+	+	+				+				+														+							+		+				+				
SIZE		+	+		+	+				-	-	-	-	-	-	-	-		-	-	-	-	-		-			-	-	-	-			-			-	-		-	-		-	-		-	-	-	-	-		-	-	
COF	+	+	+	+	+	+		+	+					+																				+									+	+		+	+							
CREO				-															+	+																																		

Obs.: The yellow highlight means that a statistically significant result showed up where there was no statistically significant result in the pure model.

The red highlight means that a statistically significant result appeared with a sign opposite to the statistically significant result that was obtained in the pure model.

Source: Author's elaboration.

To begin with, both R&D Expenditure (RDE) and Informal Methods of Intellectual Property Protection (IMIP) are not subject to the moderation by obstacles to innovation of any kind. They are consistently positively associated to the product and process innovativeness in the pure models, but after the moderation they did not display any statistically significant result that was new (yellow) or opposite (red) to the ones displayed in the pure models. At most, one can say that they lost a lot of their statistically significance after moderation, although in practice it does not necessarily mean that the obstacles to innovation are preventing their positive effect over product or process innovativeness, but just reveals an indeterminacy in the relationships between these variables as they are not statistically supported anymore. Therefore, it only suggests that these determinants of innovation are quite resilient to the various obstacles to innovation considered herein. In fact, this finding is in tune with some investigations conducted in other developing contexts pointing out to the resilience of the R&D system after acquiring a certain level of complexity (Sandu, 2016). Also, it supports evidence suggesting that on average firms rely more on informal methods of intellectual property protection than on formal ones (Hall et al., 2014), so that the strategic protection is fairly widespread and constant across time and space.

External Knowledge Acquisition (EKA) presents quite different statistically significant results in the pure models for product and process innovativeness, prevailing KIBS sectors in the former and High-tech sectors in the latter. The only overlap between the two types of innovation for this variable refers to firm level innovators operating in KIBS, which proved to be statistically significant in both cases. This is consistent with the literature pointing out to the positive relationship between knowledge absorptive capacity and innovation performance in KIBS (Tseng et al., 2011). As regards the moderation models, the results are not quite different though. In the presence of financial obstacles to innovation, EKA starts to display statistically significant and positive results for both country level product and process innovators operating in Low-tech sectors, and also for country level process innovators operating in KIBS sectors. The same happens for firm and country level product and process innovators operating in Low-tech sectors when companies face knowledge barriers. When the obstacles to innovation are network and demand barriers, EKA begins to exhibit statistically significant and positive results for firm and country level product innovators operating at Low-tech sectors once again, and in the particular case of network obstacles it also displays a new statistically significant and positive result for country level process innovators operating in KIBS sectors.

Therefore, in general, companies start to rely more on EKA to be innovative as they perceive financial, knowledge, network and demand obstacles to innovation, especially when they are operating in Low-tech sectors. This suggests that the innovation strategy of acquiring external knowledge to overcome barriers might be very useful for companies that work with less advanced technologies and innovate at lower novelty levels in Brazil. On the other hand, when companies perceive organizational obstacles, they start to display statistically significant and negative results as regards the effect of EKA on innovativeness. When facing organizational barriers, new statistically significant and negative results show up for country level product innovators operating in Low-tech and High-tech sectors, while a sign inversion (from positive to negative) occurs for world level process innovators operating in High-tech sectors. The first case means that this determinant actually might harm the companies' product innovativeness when they are facing organizational barriers, although it was statistically insignificant when these barriers were absent. The second case means that, even though such determinant could be positively associated to process innovativeness in the absence of organizational obstacles to innovation, it becomes negatively associated to it if there are organizational constraints at play. Indeed, the literature has already identified the difficulty of integrating external knowledge due to organizational barriers (Aranda and Molina-Fernández, 2002). Therefore, EKA was found to be very sensitive to the moderation from organizational obstacles to innovation in negative terms, although it also responds positively to the moderation of other innovation barriers, especially for product innovators operating in Low-tech sectors.

External Technology Acquisition (ETA) is also consistently positively associated to both product and process innovativeness in the pure models. After the moderation, it displays a new statistically significant and positive result for world level product innovators operating in High-tech sectors when companies face financial obstacles to innovation. It suggests that, in the presence of financial barriers, resorting to the external acquisition of machinery or software becomes a good strategy for some companies to keep being innovative at higher novelty levels in technologically advanced industries. However, when knowledge obstacles to innovation are at stake, ETA experiences a sign inversion (from positive to negative) as regards country level product innovators operating in KIBS sectors. This indicates that, although the outsourcing of technology is positively associated with product innovativeness in the absence of knowledge barriers, it actually becomes negatively associated with product innovativeness when knowledge shortages appear in the service sectors. Similarly, when organizational obstacles to innovation are at play, ETA also experiences a sign inversion (from positive to negative) as regards country level process innovators operating in KIBS sectors. This could be interpreted as a negative effect of this determinant over innovativeness as a consequence of undesirable organizational constraints and the consequent difficulty to incorporate new technologies by companies lacking appropriate capacities. Otherwise, this determinant would have a positive effect on companies' process innovativeness just as expected and predicted in the pure models. By and large, these results suggest that knowledge barriers impair the absorptive capacities of firms operating in KIBS sectors and consequently make ETA harmful to their innovation strategy, as well as organizational barriers impair the managerial capacities of firms operating in KIBS sectors and consequently make ETA harmful to their innovation strategy. The former is related to the typical cognitive limitations in the market for technology (Arora and Gambardella, 2010), while the latter is related to the typical internal organizational conditions that affect the participation of companies in the market for technology (Chesbrough, 2003).

The number of employees (SIZE) was the determinant that most suffered the influence from the moderation by the various obstacles to innovation considered herein. Although it displays statistically significant and positive results for both product and process innovativeness in the pure models, whenever the moderation by innovation barriers was introduced, several negative results showed up as consequence. Both new statistically significant and sign reversed results appear after the moderation, making it even hard to tell which barrier most affected this determinant, since it displays several negative signs in all moderation models regardless the type of innovation. However, it seems that financial obstacles to innovation are the ones whose moderation influence more strongly the association of SIZE to the product and process innovativeness, as only in the moderation models considering financial barriers almost all the positive associations of SIZE to both product and process innovation were inverted to negative associations. Overall, this data suggests that the effect of size on firm innovativeness is to a great extent only a proxy to other internal capabilities such as financial power and organizational structure, and as soon as innovation barriers arise the effect of size not only disappears, but also becomes harmful to the companies pursuing innovation. In other words, if a large company faces severe innovation barriers, it will most likely lack the exact conditions that are supposed to make size an important determinant of innovation while only possessing the burdens of a big company.

Cooperation with Other Firms (COF) displays several statistically significant results for both product and process innovativeness in the pure models as well. With the introduction of the interaction terms, this variable experiences some major changes for product innovativeness and some minor changes for process innovativeness. The moderation models for product innovativeness display some sign inversion (from positive to negative) in the following cases: world level product innovators operating in High-tech sectors when companies face knowledge, organizational, network and demand barriers; firm and country level product innovators operating in High-tech sectors when companies perceive network obstacles to innovation. These radical changes present three main regularities: COF is mostly negatively affected by (1) network obstacles to innovation, in the case of (2) world level product innovators, and when companies operate in (3) High-tech sectors. In general, these findings indicate that the cooperation with other firms tends to be highly negatively affected by the various obstacles to innovation (except financial barriers) when firms are pursuing product innovation of higher novelty levels, especially if they operate in High-tech sectors. Besides, the higher negative influence of the network barriers over this variable is quite understandable, as the need to establish networks is in the very nature of this determinant of innovation. The moderation models for process innovativeness, on the other hand, only display some minor change on this determinant, as some statistically significant and positive results emerge for firm level process innovators operating in KIBS when companies face both organizational and network barriers. It seems that, unlike product innovation, these barriers moderate the relationship between COF and process innovativeness by spurring the potential of this determinant to favor the pursuit of innovations at lower novelty levels.

Cooperation with Research and Education Organizations (CREO) was the only determinant to present unexpected results for both product and process innovativeness in the pure models. As regards product innovation, it displays statistically significant and positive results only for innovative companies operating in Low-tech sectors, while it displays statistically significant and negative results for innovative companies operating in High-tech sectors. In the case of process innovation, it displays only a statistically significant and negative result for firm level process innovators operating in High-tech sectors. These findings support the general idea presented in the literature that most companies relying on universities and research institutes to innovate in Brazil do not follow the typical pattern of interaction in developed countries, which takes place in advanced and technologically intensive industries, but actually are more oriented to less technologically intensive sectors and activities, reproducing the dualist economic structure of the country (Albuquerque et al., 2015; Moraes Silva et al., 2018). As regards the moderation models, the introduction of interaction terms on financial obstacles to innovation yielded a statistically significant and positive result for firm level product innovators operating in Low-tech sectors, while the moderation by knowledge barriers rendered statistically significant and positive results for both firm and country level process innovators operating in Low-tech sectors. These findings reinforce the importance of CREO for the low-tech companies as part of an innovation strategy to work around barriers.

On the other hand, the moderation by organizational obstacles to innovation shows the most interesting results for this determinant. A statistically significant and negative result emerges for firm level product innovators operating in Low-tech sectors and the sign of a statistically significant result changes from positive to negative for country level product innovators operating in Low-tech sectors. But not only that, there were also two sign changes now from negative to positive for both country and world level product innovators operating in High-tech sectors. This suggests that organizational barriers moderate negatively the influence of CREO on product innovativeness for companies operating in Low-tech sectors pursuing innovation of lower novelty levels, but it moderates positively the influence of this determinant on product innovativeness for companies operating in High-tech sectors pursuing innovation of higher novelty levels. Therefore, for those companies engaged on more advanced technologies and striving for more radical innovations, the collaboration with universities, research institutes and the like is essential to be successful when organizational constraints appear. This is probably the most surprising and interesting finding of our study, which deserves to be properly addressed through different methodological designs in order to achieve a deeper understanding of its nature and implications.

Now let us take into consideration the statistically significant results from the PSM technique applied to delve into potential unlocking effect of innovation policies over the various obstacles to innovation that we have appraised in our study. Figure 10 synthesize the statistically significant T-test results for the mean comparison of the various obstacles to innovation among companies that used and companies that did not use innovation policy instruments before and after matching. The positive sign means that the occurrence of obstacles to innovation was greater among companies that used innovation policy instruments (as compared to companies that did not use), suggesting that the instruments are not achieving their goal of unlocking innovation barriers yet. Conversely, the negative sign means that the occurrence of obstacles to innovation was greater among companies that did not use innovation policy instruments (as compared to companies that used), suggesting that the instruments are already achieving their goal of unlocking innovation barriers.

As previously discussed, the results before matching (BM) represent the so-called Average Treatment Effect (ATE), while the results after matching (AM) represent the so-called Average Treatment Effect on the Treated (ATET). The basic difference between the two is that the former is only accurate within an empirical setting in which the treatment and control groups are already quite similar, such as in random experiments, while the latter is more appropriate for observational studies in which one needs to adapt the empirical setting in order to have similar treated and untreated observations, creating a sort of artificial control group by PSM or other matching techniques. Therefore, we pay special attention to the statistically significant results after matching, indicated by the colored highlights. The red highlights show results after matching with greater occurrence of barriers among treated companies (positive sign), while the green highlight show results after matching with greater occurrence of barriers among untreated companies (negative sign). The former refers to unexpected results from the perspective of our theoretical model, as we would expect that companies receiving policy treatment would perceive innovation barriers to a lesser degree, while the latter refers exactly to expected results, as our theoretical understanding informs us that the participation in policy programs contributes to a lower perception of obstacles to innovation.

Figure 10 - Synthesis of the statistically significant results from the T-tests for the mean comparison before and after matching

	Financial obstacles						Knowledge obstacles						Organizational obstacles						Network obstacles						Demand obstacles					
	Low-tech		High-tech		KIBS		Low-tech		High-tech		KIBS		Low-tech		High-tech		KIBS		Low-tech		High-tech		KIBS		Low-tech		High-tech		KIBS	
	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM
TBP	-		-				-		-						-		-		-		-									
ESP			+										+	+					+	+				+	+					
PFP							+				+		+											+						
AMP	-	-									+		-											+	-					
PPP	-	-					+				+			+	+						+			+		-				

Obs.: The green highlight means that the occurrence of innovation barriers after matching was greater among companies that did not use policy instruments – i.e., untreated companies – as compared to companies that used innovation policy instruments – i.e., treated companies – (the expected result).
The red highlight means that the occurrence of innovation barriers after matching was greater among companies that used policy instruments – i.e., treated companies – as compared to companies that did not use innovation policy instruments – i.e., untreated companies – (the unexpected result).

Source: Author's elaboration.

Tax Breaks Programs (TBP) show negative results consistently across almost all obstacles to innovation (except demand barriers) and especially for companies operating in Low-tech and High-tech sectors, but all these results occur only before matching. Therefore, although the mean differences before matching corroborate the recent literature pointing out the importance of at least some of the tax incentives for the companies' innovativeness in Brazil (Kannebley and Porto, 2012; Mathias-Pereira, 2013), the results after matching do not testify the relevance of these policy instruments for eroding innovation barriers in the country.

Economic Subsidies Programs (ESP) display positive results consistently across almost all obstacles to innovation (except knowledge barriers), especially for companies operating in Low-tech sectors. In the case of organizational and network barriers, the positive results of ESP appear both before and after matching for companies operating in Low-tech sectors, and also after matching in the case of network barriers for companies operating in KIBS sectors. This indicates that companies accessing grants for innovation in Brazil, especially those operating in Low-tech sectors, are facing more organizational and network barriers than companies that have not access to these subsidies. Hence, despite of the fact that the literature has found that subsidies stimulate innovation and erode financial barriers (González et al., 2005), not only we did not find this relationship for the Brazilian case, but we also identified that companies participating in economic subsidies programs suffer more from organizational and network constraints.

Public Funding Programs (PFP) also exhibit positive results across several obstacles to innovation, with positive results after matching in the case of network barriers for companies operating in KIBS sectors. Once again, the network obstacles to innovation appear as a major constraint for service companies that participate in some policy program for innovation. Although the literature has found support for the hypothesis that there are additive effects of public funding on private innovation (Lööf and Heshmati, 2005), our findings did not confirm this idea when considering the effect of public funding over innovation barriers, and actually found a higher incidence of network barriers among companies receiving public funding for innovation.

Acquisition of Machinery Programs (AMP) show positive and negative results throughout the various obstacles to innovation, with negative result after matching in the case of financial barriers for companies operating in Low-tech sectors and positive result after matching in the case of network barriers for companies operating in KIBS sectors. AMP is a specific type of public funding policy instrument, which deserves to be taken into account separately due to its wide use in the Brazilian context. The negative result for companies facing financial barriers and operating in Low-tech sectors suggests that this policy instrument has been effective in lowering down finance-related obstacles to innovation for companies working with less advanced technologies. This finding is in tune with the literature pointing out that in developing economies the purchase of new machinery and equipment might be an important part of innovation strategy, so policy should help with this process of productive modernization (Alves et al., 2014). On the other hand, the positive results for companies facing network barriers and operating in KIBS sectors reinforce the aforementioned idea that network obstacles to innovation are a major constraint among service companies that participate in some policy programs, which might be related to the lack of specific policy instruments to tackle the network problems in Brazil.

Public Procurement Programs (PPP) also display both positive and negative results throughout the various obstacles to innovation, with negative results after matching in the cases of financial and demand barriers for companies operating in Low-tech sectors and positive results after matching in the cases of organizational barriers for companies operating in Low-tech sectors and network barriers for companies operating in KIBS sectors. The negative results for companies facing financial and demand barriers and operating in Low-tech sectors suggest that this policy instrument has been effective in eroding the main barriers that are targeted by a demand-side policy: monetary incentives and demand creation for innovative products. In fact, public demand is a major potential source of innovation, and although public procurement is increasingly viewed as having important potential to drive innovation, there are still substantial factors preventing the public sector from acting as an intelligent and informed customer (Uyarra et al., 2014). On the other hand, the positive results for companies facing organizational and network barriers and operating in Low-tech and KIBS sectors, respectively, just reproduced a pattern previously observed of higher incidence of organizational and especially network constraints among companies participating in policy programs.

5.2. Theoretical and policy implications

We shall summarize now the main findings of our empirical exercises in terms of some theoretical and policy implications. Firstly, as regards the theoretical implications, it is worth to mention the resilience of intramural R&D Expenditure and Informal Methods of Intellectual Property Protection as the determinants of innovation that suffered the least from the moderation of the various obstacles to innovation. Indeed, the importance of these determinants proved to be little subject to the presence of innovation barriers in the Brazilian context. Therefore, we can expect that both determinants will be part of the innovation strategy of companies to a certain extent as long as the national innovation system remains mature and well, although studies examining these variables in other contexts should be conducted to verify how generalizable is this result. In any case, our findings testify the great relevance of such determinants to the product and process innovativeness of companies and corroborate the theoretical literature.

External Knowledge Acquisition is positively moderated by various obstacles to innovation (except organizational barriers) mainly among companies operating in Low-tech sectors and pursuing innovation at lower novelty levels. This implies that less technologically intensive companies might resort to such determinant especially when facing innovation barriers in order to adapt their innovation strategy and keep being incrementally innovative. But this very same determinant is negatively moderated by organizational obstacles to innovation and as sectoral technological intensity and innovation novelty increase, the negative effect is higher. This finding points to an interesting avenue for the theoretical literature as regards the need to study the nitty-gritty of the relationship between organizational structure and acquisition of external knowledge to the innovation performance of companies. Our results suggest that organizational constraints might not only prevent the positive result of knowledge outsourcing, but also make it harmful to the innovativeness in the Brazilian context.

External Technology Acquisition is positively moderated by financial barriers among companies operating in High-tech sectors. This is in tune with a general idea found in the literature pointing that, depending on the extant hindrances, buying technology might be more interesting for the innovation strategy of companies than making it themselves (Veugelers and Cassiman, 1999). Although this is the case for High-tech companies facing financial barriers, it is not true for KIBS companies facing knowledge and organizational barriers. The former is subject to a negative moderation as they pursuit product innovation, while the latter is subject to a negative moderation as they pursuit process innovation. It seems that service companies are more affected by the lack of internal non-financial capabilities that would make the purchase of external technology an interesting component to their innovation strategy. This is largely aligned with the typical absorptive capacity argument found in the mainstream theoretical literature.

Size is strongly negatively moderated by all obstacles to innovation and across all sectoral groups and most innovation novelty levels. Basically, this implies that size is only a proxy of other companies' internal capabilities such as financial power, organizational structure, R&D capacity, global reach, brand value and so on. Therefore, as soon as innovation barriers are at play, the positive effect of size over innovativeness ceases to exist. And not only that, larger size becomes actually harmful to innovativeness when companies are facing strong obstacles to innovation, as a large company that does not have the typical internal capabilities that would make it innovative still has the burdens of being large, such as low flexibility and adaptiveness. This is not quite surprising for the theoretical literature, as many authors have already pointed out when criticizing the so-called Schumpeterian hypotheses (Cohen, 2010).

Cooperation with Other Firms is positively moderated by organizational and network barriers among companies operating in KIBS sectors and pursuing process innovation. This means that service companies resort to a collaborative strategy as they face organizational constraints and network restrictions in order to achieve process innovations. On the other hand, this very same determinant is negatively moderated by knowledge, organizational, network and demand barriers among companies operating in High-tech sectors and pursuing product innovation. These differences between positive and negative moderation ought to be understood in light of the differences between, on the one hand, process innovation in service sectors and, on the other, product innovation in High-tech sectors. As the appropriability issues are particularly striking in manufacturing sectors and especially when it comes to new products, several obstacles to innovation make collaborations more problematic for the strategy of companies. Conversely, as these concerns are smaller in services, and mainly when it comes to process innovations, some barriers actually make the cooperative engagements more interesting for the strategy of companies.

Cooperation with Research and Education Organizations is negatively moderated by organizational obstacles among companies operating in Low-tech sectors and pursuing product innovations. The same rationale used for cooperation with other firms on the problems of collaboration on manufacturing sectors as regards product innovations might be applied here as well. However, cooperation with research and education organizations is positively moderated by financial and knowledge barriers among companies operating in Low-tech sectors and pursuing product and process innovation, respectively, and also by organizational barriers among companies operating in High-tech sectors and pursuing product innovation. Interestingly, this is the only determinant that present opposite findings for the same obstacle and innovation type as just the sectoral group varies: negative moderation for Low-tech companies facing organizational barriers while pursuing product innovation, and positive moderation for High-tech companies facing organizational barriers while pursuing product innovation. This demonstrates one of the most recurrent characteristics found in the theoretical and empirical literature on university-industry relationship in developing countries: the sectoral particularity of the collaboration patterns. While the findings support the idea that university-industry cooperation in developing contexts tends to be more intense in low-tech industries regardless of the presence of obstacles to innovation, it also shows that in the specific case of organizational barriers, this determinant becomes crucial to the innovation strategy of high-tech companies pursuing product innovation at the same time that it becomes harmful to the innovation strategies of low-tech companies. Therefore, a closer look to the association between organizational structure and university-industry collaboration shall benefit the overall theoretical and empirical literature in future studies.

Finally, as regards policy recommendations, we can also draw some considerations from our empirical findings. Firstly, the policy instruments concerning the acquisition of machinery and public procurement seem to be the only ones effective in tackling financial and demand innovation barriers at the moment. Therefore, these instruments should certainly be kept and possibly expanded, as their eroding effect over barriers are only confined to low-tech industries. Organizational and, especially, network obstacles to innovation have not been addressed properly by any of the policy instruments considered herein. As a matter of fact, the companies that have been using some instruments as economic subsidies and public funding are actually experiencing more barriers of these types than the companies that do not participate in policy programs. Therefore, policymakers ought to start paying more attention to the organizational and network obstacles to innovation, which were the most powerful moderators in the econometric models, and hence they should begin to design and implement policies to properly address these issues in Brazil.

Final Remarks

The study undertaken herein aimed to shed some light at the Brazilian context as regards the struggle for innovation and socio-economic development. We started by identifying that some of the main innovation indicators in the country have been stagnant over the last years, although the use of policy instruments for supporting innovation has expanded at the same time period. Then we turned to the consideration of obstacles to innovation in Brazil as a promising avenue for research, since this topic is simultaneously at the root of the theoretical origins of the innovation concept as a socio-economic phenomenon and at the heart of the policy-driven debates that gave rise to the main initiatives for measuring innovation worldwide. This connection between theory and policy in the same topic of research made us prone to conduct a detailed study on the role of innovation barriers over innovativeness in Brazil by relying on microdata from the most recent edition of the Brazilian Innovation Survey (PINTEC 2014).

Our study was guided by three general hypotheses (see page 102), which posit the existence of a positive relationship between a set of determinants of innovation and companies' innovativeness, a moderation role played by obstacles to innovation intervening (positively or negatively) in this relationship, and an unlocking function from innovation policy instruments designed to erode innovation barriers and unleash the positive effects of the determinants of innovation. To a certain extent, all these hypotheses were at least partially confirmed by the empirical exercises. Almost all determinants considered were highly statistically significant for explaining innovativeness in Brazil. Almost all obstacles considered moderated some determinants of innovation one way or another in the empirical exercises, either by making them statistically significant (positively or negatively) for explaining innovativeness while they were not so in the absence of innovation barriers, or by inverting the influence direction (from negative to positive or the other way around) of determinants over innovativeness in the presence of innovation barriers. Almost all policies considered showed statistically significant results in terms of the differential incidence of innovation barriers among treated and untreated companies, although just a few displayed the expected unlocking function as stated in the hypothesis.

The main contribution from this thesis for the innovation studies field of research lies upon the conceptualized moderation role from obstacles to innovation over the determinants of innovation. Differently from most studies in the empirical literature, our approach considers the innovation barriers not just as factors that directly affect innovativeness (as independent variables), but as factors that indirectly affect innovativeness (as moderation variables) by intervening in the relationship between determinants of innovation (or companies' innovation strategy) and innovation performance (or companies' innovativeness). Relatedly, the way we handled the variables on innovation policy instruments as unlocking factors acting upon innovation barriers is also different from the traditional approach in the empirical literature considering policies as typical determinants of innovation. From our understanding, this is also a contribution that we bring to the innovation studies field, as it provides a more precise view on the nature of innovation policies. Therefore, we sustain that our approach represents a promising avenue for future research as it allows a more interactive and theory-grounded way of modelling the relationships between innovation determinants, obstacles and policies in order to achieve an accurate understanding of the innovation performance at different contexts.

In general, we can also say that our results might be useful for improving the understanding of the innovation challenges in Brazil. Specially, when it comes to the idea of the moderation role of obstacles to innovation that we tested empirically, which is the core argument in this doctoral thesis. However, our empirical exercises are subject to some major limitations both in terms of methods and theory. As regards the methodological issues, the fact that we are working with cross-sectional data restricts a lot the capacity of making causal claims about the relationships assessed in the econometric models. For example, we cannot claim that the determinants cause innovativeness in our empirical setting, but just that there are some positive and statistically significant associations suggesting an influence of effort indicators over performance indicators. Similarly, we cannot claim that the use of policy instruments was the cause of lower (or higher) incidence of innovation barriers among companies participating in policy programs, but only that the mean difference between the perception of obstacles to innovation among treated and untreated companies is statistically significant after making these two company groups similar by matching, which might be suggestive of a policy effect on this variable of interest.

In order to have more consistent results, both the Multinomial Logistic Regression (MLR) models and the Propensity Score Matching (PSM) techniques would require an empirical setting that takes into account the time variance in methodological designs more adequate to claim causality, such as panel data models for the former and differences-in-differences techniques for the latter. Nevertheless, one needs to understand that even these alternatives would have their own shortcomings as well. Two of them ought to be mentioned. Firstly, using PINTEC data from different survey editions would imply losing some variables and sectors that have been measured just recently, such as the variables on informal methods of intellectual property protection or public procurement for innovation. Secondly, just like any other innovation survey, PINTEC is skewed in favor of larger companies, which imply that using several waves of the survey for balanced panel data analysis would restrict the empirical setting to larger firms. Of course, resorting to unbalanced panel data analysis is an alternative, but one that involves its own methodological difficulties. Therefore, we sustain that, although the limitations of our empirical setting must be clear and explicit in order to avoid misunderstandings, any methodological choice would have specific shortcomings.

As regards the theoretical limitations, there are at least two of them that shall be highlighted herein. Firstly, as we decided to restrict the sample of companies from PINTEC 2014 to a "relevant sample" filtering out non-innovative companies unwilling to innovate in order to avoid selection bias issues, an important limitation that arises refers to the fact that we are oblivious to the reasons explaining why these companies left out of our study are not willing to pursue innovation. In fact, one of the main policy goals in Brazil and other developing countries should be to make these companies more prone towards innovation. Unfortunately, due to analytical choices, our empirical exercises omitted this discussion to focus on the so-called "revealed barriers" that companies face while trying to innovate. Other studies should try to elicit the nature and consequences of the so-called "deterring barriers" in the Brazilian context, which make so many companies shielded from the need and will to innovate. Such analysis would certainly benefit a more comprehensive understanding of the innovation troubles at play in the country.

Another theoretical limitation can be easily observed when comparing the general conceptual framework (Figure 4) developed in Chapter 1 to the operational conceptual model (Figure 8) developed in Chapter 3. The latter is basically the operationalization of the former according to the availability of data from PINTEC 2014. As one might see, most variables (determinants, obstacles and policies) included in Figure 4 could not be incorporated in Figure 8 due to data unavailability. Unfortunately, the data from PINTEC is still too focused on the innovation concept as a purely market phenomenon. This is the fundamental reason why so many variables on the individual and external environment levels were left out of our empirical models. However, some fortunate changes in the theoretical understanding of innovation are starting to emerge in the measurement circles. The most auspicious of them certainly is the recently released new edition of the Oslo Manual, which provides an extended conceptual framework for the innovation measurement that is applicable to all sectors in the economy (Business, Government, Non-profit institutions, Households) and hence contributes to building up a society-wide statistical view of innovation (OECD, 2018). If the next editions of PINTEC start following the guidelines from this new edition of the Oslo Manual, the research community would beyond question benefit from more far-reaching and theoretically up-to-date innovation indicators.

All in all, we believe that this doctoral thesis managed to advance important areas of study on the innovation realm, despite its many limitations. In fact, as a first step towards a comprehensive model encompassing innovation determinants, obstacles and policies, our empirical exercises fulfill their purposes. Besides, the theoretical and historical discussions undertaken to achieve our general conceptual framework might be very useful and timely for the recent impetus within innovation indicators towards a more general conceptualization of the innovation as a socio-economic phenomenon. Indeed, it is time to acknowledge innovation as a full-fledged study object from the whole social sciences. Hopefully, the next generation of innovation studies will be more successful in bridging the different (and complementary) perspectives on innovation to obtain a general theory that is truly systemic and multidisciplinary. Either way, this doctoral thesis contributes to lay the foundations for a new research agenda within the innovation studies, especially as regards the study of innovation determinants, obstacles and policies, so that it might serve as a map for future investigations willing to assume a complexity approach towards innovation. Although such approach involves several challenges, particularly from the operationalization perspective, we truly believe that embracing complexity is the right path to take in order to properly understand innovation, as did believe so Schumpeter, Tarde and the other founding fathers of the innovation studies. Hence, if this doctoral dissertation succeeded in facing complexity and striving for a renewed innovation theory, its mission might be considered as accomplished.

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