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# Economic Analysis of Innovation Tax incentives in Brazil: Essays on the impacts of Law 11,196/05 on industrial innovation

Análise Econômica dos Incentivos Fiscais à Inovação no Brasil:
Ensaios acerca dos impactos da Lei 11.196/05 na Inovação Industrial

São Paulo
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Tese apresentada ao Departamento de Economia da Faculdade de Economia, Administração e Contabilidade da Universidade de São Paulo, como parte dos requisitos para obtenção do grau de Doutor em Economia

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# ABSTRACT


Colombo, D. G. (2017) *Economic Analysis of Innovation Tax incentives in Brazil: Essays on the impacts of Law 11,196/05 on Industrial Innovation*. Doctoral Thesis. Faculdade de Economia, Administração e Contabilidade da Universidade de São Paulo, São Paulo.

The objective of this thesis is to empirically assess how the tax incentives of Law 11,196/05 have affected the landscape of private industrial innovation in Brazil. The main point is to verify to what extent this tax relief has contributed to the fostering of innovation in the country. To achieve this broad objective, three specific research questions were devised as axes of investigation, and they are addressed in each of the stand-alone papers that comprise this thesis. I begin by assessing whether the incentives have impacted the volume of innovation investment of beneficiary firms. This first analysis also considers the effect of the policy on innovation outputs and firms' performance. The second research question considers the behavioral additionality, estimating changes caused by the incentives on the composition of the bundle of innovation investments and on the type of innovation pursued by firms. The third investigation assesses whether the reduction of the tax burden has attracted international innovation investment by diverting it from alternative destinations, thus testing the 'footloose R&D' argument for the Brazilian case. The first two papers use microdata on Brazilian firms from the Industrial Innovation Survey (PINTEC) and other sources, and the impact is estimated through propensity score matching with difference-in-differences. The third study relies on aggregate country data, mainly on activities of foreign affiliates of U.S. multinationals and international patent applications; and panel data estimators are applied to measure and test the correlation of the Brazilian policy with international innovation investment directed to other countries. The main findings of the thesis are: (a) the average impact of the policy on R&D expenditures in 2011 was around five hundred thousand Brazilian *reais*, or 6.8% of the mean R&D spending of beneficiary firms, which is less than the average benefit per firm in the same year, suggesting some level of crowding-out in the short-run; (b) incentives also positively affected the size of R&D personnel (average effect represents 16% of the average size of R&D staff); (c) the policy raised the chances of firms to innovate between 2009 and 2011 by 16%; (d) incentives positively impacted company's growth around 5% of the mean number of employees of incentivized enterprises in 2011; (e) R&D intensity of the bulk of innovative activities increased 9.5% because of the incentives; (f) part of the R&D increase was counterbalanced by a reduction effect on spending with acquisition of external knowledge and introduction of innovations in the market; (g) beneficiary firms hired more researchers with undergraduate degrees only as an effect of the policy (18.5% of the average number of their research personnel with such educational level); and (h) in the case of multinational groups, the increase in innovation investment does not seem to have been caused by the diversion of investment from other countries. The empirical investigations present clear evidence of the three dimensions of policy impact: input, output and behavioral additionality. A number of implications are drawn from the studies for the improvement of the policy design.



Keywords*:* Tax incentive. Innovation. Impact assessment. Investment Composition. International Investment.

# RESUMO

Colombo, D. G. (2017) *Economic Analysis of Innovation Tax incentives in Brazil: Essays on the impacts of Law 11,196/05 on Industrial Innovation*. Tese de Doutorado. Faculdade de Economia, Administração e Contabilidade da Universidade de São Paulo. São Paulo.

O objetivo desta tese é avaliar empiricamente os impactos dos incentivos fiscais da Lei 11.196/05 na inovação industrial brasileira. O ponto central é identificar em que medida essa redução tributária vem contribuindo para impulsionar a inovação no país. Para atingir esse objetivo, três perguntas de pesquisa foram concebidas como eixos de investigação, cada uma sendo abordada em um dos ensaios que compõem esta tese. A primeira questão é se os incentivos fiscais elevaram o volume de investimentos das empresas beneficiárias em inovação. Essa primeira análise também considera o efeito da política sobre os resultados desses investimentos e desempenho das firmas. A segunda parte pergunta de pesquisa considera os efeitos da política sobre o comportamento das empresas, estimando as mudanças ocasionadas na composição dos investimentos e no tipo de inovação perseguido pelas firmas. O terceiro ponto de estudo é se a redução da carga tributária atraiu investimentos internacionais em inovação em detrimento de outros países, testando o argumento de '*footloose R&D'* para o caso brasileiro. Nos dois primeiros trabalhos são utilizados microdados de empresas brasileiras constantes da Pesquisa de Inovação Industrial (PINTEC) e outras fontes, sendo aplicado o escore de propensão com diferenças-em-diferenças para estimar o impacto. O terceiro estudo baseia-se em dados agregados de países, essencialmente sobre atividades de filiais estrangeiras de multinacionais norte-americanas e pedidos internacionais de patentes, sendo aplicados estimadores de painel para mensurar e testar a correlação da política fiscal brasileira com o investimento internacional em inovação direcionado para outros países. As principais conclusões da tese são: (a) o impacto médio da política nos gastos em P&D em 2011 foi de aproximadamente quinhentos mil reais, ou 6,8% da média dos investimentos em P&D das firmas beneficiárias; esse valor é inferior ao benefício médio por firma no mesmo ano, o que sugere algum nível de *crowding-out* da política no curto prazo; (b) os incentivos também afetaram positivamente o tamanho das equipes de pesquisa (efeito médio representa 16% do tamanho médio das equipes de P&D); (c) a política elevou as chances das firmas inovarem no período de 2009 a 2011 em 16%; (d) os incentivos impactaram positivamente o crescimento das firmas em cerca de 5% da força de trabalho das firmas beneficiárias em 2011; (e) a intensidade de P&D no conjunto de atividades inovativas cresceu 9,5% devido à política; (f) parte do incremento em P&D foi contrabalanceada por um redução nos gastos com aquisição de conhecimento externo e introdução de inovações no mercado; (g) empresas beneficiárias elevaram a contratação de pesquisadores com diploma de graduação (18.5% do número médio de pesquisadores com esse nível educacional nas firmas beneficiárias em 2011); e (h) no caso de grupos multinacionais, o aumento nos investimentos em inovação não parece ter sido causado pela realocação de investimentos de outros países. As análises empíricas apresentam evidência das três dimensões de impacto da política fiscal: insumos, resultados e comportamental. Diversas lições são extraídas dos estudos para o aprimoramento do desenho da política.

Palavras-chave: Incentivo fiscal. Inovação. Análise de impacto. Composição de investimentos. Investimento Internacional.

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# 1 INTRODUCTION

In 2005, as part of a broader industrial policy and tax reform, the Brazilian Congress approved a new framework of tax incentives to promote business innovation in the country. Law 11,196/05 (also known as the '*Goodness Law'*) established a horizontal innovation policy that allowed the enhanced deduction of expenses in research and development (R&D) from the taxable income of beneficiary firms, among other incentives.

This thesis presents an economic analysis of the impact of these incentives, following the objectives set forth in this introductory chapter. This part also presents a broad overview of the topic, setting the stage for the research. The first section below presents the theoretical debate on innovation policies and recent developments on international practice. The second section is dedicated to the role of tax incentives within this policy framework. The third provides a brief introduction to the Brazilian innovation tax policy and its fundamentals. The fourth presents three dimensions or analytical perspectives to assess the impact of innovation policies. Based on the elements discussed in these sections, the fifth and last part outlines the general and specific objectives of this thesis, its structure and main methodological choices.

## 1.1 The Theoretical Debate and Recent Developments on Innovation Policies

One advantage of empirical research on innovation policies is that there is little disagreement at the theoretical level on whether they ought to be implemented or not. Both the neoclassical 'market failure' approach and the neoschumpeterian theory agree there is a role for the government on promoting innovation. The consensus, however, does not go much further, as the appropriate scope and reach of policies is subject to debate. Authors of the market failure theory understand government intervention should be limited to create the appropriate conditions for business innovation. Evolutionary or neoschumpeterian economists, on the other hand, attribute a more prominent role to the state: it should lead the industrial development and directly pursue radical innovation or the development of strategic technologies necessary for economic growth (Mazzucato, 2011).

The market failure theory is based on the general idea that perfect markets would allocate resources for innovation (or any other activity) efficiently, generating a social Pareto optimum. In the case of innovation or the production of information, however, a group of market failures does not allow such an outcome to arise, leading to underinvestment (Arrow, 1962). The main market failures currently used to justify innovation policies are substantial positive externalities in the form of knowledge spillovers (Köhler, Laredo & Rammer, 2012; Griffith, Sandler & Van Reenen, 1995; EC, 2014). There are others identified and tested by the literature, such as indivisibility of results, moral hazard, coordination failures and imperfect competition (Hall & Lerner, 2009; Mazzucato, 2015).

Based on this reasoning, the aim of innovation policy should be to correct market imperfections or supplement private investment, bringing it closer to social optimum levels (Martin & Scott, 1988). Governments should focus on policies that increase R&D expenditure, human capital and productivity within firms. In cases where positive externalities are too great (such as basic research - Nelson, 1959), direct public provision by the government may be more efficient (Griliches, 1986; U.S. J.E.C., 2010). According to OECD (2015d), market failures are the rationale for ‘well-recognized’ innovation policy instruments, such as direct subsidies for business R&D, investment in basic research and infrastructure and regulation of environmental externalities.

Besides the scope, another relevant constraint to innovation policies in this approach is the inefficiency created by government intervention. This topic was mainly developed by the public choice and government failure literature. These studies challenged both the intention and capacity of government officials to formulate and implement policies to correct market failures. Policies can be incorrectly timed, their magnitude may be excessive, and they may remain in effect after no longer necessary because of rents (Tullock, Seldon & Brady, 2005). Wolf (1986) listed four main sources of government failures: redundancy and rising costs; “private” goals of public agencies; derived externalities or side effects; and distributional inequity. Chang (1994) stated the public choice literature changed the terms of the industrial policy debate: although it is accepted that the policy may have positive implications by correcting or counter balancing market failures, it is uncertain whether the net outcome is efficiency-improving.

The evolutionary theory applies a different set of decision-making principles and market dynamics to model some of the features of the innovative process, such as uncertainty, heterogeneity of firms’ behavior and schumpeterian competition (Nelson & Winter, 2005). Its major commitment is to a ‘behavioral’ approach, meaning firms respond diversely to inputs from the environment according to a set of rules (Nelson & Winter, 1974). Dosi and Marengo (2007) emphasize the relevance of dynamics, bounded rationality and selection mechanism. The schumpeterian concept of ‘creative destruction’ is modelled through drastic innovations that render older technologies obsolete and change firms in the knowledge frontier, affecting chances of survival (Vonortas & Aridi, 2012). In Nelson and Winter's simulated growth model, firms select between alternative production methods generated by new discoveries but also by the interaction and exchange of information among agents, thus blurring the concept of production function.

The neoschumpeterian approach sees a different role for the state in the innovation process. Mowery (1991) argued that government intervention has been central to the United States (U.S.) postwar innovation system, especially through the antitrust policy, public R&D expenditure and the national defense budget. Freeman (1988) suggested the MITI has shaped the structural change of the Japanese economy based on its judgements about the future of technological progress. Mazzucato (2011, 2015) criticized the market failure theory for ignoring the leadership the state has historically had in technological development.

This approach has profound implications in terms of the design of innovation policies. The main message, according to Nelson and Winter (2005), is that the appropriate policy cannot be determined *a priori* based on a theoretical ahistorical analysis, but it should be outlined taking into consideration the particularities of the concrete case, including past experiences and the applicable institutional framework. The neoschumpeterian approach emphasizes the 'trial-and-error learning process', and, for this reason, public support should target various formal and informal learning approaches (Seravalli, 2009). In this scenario, a policy is likely to include several distinct tools, each designed to tackle specific challenges of sectors and networks. Mazzucato (2011) summarized this idea by stating that 'R&D is not enough', implying that the policy goal cannot be limited to increasing R&D spending or intensity, as 'societal challenges' and the distribution of knowledge must be considered.

Until the financial crisis in the second half of the last decade, broad innovation policies were on the rise. OECD countries adopted comprehensive national innovation plans setting ambitious objectives and addressing major challenges, including mitigating environmental problems and developing strategic sectors as nanotechnology (OECD, 2006a). Government support to open innovation and partnership between firms and universities tried to foster research collaboration and knowledge transfer and distribution. A variety of policy tools were adopted, including tax incentives, early-stage capital funds and regional or sub-central policies (OECD, 2006a). The World Bank (2010) guidelines for innovation policy made clear reference to the importance of collaboration and systemic perspective in an uncertain environment.

Although it is not possible to frame such a policy description into one theoretical paradigm only, the presence of concepts and objectives of neoschumpeterian orientation seems clear. Hartmann (2007) considered the approach adopted by the European Council in the 2005 version of the Lisbon Strategy as being built upon and strongly influenced by evolutionary economics, as it relies on concepts such as innovation system and the triple-helix.

The global economic crisis that began in 2008 affected this landscape. Although national strategies to face the crisis kept acknowledging the relevance of innovation for resuming a growth trajectory, budgetary cuts have affected governments' capacity to offset the drop of business R&D, attract and lever knowledge-based capital and finance comprehensive policy schemes (OECD, 2016). The Lisbon Strategy failed to meet its main targets (including the increase in R&D per gross domestic product - GDP ratio to 3%; EC, 2010), and was replaced by a new plan - the Europe 2020 Initiative (EC, 2011) - based on targeted public support of R&D and well-identified market failures. The '*Strategy for American Innovation'* (U.S., 2015) followed the same idea: the main guideline to fuel business innovation was to address market failures and ensure friendly framework conditions. The United Kingdom (U.K.) "Plan for Growth" strongly emphasized the need to lessen the regulatory burden to encourage innovation (B.I.S., 2011).

The previous emphasis on variety of tools and coordinated groups of incentives was replaced by rationalization of efforts, reduction of fragmentation and value for money (EC, 2011). Such a change of paradigm on innovation policy is subtle and should not be found in broad aggregate indicators, as the modifications are mostly of a qualitative nature. According to the EC and OECD survey on innovation policy, concern for the governance of innovation policies has grown more than for any other topic among policy-makers, and it is currently one of the most relevant issues to be addressed (OECD, 2016). The survey also pointed out that rationalizing public research, remodeling the policy mix for business R&D and improving policy governance with a focus on evaluation are recent relevant changes in the design of innovation strategies. A similar trend is suggested by Izsak, Markianidou, Lukach and Wastyn (2013) based on the '*Erawatch and INNO Policy TrendChart country reports*', as funding and prioritization or targeting are described as top challenges for national innovation policies.

Budgetary constraints, excessive regulation and lack of confidence in governments due to their inability to prevent the economic crisis (OECD, 2016) have reduced the attractiveness of the idea of a large public sector driving the technological progress. This suggests a change of focus towards firm-based innovation and policies with specific objectives aimed at boosting such potential. As suggested by Mazzucato (2011), "across the globe we are hearing that the state has to be cut back in order to foster a post-crisis recovery, unleashing the power of entrepreneurship and innovation in the private sector" (p. 17). This recent movement, however, should not be understood as a drastic change. As argued by Izsak et al. (2013), innovation policy mixes presented a high rigidity and did not change substantially during the crisis, although realignment of some of its main objectives did take place.

## 1.2 The role of Tax Incentives

It is not straight forward to interpret tax incentives in light of the discussed theoretical framework and policy context, as they can serve different purposes, depending on the adopted structure.[1] Throughout this thesis, I follow EC (2014) and use a broad and simple definition of tax incentives as (a) any form of tax reduction granted by the government to firms that have positive expenditure on innovative activities (input-related) or, (b) any favorable tax treatment to income arising from innovation results or intellectual property rights (output-related). Although such incentives were initially adopted by a few countries during the 1960-1980 period, their use was intensified mostly as from the 1990s (Bloom, Chennells, Griffith & Van Reenen, 1997).

Tax incentives are commonly interpreted as being closer to the market failure rationale, since they partially compensate for limited appropriability of the results of innovation (Köhler et al., 2012), but at the same time public officials have no further power to interfere in the decision-making process of the firm. Edler et al. (2013) suggested that, unlike the majority of innovation policies or instruments that are grounded on a mix of different rationales, tax incentives are 'largely based on market failure'. Metcalfe (1994) argued that tax incentives are part of a group of policy instruments that take the innovation possibilities of firms as given and do not try to enhance them. Griffith, Miller and O'Connell (2010) and EC (2014) justified the use of these benefits because of high levels of knowledge spillovers, and criticized their use when market failures are not clear, such as the 'patent box' schemes.[2]

But, even considering these issues, it is possible to argue that tax incentives can have a role in an evolutionary innovation strategy. There is an array of possible arrangements that governments can employ for the design of these benefits,[3] and it is possible to combine a horizontal rationale of compensation for knowledge spillovers with targeting objectives typical of a neoschumpeterian policy setup. For example, particular groups of firms (such as small

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[1] In Chapter 2, I discuss different types and designs of fiscal incentives.
[2] "Furthermore, it is hard to make the argument why a patent box would reduce market failure caused by knowledge spillovers: patent boxes introduce a preferential rate for income from innovations that are already protected by IPR". (EC, 2014, p. 22).
[3] In Chapter 2, different structures of innovation tax policies adopted internationally are presented.

businesses) can enjoy a higher incentive rate, or access to incentives can be restricted to strategic sectors or types of R&D expenditure. Teubal (1997) analyzed innovation policies and concluded that horizontal schemes such as tax breaks are important in an evolutionary perspective, especially during the infant phase when it is important to promote both variety and competitive systems of market selection. Azurmendi, Aramburu and Amozarrain (2008) analyzed the innovation system of the Basque Country economy using a neoschumpeterian model, and concluded that the tax policy was relevant to the innovation strategy by fostering business R&D.

## 1.3 Three Dimensions of Policy Impact

In order to have a comprehensive picture of the impact of an innovation tax policy, three main points need to be addressed. This section summarizes these research topics, briefly presenting the question or problem, its economic importance and a reference to the relevant literature.

### 1.3.1 Innovation inputs, outputs and firms' performance.

The main point of an innovation tax incentive is to raise the volume of investment in R&D and other innovative activities, by indirectly financing part of the cost through tax breaks. The general reasoning, as discussed previously, is to compensate for high positive externalities and other market failures, leading investments to a higher level closer to a social optimum.

It is therefore natural that the first question to be addressed in an empirical investigation about a policy of this type is whether it actually increases private expenditure. The economic literature has identified reasons to argue that public support might not fully achieve this objective. The main point is the crowding-out effect, meaning beneficiary companies can divert additional resources to other ends not related to innovation (Hall & Van Reenen, 2000). This is a particularly relevant problem in the case of tax incentives, as the empirical literature seems to agree that the elasticity of R&D investment to tax breaks is usually less than one, at least in the short run (EC, 2014; Van Pottelsbergue, 2003). Additionally, an upsurge of inputs' prices due to inelastic supply might negatively affect the impact of an innovation policy on investment (David, Hall & Toole, 2000).

Another topic that has recently attracted the attention of researchers is whether innovation results and firms' performance are also affected by tax breaks. Even assuming R&D inputs increase, the development of innovation projects is influenced by a number of different factors, besides being subject to high levels of uncertainty. Moreover, moral hazard (Arrow, 1962) and relabeling of different activities as innovation expenditure (Köhler et al., 2012) may also reduce the impact of indirect funding on innovation results. Empirical investigations regarding these issues are more recent and less numerous (EC, 2014). The main variables used for these analyses are new products' sales, novelty of innovation and firm productivity. The few studies that investigated these matters found significant results (Aralica & Botrić, 2013; Czarnitzki, Hanel & Rosa, 2011; Bérubé & Mohnen, 2009), but their number is not sufficient to state this is a consensus.[4] This constitutes an important research agenda for the development of the literature and the understanding of innovation policies.

### 1.3.2 The composition of investment and types of innovation.

In addition to the effects on innovation inputs and outputs, policies can also influence how firms perform R&D (Falk, 2007; OECD, 2006b). Based on the idea of 'behavioral additionality' (Georghiou, 1994; and Buisseret, Cameron & Georghiou, 1995) more recent studies tried to estimate the impact of policies on the composition of private investment.[5] These analyses take the structure of the bundle of investments (among other variables) as a proxy for firms' strategies for pursuing innovation. The objective is to 'open the R&D black box' (David & Hall, 2000) to identify channels through which government support affects business innovation efforts.

The concept of behavioral additionality is broad and allows for multiple analyses considering different dimensions of firms' behavior or categories of variables (OECD, 2006b, describes several studies using this approach). For this reason, Neicu et al. (2014) and Gök and Edler (2012) argued that these investigations are closer to an evolutionary perspective, since they do not limit their interest to the correction of market failures and to the increase of suboptimal levels of R&D.

In this thesis, I call attention to four different classifications of innovation investment. The first is the group of different innovative activities. According to the Oslo Manual (OECD, 2005), this concept is broad and encompasses "all scientific, technological, organizational, financial and commercial steps which actually lead, or are intended to lead, to the implementation of innovations" (p. 18). The second refers exclusively to R&D, considering the share that is subcontracted to third parties. Analyses of R&D outsourcing are mainly based on

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[4] See Table 2.4 in Chapter 2.
[5] See section 3.2 of Chapter 3.

the theory of transaction costs (Coase, 1937; Williamson, 1989). The third is the educational level of firms' research personnel. The economic literature has acknowledged the importance of the quality of human resources for the success of innovation projects (Dumont, Spithoven & Teirlinck, 2014; Spithoven & Teirlinck, 2010), and formal education is considered a main source of new skills for firms (OECD, 1995). Finally, the fourth is the distinction between product and process innovation. Even though both types can positively affect firms' output and performance, process innovation is usually understood as productivity increase or reduction of costs, while product innovation refers to new or better-quality goods introduced by firms in the market (Saha, 1999).

### 1.3.3 Attraction of international investment.

The greater part of private investment in innovation comes from multinational enterprises (MNEs), according to UNCTAD (2005a) and OECD (2008b). Since the 1990s, these groups have offshored more R&D to other countries, mainly to support and adapt products to foreign markets and customers, but also to explore local advantages (Thomson, 2009; OECD, 2008). Up to this point, Brazil has not attracted a substantial share of these resources (especially considering the size of its economy), but the flow of investment has risen, mostly in the last decade.

As discussed in Chapter 4, the role of innovation policies in R&D internationalization is not certain, as it depends on the type of R&D undertaken by MNEs in each country and other investment attraction forces at play. Considering this scenario, it is a relevant point for policy analysis to investigate if reductions in the tax burden are a relevant factor that affects the international flow of investment. One of the main debates of economic literature on this topic is whether tax incentives are beggar-thy-neighbor strategies, meaning the increase in international R&D investment directed to one country comes from the reallocation of resources by MNEs in order to take advantage of fiscal benefits. This has significant implications for policy coordination at the international level, for, if confirmed, it implies a zero-sum game between countries. The 'footloose R&D' argument was initially developed by Bloom and Griffith (2001), and it was mentioned by OECD (2013a) as one potential major downside of favorable tax treatments for innovation. Empirical evidence on this topic is not convergent, as there are studies that confirm (Wilson, 2009; Baumann, Knoll & Riedel; 2014) and disprove (Athukorala & Kohpaiboon, 2006; Thomson, 2009) the 'footloose' R&D argument.

**1.4 The Brazilian Innovation Tax Policy**

Law 11,196/05 provided the main group of horizontal tax incentives for innovation currently in place in Brazil. It was approved in a political context in favor of industrial policy initiatives and of an active role by the government to foster innovation. The main official documents that set this orientation and the institutional framework were the Industrial, Technological and Foreign Trade Policy (PITCE)[6] of 2003 and the 'Innovation Law' (Law 10,973/04).

In general, the design and rationale of the incentives follow international practice: firms with positive R&D expenditure are entitled to the enhanced deduction of such spending from the taxable base of income tax and social contribution to the net profit, up to the limits provided by the law. This reduces the tax cost of innovating firms, offsetting part of the positive externalities. Incentives rates can rise in case companies hire more researchers, develop a patented technology or collaborate with public research institutions. There are specific provisions for the purchase of research equipment or the acquisition of technology from third parties. Most of the incentives are input-related, but the law also provides for tax exemption for the registration of intellectual property rights.[7]

This policy can be considered an improvement if compared to the country's previous experience with tax incentives. According to the Ministry of Science, Technology and Innovation (MCTI), more than a thousand and two hundred companies applied for these incentives in 2014. The sectors with the greatest number of beneficiary companies are transportation equipment, software, chemicals and electronics. The total volume of tax breaks for the 2006-2014 period is around seventeen billion Brazilian *reais*[8] (around six billion U.S. dollars)[9] (MCTI, 2016). These data suggest this policy currently has an important role in the national innovation strategy.

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[6] "*Política Industrial, Tecnológica e de Comércio Exterior*".

[7] Details of the policy and available data on beneficiary firms are presented in the papers that comprise this thesis. Chapter 2 summarizes the incentives and requirements, and also presents data on the volume of tax breaks and investments. Chapter 3 supplements such description by analyzing how the policy design affects the relative tax cost of different categories of expenditure composition. Finally, Chapter 4 discusses the origin of capital of beneficiary enterprises.

[8] Real value in December, 2016, adjusted using the IGP-M/FGV index of the last month of each year. Sum of nominal values is around twelve billion Brazilian *reais.*

[9] According to the exchange rate applicable on the last day of the year.

## 1.5 Objectives and Structure of the Thesis

The general objective of this thesis is to empirically assess how the tax incentives of Law 11,196/05 have affected the landscape of private industrial innovation in Brazil, providing a comprehensive picture of this innovation policy. The main point is to verify whether and to what extent this tax relief has actually contributed to the fostering of innovation in the country.

To achieve this broad objective, three specific research questions were devised as axes of investigation, following the topics presented previously. I begin by testing whether the tax incentives have impacted the innovation investments of beneficiary firms. This first analysis also considers the effect of the policy on innovation outputs and firms' performance. The second research question considers the behavioral additionality approach: the idea is to estimate changes on the composition of the bundle of innovation investments and on the type of innovation pursued by firms as a result of the incentives. The third object of study is whether the reduction of the tax burden has attracted international innovation investment by diverting it from alternative destinations, thus testing the 'footloose R&D' argument for the Brazilian case.

This thesis comprises this introductory part, three stand-alone papers[10] and the conclusion. The papers constitute separate investigations about the tax policy addressing the mentioned research questions. However, considered jointly, the results of these three investigations should provide a comprehensive picture of how this policy has affected firms' innovation efforts and results, thus achieving the general objective stated above. This is the purpose of the concluding chapter that summarizes the findings of the three papers and their policy implications. By analyzing all results collectively, I try to reach more general conclusions on the policy and its contributions to the Brazilian innovation scenario.

The thesis is eminently empirical. Although the investigations are strongly based on economic theory, they rely on econometric analyses and impact assessment techniques to measure the magnitude, sign and significance of causal relationships or correlation between variables. Results, therefore, are strictly valid to the case under study, although they provide empirical support to confirm or refute the applicability of theories and models discussed throughout the papers to the Brazilian experience.

The first two papers (Chapters 2 and 3) use microdata at the firm level. The main sources of information are (a) the list of firms that applied for and benefited from the innovation tax incentives each year;[11] (b) disaggregate data gathered by the Brazilian Institute of Geography

[10] Each paper is presented as one of the Chapters (2 to 4) of this thesis.
[11] Firms claiming tax incentives must submit a report each year to the MCTI, detailing the activities and expenditures to be deducted for tax purposes. The MCTI technical staff checks if firms complied with the legal

and Statistics (IBGE)[12] for the 2008 and 2011 editions of the *Industrial Innovation Survey* (PINTEC)[13]; and (c) list of exporting and importing firms (MDIC, n.d.). The third paper (Chapter 4) relies on aggregate country data from the following sources: (a) the '*1-(b-index)*' (Warda, 2013; Stewart, Warda & Atkinson, 2012; OECD, 2014; and Araujo, 2010); (b) data on U.S. MNEs' foreign affiliates (U.S. B.E.A., n.d.); (c) data on patent applications extracted from the European Patent Office (EPO, 2015); and (d) country data from diverse sources.

Further details on data and research strategy used in each investigation are presented in the papers, including a description of the empirical models, estimators applied, robustness checks and sensitivity analyses.

The thesis presents various contributions to the existing literature on the Brazilian innovation policy, as detailed in the papers. To sum up, the impact of the policy is measured not only on R&D spending, but also on the broad category of innovative activities, on the base of companies investing and achieving innovation, and on a group of innovation output and firms' performance variables not considered by previous studies (probability of innovation; share of new products in sales and exports; net revenue and net revenue per employee); plus, this is the first investigation on behavioral additionality of the policy, measuring how it affected the composition of innovation investment; and finally, this is also the first analysis on the effects of the incentives on the attraction of international investment in R&D. In addition, as the literature on innovation tax incentives mainly focuses on experiences in developed countries, this thesis presents evidence of the impact of such a policy instrument in a developing economy, adding to the existing body of knowledge on the subject.

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requirements on R&D investment. Such analysis usually only takes place after firms have filed their tax returns. In cases where the tax authorities believe a company did not comply with the necessary requirements, the firm is fined and must pay the value of the incentives (art. 13 of Decree 5,798/06).

[12] "*Instituto Brasileiro de Geografia e Estatística*".

[13] "*Pesquisa de Inovação Industrial*". Access to the disaggregate data was granted in IBGE's confidentiality room, according to the terms of a non-disclosure agreement and exclusively for research purposes.

# 2 IMPACT ASSESSMENT OF TAX INCENTIVES TO FOSTER INDUSTRIAL INNOVATION IN BRAZIL: THE CASE OF LAW 11,196/05

Abstract

This paper evaluates the effects of tax incentives for technological innovation in Brazil established by the Law 11,196/05 ("*Lei do Bem*"), to test whether they have increased resources for business innovation projects and had any significant impact on their results. The average treatment effect on the treated (ATT) is estimated using microdata on the firm level from the Brazilian Industrial Innovation Survey (PINTEC) conducted by IBGE, and applying a propensity score matching (PSM) with difference-in-differences, used in recent similar analyzes. Results suggest a causal impact of the policy on R&D expenditures (average of around five hundred thousand Brazilian *reais* in 2011) and number of research staff (average of five researchers). Mean impact on spending, nevertheless, falls short of the average tax break per firm. The policy also increased average chances of firms to start investing in innovative activities (23%) and R&D (11%), and also their average chances to innovate (12%). Beneficiary firms grew more in terms of personnel size (average impact of 107 new employees). Such results are in accordance with findings of most of the empirical literature on innovation tax incentives. The study provides empirical support in favor of tax incentives as part of a government strategy to boost entrepreneurial innovation in the country.

Keywords**:** Tax incentives. Innovation. Impact assessment.

## 2.1 Introduction

Governments have devised and adopted policies to foster industrial innovation at least since the second half of the 20th century (Bloom, Griffith & Van Reenen, 2002). Industrial innovation strategies have evolved substantially over time: the introduction of research and development (R&D) incentive schemes in the 1970s; the emergence of regional or territorial policies and the concept of 'national system of innovation' in the 1980s; and the growth of horizontal policies to avoid government failures in the 1990s (World Bank, 2010).

Different countries have resorted to tax incentives as part of their strategy to indirectly finance business innovation projects. Such instruments are said to reduce economic distortions caused by public sector action and are more 'market friendly' (Hall & Van Reenen, 2000; OECD, 2014a). According to Bloom, Chennells, Griffith and Van Reenen (1997), since the 1990s policy-makers became increasingly interested in tax incentives. Since then, a substantial body of knowledge on the subject has been produced including several empirical studies that tried to identify and measure impacts of this policy tool (as detailed in section 2.3).

This paper's aim is to contribute to this discussion by understanding the Brazilian experience with tax incentives for innovation. The object of the analysis is the horizontal fiscal policy at the federal level established by Law 11,196/05, also known as the 'Goodness Law' ("*Lei do Bem"*). The objective is to present a quantitative impact assessment of these incentives, in order to check whether they have contributed to increase business innovation investments and efforts (measured by firms' expenditures and research personnel), as well as to their results (assessed through success in innovating, firm growth and productivity).[14] The policy impact is estimated using disaggregated data at the firm level from the Industrial Innovation Survey (PINTEC)[15] collected by the Brazilian Institute of Geography and Statistics (IBGE) and applying the propensity score matching (PSM) with difference-in-differences to estimate the average treatment effect on the treated (ATT).

The second part of the paper following this introduction presents the concept and economic rationale for tax incentives, along with data that shows the increasing use of this policy tool in the last decades across countries. In the third section the relevant literature related to evaluation and impact assessment of innovation tax incentives is reviewed, summarizing the most important and frequent findings. The fourth part describes the implementation and institutional framework of the Brazilian tax policy, and presents a general overview of the incentives using aggregate data. The fifth part details the empirical research strategy, including the estimation method and data. The sixth part presents and discusses the results of this study. The seventh and final section summarizes the findings and provides concluding remarks.

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[14] For a detailed description of the outcome variables, see section 2.5.4.
[15] *"Pesquisa de Inovação Industrial"*.

## 2.2 Tax Incentives for Industrial Innovation

### 2.2.1 Theoretical background and economic rationale: distinctions between direct subsidies and tax incentives.

Public financing of innovation activities and expenditures is supported by different economic theories, as discussed in the introductory chapter. The presence of market failures renders private investment in this activity suboptimal, thus requiring additional public resources to supplement it. The seminal works of Nelson (1959) and Arrow (1962) presented some of the first and most influential theoretical arguments on the subject. The first focused on basic research, which requires public support due to the uncertainty inherent to such projects. Arrow argued that under a perfect competitive market the allocation of resources for innovation would be optimal, but three market failures do not allow such a situation to arise: indivisibility of results, inappropriability (presence of positive externalities), and uncertainty.

This literature developed and tested other arguments, such as information asymmetry and moral hazard (Hall & Lerner, 2009), financial constraints (Hall, 1990; Himmelberg & Petersen, 1994), job qualifications and salary increase (Berman, Bound & Griliches, 1994) and capacity for imitation (Cohen & Levinthal, 1989).

Currently, the main argument raised to justify public financing of innovation is the limited appropriability of results caused by knowledge spillovers (Köhler, Laredo & Rammer, 2012;[16] Griffith, Sandler & Van Reenen, 1995;[17] EC, 2014.[18]). The main point is that technological innovation, understood as the creation of knowledge and its application to practical purposes (Frascati Manual - OECD, 2015a), cannot be fully appropriated due to its non-rival and non-excludable properties (Arrow, 1962). Intellectual property laws can only mitigate this market failure by granting monopoly rights to the inventor (Griffith et al., 1995), as such protection is usually limited in time and scope.

A vast body of literature attempted to measure the percentage of knowledge spillovers of technological innovation (for a review of this topic, see Griliches, 1992; and Wieser, 2005). These analyses suggest the level of spillovers can change drastically, depending on their

[16] "The principal economic rationale for business R&D tax incentives – as for any government support of private R&D – is the presence of knowledge spillovers." (Köhler et al., 2012, p. 7).

[17] "The main economic argument in favor of government support for industrial R&D, which is based on the idea that society benefits from this R&D via 'spillovers' […]". (Griffith et al., 1995, p. 24).

[18] "But markets left on their own will probably generate less innovation than would be desirable from society's point of view. The reason is that knowledge is not completely excludable: ideas can be easily copied and used by other firms." (EC, 2014, p. 18).

geographic dispersion (Jaffe, 1993; Peri, 2005), economic sector (Malerba, Mancusi & Montobbio, 2013), or scope (basic or applied) of the R&D activity (Nelson, 1959; U.S. JEC, 2010). Regardless of such differences, spillovers represent a substantial share of the results of firms' technological efforts. In a recent analysis, Bloom, Schankerman and Van Reenen (2015) estimated them to be at least twice the size of internalized returns. For this reason, technological innovation can be considered for analytical purposes as an activity similar to the provision of public goods (as suggested in Hall & Van Reenen, 2000;[19] Verspagen & De Loo, 1999;[20] Verspagen, 1992;[21] and Malerba et al. 2013)[22]. Government funding is then justified as relevant to raise R&D to socially efficient levels.

But knowledge spillovers and positive externalities are only part of the reason why governments employ resources for funding R&D. A second motivation is the importance of innovation as a driver of economic growth, as acknowledged by economic theory since the works of Schumpeter (2008) and Solow (1957), and constituting the building blocks of neoclassical and neoschumpeterian growth models (Rivera-Batiz & Romer, 1991; Grossman & Helpman, 1991; Romer, 1990; Sala-i-Martin, 1990; Nelson & Winter, 2005; and, more recently, Bloom et al., 2015).[23]

On the other hand, theoretical arguments also suggested the existence of negative effects and externalities arising from R&D activities. The most important are losses incurred by firms using technologies that became obsolete (Aghion & Howitt, 1992), and redundancy of research conducted by different firms in isolation (Jones & Williams, 1998). However, even considering these negative factors, different studies (Russo, 2004; Jones & Williams, 1998; and Griliches, 1992)[24] concluded that positive externalities seem to prevail, leading to suboptimal private investment in innovation and efficiency-enhancing properties of government funding.

To correct or reduce inefficiencies caused by market failures and increase the technological and growth levels of the economy, governments have a range of policy tools, such as conducting research in public laboratories and institutions, directly financing business

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[19] "Economists generally agree that the market will fail to provide sufficient quantities of R&D as it has some characteristics of a public good." (Hall & Van Reenen, 2000).
[20] "The public good character of knowledge has recently been widely recognized in economics." (Verspagen & De Loo, 1999, p. 216).
[21] "Intuitive support for the assumption of exogenous technological change might be found in the public good characteristics of innovation." (Verspagen, 1992, p. 634).
[22] "Technology is typically considered as non-rival and R&D investments have both private and public returns." (Malerba et al., 2013, p. 699).
[23] For a review of the neoclassical approach see Verspagen (1992).
[24] "In spite all of these difficulties, there has been a significant number of reasonably well done studies all pointing in the same direction: R&D spillovers are present, their magnitude may be quite large, and social rates of return remain significantly above private rates." (Griliches, 1992, p. 24).

projects, increasing human capital, and implementing economic regulation (for a review on these measures, see Edler, 2013; and Edler, Cunningham, Gök & Shapira, 2013).

According to Bloom et al. (2002), from the second half of the 20th century the U.S. and European countries adopted tax incentives to indirectly finance innovation in industry, in order to face the competition from other economies with high rates of technological progress, such as Japan and South Korea. Bloom et al. (1997) explained the evolution of these benefits in eight developed countries, drawing attention to the leadership of Canada during most of the 1980s and early 1990s. In the U.S., the 'Economic Recovery Tax Act' enacted in the early 1980s approved a tax credit for incremental R&D outlays. In the first five years, the amount of tax waiver was about seven billion U.S. dollars[25] (U.S. G.A.O., 1989; Hall, 1995).

The theoretical reasoning to justify tax incentives is the same as for other types of innovation support. Their implementation and economic rationale, however, follow a different argument. Tax incentives do not supplement private investment as direct funding schemes, but they reduce the tax cost of innovation projects (or the 'user cost of R&D capital', as the concept adopted by Bloom et al., 1997; Hall & Van Reenen, 2000; and Bloom et al., 2002), thereby increasing the number of economically profitable and viable projects.

Tax reduction affects firms' economic incentives and business strategies differently than direct funding. The main advantage of this policy strategy reported in the literature is its 'market-oriented' nature, in the sense that the government does not decide the projects to be funded (Hall & Van Reenen, 2000; OECD, 2014a). Private decision-making and allocation of resources is thus preserved, reducing allocative distortions arising from government intervention.

Moreover, tax incentives are less subject to the informational problem of public agents. EC (2014) argued that the state agent seldom is in a better position to identify projects or enterprises with greater profit or success potential. Exempting the government of such responsibility also reduces the size and cost of the administrative structure necessary to manage the incentives. Finally, this type of incentive tends to reduce uncertainty, favoring long-term business planning (Köhler et al., 2012).

Other positive features of tax incentives *vis-à-vis* direct benefits are: (a) neutrality and impartiality, for tax breaks apply to all firms indistinctly, without picking off winners (Nelson & Winter, 2005); (b) a lower sensitivity to short-run political changes (EC, 2014; Hall & Van

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[25] Nominal values.

Reenen, 2000); and (c) indirect subsidies through taxation are more tolerated in international trade agreements (OECD, 2013a).

Economic literature has also pointed to disadvantages of the fiscal approach. The leading downside is a possible low elasticity of R&D spending with respect to the reduction of tax costs due to the crowding-out effect (Hall & Van Reenen, 2000). Another drawback is the potential conflict of interests: public money should preferentially finance projects with high levels of knowledge spillovers. Companies, on the other hand, would rather reduce positive externalities by developing technologies with higher rates of appropriability and internalized returns (Hall & Van Reenen, 2000). In the extreme case of sectors with very high levels of spillovers or low private return of innovations, direct financing can be a more suitable strategy (EC, 2014).

General tax rules can also make it more difficult for incentives to be customized to suit specific cases, such as young start-ups or enterprises without a substantial taxable income base. Furthermore, a sudden increase of demand for researchers can impact wages because of inelasticity, thus reducing R&D additionality (OECD, 2014a). Avellar (2008) suggested tax reliefs may not affect firms' perception of technological risks, and therefore not increase the base of innovative companies. OECD (2011a) and Bastos (2004) challenged the neutrality argument by sustaining that tax incentives mostly benefit large corporations (although OECD, 2011a, also argued that small firms are usually more responsive to R&D tax credits).

A final and important issue that puts fiscal policies for innovation in check is government competition to attract investment, that may lead to a zero-sum game with budget reductions in all relevant countries (OECD, 2013a).[26]

### 2.2.2 Institutional arrangement and structures of tax incentives.

A tax relief is any form of discount, credit or special treatment granted by the government to firms with positive innovation spending or implementing innovative projects (OECD, 2015; EC, 2014; Köhler et al., 2012). These incentives can have different arrangements or levels of tax breaks, depending on policy objectives and specific features of the tax system. OECD (2011a, 2014a, 2015b), Van Pottelsberghe (2003), EC (2014) and Köhler et al. (2012) divide such arrangements into similar categories (with minor differences), as follows:

[26] This topic is discussed in further detail in Chapter 4.

1. *Tax credits* are subtracted directly from the amount of tax due after it has been calculated, reducing the tax burden. According to Köhler et al. (2012), it is currently the most widespread form of incentives.

2. *Allowances* are deducted from the tax base before liability is calculated, thus allowing firms to subtract R&D outlays from the taxable profit or income. In the case of special or privileged deductions (‘enhanced'), the amounts to be deducted are multiplied by a factor determined by the legislation.

3. *Accelerated depreciation or amortization* of equipment or technology acquired from third parties at higher rates for accounting purposes, reducing taxation in the short run.

4. *Reduction or exemption of taxes levied on innovation inputs*, such as researchers' compensation or value added tax on purchased equipment.

5. *Reduction or exemption of taxes levied on innovation output,* as the case of licensing rights or income arising from the sale of new products, such as "patent box" schemes (EC, 2014; OECD, 2014a; Köhler et al., 2012).

Despite the differences, it is not clear in the literature what type of incentive is more appropriate or suitable to each specific situation or objective. Such decision should be taken considering the features of each tax system, the group of potential beneficiaries and the objectives pursued by the policy. OECD (2011a) and Van Pottelsberghe (2003) presented a set of guidelines for the design of tax incentives, stressing the importance of internal coherence of the policy. EC (2014) detailed a list of best practices, that includes the use of tax credits (as opposed to enhanced allowances), input related incentives, volume-based (as opposed to incremental) and targeting young firms. It is common that different benefits are combined into a broader policy design (as presented in section 2.2.3 below).

In addition to these basic categories, there is a set of secondary features or options distinguishing tax incentives in different countries. Table 2.1 summarizes the main points discussed or reported in the literature. These studies do not recommend a best design or strategy to be followed *a priori,* although this does not mean such features are not relevant. Griffith et al. (1995) pointed out that the design of fiscal policy can substantially impact its results, generating inefficiencies or distortions on economic incentives. These features should not, therefore, be considered simple administrative details. Hall (1993) concluded that about 30% of companies benefiting from tax incentives in the U.K. actually had negative tax credit in 1989.

Many of these policy design choices imply a tradeoff between comprehensiveness and cost of the policy; or between horizontal or vertical strategies. Loose or broad definitions of R&D or authorized expenditures, for example, expand the scope of incentivized activities, but also increase the budget cost of the policy. Incentives may be applicable to the entire industry (horizontal benefits) or only to sectors deemed strategic by the government.

Table 2.1

*Possible arrangements for the design of tax incentives*

| Policy feature | Relevance for policy design | Possible arrangements |
|---|---|---|
| Definition of R&D | Identification and delimitation of incentivized projects and activities | Different possibilities (international standard - Frascati Manual, OECD, 2015a). |
| Deductible expenses | Definition of deductible operations and expenditures | (a) Cost only; and<br>(b) Cost and capital (includes purchase of equipment and capital goods). |
| Incentive scheme | Defines the R&D expenditure criteria considered to calculate the incentive | (a) Volume (all spending considered); and<br>(b) Incremental (only the amount exceeding previous years' expenditures - fixed or moving base). |
| Incentive rate | Percentage of expenditures' deduction or tax reduction | Different values. |
| Cap/ceiling | Maximum value of benefits or allowed percentage of deduction | Different values. |
| Beneficiary company | Definition of firms allowed to benefit from the tax break | (a) Only the R&D performing company; and<br>(b) Other firms of the group. |
| Targeting (1) | Features limiting the group of eligible beneficiary companies | (a) All firms (no targeting); and<br>(b) Only firms that comply with particular requirements (e.g., micro and small enterprises). |
| Targeting (2) | Beneficiary sectors | (a) Horizontal policy (applicable to all industrial sectors); and<br>(b) Vertical policy (strategic sectors or activities only). |
| Location of R&D | Location of R&D activities | (a) Only activities within the country or in particular regions; and<br>(b) No geographical restrictions. |
| Time for claiming incentives | Fiscal year in which expenditures can be deducted or tax credits can be used | (a) In the same fiscal year; and<br>(b) Subsequent (carry-forward) or previous (carry-back) years. |
| Policy term | Defines period of time for which incentives are valid | (a) Indeterminate; and<br>(b) Temporary. |

Source: Van Pottelsberghe (2003), EC (2014), OCDE, (2014a and 2015a) and Köhler et al. (2012).

### 2.2.3 Summary of the international experience.

Since the first experiences in the second half of the $20^{th}$ century, many countries have approved tax regimes that favor innovation and R&D related activities. According to an OECD report (2015a), 28 countries of the group have resorted to some form of tax relief for this purpose in 2015, in addition to other important economies like India, China, Russia, South Africa and Brazil. Deloitte (2014) presented a detailed description of incentives in thirty countries considered attractive for technological development. OECD (2014a) pointed out tax incentives are present in virtually every nation, the main exceptions being Mexico,[27] Germany,[28] Estonia and Switzerland.

As mentioned, the institutional structure of incentives varies significantly from one country to another, considering the categories and criteria described in section 2.2.2 above. Table 2.2 summarizes data collected and presented in OECD (2015b) for a group of selected countries. This schematic summary reveals the multiplicity of possible arrangements, although some practices or strategies are more frequent. Hall and Van Reenen (2000) stressed that country factors and features that lead to the design of fiscal policies is an important topic of political economy that may present important insights.[29] Köhler et al. (2012) emphasized policies impact innovation spending and firms' behavior and productive structure, including their collaboration networks, making incentives' design even more relevant.

Not only more countries are resorting to this policy tool, but its use has also been intensified, giving tax incentives a greater relevance within innovation strategies. As estimated by Warda (2013), the '*1-(b-index)*'[30] for the average of OECD countries increased from 0.02 to 0.12 for 1981 and 2011; cases of significant raise in the generosity of the tax regime happened in France (from -0.01 to 0.34), Portugal (-0.01 to 0.41), Spain (0.14 to 0.35) and South Korea (from -0.03 to 0.1). Figure 2.1 presents the evolution of this index for a group of countries, including the Brazilian case for comparative purposes, using the estimates of Araújo (2010).

Estimates of tax relief for R&D activities in OECD countries is estimated around forty billion U.S. dollars in 2013, and the value increases by another ten billion if China, Brazil and South Africa are considered (OECD, 2015b). Figure 2.2 presents the total volume of tax incentives for a group of countries in 2013. It is interesting to note that a high volume is not necessarily linked to a high rate of incentives, in light of the size of the national industry and economies of scale that arise thereof. As an example, the '*1-(b-index)*' of the two countries with highest volumes of tax breaks (U.S. and China) was 0.07 and 0.14, respectively.

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[27] According to Deloitte (2014), tax incentives were abolished as part of a reform of the fiscal legislation in 2010. They were replaced by direct funding.
[28] The country abolished tax benefits due to the complexity of the tax system (Van Pottelsberghe, 2003). Deloitte (2014) informed their reintroduction is currently under discussion.
[29] "Finally, the issue political economy cuts through many of the issues here. […] Understanding the process by which different policies are conceived and come to life is as important as evaluating their effects once they are born and grown up." (Hall & Van Reenen, 2000, p. 467).
[30] The 'b-index' measures the gross profit a representative company must have to offset a monetary unit of R&D outlay. The value is reduced by the tax incentive, for part of the cost is compensated by the benefit. Thus, the '*b-index*' decreases with an increase of the incentive rate. The '*1-(b-index)*', on the other hand, modifies such metric, turning it into a measure of tax generosity. It is directly proportional to the incentive rate.

Table 2.2

*Summary of tax incentives schemes in selected countries*

| Country | Tax credit | | Allow-ances | Accel. deprec./ amort. | Capital spending[a] | | Favored treatment for small enterprises | Innovation results |
|---|---|---|---|---|---|---|---|---|
| | Volume | Incre-mental | | | Machin-ery | Intan-gible assets | | |
| Austria | X | | | | X | X | | |
| Australia | X | | | | X | X | X | |
| Belgium | X | | X | X | | X | X | X |
| Brazil[b] | | | X | X | X | X | | |
| Canada | X | | | | | | X | |
| Chile | X | | | X | X | X | | |
| China | | | X | X | | | | X |
| South Korea | | X | | | | | X | X |
| Denmark | X | | | X | | | | |
| Spain | | X | | X | X | X | X | X |
| U.S. | | X | | | | | | |
| France | X | | | X | | X | X | X |
| Ireland | X | | | | X | X | | X |
| Iceland | X | | | | X | X | | X |
| Italy | | X | | | | X | X | |
| Japan | | X | | | | X | X | |
| Netherlands | | | X | | X | X | X | X |
| Norway | X | | | | X | | X | |
| U.K. | X | | X | X | | X | X | X |
| Russia | | | X | X | X | | | X |
| Sweden | | | | | | | | |
| Turkey | | | X | | X | X | | X |

[a] Expenditures on real estate not considered.
[b] OECD (2015b) does not mention tax incentives for machinery and equipment in Brazil. Nonetheless, Tax on Industrialized Products (IPI) exemption may be considered a tax credit, as described in section 2.4.2 below.
Source: OECD (2015b). Data refer to December 2015.

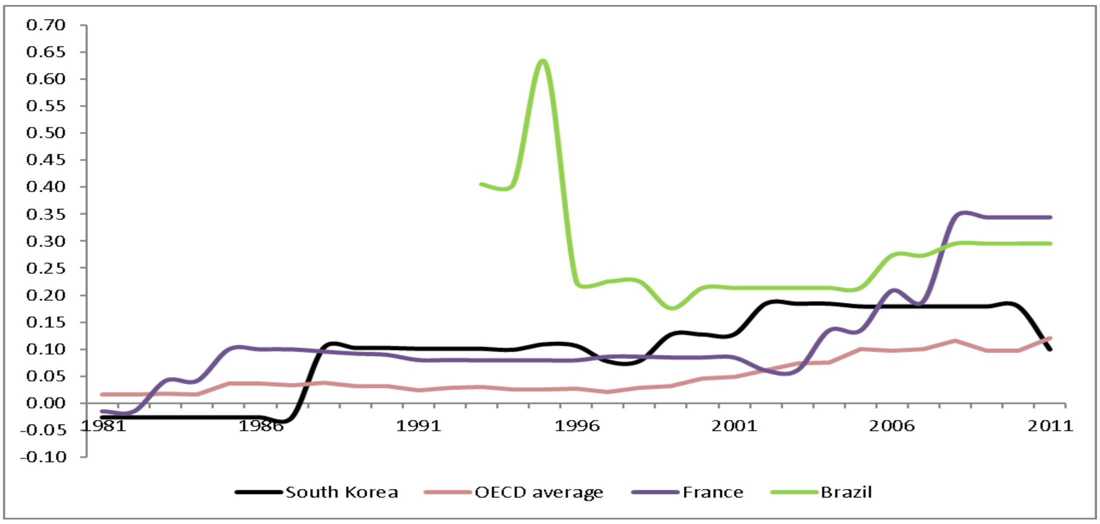


*Figure 2.1.* Evolution of the '*1-(b-index)*' for selected countries. Source: Warda (2013) and Araujo (2010).

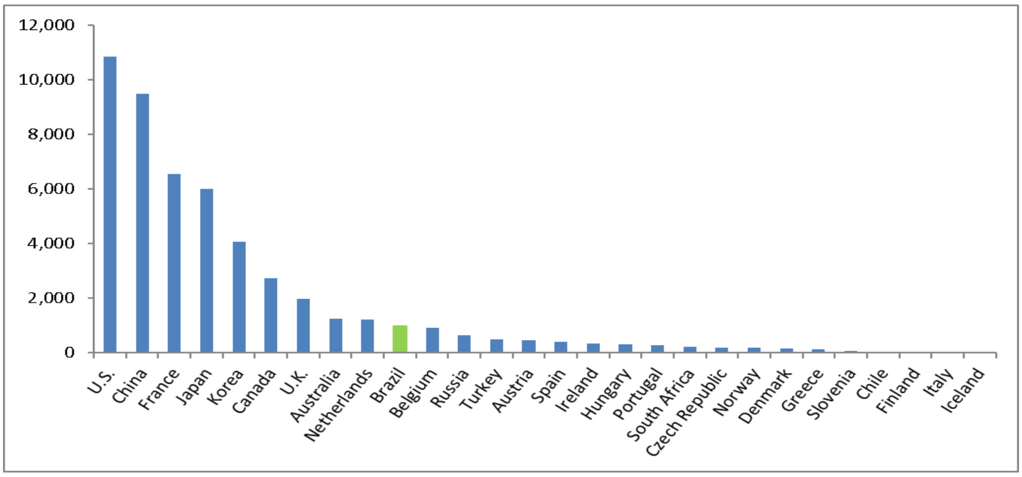


*Figure 2.2.* Volume of tax breaks for innovation in selected countries. Nominal values in US$ 1,000,000 of 2013. Source: OCDE (n.d.).

The upsurge in the values of tax waivers is influenced by the increasing importance attributed to innovation policies over the past decades, along with the rise of GDP, business R&D expenditures, and the diversification of countries and actors competing for innovation resources (OECD, 2008).[31] But these general trends only partially explain the trajectory of tax incentives. Figure 2.3 shows how much of government incentives were granted to business innovation through tax benefits in 2006 and 2013. In most countries the proportion has increased, suggesting fiscal benefits did not only increase but became relatively more important in national innovation strategies.

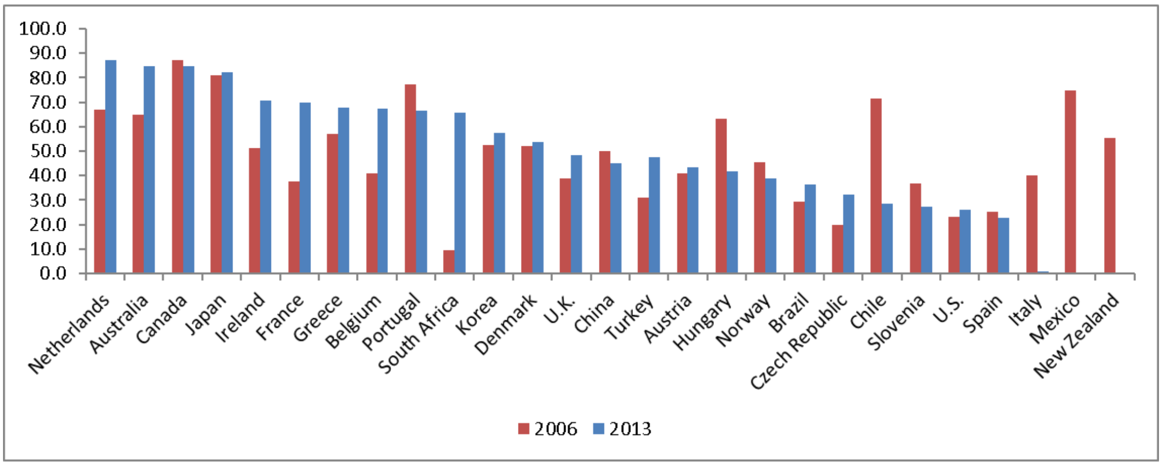


*Figure 2.3.* Tax Incentives as percentage of total government support to business R&D. Source: OECD (2015b).

[31] The rising trend was however reduced by the international crisis of 2008-2010, as companies and governments had to adjust the innovation budgets and change their composition, focusing on productivity enhancing projects and reducing fragmentation of resources (OECD, 2014a).

### 2.3 The Economic Literature on Impact Assessment of Innovation Tax Policies

The existence of theoretical arguments backing the implementation of tax measures does not mean they are necessarily successful in increasing innovation investment, in light of the shortcomings of such tools discussed in section 2.2.1. Studies assessing the impact of these policies have made substantial progress in recent decades by incorporating new quantitative and econometric methods. One of the pioneering analyses in this field is Griliches (1958), who estimated the impact of public and private funds in hybrid corn research and found positive results of government investment in R&D.

Evaluation of innovation tax policies became more frequent since the 1980s along with their increased use in different countries. A large body of literature analyzed and assessed incentives in several countries. Due to the relevance of the subject for policy recommendations and the growing number of empirical studies, different authors prepared literature surveys, trying to compare and summarize the findings and investigation strategies. I use surveys dated in different moments to track the evolution of this literature over time, summing up the main points and challenges identified at each moment in Table 2.3. Reviews and meta-analyses considered but not expressly included in the table are: Brown (1985), Daguenais et al. (1997), Mohnen (1999), Klette, Moen and Griliches (2000), Ientile and Mairesse (2009), OECD (2011a), Castellacci and Lie (2013) and Gaillard-Ladinska, Non and Straathof (2014).

These surveys suggest majority of studies reach similar conclusions for the impact of tax incentives on R&D inputs. The findings generally point to: (a) evidence of impact even in the short run; (b) a return close to (but lower than) one; and (c) a growing impact in the long run. Evolution of employed methods of analysis suggests studies at the firm level gained importance over aggregate investigations. They also became more sophisticated by using more rigorous estimation techniques (such as instrumental variables, GMM and matching). The challenges raised by more recent surveys refer to advanced and contemporary econometric and quantitative topics, instead of more general and basic problems pointed to by the first surveys.

According to Hall (1995) and Hall and Van Reenen (2000), limited availability of data explains the relative small number of studies estimating social costs and benefits of tax policies. For this reason, most of the analyses resort to the cost-benefit approach, comparing the amount of tax break with the incremental R&D by firms.

The literature surveys and meta-analyses also suggest two groups of methods for estimating the impact of tax incentives: the structural and direct approach (as the categories used by EC, 2014; and Gaillard-Ladinska et al., 2014. Hall & Van Reenen, 2000; and Ientile &

Mairesse, 2009 also mention case studies and quasi-experiments, but the volume of papers is not large).

Table 2.3

*Summary of surveys on the literature of impact assessment of tax incentives for innovation*

| Study | No. of analyzed studies | Period of publication of studies | Main methods of analysis identified | Findings on methods of analysis | Findings on impact estimate |
|---|---|---|---|---|---|
| Hall (1995) | 16 | 1983-1993 | Estimation of R&D demand equation, estimation of cost elasticity, case study and interviews. | Estimation of social return seldom applied; few studies at the firm level; administrative costs not considered. | Incremental R&D is slightly smaller than tax waive. Effects grow over time. |
| Hall and Van Reenen (2000) | 20 | 1983-1997 | Estimation of R&D demand equation, estimation of cost elasticity and case study. | Estimation of social return seldom applied; few analyzes of policies outside the U.S.; scarce attempts to assess impact on variables other than R&D expenditures. | Small impact of incentives – elasticity of R&D close to unitary; small effect on the short run, but grows with time. |
| Van Potthels-berghe (2003) | 20 | 1983-2003 | Estimation of R&D demand equation, estimation of cost elasticity and case study. | Studies at the micro level fail to consider knowledge spillovers. Studies at the macro level assign direct impacts to incentives. Analyses are complementary. | Tax incentives increase R&D spending; low price elasticity; larger long-run effects. |
| Köhler, et al. (2012) | 18 | 1993-2012 | Estimation of R&D demand equation, estimation of cost elasticity, matching, regressions using different estimators (logit, probit, GMM) | Main shortcomings: reverse causality; valid instrumental variables; high adjustment costs; definition of a control group; relabeling; dated studies. | Incentives impact R&D spending even in the short run; tax credits and incentives on total R&D have higher impact; firms' innovation rate is also affected, but impact on productivity is unclear. |
| EC (2014) | 34 | 1997-2013 | Structural Approach[a] Direct Approach [b] | Main challenges: use of natural and social experiments; reverse causality; selection bias; adjustment costs; relabeling; multiple treatments; publication bias; emphasis of the literature on R&D spending. | Most studies identify impact on R&D spending. More rigorous studies identify elasticity less than one. Incentives impact innovation generated by firms. Results vary according to the design of incentive and size of firms. |

[a] Estimates elasticity of R&D to changes in the tax cost.
[b] Compares treatment and control groups.

In the structural approach the researcher estimates the change in the innovation investment levels caused by a reduction of the user cost of R&D using a model expressed by an R&D demand equation (EC, 2014). The concept was developed and first used by Hall and Jorgenson (1967), Auerbach (1982) and King and Furleton (1984), and it aims to summarize in a single measure the tradeoff of innovation projects faced by firms, including capital depreciation, tax costs, and discount rate (Auerbach, 1982; Wilson, 2009). The estimated coefficient of the user cost of R&D variable represents the elasticity of spending. A similar but alternative technique replaces the variable for a dummy indicating the firm received tax incentives (Hall, 1995).

The structural approach was the chief method used in studies during the 1980s and 1990s. Some of the papers using this method are Eisner et al. (1984), Bernstein (1986), Hall (1993), Berger (1993), Daguenais et al. (1997), Bloom et al. (1998), Bloom et al. (2002), Klassen et al. (2004), Wilson (2009), McKenzie and Sershun (2010) and Crespi, Giuliodori, Giuliodori and Rodriguez (2016). Its main advantage is the theoretical foundation, for it requires an explicit model explaining how tax incentives impact R&D spending. The main drawback, on the other hand, is the reverse causality problem. As tax incentives and innovation investment are simultaneously observed and assessed, this raises concerns about endogeneity and consistency of regressions.

The direct approach is more recent (all studies mentioned in EC, 2014, were published after 1990). Impact is estimated as a treatment effect or through regressions that do not require an implicit economic structural model. It relies less on economic theory and uses the comparison between treatment and selected control groups (EC, 2014). Such empirical strategies necessarily employ analysis at the firm level, thus requiring greater data availability.

The main advantage of the direct approach is the array of statistical techniques and econometrics. On the other hand, it usually lacks (or is not built upon) an economic model that explains firms' behavior and how they react to tax incentives. Moreover, considering tax benefits are rarely assigned randomly, estimation in this case is subject to selection bias, meaning treated companies may be intrinsically superior to the control group, thus overestimating treatment effects. Different techniques are used in order to mitigate this problem, such as matching, difference-in-differences and sensitivity analysis.

Table 2.4 presents an overview of selected studies using the direct approach.[32] The table specifies the country or region considered in each study, the main methodological choices and findings. Although this literature review is limited to tax incentives, the approach has also been extensively used to evaluate direct government funding for innovation, as in Aschhoof (2009), Almus and Czarnitzki (2003), Benavente et al. (2012), Araujo et al. (2012) and De Negri et al. (2009).[33]

[32] This literature summary is limited to such method because it is the one applied in this empirical study, as justified in section 5.
[33] For a review of the literature on direct incentives, see Cunningham, Gök and Larédo (2012).

Table 2.4

*Literature review – Estimation of Impact of Tax Incentives Using the Direct Approach*

| Study | Country / region | Dependent variable (input)[a] | Dependent variable (output) | Estimator / empirical strategy | Tax incentive variable | Main findings |
|---|---|---|---|---|---|---|
| Guceri (2015) | UK | R&D spending | | Diff-in-diff | Treatment dummy | 18% increase in R&D spending. |
| Aralica et al. (2013) | Croatia | R&D spending | New products<br>New processes | Matching – nearest neighbor; kernel; within caliper | Treatment dummy | Incentives increase the number of innovative firms, but not R&D spending; significant impact on new products, not on new processes. |
| Dumont (2013) | Belgium | Private R&D spending | | Two-stages Heckman<br>Maximum likelihood | Tax incentives only or with regional subsidies | Additionality effect of tax incentives decreases if firms also receive regional subsidies. |
| Yang et al. (2012) | Taiwan | R&D spending | | Kernel matching | Treatment dummy | 53.8% increase on R&D spending; impact varies according to the sector. |
| Duguet (2012) | France | Private R&D spending; no. of researchers | | Kernel matching | Treatment dummy | Incentives increase R&D and number of researchers. |
| Czarnitzki et al. (2011) | Canada | | New product; new product sales; originality of innovation; profitability of firm; Market share; competitiveness | Nearest neighbor matching | Treatment dummy | Impact on new products, sale of new products and originality of innovation; no significant difference in performance variables (profitability, market share and competitiveness). |
| Carboni (2011) | Italy | Private R&D spending | | Nearest neighbor matching | Treatment dummy | Increase of € 1,163.00 in R&D spending. Tax incentives have a greater impact than direct incentives. |
| Yohei (2011) | Japan | R&D spending | | Matching - nearest neighbor; kernel; within caliper | Treatment dummy | Incentives impact decision to carry out R&D, and increases spending by more than two times. |

(continued)

| Study | Country / region | Dependent variable (input)[a] | Dependent variable (output) | Estimator / empirical strategy | Tax incentive variable | Main findings |
|---|---|---|---|---|---|---|
| Bérubé and Mohnen (2009) | Canada | | New product sales; new product; innovation novelty | Nearest neighbor matching | Tax incentives only or with direct funding | Firms receiving both tax incentives and direct funding innovate more and with greater originality. |
| Corchuelo and Martinez-Ros (2009) | Spain | R&D spending | | Two-stages Heckman<br>Matching – nearest neighbor; kernel | Treatment dummy | Incentives positively affect technological efforts, but impact is only significant for large firms. |
| Hægeland and Møen (2007) | Norway | R&D spending | | Diff-in-diff | Treatment dummy | Positive impact on number of innovative firms and R&D spending; greater impact on smaller firms, with low technological levels or skills.<br>Weak impact on cooperation with universities. |
| Ho (2006) | US | R&D spending<br>Employment | | Diff-in-diff<br>Diff-in-diff-in-diff<br>Matching – nearest neighbor; within caliper | Treatment dummy | Positive impact on R & D spending; no evidence of impact on employment in the whole sample. Weak evidence of positive impact on high-tech industry. |
| Avellar (2008) | Brazil | R&D spending<br>Innovation expenditures | | Nearest neighbor matching | Treatment dummy | Beneficiary firms increased R&D spending by 64%. No significant impact on innovation expenditures. |
| Kannebley Jr. and Porto (2012) | Brazil | Technical personnel | | Tobit with fixed effects<br>Matching – nearest neighbor; kernel; within caliper | Treatment dummy | Informatics Law: no evidence of significant impact on R&D spending; Law 11,196/05: significant impact on R&D of 7% to 11% on average. |
| Kannebley Jr., Araújo, Maffioli and Stucchi (2013) | Brazil | Technical personnel | Export performance, size labor productivity, indirect effects (spillovers) | Random and fixed effects panel estimators | Treatment dummy | Positive effects on hiring of technical personnel (7%), firm size (from 5.7% to 8.5%) and exports per employee. Significant indirect effects of the policy. Effect on labor productivity is unclear. |
| Shimada, Kannebley Jr. and De Negri (2014) | Brazil | R&D spending<br>Technical personnel | | Tobit with fixed effects<br>Nearest neighbor matching | Treatment dummy | Significant impact of 86% to 108% on R&D spending, and of 9% on technical personnel. |

[a] The variable "R&D spending" is used in different forms (absolute value, value per worker, log-linear transformation, growth rate or percentage of sales).

The results of these studies confirm what the literature surveys previously discussed. They all identify a significant impact of tax incentives on innovation input, although the magnitude of the effect varies and some specific results are conflicting (Corchuelo & Martinez-Ros, 2009 did not find significant results for small firms, while Hægeland & Moen, 2007 found the additionality for these companies to be higher than for other groups).

The majority of studies limit their analysis to the impact of incentives on R&D spending or innovation inputs, confirming the conclusions of Hall and Van Reenen (2000) and EC (2014). The few studies that investigated innovation output found significant results, suggesting these are relevant matters to be addressed. Firms' performance, on the other hand, is mainly analyzed by Czarnitzki, Hanel and Rosa (2011), who could not find significant differences between treated and control units, and Kannebley Jr., Araújo, Maffioli and Stucchi (2013), who found impact on export levels.

The most frequent empirical strategies used to mitigate the selection bias problem are the propensity score matching (with nearest neighbor, kernel and radius matching algorithm) and two-stages Heckman estimation.

Table A2.1 in the Appendix builds on the literature review by presenting information on covariates used in each study to match treatment and control groups. It is relevant to note the diversity of variables considered in each study. This may be partially attributed to different understandings among scholars about relevant factors affecting probability of treatment, but it also reflects differences in the requirements and institutional design of tax policies, along with data availability for each country. One can find, nonetheless, that the following group of variables is more frequently employed in these studies: (a) firm size (measured by number of employees); (b) economic sector; (c) geographical location; (d) exports; (e) age; and (f) a measure of financial constraint or availability of resources (measured either by size of debts, profitability or access to external funds).

Nearly all studies displayed in Table 2.4 investigate policies implemented in developed countries. One of the few exceptions, Aralica et al. (2013) noted one should not expect the same results to be found in developing economies as in developed countries. In this case, firms' behavior and technological strategies are more focused on improving productivity through acquisition of new equipment and knowledge from companies in developed countries.

Finally, the last four papers of the table are studies that evaluated tax incentives for innovation in Brazil using the direct approach. Avellar (2008) investigates the impact of the previous policy in place until 2005. Kannebley Jr. and Porto (2012), Kannebley et al. (2013) and Shimada et al. (2014) analyzed the current policy established by Law 11,196/05. The results of these papers do not present relevant differences from international studies, except for Kannebley Jr. and Porto's (2012) findings that the national informatics policy did not have a significant impact on the industry's innovation levels.

## 2.4 Tax Incentives for Innovation in Brazil: The Law 11,196/05

This section describes the fiscal policy for innovation in Brazil, including a brief review of the political context in which these measures were adopted (subsection 2.4.1), the institutional framework and main rules shaping the incentives (subsection 2.4.2), main aggregate data available on the tax waiver and beneficiary companies (subsection 2.4.3), and previous studies on and evaluations of the policy (subsection 2.4.4).

### 2.4.1 Industrial policy and tax incentives for innovation in Brazil as from the 1990s.

Tax benefits became relevant as a policy tool to increase industry's competitiveness and technology levels in Brazil from the beginning of the 1990s. This policy shift can be better understood in the context of the broad structural reform taking place in the country during this period, affecting the monetary, fiscal and foreign trade policies, with the objective of promoting liberalization and opening of the market to foreign competition (Baumann, 1999; Castro, 2011; Pinheiro, Gill, Servén & Thomas, 2004).

These reforms changed the landscape of the Brazilian science and technology policy. Up to that point, the focus of the government had been on building up a research infrastructure by setting up and equipping laboratories and research institutes. Promoting business innovation was not considered a priority (Tigre et al., 1999). The Industrial and Foreign Trade Policy[34] enacted by President Collor de Mello in 1990, on the other hand, was based on fostering competition and competitiveness of national firms (Erber & Vermulm, 1993). The government reduced (or, in some cases, extinguished) market reserve and protectionist measures, and tax breaks were used to preserve the national industrial sector and foster its technological development. The Informatics Law (Law 8,248/91) and the reform of the Manaus Free Trade Zone (Law 8,387/91) are examples of such policies.

In 1993, the government enacted Law 8,661/03, approving a comprehensive innovation tax policy for the industry (the Industrial Technological Development Program[35] - PDTI) and

[34] "*Política Industrial e de Comércio Exterior*".
[35] "*Programa de Desenvolvimento Tecnológico Industrial*".

for the agricultural sector (the Agricultural Technological Development Program[36] - PDTA). In the case of PDTI, the benefits were: deductibility of R&D expenses from the income tax base (IR) up to 8% of the total tax due; exemption of the Tax for Industrialized Products (IPI)[37] for equipment and machinery; accelerated depreciation or amortization of purchased machinery, equipment and technology; tax credit for withhold income tax and reduction of the Tax on Financial Operations in the case of payments of royalties abroad; and deductibility of payments for technology transfer agreements (Law 8,661/93, art. 4, I to VI).

The PDTI tax incentives were later substantially reduced, as part of a broader fiscal reform introduced by Law 9,532/97. Tigre et al. (1999) argued that such incentives were 'virtually extinguished', a reference to the drop on the number of approved projects (Corder & Salles-Filho, 2004). New incentives were later introduced by Law 10,637/02: benefiting firms were allowed to deduct R&D spending from the income tax base for the purpose of calculating both the IR and the Social Contribution on Net Profit (CSLL).[38]

The number of beneficiary firms and the results of the PDTI may be considered modest, if taken into account that this was a comprehensive policy applicable to the entire industrial sector. In eleven years, only 267 companies benefited from the program, and the total volume of tax breaks did not reach 100 million U.S. dollars[39] (Avellar, 2008). According to Pacheco (2007) and Corder and Salles-Filho (2004), the main problems that impaired a further expansion of the PDTI were the high concentration of R&D activities in a few industrial groups and the non-applicability of the most important incentive, deductibility for income tax calculation, to small businesses.

Nevertheless, Pacheco (2007) and Avellar (2008) highlighted the leverage of the policy, with high values of R&D investment per beneficiary firms. Furthermore, the empirical study by Avellar (2008) found statistically significant impacts of the PDTI for R&D spending of 86% to 108%.

In the first half of the 2000s, a new industrial policy framework brought tax incentives to a more central position in the innovation policy debate. The Industrial, Technological and Foreign Trade Policy (PITCE)[40] of 2003 emphasized the importance of innovation from a different perspective than development policies of the 1970s and 1980s, focusing on raising competitiveness and building comparative advantages at the international level. According to

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[36] "*Programa de Desenvolvimento Tecnológico da Agropecuário*".
[37] "*Imposto sobre Produtos Industrializados*".
[38] "*Contribuição Social sobre o Lucro Líquido*".
[39] Nominal value.
[40] "*Política Industrial, Tecnológica e de Comércio Exterior*".

Campanário, Silva and Costa (2005), horizontal policy and innovation are cornerstones of the PITCE.

In light of this new policy concept, in 2004 Congress approved Law 10,973/04, also known as the "Innovation Law", with a set of regulations and incentives to foster innovation, entrepreneurial R&D, and also cooperation between companies and research institutes. The law provided for the approval of new tax incentives, according to a bill to be proposed by the government executive branch (art. 28 of Law 10,973/04).

The federal government enacted Provisional Measure 252/05, with a set of tax reductions to boost the economy and increase competitiveness of the productive sector. Tax incentives for innovation were designed as part of this broader tax reform. The Explanatory Memorandum submitted by the Ministries of Finance and of Development, Industry and Foreign Trade stated: "[...] the adopted measures increase the economic efficiency and support productive investment, creating conditions for a faster growth over the next years [...]".[41]

Provisional Measure 252/05 became ineffective as it was not approved by Congress within the time limit determined by the Brazilian Constitution.[42] The incentives and tax breaks were later included into another bill (result of Congress debates on Provisional Measure 255/05) that was approved and converted into Law 11.196/05, commonly referred to as "Law of Goodness".

### 2.4.2 The Tax Incentives of Law 11,196/05.

Chapter III of Law 11,196/05 ended the PDTI, while establishing a new institutional framework expanding tax incentives for innovation. At first the law provided for six tax benefits, but this number was later increased by amendments introduced by Laws 11,487/07, 11,744/08 and 12,350/10. Table 2.5 describes and classifies the incentives according to the analytical groups discussed in subsection 2.2.2 above.

The law adopts a broad and internationally accepted definition of technological innovation as any new product or manufacturing process that enhances productivity or increases competitiveness, following the Oslo (OECD, 2005) and Frascati (OECD, 2015a) Manuals. Deductible expenses are all labeled by the law as ‘research and development’, although such concept actually encompasses a far broader range of activities than the ‘strict R&D’ defined in

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[41] “[...] *as medidas ora adotadas, ao ampliar a eficiência econômica e estimular o investimento produtivo, criam condições para um crescimento mais acelerado da economia ao longo dos próximos anos* [...]”. (CD, n.d.).

[42] Art. 62 of the Federal Constitution determines provisional measures should lose effectiveness if not converted into law within a period of sixty days, renewable once for an identical period of time.

the mentioned international references. Art. 2 of Decree 5,798/06 states deductible expenses includes basic and applied research, experimental development, basic industrial technology, and technical support services.

Table 2.5

*Tax incentives of Law 11,196/05 and later amendments*

| Activity or spending | Relevant tax | Type of incentive | Description of the incentives |
|---|---|---|---|
| R&D expenditures | | | |
| Internal R&D spending, contracts with universities or research institutes; outsourcing to micro and small firms | IR[a] CSLL[b] | Allowance | Deduction of 160% of R&D spending (art. 17, I, §2 and art. 19)<br>Additional 20% deduction in case of new research staff (art. 19, §1)<br>Additional 20% deduction in the case of patented or registered agricultural product (art. 19, §3) |
| Research projects with science and technology institutes | IR[a] CSLL[b] | Allowance | 50% to 250% of the cost of the Project (does not add to other incentives; art. 19-A)[e] |
| Fixed capital expenditures | | | |
| Purchase of machinery and equipment | IPI[c] | Tax reduction | 50% of the tax value (art. 17, II) |
| | IR[a] | Accelerated depreciation | Full depreciation at the first year (art. 17, III)[f] |
| | CSLL[b] | Accelerated depreciation | Full depreciation at the first year (art. 17, III)[f] |
| Purchase of facilities, machinery and equipment | IR[a] | Allowance | Non-depreciated assets may be deducted from profit tax base (art. 20)[e] |
| Intangible goods | IR[a] | Accelerated amortization | Full depreciation at the first year (art. 17, IV)[e] |
| IP protection | | | |
| Registration of intellectual property | IRF[d] | Tax reduction | Total exemption (art. 17, VI)[e] |

[a] Income Tax.
[b] Social Contribution on Net Profit.
[c] Tax on Industrialized Products.
[d] Withhold Income Tax.
[e] According to an amendment by Law 11,487/07.
[f] According to an amendment by Law 11,774/08.

The law does not clearly state the requirements for firms to benefit from the tax incentives. Taking only the deductibility of R&D expenses (the most important incentive in terms of volume, as discussed below), the minimum eligibility requirements are:

1. operate under the real profit tax regime: this is the tax base from which expenditures are deducted (art. 19);
2. tax clearance certificate (art. 23);
3. R&D expenditures during the fiscal year; and
4. taxable income at the same fiscal year: the law does not provide for deduction of expenses in subsequent or previous years (carryforward or carryback schemes).

In the case of IPI reduction for the purchase of machinery and equipment, the only requirement established by the law is proof of tax clearance.

The incentives may be considered a horizontal policy, in the sense they do not focus on specific industrial sectors or activities nor differentiate rates according to geographical criteria. The law requires, however, that spending should be made or paid to persons or companies located within national territory (art. 22, II).

Unlike other countries (see Table 2.2), Brazil does not adopt any favored treatment for small enterprises, with the only exception that R&D outsourced to these firms can be included in the calculation of incentives by the contracting company.

The policy design actually makes it more difficult for small firms to obtain the tax benefits. The requirement that companies operate under the real profit tax regime works as an entry barrier. Pursuant to the Brazilian tax legislation, firms with yearly revenue of up to 78 million Brazilian *reais* (around twenty-five million U.S. dollars)[43] can opt for the presumed profit regime (excluding specific cases such as financial institutions), and those with even lower income (up to 3.6 million Brazilian *reais* or approximately one point two million U.S. dollars[44] annually) can opt for the SIMPLES regime.[45] In such cases, the law assumes a percentage of the revenue to be considered as profit for tax purposes. As these schemes are based on a presumed tax base, regulations expressly forbid these companies to benefit from any tax deduction,[46] including those provided for in Law 11,196/05.

In order to better understand how restrictive this limitation is under an innovation policy perspective, it is worth considering that in 2013 only 155,000 firms opted for the real profit tax regime, which represents approximately 3% of the total number of operating companies in the country in that year (Receita Federal, 2015).

Regarding the duration of the policy, currently the law does not establish any deadline for the incentives, neither a maximum time limit nor a number of years for a company to benefit from them.

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[43] Considering the exchange rate of R$1,00=US$ 0,30, effective on August 3rd, 2016.
[44] Considering the exchange rate of R$1,00=US$ 0,30, effective on August 3rd, 2016.
[45] "*Regime Especial Unificado de Arrecadação de Tributos e Contribuições devidos pelas Microempresas e Empresas de Pequeno Porte - SIMPLES Nacional*".
[46] Decree 3.000/99, art. 526; and art. 19 of Normative Instruction SRF 608/06.

### 2.4.3 Main aggregate data about the incentives.

Firms claiming tax incentives must submit each year a report to the Ministry of Science, Technology and Innovation (MCTI),[47] detailing the activities and expenditures to be deducted for tax purposes. Based on this information, MCTI publishes an annual report of tax incentives for innovation with aggregate data on beneficiary firms. According to the 2014 report, around twelve hundred companies claimed at least one of the incentives provided by the law that year. MCTI technical staff recommended the approval for nearly a thousand firms (MCTI, 2016).[48]

Figure 2.4 and Figure 2.5 present the evolution of the main indicators of incentives: The first displays total volume of R&D investment and tax break of beneficiary firms, as well as the leverage of the policy; and the second shows the total number of recommended firms, along with the average tax incentive and R&D investment per year.

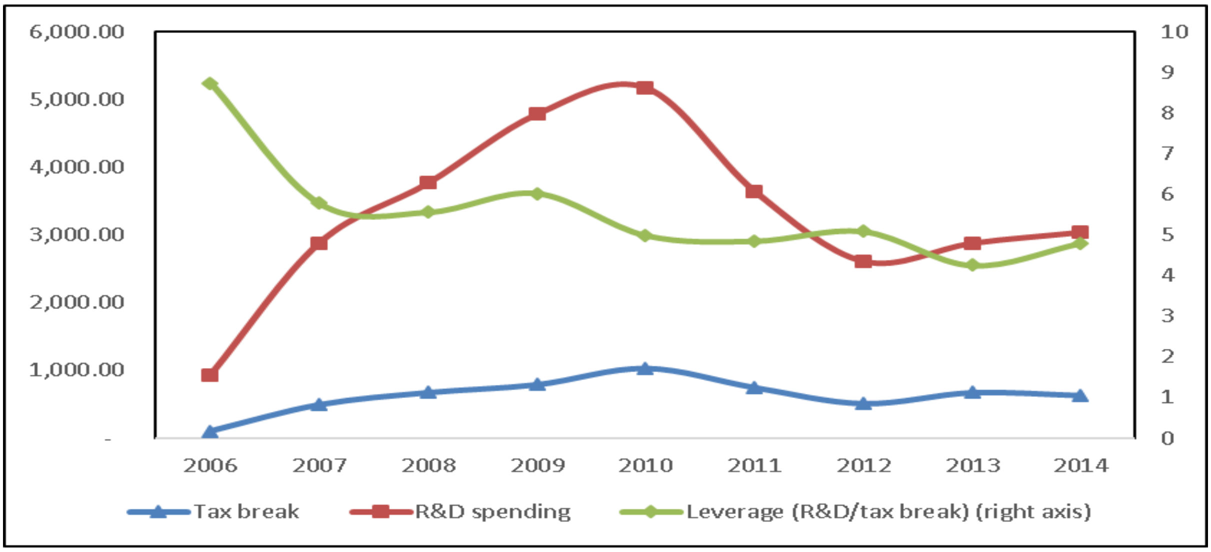


*Figure 2.4.* Aggregate investment in R&D, tax break and policy leverage for the group of beneficiary firms (recommended by the MCTI). Real values in U.S.$ 1,000,000. Values adjusted according to the exchange rate applicable on the last day of each fiscal year. Source: MCTI (2016, 2015, 2013, 2012, 2011, 2010, 2009, 2008, 2007).

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[47] Currently the Ministry of Science, Technology, Innovations and Communications.

[48] The MCTI technical staff merely checks if firms complied with the legal requirements. Such analysis does not constitute prior approval of the incentives by government officials.

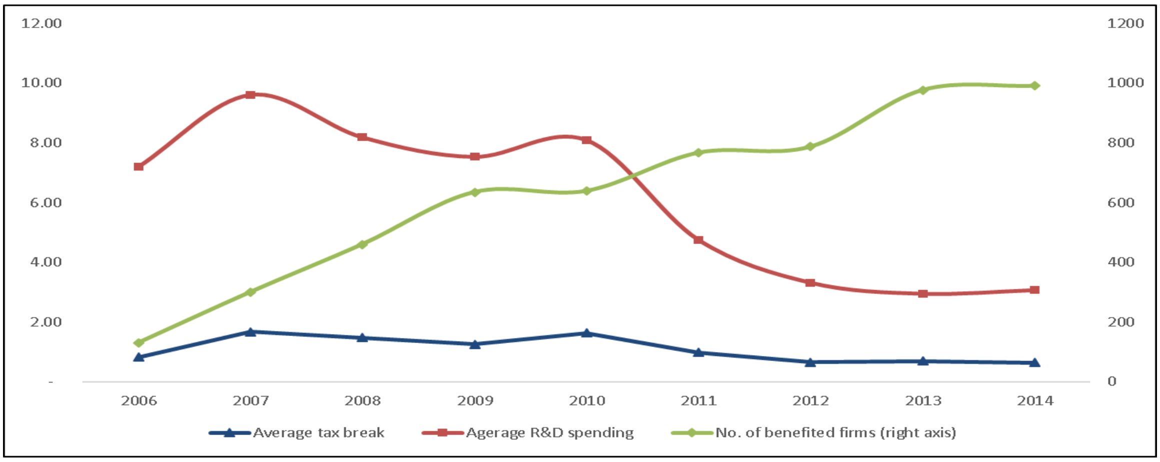


*Figure 2.5.* Average investment in R&D and tax incentive per firm; number of beneficiary companies (recommended by the MCTI). Real values in U.S.$ 1,000,000. Values adjusted according to the exchange rate applicable on the last day of each fiscal year. Source: MCTI (2016, 2015, 2013, 2012, 2011, 2010, 2009, 2008, 2007).

Comparing these data against the previous policy (the PDTI) as discussed above, one can see the new framework established by Law 11,196/05 constituted a turning point in terms of the number of beneficiary companies and volume of incentives. During the early years (2006-2009), innovation investment and tax incentives grew sharply. In the following period (2010-2012), however, both indicators experienced a decrease, in spite of the continuous rise in the number of participating companies. The MCTI attributed this problem to "bad economic results", without providing further details (MCTI, 2013, p. 25). The growing number of beneficiary firms along with the drop of aggregate investment and tax breaks led to a sharp decline in the average indicators per firm, as shown in Figure 2.5. The last two years of the series (2013-2014) suggest the downward trend may have ceased, which can only be assessed once data for the following years are disclosed.

Table 2.6 shows the number of beneficiary firms per region, according to data disclosed by MCTI. Most of the companies are located in the southeast, particularly in the state of São Paulo. Beneficiary firms operate in different industrial sectors, as presented in Table 2.7. The industries with the highest levels of participation in the policy are transport equipment, software, chemical/petrochemical and electronics.

As a last remark, according to the MCTI report (MCTI, 2016), deductibility of R&D expenses represents the largest bulk of incentives petitioned by firms. Around 74% of the total refers to deduction from the income tax base, 26% refers to deduction from CSLL, and less than 1% comes from the reduction of the IPI (data refers to 2014).

Table 2.6

*Beneficiary firms, innovation investment, and volume of tax break per country region (2014).*

| Country region | Beneficiary firms | | Innovation Investment | | Tax incentives | |
|---|---|---|---|---|---|---|
| | No | % | U.S. millions | % | U.S. millions | % |
| Southeast | 727.00 | 60.28 | 2349.03 | 77.29 | 485.43 | 76.70 |
| South | 388.00 | 32.17 | 435.97 | 14.34 | 93.76 | 14.82 |
| Northeast | 43.00 | 3.57 | 81.43 | 2.68 | 18.55 | 2.93 |
| North | 26.00 | 2.16 | 145.72 | 4.79 | 29.79 | 4.71 |
| Midwest | 22.00 | 1.82 | 27.03 | 0.89 | 5.34 | 0.84 |
| Total | 1206 | 100 | 3039.18 | 100 | 632.86 | 100 |

[a] Only firms recommended by the MCTI.
Source: MCTI, 2016.

Table 2.7

*Number of beneficiary firms per year and industrial sector*

| Industrial Sector | Number of beneficiary firms[a] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Year | | | | | | | | |
| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
| Transport equipment | 30 | 81 | 114 | 111 | 147 | 154 | 125 | 189 | 190 |
| Software | 4 | 1 | 20 | 31 | 45 | 57 | 65 | 98 | 141 |
| Chemical / Petrochemical | 22 | 26 | 32 | 55 | 67 | 70 | 99 | 97 | 81 |
| Electronics | 13 | 45 | 66 | 53 | 42 | 65 | 57 | 72 | 86 |
| Food | 4 | 14 | 33 | 40 | 46 | 57 | 67 | 71 | 74 |
| Consumer goods | 2 | 21 | 33 | 37 | 46 | 52 | 49 | 59 | 36 |
| Metallurgy | 22 | 26 | 32 | 43 | 45 | 43 | 47 | 43 | 39 |
| Pharmaceutical | 11 | 13 | 16 | 31 | 37 | 37 | 42 | 39 | 44 |
| Mining | 2 | 1 | 1 | 4 | 7 | 13 | 18 | 19 | 17 |
| Paper | 5 | 7 | 7 | 12 | 13 | 14 | 17 | 17 | 19 |
| Textile | 1 | 4 | 6 | 9 | 9 | 10 | 6 | 17 | 4 |
| Construction | 3 | 7 | 17 | 17 | 7 | 13 | 11 | 16 | 17 |
| Furniture | 0 | 8 | 11 | 14 | 8 | 21 | 22 | 15 | 4 |
| Agribusiness | 0 | 14 | 23 | 20 | 10 | 13 | 11 | 13 | 15 |
| Telecommunications | 0 | 3 | 17 | 21 | 6 | 2 | 1 | 9 | 12 |
| Others | 11 | 29 | 32 | 44 | 104 | 146 | 150 | 203 | 212 |
| Total | 130 | 300 | 460 | 542 | 639 | 767 | 787 | 977 | 991 |

[a] Only firms recommended by the MCTI.
Source: MCTI (2016, 2015, 2013, 2012, 2011, 2010, 2009, 2008 and 2007).

### 2.4.4 Previous studies and evaluations.

The MCTI annual reports have a descriptive and informative character and do not focus on measuring the results or the impacts of the incentives. They present, nevertheless, general conclusions and information regarding the implementation of the policy. The 2014 report (MCTI, 2016) affirmed that Law 11,196/05 supports the development of business R&D,

improving and adding new features to products and processes. It also presented a critical appraisal about the innovation projects described by firms, noting that in many cases they fail to adequately explain the new technology and novelty of the research. Problems in the spending breakdown are also common (MCTI, 2016). The general picture points to R&D not being a systematic and continuous activity conducted by the firms, thus raising problems in its implementation and bookkeeping.

So far only few studies have investigated and assessed the results of tax incentives for innovation of Law 11,196/05. Three of them are econometric assessments mentioned in Table 2.4. In Kannebley Jr. and Porto (2012) and Shimada et al. (2014), the objective is to evaluate the policy impact on innovation inputs. Both papers present similarities in their empirical strategy approach and choice of estimators: they first apply a matching algorithm to select a control group, which is followed by panel data with fixed effects estimators. Kannebley Jr. and Porto (2012) used research technical staff as the dependent variable, and Shimada et al. (2014) also introduced R&D expenditures. Both studies found similar additionality impact on research technical staff (around 10%), while the effect on R&D spending found by Shimada et al. (2014) is substantially higher (over 100%).

Kannebley Jr. and Porto (2012) also employed qualitative techniques to evaluate the policy, based on interviews with firms' management. They claimed the incentives were relevant to preserve the levels of R&D investment and take higher risks. They also enabled firms to intensify or pursue their innovation strategies further, in accordance with the 'market-oriented' nature of tax incentives argument. The shortcomings pointed by firms were mainly related to the management and control processes established by government authorities, rather than to the incentives themselves. Documents and bureaucratic procedures were considered excessive and burdensome, and particularly not suited for small and medium-sized enterprises.

Kannebley Jr. et al. (2013) investigated the effects of incentives on firm size export variables. According to their findings, the policy does not impact probability of exporting (export status), but it does impact export per employee, technical personnel and firm size. They also found significant indirect effects of the policy due to labor mobility (spillovers).

Other studies used different methodologies to evaluate the incentives. Araujo (2010) calculated their impact on the '*b-index*' around 8%, with further reductions due to subsequent amendments. Calzolaio and Dathen (2012) used aggregate data and found the law intensified innovation activities but failed to increase the pool of innovative firms. Fabiani and Sbragia (2016) analyzed data from 26 beneficiary firms and concluded the incentives are relevant to foster R&D but improvements on the policy design are necessary to increase results. Matias-

Pereira (2015) analyzed the MCTI reports and other studies and found evidence that gains were achieved by participating companies.

## 2.5 Empirical Analysis: Research Strategy and Data

The econometric study described herein aims to assess and estimate the impact of the tax incentives provided by Law 11,196/05 on beneficiary firms. The first part of the investigation focuses on firms' innovation efforts and investment. The objective is to test for the presence and to measure the magnitude of additionality effects of the incentives, so as to verify whether there was an actual increase in the levels of innovation inputs, or if this is a case of full crowding-out, in which firms diverted additional resources to other activities.

The presence of positive impacts on inputs does not necessarily imply that outputs and firms' performance are also positively affected. The final outcome of innovation projects is influenced by different factors other than total volume of investment. As discussed in section 2.2.1 above, there are arguments to maintain that outputs may not be impacted by public support, even if inputs are: (a) moral hazard, suggesting firms develop riskier projects when financed by public funds (Arrow, 1962); (b) upsurge of inputs' price, especially through researchers' compensation; and (c) relabeling of different activities as innovation expenditures. For these reasons, the second part of this empirical investigation assesses whether the fiscal policy had any observable and measurable impact on firms' innovation results and business performance.

For this study, I use disaggregate data at firm level and adopt the direct approach mentioned in section 2.3 above. Treatment impact is estimated through propensity score matching (PSM) with difference-in-differences, following part of the literature summarized in Table 2.4. The main references used for the development of the empirical strategy are Rosenbaum and Rubin (1983), Dehejia and Wahba (1999, 2002), Caliendo and Kopeinig (2005), Wooldridge (2002) and Rosenbaum (2010), to which I refer to for a detailed explanation of the PSM method.

This empirical strategy was chosen for a number of reasons. First, the available data is more suited for this method, for the identification of beneficiary firms is disclosed in MCTI annual reports, but the breakdown of incentives per company is classified information and not available under Brazilian law. With such information, it was possible to generate binary treatment dummy variables indicating participation in the policy, and dividing firms into treatment and control groups.[49]

Furthermore, by ensuring the common support assumption and balancing the distribution of covariates, PSM permits a direct comparison of outcomes and a more robust estimation of causality. Linear regression analyses, on the other hand, commonly uses all units within the sample, skipping or disregarding large differences between them, thus affecting the consistency and reliability of results (Domingue & Briggs, 2009).[50]

Another advantage of PSM is it does not depend on the correct functional form of the model to estimate the causality between treatment and outcome variables (Zanutto, 2006). Rubin (2006) also mentioned PSM enjoys an "ethical advantage", because the outcome variable is not considered in the estimation of the propensity score, therefore it does not influence the treatment probability model. This is not the case in most linear or parametric regressions.

Finally, the direct approach is currently applied in a great number of empirical studies investigating innovation policies, as discussed in section 2.3. The use of the same research method makes the results more comparable with this literature.

This empirical research complements and advances in several ways the previous quantitative impact assessments of the tax incentives provided by Law 11,196/05 (as mentioned in Table 2.4). First, the impact of the policy is measured not only on R&D spending but also on the broad category of innovative activities (as defined in subsection 2.5.4). Second, I also investigate whether the policy increased the base of companies investing and achieving innovation. And, finally, I investigate a group of innovation output and firms' performance variables not considered by previous studies: probability of innovation; share of new products in sales and exports; net revenue and net revenue per employee. These additional variables provide a more comprehensive and detailed understanding of how the policy affects the technological efforts of firms.

This study is also the first to assess the impact of the Brazilian policy using the Average Treatment Effect on the Treated (ATT) estimator (Dehejia & Wahba, 1999, as explained below) in a difference-in-differences framework.[51] Finally, the earlier analyses did not use data from the 2011 edition of PINTEC (IBGE, 2013). In this sense, the results described herein can be

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[49] The estimation of a R&D demand equation, on the other hand, would require the value of incentive for each firm.

[50] For this reason, Angrist and Pischke (2008) suggest to use the PSM to select the sample, but estimate the impact through linear regression.

[51] The previous studies have used the PSM to select the observations, but the impact was not estimated through the ATT.

used to compare whether previous findings remain valid or if later developments of the policy led to significant changes in its impact.

### 2.5.1 Theoretical basis of the research strategy.

The rationale and main goal of the selected research strategy is to estimate the causal effect of treatment - in this case, the tax incentives for innovation established by the law. Dehejia and Wahba (2002) defined causality as "a manipulation or treatment that brings about a change in the variable of interest, compared to some baseline, called the control" (p. 152).

The question is presented by the authors as follows: in a population indexed by ($i$), ($Y_{i1}$) is the value of the outcome variable if unit $i$ is exposed to treatment ($T = 1$), while ($Y_{i0}$) is the value if the unit is subject to control (absence of treatment; $T = 0$). The parameter of interest is the average effect of treatment on treated units ($\tau|T = 1$), which, by definition, means the difference between the expected value of the outcome variable in these individuals and the value of that variable if they had not received treatment:

$$\tau|_{t=1} = E[Y_{i1}|T_i = 1] - E[Y_{i0}|T_i = 1] \tag{1}$$

As one cannot observe both values for one single unit, it is necessary to apply a counterfactual method to estimate the expected value for treated units in the absence of treatment ($E[Y_{i0}|T_i = 1]$). In the case of experimental studies, the expected value of the control group serves such purpose, since random treatment assignment ensures it to be the same as the treatment group if it had not been treated.

$$Y_{i0} \perp\!\!\!\perp T_i \implies E[Y_{i0}|T_i = 1] = E[Y_{i0}|T_i = 0] \implies \tau|_{T=1} = E[Y_{i1}|T_i = 1] - E[Y_{i0}|T_i = 0] \tag{2}$$

In the case of observational studies, however, the researcher must take into account a possible selection bias problem (Dehejia & Wahba, 2002), making the counterfactual estimation a more complex operation. For innovation policies, it is likely and expected that treatment assignment is not random, and that companies benefiting from government incentives are on average already in a better position or have higher skills or capacity to innovate. Such differences on units' features tend to create a bias that overestimates the impact of the policy in case of a direct comparison between the two groups, for the baseline expected value of the treatment group may be higher than that of the control group ($E[Y_{i0}|T_i = 1] > E[Y_{i0}|T_i = 0]$).

In order to overcome this problem, the estimation requires a preliminary step that minimizes such differences, making the control group a suitable counterfactual for treated units. The objective of the PSM is to work as this first stage. The main assumptions of the method are:

1. *Conditional independence assumption (selection on observables)*:[52] treatment assignment can be considered as if determined by a set of independent observable variables ($X_i$). Once these are controlled for, assignment can be deemed as random, and there is no significant difference between individuals subject to treatment and those in the control group. The value of ($Y_{i0}$) thus becomes independent of treatment.

$$Y_{i0} \perp\!\!\!\perp T_i | X_i \Rightarrow E[Y_{i0}|X_i, T_i = 0] = E[Y_{i0}|X_i, T_i = 1] \qquad (3)$$

2. *Propensity score:* the set of independent observed variables ($X_i$) can be merged into a single propensity score ($p(X_i)$) that reflects the probability of treatment assignment (Dehejia & Wahba (1999)). The purpose and advantage of this index is to deal with the 'curse of dimensionality' (Caliendo & Kopeinig, 2005) of the model.

$$T_i \perp\!\!\!\perp X_i | p(X_i) \;\Rightarrow\; Y_{i0} \perp\!\!\!\perp T_i | p(X_i) \qquad ; \qquad p(X_i) = \Pr(T_i = 1|X_i) = E(T_i|X_i) \qquad (4)$$

3. *Stable unit treatment value assumption* (Wooldridge, 2002): treatment impacts only the unit receiving it, without any spillovers or secondary impact on control units. This assumption is hardly true in the case of innovation policies because of knowledge spillovers. Such violation, however, actually means the impact is underestimated, for it does not take into consideration the effect of the policy on the expected value of ($Y_{i0}$), the baseline value. Estimated results of the empirical study, for this reason, can be interpreted as a minimum additionality effect, disregarding spillovers.

4. *Common support* (Aschhoff, 2009): for each treatment or control unit there is at least one observation in the other group, respectively, with a similar set of observable variables. This assumption requires the exclusion of observations with a propensity score above the maximum level common to both groups, as well as those below the minimum common level.

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[52] Proposition 1 in Dehejia e Wahba (2002), ignorability of treatment in Rosenbaum and Rubin (1983), or assumption ATE.1 in Wooldridge (2002).

If these assumptions are met, the ATT can be identified as in Dehejia and Wahba (1999). In this study, this specification is used for dummy outcome variables.

$$\tau|_{T=1} = E[Y_{i1}|p(X_i), T_i = 1] - E[Y_{i0}|p(X_i), T_i = 0] \tag{5}$$

For continuous and discrete outcome variables, the ATT is estimated using a difference-in-differences framework, that considers these variables before ($Y_{iT}^0$) and after ($Y_{iT}^1$) treatment effect took place. This method weakens the conditional independence assumption, for it allows time-invariant non-observable factors to influence treatment assignment probability (since they are excluded from the estimation as fixed effects). Its key assumption is that, in the absence of treatment, paths for treated and control units would be similar (the parallel path assumption). Treatment, therefore, changes the evolution of outcome variables for treated units, and the impact is measured by estimating the departure from the trend of the control units (Blundell & Dias, 2000; Angrist & Pischke, 2008). The ATT in this case is identified as:

$$\tau|_{T=1} = E[Y_{i1}^1 - Y_{i1}^0|p(X_i), T_i = 1] - E[Y_{i0}^1 - Y_{i0}^0|p(X_i), T_i = 0] \tag{6}$$

The PSM is implemented in two stages. First, it is necessary to estimate the propensity score with the available variables, using a probit or logit probability model. After estimating ($p(X_i)$), the second step is to select and apply an algorithm to match treated and control units (Dehejia & Wahba, 1999). This is a particularly important choice, each of which present advantages and disadvantages. Algorithms using few control units (nearest neighbor, radius matching with reduced caliper) have the advantage of comparing more homogeneous individuals, but they discard or disregard a large number of observations from the sample. On the other hand, matching using a greater number of controls (kernel or radius matching with a high caliper) use more information from different observations, with a greater heterogeneity that may jeopardize one of the main advantages of the PSM.

The specification and matching should be evaluated with a means test to confirm that matched treatment and control groups do not have an average with statistically significant variations in the observable variables (balancing condition).

***2.5.1.1 Sensitivity analysis to hidden variable bias.***

Even after applying the difference-in-differences PSM, there still remains the risk of selection bias caused by unobserved variables, so that conditional probability of treatment assignment for treated and control groups is not the same. According to Rosenbaum (2010), in observational studies one can never completely eliminate the possibility of such bias. For this reason, the author suggests a sensitivity test that measures the maximum size this bias can take before compromising the results of the PSM.[53]

Essentially, the Rosenbaum bounds test investigates the ratio of odds of treatment for treated ($\pi_k$) and control ($\pi_l$) units (represented by the parameter ($\Gamma$)), calculated as follows (Rosenbaum, 2010):

$$\frac{1}{1+\Gamma} < \frac{\pi_k}{\pi_k+\pi_l} < \frac{\Gamma}{1+\Gamma} \tag{7}$$

The test gradually increases the parameter ($\Gamma$), in order to find the maximum value it can take due to the presence of unobserved variables. To sum up, if the impact estimate remains statistically significant (pursuant to the adopted confidence level) for high values of ($\Gamma$), the results are considered sufficiently insensitive to a possible hidden selection bias.

There is no rule of thumb recommended by the literature for a minimum acceptable value of ($\Gamma$). According to Becker and Caliendo (2007), the test indicates the worst-case scenario in which bias caused by an omitted variable would invalidate the results, but that does not mean such bias actually exists or has such magnitude. Diprete and Gangl (2004) argued that, for the confidence interval to include zero (removing statistical significance), it is necessary that any omitted variables (a) actually affect the chances of treatment assignment differently for treated and control groups, increasing the odds ratio to at least the size of the observed bounds; and (b) also influence the outcome variable so strongly as to almost perfectly determine the difference between matched observations. One can also argue that, as a comprehensive group of relevant covariates influencing treatment is included in the estimation of the propensity score, the accepted threshold should decrease, for it is less likely that remaining omitted variables would influence the results substantially.

[53] "The sensitivity of an observational study to bias from an unmeasured covariate $u$ is the magnitude of the departure from the naive model that would need to be present to materially alter the study's conclusions." (Rosenbaum, 2010, p. 76).

As examples of values of this test accepted in the literature, Aralica and Bótric (2013) found R&D spending to lose significance at a 90% confidence level for ($\Gamma < 1.4$), while Diprete and Gangl (2004) accepted ($\Gamma$) values ranging between 1.15 and 2.3.

### 2.5.2 Empirical strategy: practical features.

This section summarizes the key choices for the implementation of the PSM analysis. In the research design, I have followed closely the international literature reviewed in section 2.3, with minor changes to adapt to the Brazilian policy context and availability of data.

The average treatment effect on the treated (ATT) is estimated for two groups of outcome variables: first, those measuring technological efforts or inputs; and those indicating innovation output and performance of firms.

PSM was estimated using the covariates described in section 2.5.4 below and a logistic functional distribution, following Busom, Corchuelo and Martinez-Ros (2014), Becker and Caliendo (2007) and Yang (2012).[54] Considering the sample of firms changes for each outcome variable in light of missing values and the objective of each regression (as explained in subsection 2.5.3 below), a specific propensity score is estimated for each case, so it would more appropriately reflect the probability of treatment for that group. Following different empirical studies presented in Table 2.4, treated observations are matched with their first nearest neighbor in the control group.

It is assumed that, in the case of spending and other input variables, impact takes place and is observed at the same year of treatment, i.e. 2011. As for the output and performance variables, there must be a time lag for projects and investments fostered or funded by the incentives to mature, so that their results can be assessed. As the main database is updated every three years, this is considered the maturing period. This is close to the international practice (*t-2*) recommended by the Oslo Manual (OECD, 1997). Therefore, for these variables, I consider treatment occurs in 2008 and results are observed in 2011.

In order to obtain the confidence interval and significance value of the regressions, I estimate the heteroskedasticity-consistent analytical standard errors as proposed by Abadie and Imbens (2006), using two neighbors to calculate conditional variance.

For each case, quality of matching is assessed through a means test, ensuring covariates are balanced between the two compared groups. In this test, the following indicators are

[54] Caliendo and Kopeinig (2005) stated the choice between logistic and probit models is not critical for the binary treatment case.

analyzed (a) the t-test results for each covariate, to check if differences in means are significant; (b) reduction on the standardized bias for each covariate; (c) reduction of the pseudo-$R^2$ value for the matched sample, that indicates how much regressors explain participation probability; (d) the joint significance F-test; and (e) the mean and median bias for the matched sample (Caliendo & Kopeinig, 2005).

The sensitivity analysis is calculated through the Wilcoxon sign rank test (upper and lower bounds for p-values) and the Hodges-Lehman point estimates and confidence intervals, using ($\Gamma$) intervals of (*0.1*) up to the value of two. Parameter ($\Gamma$) reaches critical value when the upper bound reaches zero or p-value is greater than 0.05. Sensitivity to hidden bias is indicated by how close the critical value of ($\Gamma$) is to one.

As robustness checks, PSM is again estimated applying two alternative algorithms, to minimize the shortcomings of the nearest neighbor matching: kernel; and radius matching within caliper of 20% of the standard deviation of the propensity score (as recommended in Austin, 2011).[55] As an alternative specification, I calculate the ATT excluding the sector dummy variables from the propensity score model.

#### 2.5.3 Dataset and sample design.

Three databases with information disaggregated at the firm level were merged to generate the dataset used in this empirical study. The main one is the PINTEC, a comprehensive survey on industrial innovation conducted by IBGE every three years. For this analysis, the 2008 and 2011 editions (IBGE, 2010 and 2013) are considered.

The list of firms that benefited from the tax incentives is disclosed by the MCTI in its yearly reports (MCTI, 2009 and 2012b). The third database is the list of exporting and importing firms in the year preceding participation in the policy (2007 and 2010), disclosed by the Brazilian Ministry of Development, Industry and Foreign Trade (MDIC, n.d.).

Disaggregated firm data were merged and organized in an unbalanced panel dataset with two periods ($t$ = 2008, 2011), thus allowing intertemporal analysis of policy impact (difference-in-differences). Only firms present in both editions of PINTEC are used in the analysis. Nominal values for 2008 were adjusted using the IGP-DI index.[56]

The baseline value for the outcome variables is observed in ($t$-$3$), i.e., 2008. For this reason, all firms that benefited from the tax incentives before this year were excluded from the

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[55] As the Abadie and Imbens (2006) standard errors estimation procedure is not applicable to these cases, regressions were bootstrappted using one hundred repetitions.
[56] This is the same deflation index used in FAPESP (2011) for innovation expenditure.

dataset, ensuring the trend is not biased at the outset. I also ignored all firms of the control group that received incentives at any point in time, in order to assure secondary effects will not disturb the results. In the case of outcome variables indicating innovation input, treated firms that benefited from the incentives in 2008 were ignored. Table 2.8 summarizes the sample design of treatment and control groups for the two analyses (input, and output/performance variables).

Table 2.8

*Requirements for a firm to be in the treatment or control group*

| Outcome variables | Group | Firm was only considered if all following requirements are met | | | |
|---|---|---|---|---|---|
| | | Did the firm participate in the policy | | | |
| | | before 2008? | in 2008? | between 2008 and 2011? | in 2011? |
| Input | Treatment | No | No | Yes or no | Yes |
| | Control | No | No | No | No |
| Output | Treatment | No | Yes | Yes or no | Yes or no |
| | Control | No | No | No | No |

The PINTEC sample comprises a large and diverse group of firms with different capabilities and potentials for innovation. In order to enhance quality of the matching, size of the sample was limited using variables present in the survey. Samples were chosen for each outcome variable under analysis, considering the objective of the investigation and in order to balance number of observations and homogeneity of firms for each case. Table 2.10 below presents the sample criteria used for each outcome variable. Finally, in order to avoid that outlier observations bias the analysis, maximum and minimum values were established for each variable, excluding observations out of this range.

### 2.5.4 Variables and descriptive statistics.

Treatment variables are binary dummies indicating whether the firm benefited from the tax incentives in the relevant year. Table 2.9 presents the number of firms in the treatment and control groups considering different samples.

Table 2.9

*Number of observations per treatment group*

| Sample delimitation criterion | No. of observations | | | |
|---|---|---|---|---|
| | Treatment in 2008 (Output and performance variables) | | Treatment in 2011 (input variables) | |
| | Control | Treated | Control | Treated |
| Whole PINTEC sample | 13,403 (98.7%) | 177 (1.3%) | 13,403 (97.8%) | 303 (2.2%) |
| Innovated in the last 3 years | 5,901 (97.5%) | 151 (2.5%) | 5,901 (95.7%) | 267 (4.3%) |
| Positive innovative spending | 5,072 (97.2%) | 146 (2.8%) | 5,072 (95.0%) | 264 (5.0%) |
| Positive R&D spending | 1,874 (93.5%) | 131 (6.5%) | 1,874 (89.1%) | 228 (10.9%) |

Percentage of observations for each group of total in parenthesis. Number of control units for both treatment years match because they present the same requirements (see Table 2.8).

Outcome variables are defined in Table 2.10, along with the delimitation criterion used to select the sample for each analysis. Continuous variables represent the difference between real values in 2011 and 2008, while dummy variables consider exclusively the value in 2011.

Effect of the policy on input or technological effort was measured through five indicators: firms' spending with innovation, considering both innovative activities and strict R&D; size of R&D staff; and whether firms that did not have any expenditures in innovative activities and R&D in 2008 started investing by 2011. The broad category of innovative activities adopted by PINTEC follows the Oslo Manual (OECD, 2005) and includes: internal and external R&D; acquisition of knowledge from third parties; software license or acquisition; acquisition of machinery and equipment; training; introduction of innovations in the market; and industrial design and other measures for production and distribution (IBGE, 2013).

The investigation on the effects of the policy on the chances of firms starting to invest in innovation requires two clarifications: first, a firm benefiting from the incentives does not necessarily have positive R&D expenditure, for the concept of deductible expenses adopted by the law is far broader than the definition of PINTEC and the Oslo Manual (IBGE, 2013; and OECD, 2005), as discussed in subsection 2.4.2; and second, such firm may not even have positive innovative activities expenditure, as evidenced by Figure 2.9 and Table 2.11.

For the output and performance analysis, six outcome variables were considered: whether government funding increased the chances of a firm to innovate, impacting the base of innovative companies; if newly developed products represented a higher share of sales and exports of incentivized firms; and if, after the maturing period, beneficiary firms had significantly outperformed their control group matches in terms of total employment, net revenue, and net revenue per employee (as a measure of labor productivity).

Table 2.10

*List of outcome variables, definition and sample delimitation criterion*

| Group | Variable | Description | Sample delimitation criterion |
|---|---|---|---|
| Input | *in_exp* | Innovative activities expenditures - difference between 2011 and 2008 values (continuous) | Firms that innovated in the last 3 years and had positive innovative activities expenditures in the last year.[a] |
| | *rd_exp* | R&D expenditures - difference between 2011 and 2008 values (continuous) | Firms that innovated in the last 3 years and had positive R&D expenditures in the last year. |
| | *researcher* | Total number of R&D personnel - difference between 2011 and 2008 values (continuous)[c] | Firms that innovated in the last 3 years and had positive R&D expenditures in the last year.[b] |
| | *in_dummy* | Positive innovative activities expenditures (dummy) | Firms with no innovative spending in 2008. |
| | *rd_dummy* | Positive R&D expenditures (dummy) | Firms with no R&D spending in 2008. |
| Output and performance | *inovator* | Firm innovated in the last 3 years (dummy) | Whole PINTEC sample |
| | *new_sales* | Share of new products in total sales - difference between 2011 and 2008 values (continuous) | Whole PINTEC sample |
| | *new_exp* | Share of new products in total exports - difference between 2011 and 2008 values (continuous) | Whole PINTEC sample |
| | *revenue* | Net revenue- difference between 2011 and 2008 values (continuous) | Whole PINTEC sample |
| | *personnel* | Total employment- difference between 2011 and 2008 values (continuous) | Whole PINTEC sample |
| | *rev_person* | Net revenue per employee- difference between 2011 and 2008 values (continuous) | Whole PINTEC sample |

[a] The PINTEC only requests information on expenditures for the last year of each survey.
[b] Part-time researchers are weighted according to the work time dedicated to firm's R&D.

Following the recent literature (Guceri, 2015; Dumont, 2013; Duguet, 2012, and Yang, 2012), Figures 2.6 to 2.16 present the 'naïve estimator' for each outcome variable, or the direct comparison of means for treated and control groups without any prior matching. It provides a first indication on whether treated units present a superior outcome, without considering selection bias problems. Continuous variables are displayed in a boxplot format, while binary ones are depicted in stacked percentage columns. Moreover, Table 2.11 provides descriptive statistics for all outcome variables.

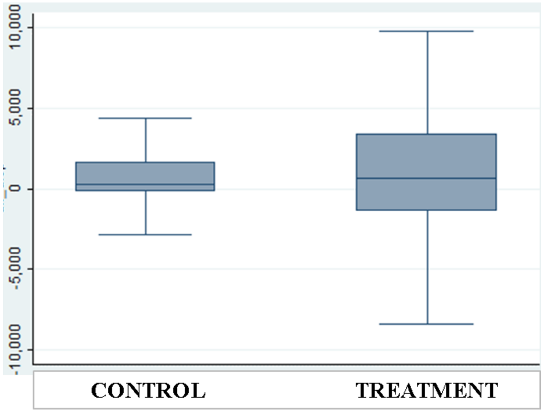


*Figure 2.6.* Innovative activities expenditures for control and treatment groups (difference between 2011 and 2008 real values). Treatment in 2011. Excludes outside values. Source: IBGE (2010 and 2013; confidential data).

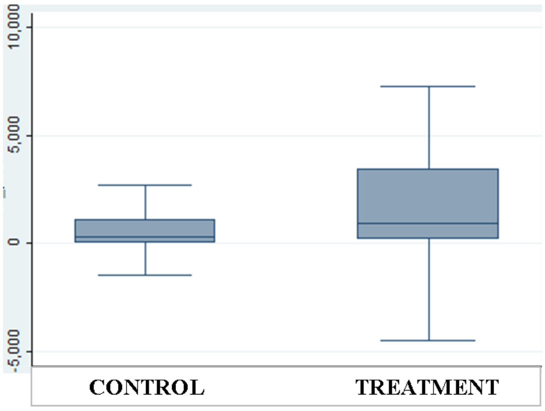


*Figure 2.7.* R&D expenditures for control and treatment groups (difference between 2011 and 2008 real values). Treatment in 2011. Excludes outside values. Source: IBGE (2010 and 2013; confidential data).

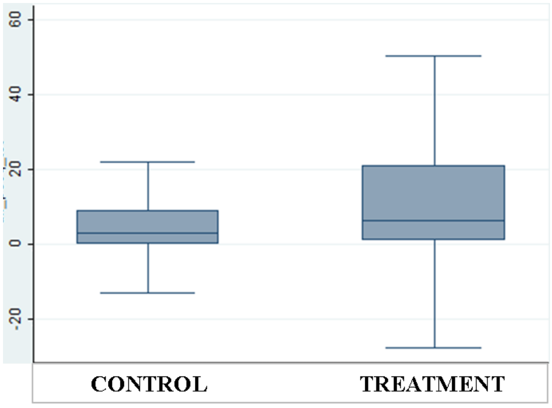


*Figure 2.8.* Total number of researchers for control and treatment groups (difference between 2011 and 2008 real values). Treatment in 2011. Excludes outside values. Source: IBGE (2010 and 2013; confidential data).

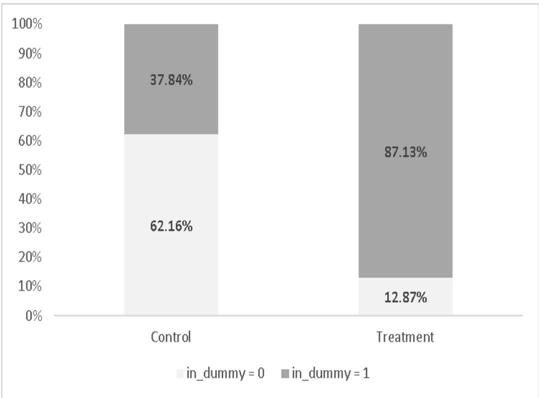


*Figure 2.9.* Share of firms with positive innovation activities expenditures in the treatment and control groups. Treatment in 2011. Source: IBGE (2010 and 2013; confidential data).

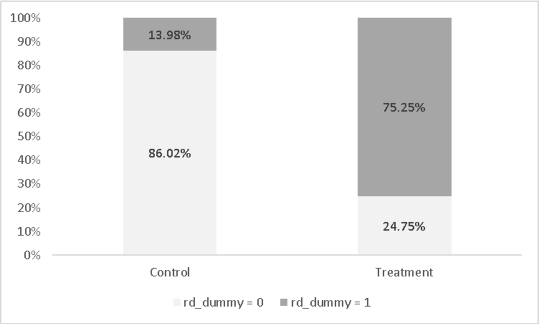


*Figure 2.10*. Share of firms with positive R&D expenditures in the treatment and control groups. Treatment in 2011. Source: IBGE (2010 and 2013; confidential data).

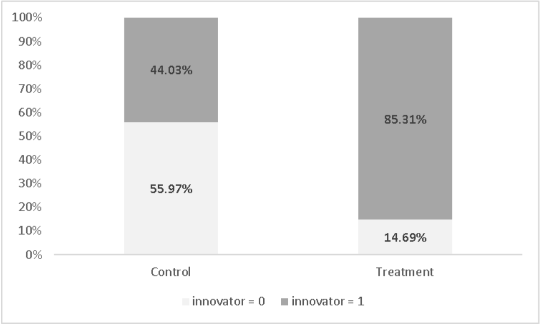


*Figure 2.11*. Share of firms that innovated in the 2008-2011 period for treatment and control groups. Treatment in 2008. Source: IBGE (2010 and 2013; confidential data).

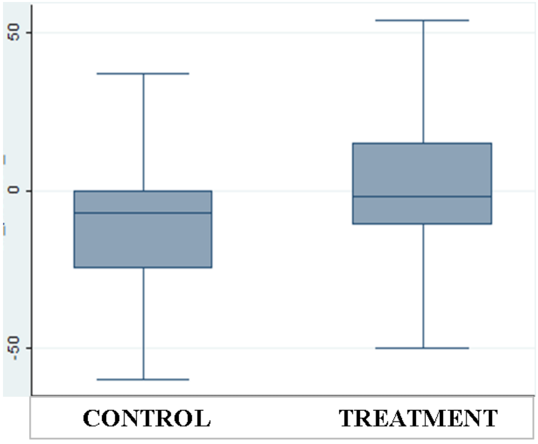


*Figure 2.12*. Share of new products in total sales (difference between 2011 and 2008 real values). Treatment in 2008. Outside values excluded. Source: IBGE (2010 and 2013; confidential data).

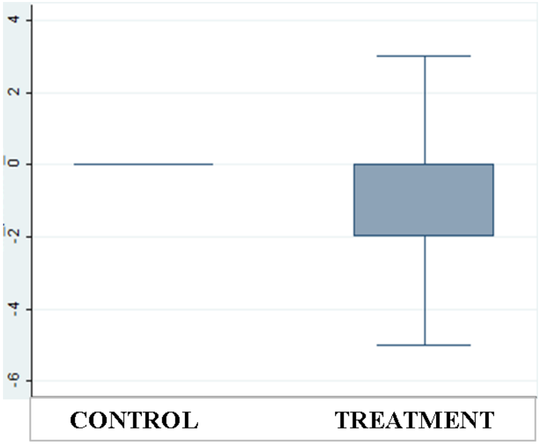


*Figure 2.13*. Share of new products in total exports (difference between 2011 and 2008 real values). Treatment in 2008. Outside values excluded. Source: IBGE (2010 and 2013; confidential data).

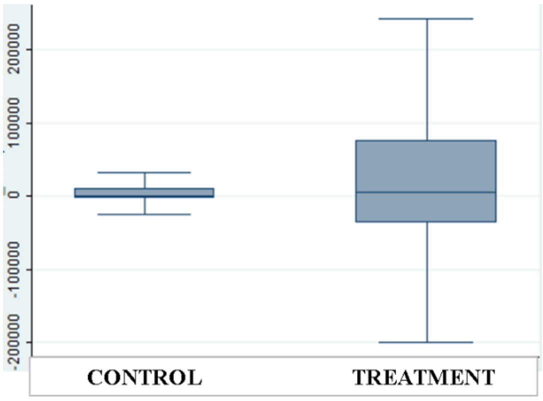


*Figure 2.14*. Net revenue for treatment and control groups (difference between 2011 and 2008 real values). Treatment in 2008. Outside values excluded. Source: IBGE (2010 and 2013; confidential data).

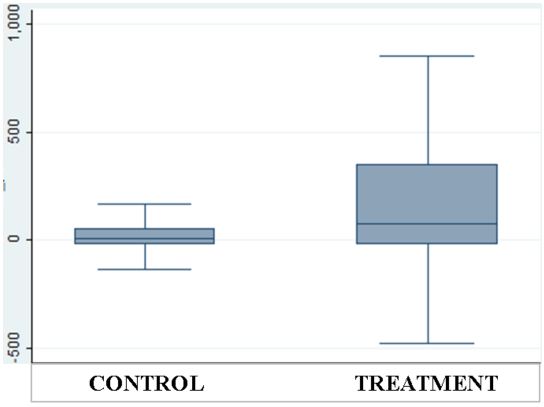


*Figure 2.15*. Total employment for treatment and control groups (difference between 2011 and 2008 real values). Treatment in 2008. Outside values excluded. Source: IBGE (2010 and 2013; confidential data).

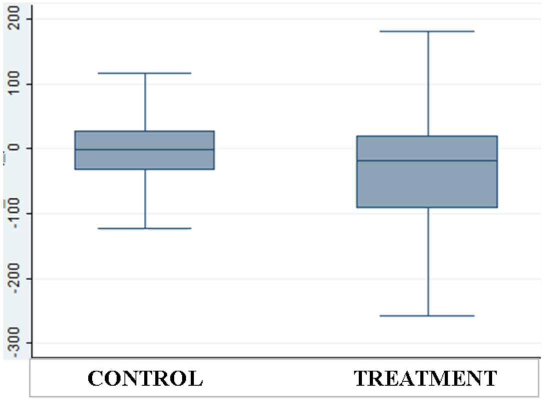


*Figure 2.16.* Net revenue per employee for treatment and control groups (difference between 2011 and 2008 real values). Treatment in 2008. Outside values excluded. Source: IBGE (2010 and 2013; confidential data).

Table 2.11

*Descriptive Statistics of outcome variables*

| Group | Variable | Unit | Treatment | N | Mean | Std.Dv. |
|---|---|---|---|---|---|---|
| Input | *in_exp* | R$1,000 | 0 | 2540 | 2865.72 | 70514.74 |
| | | | 1 | 220 | -1260.73 | 38929.78 |
| | *rd_exp* | R$1,000 | 0 | 1135 | 2136.02 | 36877.84 |
| | | | 1 | 189 | 3862.40 | 23897.93 |
| | *researcher* | No. of researchers[a] | 0 | 1135 | 12.87 | 159.35 |
| | | | 1 | 189 | 15.83 | 40.24 |
| | *in_dummy* | Binary | 0 | 13403 | 0.378 | 0.485 |
| | | | 1 | 303 | 0.871 | 0.335 |
| | *rd_dummy* | Binary | 0 | 13403 | 0.140 | 0.347 |
| | | | 1 | 303 | 0.752 | 0.432 |
| Output and performance | *inovator* | Binary | 0 | 13403 | 0.440 | 0.496 |
| | | | 1 | 177 | 0.853 | 0.355 |
| | *new_sales* | % of total sales | 0 | 2235 | -10.143 | 2.175 |
| | | | 1 | 133 | 3.233 | 0.270 |
| | *new_exp* | % of exports | 0 | 2235 | -2.622 | 0.393 |
| | | | 1 | 133 | -.2093 | 0.031 |
| | *revenue* | R$1,000 | 0 | 6406 | 8226.55 | 213812.8 |
| | | | 1 | 155 | 27650.29 | 715835.8 |
| | *personnel* | No. of employees | 0 | 6412 | 36.77 | 489.75 |
| | | | 1 | 155 | 268.75 | 1164.98 |
| | *rev_person* | R$1,000 | 0 | 6271 | -3.46 | 322.55 |
| | | | 1 | 154 | -112.07 | 408.52 |

Source: IBGE (2010 and 2013; confidential data).

The naive estimator suggests the policy affected four out of five input variables, i.e. positively impacting R&D expenditures, hiring of research personnel and base of firms investing in both innovative activities and R&D. The mean value of innovative expenditures for control and treated groups, on the other hand, is highly similar, suggesting absence of effect.

The direct comparison also indicates that the policy positively impacted the base of innovative companies, share of new products in total sales and company size, and that it had no effect on share of new products in exports and net revenue. Surprisingly, the productivity variable (*rev_person*) points to a negative impact of the policy.

These results provide a first basis for the empirical study, as it suggests the tax benefits have affected innovation investment, results and performance of beneficiary firms.

As explained in subsection 2.5.1, the role of observable covariates is to control for treatment assignment probability. The main requirements for a firm to benefit from the main incentive of the policy (enhanced allowance) are positive taxable income and to operate under the real profit tax regime, which is mainly determined by the size of revenue.[57] However, following the main literature, I include in the propensity score a higher number of covariates, in order to take into consideration more factors affecting odds of treatment: (a) firm size (number of employees – log-linearized; *personnel*); (b) net revenue; (log-linearized; *revenue*); (c) age (*age*); (d) dummy for national controlling capital (*nac_control*); (e) dummy for foreign controlling capital (*for_control*); (f) dummy for continuous R&D activity in the last three years (*rd_cont*); (g) dummy for firms part of a corporate group (*group*); (h) dummy for importing firms in (*t-1*; *imp*); (i) dummy for exporting firms in (*t-1*; *exp*); (j) dummy for main firm market being international (*for_market*); (ix) dummies for each of the five country regions (North - N, Northeast - NE, Middle west - CO, Southeast - SE and South - S), excluding the state of São Paulo to avoid collinearity; and (k) industrial sector dummies, using the National Classification of Economic Activities.[58] Main descriptive statistics for these variables are shown in Tables A2.2 and A2.3 in the Appendix.

## 2.6 Results

This section describes and analyses the results pursuant to the described empirical strategy. The first subsection shows the estimations for input or technological efforts variables

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[57] The other two requirements are tax clearance and positive innovation expenditures (see section 2.4.2). As the later is one of the outcomes of the analysis, it is not included as an observable covariate.

[58] CNAE 2 digits. The respective industrial sector is informed by the number after the prefix '*cnae_*' for each dummy variable.

and the second focuses on output and performance. The third part presents the results for sensitivity analysis and robustness checks, and the fourth discusses the findings.

### 2.6.1 Input or technological effort variables.

Table 2.12 presents the estimated logit propensity score for the input outcome variables, with the effect of each covariate on probability of treatment in 2011. The estimated models reveal relevant information about factors determining participation in the policy. Net revenue is the single most important continuous covariate, with a positive and significant coefficient at a 99% confidence level for all cases, meaning that companies with higher income are more likely to benefit. Continuous development of R&D activities also increases probability of obtaining tax incentives. Other variables that present significant results (at a 95% confidence level) in at least some of the estimations are export in the previous year (positive impact) and dummy for foreign market being firm's main target (negative effect).

The results of the means test for covariates and for the propensity score in each model are presented in Tables A2.4 to A2.8 of the Appendix. For all models, variables do not present significant differences (at a 95% confidence level) for treatment and control groups, with the single exception of the *'revenue'* variable for the *'in_dummy'* propensity score. Standardized bias is substantially reduced for majority of variables. In all cases, log-likelihood test ($p>chi^2$) does not reject joint insignificance hypothesis for matched samples, and pseudo-$R^2$, mean and median bias also drop considerably. In light of these results, I understand to have good grounds to accept the propensity score specification, as it has balanced nearly all covariates between the two groups, thus reducing differences between matched observations and mitigating possible bias selection.

The estimated ATTs are displayed in Table 2.13. Results confirm the naïve estimator previously presented, although with an expected smaller magnitude. I find the policy has had a significant average impact on R&D expenditures of treated firms of around five hundred thousand in Brazilian *reais* of 2011[59] (around two hundred and sixty-four thousand U.S. dollars)[60]. This effect represents 6.8% of the mean R&D spending of beneficiary firms in 2011,[61] and around 76% more than it would have in the absence of the policy.

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[59] Approximately seven hundred thousand Brazilian *reais* readjusted to December, 2016, using the IGP-M/FGV index of the last month of each year.
[60] Real value in Brazilian *reais* adjusted using the IGP-M/FGV index of the last month of each year. Value in U.S. dollars converted according to the exchange rate applicable on the last day of 2011.
[61] Mean R&D spending of beneficiary firms in 2011: R$ 7,288,276.00.

Table 2.12

*Estimated propensity score - input outcome variables*

| Covariates | Outcome Variables | | | | |
|---|---|---|---|---|---|
| | *in_exp* | *rd_exp* | *researcher* | *in_dummy* | *rd_dummy* |
| *personnel* | -0.148(0.156) | -0.04(0.166) | 0.012(0.148) | -0.145(0.191) | -0.104(0.133) |
| *age* | 0.006(0.008) | 0.004(0.008) | 0.004(0.008) | -0.012(0.013) | 0(0.008) |
| *nac_control* | -0.762(0.595) | -1.357(0.679)** | -0.789(0.511) | 0.697(0.561) | 0.193(0.42) |
| *for_control* | -0.695(0.58) | -1.021(0.658) | -0.507(0.496) | 0.326(0.558) | -0.092(0.403) |
| *rd_cont* | 1.381(0.217)*** | 1.056(0.451)** | 0.926(0.385) | 2.043(0.307)*** | 2.086(0.203)*** |
| *group* | 0.301(0.222) | 0.247(0.241) | 0.28(0.206) | 0.357(0.333) | 0.334(0.217) |
| *revenue* | 0.744(0.145)*** | 0.513(0.152)*** | 0.508(0.132)*** | 0.856(0.19)*** | 0.769(0.124)*** |
| *imp* | 0.824(0.41)** | 0.674(0.431) | 0.808(0.425)* | 0.644(0.567) | 0.34(0.335) |
| *exp* | 0.67(0.298)** | 0.462(0.325) | 0.266(0.29) | 0.885(0.465)* | 0.649(0.272)** |
| *for_market* | -1.181(0.466)** | -0.794(0.48)* | -0.781(0.368)** | 0.486(0.506) | -0.408(0.397) |
| *dummyN* | -0.093(0.814) | -1.225(1.102) | -1.226(0.765) | n/a[b] | -1.103(0.799) |
| *dummyNE* | -0.474(0.475) | -0.428(0.485) | -0.508(0.458) | -0.103(0.645) | -0.047(0.437) |
| *dummySE*[a] | -0.164(0.298) | -0.078(0.306) | 0.122(0.268) | -0.031(0.476) | 0.207(0.295) |
| *dummyS* | 0.347(0.223) | -0.03(0.245) | 0.11(0.229) | 0.884(0.36)** | 0.727(0.236)*** |
| *dummyCO* | -0.932(0.797) | -1.393(1.099) | -0.627(0.705) | n/a[b] | -1.954(1.19) |
| *cnae_10* | -1.34(1.178) | -1.943(0.554)*** | -3.14(1.553)** | -2.787(1.38)** | -2.025(1.166)* |
| *cnae_11* | -1.147(1.406) | -1.647(0.906)* | -3.188(1.697)* | -0.738(1.45) | -0.348(1.237) |
| *cnae_12* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_13* | -2.075(1.315) | -2.221(0.807)*** | -3.446(1.654)** | -1.176(1.414) | -1.796(1.319) |
| *cnae_14* | n/a[b] | n/a[b] | -3.705(1.881)** | -1.863(1.65) | -2.135(1.515) |
| *cnae_15* | -1.678(1.378) | -1.742(0.802)** | -2.784(1.662)* | -2.288(1.62) | -1.852(1.337) |
| *cnae_16* | n/a[b] | n/a[b] | -2.798(2.006) | n/a[b] | -1.872(1.585) |
| *cnae_17* | -0.789(1.234) | -1.545(0.716)** | -2.882(1.594)* | -1.266(1.35) | -1.41(1.232) |
| *cnae_18* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_19* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | -1.948(1.539) |
| *cnae_20* | -1.08(1.19) | -1.657(0.575)*** | -2.764(1.54)* | -2.083(1.352) | -1.26(1.151) |
| *cnae_21* | -0.196(1.241) | -0.887(0.678) | -2.154(1.569) | -0.43(1.379) | -0.041(1.18) |
| *cnae_22* | -1.844(1.268) | -3.033(0.877)*** | -4.104(1.648)** | -1.407(1.347) | -1.412(1.197) |
| *cnae_23* | -0.742(1.246) | -1.843(0.75)** | -2.941(1.609)* | -0.344(1.27) | -0.732(1.187) |
| *cnae_24* | -1.892(1.388) | -1.939(0.861)** | -2.722(1.616)* | -1.722(1.558) | -0.686(1.187) |
| *cnae_25* | -1.354(1.238) | -1.58(0.646)** | -2.777(1.572)* | -2.186(1.551) | -1.249(1.194) |
| *cnae_26* | -1.582(1.273) | -2.547(0.768)*** | -2.872(1.561)* | -1.119(1.589) | -0.962(1.229) |
| *cnae_27* | -0.938(1.203) | -1.355(0.593)** | -2.361(1.551) | n/a[b] | -0.438(1.162) |
| *cnae_28* | -1.26(1.197) | -1.821(0.6)*** | -2.79(1.555)* | -0.361(1.251) | -0.376(1.137) |
| *cnae_29* | -0.237(1.195) | -1.147(0.617)* | -1.976(1.552) | 0.183(1.248) | -0.141(1.137) |
| *cnae_30* | 0.335(1.338) | 0.278(1.045) | -0.982(1.66) | n/a[b] | 0.478(1.26) |
| *cnae_31* | -0.724(1.235) | -1.17(0.715) | -2.245(1.616) | -0.786(1.389) | -0.257(1.18) |
| *cnae_32* | -1.013(1.328) | -1.516(0.808)* | -2.733(1.642)* | -0.192(1.603) | -0.743(1.352) |
| *cnae_33* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_35* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_38* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_50* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_58* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | -0.633(1.344) |
| *cnae_59* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_60* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_61* | -1.165(1.531) | -1.161(1.057) | -3.348(1.819)* | -2.043(1.876) | -0.723(1.465) |
| *cnae_62* | 1.243(1.118) | n/a[b] | -1.197(1.589) | 1.005(1.306) | 0.609(1.162) |
| *cnae_63* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_71* | n/a[b] | n/a[b] | -2.386(2.257) | n/a[b] | -1.278(1.959) |
| *cnae_72* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_81* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_89* | n/a[b] | n/a[b] | -0.186(2.303) | n/a[b] | n/a[b] |
| *cnae_91* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_99* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *constant* | -10.381(1.626)*** | -6.435(1.304)*** | -6.146(2.012)*** | -13.726(2.182)*** | -12.435(1.58)*** |
| N | 2062 | 988 | 1155 | 2492 | 5212 |
| Log-likelihood | -411.923 | -332.296 | -407.71255 | -189.60668 | -437.274 |
| Pseudo-R2 | 0.251 | 0.165 | 0.173 | 0.3548 | 0.3177 |
| Prob > chi2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

[a] Not considered firms in the state of São Paulo.

[b] Excluded due to collinearity.

Logit model.

Standard errors in parenthesis. * p<.10; ** p<.05; *** p<.01.

Table 2.13

*Estimated Average Treatment Effect on the Treated – Input variables*

| Outcome Variable | Unit | Sample | Mean | | Difference | Relative effect |
|---|---|---|---|---|---|---|
| | | | Treated | Controls | | |
| *in_exp* | R$ 1,000 | Unmatched | 597.157 | 506.924 | 90.233 (170.874) | 0.178 |
| | | ATT | 497.753 | 969.862 | -472.108 (373.262) | -0.487 |
| *rd_exp* | R$ 1,000 | Unmatched | 1149.307 | 646.055 | 503.252 (101.293)*** | 0.779 |
| | | ATT | 1151.187 | 655.466 | 495.722 (169.634)*** | 0.756 |
| *researcher* | No. of researchers | Unmatched | 14.190 | 7.462 | 6.728 (1.332)*** | 0.902 |
| | | ATT | 14.391 | 9.541 | 4.850 (2.217)** | 0.508 |
| *in_dummy* | Binary | Unmatched | 0.825 | 0.317 | 0.508 (0.059)*** | 1.603 |
| | | ATT | 0.820 | 0.590 | 0.230 (0.094)** | 0.390 |
| *rd_dummy* | Binary | Unmatched | 0.698 | 0.133 | 0.565 (0.030)*** | 4.248 |
| | | ATT | 0.689 | 0.578 | 0.111 (0.038)*** | 0.192 |

Standard errors in parenthesis. * p<.10; ** p<.05; *** p<.01.
Matching algorithm: nearest neighbor.
Standard error estimated according to Abadie and Imbens (2006).

I also find an average impact of around five researchers on R&D personnel. This represents 16% of the average number of R&D staff of beneficiary firms in 2011,[62] and a 51% relative effect compared to the growth observed in (matched) control units.

Results also indicate that the policy contributed to increase the base of companies pursuing innovation. Beneficiary enterprises that did not have any spending in innovative activities in 2008 were 23% more likely to start investing by 2011 (a 39% relative effect, if compared to the chances of firms in the control group). In the case of strict R&D, the chances increased by 11% (a 19.2% relative effect). On the other hand, no significant evidence of impact on general spending on innovative activities was found.

### 2.6.2 Innovation output and performance variables.

Table 2.14 displays the estimation results for the treatment probability model for innovation outcome and performance variables. As in the case of input variables, revenue, continuous R&D and exports are relevant factors positively influencing participation in the policy in 2008. In addition, chances of obtaining tax incentives also grew with firm size, foreign capital control and location in the South region.

[62] Mean number in 2011 is 30.39 researchers per treated firm.

Table 2.14

*Estimated propensity score - output and performance outcome variables*

| Covariates | Outcome Variable | | | | | |
|---|---|---|---|---|---|---|
| | *inovator* | *new_sales* | *new_exp* | *revenue* | *personnel* | *rev_person* |
| *personnel* | 0.352(0.162)** | 0.263(0.185) | 0.263(0.185) | 0.335(0.163)** | 0.431(0.18)** | 0.335(0.163)*** |
| *age* | -0.006(0.008) | 0.001(0.009) | 0.001(0.009) | -0.005(0.008) | -0.011(0.009) | -0.005(0.008) |
| *nac_control* | 0.544(0.406) | 0.65(0.471) | 0.65(0.471) | 0.537(0.425) | 0.461(0.455) | 0.537(0.425) |
| *for_control* | 1.001(0.409) | 0.967(0.472)** | 0.968(0.472)** | 0.984(0.427)** | 0.948(0.451)** | 0.984(0.427)** |
| *rd_cont* | 2.005(0.222)*** | 1.356(0.256)*** | 1.357(0.256)*** | 1.986(0.223)*** | 2.013(0.232)*** | 1.986(0.223)*** |
| *group* | 0.171(0.228) | 0.106(0.255) | 0.106(0.255) | 0.157(0.23) | 0.166(0.241) | 0.157(0.23) |
| *revenue* | 0.528(0.137)*** | 0.623(0.16)*** | 0.623(0.16)*** | 0.552(0.138)*** | 0.586(0.149)*** | 0.552(0.138)*** |
| *imp* | -0.378(0.255) | -0.326(0.299) | -0.327(0.299) | -0.37(0.255) | -0.474(0.263)* | -0.37(0.255) |
| *exp* | 0.821(0.357)** | 0.935(0.463)** | 0.934(0.463)** | 0.828(0.359)** | 0.983(0.378)** | 0.828(0.359)** |
| *for_market* | -0.517(0.373) | -0.303(0.417) | -0.303(0.417) | -0.626(0.385) | -1.041(0.479)** | -0.626(0.385) |
| *dummyN* | -0.118(0.565) | -0.483(0.649) | -0.483(0.649) | -0.168(0.568) | -0.224(0.59) | -0.168(0.568) |
| *dummyNE* | -0.356(0.526) | 0.001(0.559) | 0.002(0.559) | -0.371(0.528) | -0.451(0.547) | -0.371(0.528) |
| *dummySE*[a] | -0.392(0.364) | -0.283(0.407) | -0.282(0.407) | -0.478(0.376) | -0.499(0.41) | -0.478(0.376) |
| *dummyS* | 1.21(0.236)*** | 1.298(0.272)*** | 1.299(0.272)*** | 1.214(0.237)*** | 1.246(0.248)*** | 1.214(0.237)*** |
| *dummyCO* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_10* | -3.069(1.266)** | -1.362(0.893) | -1.361(0.893) | -3.307(1.315)** | -3.327(1.375)** | -3.307(1.315)** |
| *cnae_11* | -4.07(1.763)** | -2.087(1.477) | -2.083(1.479) | -4.292(1.815)** | -2.854(1.678)* | -4.292(1.815)** |
| *cnae_12* | -3.039(1.821)* | -1.3(1.632) | -1.301(1.632) | -3.254(1.855)* | -3.336(1.909)* | -3.254(1.855)* |
| *cnae_13* | -3.948(1.439)*** | -1.926(1.117)* | -1.925(1.117)* | -4.203(1.484)*** | -4.317(1.544)*** | -4.203(1.484)*** |
| *cnae_14* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_15* | -3.914(1.457)*** | -1.325(1.166) | -1.325(1.167) | -4.168(1.501)*** | -4.764(1.719)*** | -4.168(1.501)*** |
| *cnae_16* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_17* | -3.577(1.449)** | -1.548(1.134) | -1.548(1.134) | -3.784(1.493)** | -4.049(1.562)** | -3.784(1.493)** |
| *cnae_18* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_19* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_20* | -2.989(1.289)** | -1.301(0.94) | -1.301(0.94) | -3.279(1.34)** | -3.701(1.406)*** | -3.279(1.34)** |
| *cnae_21* | -2.159(1.331) | -0.171(0.974) | -0.17(0.974) | -2.453(1.378)* | -2.863(1.455)** | -2.453(1.378)* |
| *cnae_22* | -3.066(1.31)** | -1.173(0.983) | -1.172(0.983) | -3.339(1.358)** | -3.728(1.432)*** | -3.339(1.358)** |
| *cnae_23* | -3.294(1.376)** | -1.503(1.133) | -1.502(1.133) | -3.472(1.42)** | -4.198(1.541)*** | -3.472(1.42)** |
| *cnae_24* | -3.03(1.33)** | -0.995(1.044) | -0.995(1.044) | -3.073(1.377)** | -3.451(1.438)** | -3.073(1.377)** |
| *cnae_25* | -3.106(1.338)** | -0.757(0.984) | -0.756(0.984) | -3.369(1.386)** | -3.589(1.446)** | -3.369(1.386)** |
| *cnae_26* | -1.434(1.266) | 0.607(0.871) | 0.608(0.871) | -1.669(1.316) | -1.976(1.385) | -1.669(1.316) |
| *cnae_27* | -2.236(1.289)* | -0.246(0.917) | -0.245(0.917) | -2.497(1.337)* | -2.746(1.412)* | -2.497(1.337)* |
| *cnae_28* | -2.013(1.257) | 0.091(0.854) | 0.092(0.854) | -2.272(1.306)* | -2.55(1.375)* | -2.272(1.306)* |
| *cnae_29* | -1.704(1.252) | 0.613(0.882) | 0.611(0.882) | -1.929(1.304) | -2.409(1.381)* | -1.929(1.304) |
| *cnae_30* | -3.592(1.586)** | -1.199(1.37) | -1.199(1.37) | -3.812(1.625)** | -4.124(1.916)** | -3.812(1.625)** |
| *cnae_31* | -2.476(1.379)* | -1.456(1.333) | -1.455(1.333) | -2.746(1.426)* | -2.977(1.486)** | -2.746(1.426)* |
| *cnae_32* | -2.094(1.352) | 0.107(1.046) | 0.108(1.046) | -2.351(1.398)* | -2.661(1.469)* | -2.351(1.398)* |
| *cnae_33* | -2.255(1.59) | 0.237(1.421) | 0.236(1.421) | -2.444(1.627) | -2.68(1.695) | -2.444(1.627) |
| *cnae_35* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_38* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_50* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_58* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_59* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_60* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_61* | -4.815(1.505)*** | -3.678(1.397)*** | -3.68(1.397)*** | -5.095(1.544)*** | n/a[b] | -5.095(1.544)*** |
| *cnae_62* | -2.356(1.423)* | n/a[b] | n/a[b] | -2.596(1.459)* | -2.716(1.526)* | -2.596(1.459)* |
| *cnae_63* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_71* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_72* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_81* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_89* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_91* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *cnae_99* | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] | n/a[b] |
| *constant* | -11.214(1.56)*** | -13.566(1.42)*** | -13.57(1.42)*** | -11.117(1.63)*** | -11.651(1.80)*** | -11.117(1.63)*** |
| N | 5397 | 2061 | 2061 | 5241 | 5169 | 5285 |
| Log-likelihood | -408.62534 | -299.83656 | -299.86132 | -352.62538 | -364.634 | -403.20654 |
| Pseudo-R2 | 0.4099 | 0.3784 | 0.3783 | 0.399 | 0.41 | 0.412 |
| Prob > chi2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

Logit model.

Standard errors in parenthesis. * p<.10; ** p<.05; *** p<.01.

[a] Not considered firms in the state of São Paulo.

[b] Excluded due to collinearity.

Tables A2.9 to A2.14 in the Appendix display the means tests for covariates. Again, I consider the results satisfy the balancing condition in general. Very few variables present significant difference after the matching, with substantial reduction of the standardized bias for the majority of the cases. Likelihood-ratio test ($p>chi^2$) does not present evidence of significant joint differences in any of the matched samples, and pseudo-$R^2$, mean and median bias also display low values.

Finally, Table 2.15 provides results for the ATT. The only significant impacts are on probability of innovation and firm size. The estimation suggests firms benefiting from the tax incentives had on average 12% more chance of innovating within the next three years (relative effect of 16.2%).

Table 2.15

*Estimated Average Treatment Effect on the Treated – Output and performance variables*

| Outcome Variable | Unit | Sample | Treated | Controls | Difference | Relative effect |
|---|---|---|---|---|---|---|
| *inovator* | Binary | Unmatched | 0.849 | 0.497 | 0.351 (0.041)*** | 0.706 |
| | | ATT | 0.841 | 0.724 | 0.117 (0.050)** | 0.162 |
| *new_sales* | Percentage of total sales | Unmatched | 3.233 | -10.144 | 13.376 (3.234)*** | -1.319 |
| | | ATT | 3.787 | -3.967 | 7.754 (5.733) | -1.955 |
| *new_exp* | Percentage of total exports | Unmatched | -0.209 | -2.622 | 2.412 (2.304) | -0.920 |
| | | ATT | 0.016 | -1.451 | 1.467 (5.050) | -1.011 |
| *revenue* | R$ 1,000 | Unmatched | 15027.197 | 4501.571 | 10525.626 (3963.172)*** | 2.338 |
| | | ATT | 11207.670 | 3016.920 | 8190.750 (16978.925) | 2.715 |
| *personnel* | No. of employees | Unmatched | 136.143 | 31.940 | 104.203 (12.849)*** | 3.262 |
| | | ATT | 140.674 | 33.194 | 107.481 (37.336)*** | 3.238 |
| *rev_person* | R$ 1,000 | Unmatched | -112.556 | -7.197 | -105.359 (25.937)*** | 14.639 |
| | | ATT | -111.265 | -13.604 | -97.661 (66.951) | 7.179 |

Standard errors in parenthesis. * p<.10; ** p<.05; *** p<.01.
Matching algorithm: nearest neighbor.
Standard error estimated according to Abadie and Imbens (2006).

The estimated impact on firm size is substantial. Treated companies grew on average more than four times their respective matches from the control group, and around 5% of the mean size of treated units in 2011.[63] Contrary to the naive estimator, there is no evidence of impact on the share of new product on sales, although the coefficient is positive as expected. Results for other variables also did not achieve statistical significance.

[63] Mean value for treated firms in 2011: 2,140.45 employees.

### 2.6.3 Sensitivity analysis and robustness checks.

Sensitivity of the estimates to hidden bias due to omitted variables was tested through the Rosenbaum bounds procedure, as explained in section 2.5.1.1. The test was only applied to the outcome variables with statistically significant impact. Results are displayed in Table 2.16.

In the case of R&D expenditures and firm size, the cut-off point is found within the interval ($1.2 < \Gamma < 1.3$) for the Hodges-Lehmann estimates (columns 7 and 8) and ($1.3 < \Gamma < 1.4$) for the Wilcoxon signed-rank test (column 3). This means the odds ratio between treatment and control groups has to rise at least 20% above unity to render the ATT statistically insignificant. Considering the comprehensiveness of covariates used in the study, I understand the result is moderately insensitive to hidden bias.

The Wilcoxon signed-rank test (column 3) indicates the ATT loses significance at ($\Gamma > 1.4$) for the innovative expenditures dummy, and at ($\Gamma > 1.3$) for the R&D expenditures and innovation dummies. These results suggest the estimates are fairly insensitive and robust. However, the Hodges-Lehmann estimates (columns 7 and 8) challenges such conclusion, as the critical value is found at low levels of ($\Gamma$).

In the case of R&D personnel, both tests indicate significance is lost at low ($\Gamma$) values, meaning this estimate may be very sensitive to influence from unobserved variables.

Estimates for robustness checks (alternative matching algorithms and model specification) are presented in Table 2.17. Results persist to be valid in at least two of the alternative specifications for all input outcome variables with the exception of research personnel, which remains positive but loses statistical significance.

Results for the innovator dummy and firm size are positive in all cases, and remain statistically significant in two and one of the alternative specifications, respectively. It is also interesting to note that the share of new products in total sales is found to be significant in two of the robustness checks, indicating a possible impact on this variable as well.

Table 2.16

*Rosenbaum bounds sensitivity analysis of hidden bias due to omitted variables*

| Outcome Variable | Gamma | sig+ | sig- | t-hat+ | t-hat- | CI+ | CI- |
|---|---|---|---|---|---|---|---|
| | 1 | 0.000603 | 0.000603 | 453.136 | 453.136 | 199 | 712.235 |
| | 1.1 | 0.002887 | 0.000099 | 396.141 | 517.623 | 131.732 | 783.773 |
| | 1.2 | 0.00989 | 0.000015 | 340.37 | 569.711 | 59.7755 | 851.316 |
| | 1.3 | 0.026253 | 2.20E-06 | 289.882 | 624.975 | -3.02048 | 914.139 |
| | 1.4 | 0.05714 | 3.10E-07 | 239.029 | 671.271 | -60.7515 | 984.084 |
| *rd_exp* | 1.5 | 0.106327 | 4.10E-08 | 193.051 | 718.53 | -109.885 | 1050.95 |
| | 1.6 | 0.174582 | 5.40E-09 | 143.979 | 767.018 | -148.164 | 1105.84 |
| | 1.7 | 0.259197 | 6.90E-10 | 103.621 | 813.977 | -193.754 | 1155.25 |
| | 1.8 | 0.35473 | 8.60E-11 | 57.7 | 854.867 | -232.533 | 1205.1 |
| | 1.9 | 0.45446 | 1.10E-11 | 15.855 | 895.686 | -269.458 | 1249.73 |
| | 2 | 0.551896 | 1.30E-12 | -17.9925 | 935.621 | -310.24 | 1295 |
| | 1 | 0.077376 | 0.077376 | 2.2 | 2.2 | -0.725 | 5.6 |
| | 1.1 | 0.19005 | 0.024339 | 1.3 | 3.175 | -1.6 | 6.675 |
| | 1.2 | 0.35133 | 0.006643 | 0.525 | 4.025 | -2.42 | 7.68 |
| | 1.3 | 0.529442 | 0.001619 | -0.095 | 4.85 | -3.3 | 8.7 |
| | 1.4 | 0.689974 | 0.00036 | -0.65 | 5.5 | -4.025 | 9.8 |
| *researcher* | 1.5 | 0.813043 | 0.000074 | -1.275 | 6.2775 | -4.695 | 10.7 |
| | 1.6 | 0.895823 | 0.000014 | -1.825 | 6.95 | -5.3 | 11.55 |
| | 1.7 | 0.945847 | 2.70E-06 | -2.4 | 7.625 | -5.89 | 12.55 |
| | 1.8 | 0.973509 | 4.70E-07 | -3 | 8.3375 | -6.45 | 13.675 |
| | 1.9 | 0.98771 | 8.00E-08 | -3.5 | 9 | -6.9 | 14.69 |
| | 2 | 0.994556 | 1.30E-08 | -4 | 9.7 | -7.45 | 15.525 |
| | 1 | 0.005294 | 0.005294 | 4.40E-07 | 4.40E-07 | -4.40E-07 | 0.5 |
| | 1.1 | 0.010786 | 0.002401 | 4.40E-07 | 0.5 | -4.40E-07 | 0.5 |
| | 1.2 | 0.019383 | 0.001082 | -4.40E-07 | 0.5 | -4.40E-07 | 0.5 |
| | 1.3 | 0.031621 | 0.000486 | -4.40E-07 | 0.5 | -4.40E-07 | 0.5 |
| | 1.4 | 0.047809 | 0.000217 | -4.40E-07 | 0.5 | -4.40E-07 | 0.5 |
| *in_dummy* | 1.5 | 0.068019 | 0.000097 | -4.40E-07 | 0.5 | -4.40E-07 | 0.5 |
| | 1.6 | 0.092105 | 0.000043 | -4.40E-07 | 0.5 | -4.40E-07 | 0.5 |
| | 1.7 | 0.11975 | 0.000019 | -4.40E-07 | 0.5 | -4.40E-07 | 0.5 |
| | 1.8 | 0.150515 | 8.50E-06 | -4.40E-07 | 0.5 | -4.40E-07 | 0.5 |
| | 1.9 | 0.183879 | 3.80E-06 | -4.40E-07 | 0.5 | -4.40E-07 | 0.5 |
| | 2 | 0.219289 | 1.70E-06 | -4.40E-07 | 0.5 | -4.40E-07 | 0.5 |
| | 1 | 0.005615 | 0.005615 | -4.20E-07 | -4.20E-07 | -4.20E-07 | -4.20E-07 |
| | 1.1 | 0.012026 | 0.002398 | -4.20E-07 | -4.20E-07 | -4.20E-07 | -4.20E-07 |
| | 1.2 | 0.022431 | 0.001014 | -4.20E-07 | -4.20E-07 | -4.20E-07 | -4.20E-07 |
| | 1.3 | 0.03762 | 0.000426 | -4.20E-07 | -4.20E-07 | -4.20E-07 | -4.20E-07 |
| | 1.4 | 0.058042 | 0.000178 | -4.20E-07 | -4.20E-07 | -4.20E-07 | 4.20E-07 |
| *rd_dummy* | 1.5 | 0.083773 | 0.000074 | -4.20E-07 | -4.20E-07 | -4.20E-07 | 0.5 |
| | 1.6 | 0.114551 | 0.00003 | -4.20E-07 | -4.20E-07 | -4.20E-07 | 0.5 |
| | 1.7 | 0.149839 | 0.000013 | -4.20E-07 | -4.20E-07 | -4.20E-07 | 0.5 |
| | 1.8 | 0.188911 | 5.20E-06 | -4.20E-07 | -4.20E-07 | -4.20E-07 | 0.5 |
| | 1.9 | 0.230936 | 2.10E-06 | -4.20E-07 | -4.20E-07 | -4.20E-07 | 0.5 |
| | 2 | 0.275049 | 8.70E-07 | -4.20E-07 | -4.20E-07 | -4.20E-07 | 0.5 |
| | 1 | 0.004764 | 0.004764 | -4.50E-07 | -4.50E-07 | -4.50E-07 | -4.50E-07 |
| | 1.1 | 0.011221 | 0.001819 | -4.50E-07 | -4.50E-07 | -4.50E-07 | -4.50E-07 |
| | 1.2 | 0.0225 | 0.000683 | -4.50E-07 | -4.50E-07 | -4.50E-07 | -4.50E-07 |
| | 1.3 | 0.039876 | 0.000253 | -4.50E-07 | -4.50E-07 | -4.50E-07 | 4.50E-07 |
| | 1.4 | 0.06415 | 0.000093 | -4.50E-07 | -4.50E-07 | -4.50E-07 | 0.5 |
| *inovator* | 1.5 | 0.095538 | 0.000034 | -4.50E-07 | -4.50E-07 | -4.50E-07 | 0.5 |
| | 1.6 | 0.133681 | 0.000012 | -4.50E-07 | -4.50E-07 | -4.50E-07 | 0.5 |
| | 1.7 | 0.177745 | 4.40E-06 | -4.50E-07 | -4.50E-07 | -4.50E-07 | 0.5 |
| | 1.8 | 0.226569 | 1.60E-06 | -4.50E-07 | -4.50E-07 | -4.50E-07 | 0.5 |
| | 1.9 | 0.278817 | 5.60E-07 | -4.50E-07 | 4.50E-07 | -4.50E-07 | 0.5 |
| | 2 | 0.333114 | 2.00E-07 | -4.50E-07 | 4.50E-07 | -4.50E-07 | 0.5 |
| | 1 | 0.000958 | 0.000958 | 83.5 | 83.5 | 29 | 152.5 |
| | 1.1 | 0.004185 | 0.000174 | 69 | 102 | 16.5 | 167.5 |
| | 1.2 | 0.01333 | 0.00003 | 56 | 117 | 6.5 | 182 |
| | 1.3 | 0.033359 | 4.80E-06 | 46 | 130 | -3.5 | 196 |
| | 1.4 | 0.069213 | 7.50E-07 | 36.5 | 142 | -15 | 212 |
| *personnel* | 1.5 | 0.123858 | 1.10E-07 | 28.5 | 152.5 | -23 | 225.5 |
| | 1.6 | 0.196985 | 1.60E-08 | 19.5 | 163 | -31 | 236.5 |
| | 1.7 | 0.284956 | 2.40E-09 | 14 | 172.5 | -38.5 | 246.5 |
| | 1.8 | 0.381837 | 3.30E-10 | 7.00001 | 181 | -46 | 256.5 |
| | 1.9 | 0.480924 | 4.60E-11 | 1.99998 | 189.5 | -52.5 | 267 |
| | 2 | 0.576122 | 6.30E-12 | -5 | 198.5 | -60.5 | 275.5 |

* gamma - log odds of differential assignment due to unobserved factors; sig+ - upper bound significance level; sig- - lower bound significance level; t-hat+ - upper bound Hodges-Lehmann point estimate; t-hat- - lower bound Hodges-Lehmann point estimate; CI+ - upper bound confidence interval (a= .95); CI- - lower bound confidence interval (a= .95).

Table 2.17

*Robustness checks results*

| Group | Variable | Sample | Kernel Matching[a] | Radius Matching[b] | Nearest Neighbor (no sector dummies)[c] |
|---|---|---|---|---|---|
| Input | *in_exp* | Unmatched | 90.233(170.874) | 90.233(170.874) | 86.41(167.71) |
| | | ATT | -183.263(240.921) | -162.852(243.528) | -304.62(322.52) |
| | *rd_exp* | Unmatched | 503.252(101.293)*** | 503.252(101.293)*** | 500.38(100.34)*** |
| | | ATT | 266.682(134.513)** | 188.605(136.852) | 382.94(181.06)*** |
| | *researcher* | Unmatched | 6.728(1.332)*** | 6.728(1.332)*** | 6.44(1.36)*** |
| | | ATT | 3.708(1.95)* | 3.157(1.985) | 2.71(2.54) |
| | *in_dummy* | Unmatched | 0.508(0.059)*** | 0.508(0.059)*** | 0.52(0.06)*** |
| | | ATT | 0.225(0.065)*** | 0.174(0.067)*** | 0.13(0.06)** |
| | *rd_dummy* | Unmatched | 0.565(0.03)*** | 0.565(0.03)*** | 0.57(0.03)*** |
| | | ATT | 0.129(0.043)*** | 0.082(0.044)* | 0.09(0.04)** |
| Output and performance | *inovator* | Unmatched | 0.351(0.041)*** | 0.351(0.041)*** | 0.37(0.04)*** |
| | | ATT | 0.14(0.042)*** | 0.132(0.045)*** | 0.06(0.05) |
| | *new_sales* | Unmatched | 0.266(0.079)*** | 0.266(0.079)*** | 0.26(0.08)*** |
| | | ATT | 0.158(0.071)*** | 0.165(0.072)** | -0.01(0.06) |
| | *new_exp* | Unmatched | 0.01(0.061) | 0.01(0.061) | 0.01(0.06) |
| | | ATT | 0.069(0.078) | 0.098(0.08) | -0.03(0.09) |
| | *Revenue* | Unmatched | 10525.626(3963.172)*** | 10525.626(3963.172)*** | 10398.43(3848.62)*** |
| | | ATT | 8782.778(8608.515) | 5833.114(8558.738) | 16700.84(14766.85) |
| | *Personnel* | Unmatched | 104.203(12.849)*** | 104.203(12.849)*** | 106.09(12.81)*** |
| | | ATT | 62.125(25.851)** | 30.7(24.151) | 31.02(33.37) |
| | *rev_person* | Unmatched | -105.359(25.937)*** | -105.359(25.937)*** | -107.24(25.32)*** |
| | | ATT | -57.833(39.174) | -58.699(38.691) | -108.59(68.43) |

Standard errors in parenthesis. * p<.10; ** p<.05; *** p<.01.
[a] Matching algorithm: kernel. Standard error estimated by 100 bootstrap iterations.
[b] Matching algorithm: radius within caliper (20% of the standard deviation of the propensity score). Standard error estimated by 100 bootstrap iterations.
[c] Matching algorithm: nearest neighbor. Standard error estimated according to Abadie and Imbens (2006).

### 2.6.4 Discussion of the results.

In this subsection, I analyze the results of this empirical study in light of the literature on innovation tax incentives and impact assessment summarized in sections 2.2 and 2.3, and the features and specifics of the Brazilian policy described in section 2.4. Based on such analysis and on other parts of the paper, a number of conclusions and recommendations for policy improvement are presented.

The first relevant point is the positive impact on R&D spending of beneficiary firms, indicating the incentives effectively increase private investment on innovation and technological efforts of local industry. The estimation indicates a positive impact on the trend of expenditures, representing around 7% of the mean R&D spending of beneficiary firms. Considering the theoretical motivations of innovation policies, this may be understood as empirical evidence that, in this case, government intervention corrects market failures to a certain level. Moreover, the study empirically rejects the hypothesis of full crowding-out, meaning public indirect financing partially complements private resources.

As a downside, the estimated impact per firm (around five hundred thousand Brazilian *reais* in 2011) was less than a quarter of the average value of tax incentives each firm obtained in the same year (around two million Brazilian *reais*).

Such results follow the standard findings of the empirical literature on tax incentives. As discussed and summarized in Table 2.3, most of the studies so far have found the additional investment per dollar of incentive to be less than one, at least in the short run. The estimated impact relative to 2011 mean value (6.8%) is substantially lower than the effect found by Guceri (2015), Yang et al. (2012) Avellar (2008) and Yohei (2011). The analysis also confirms findings of previous studies on the Brazilian tax incentives for innovation, and the result is closer to Kannebley Jr. and Porto (2012) - 7% to 11% - than to Shimada et al. (2014): 86% to 108%.

There is also evidence that the policy increased hiring of research personnel, although such result should be taken with caution, for it did not prove to be very robust to hidden bias or model specification. Positive impact on R&D staff is in accordance with the conclusions of Duguet (2012), Shimada et al. (2014), Kannebley et al. (2013) and Kannebley Jr. and Porto (2012).

The results also indicate the Brazilian policy was successful in encouraging firms to begin investing in innovation. The same empirical finding was obtained by Aralica et al. (2013) and Hægeland and Møen (2007), and it challenges the theoretical argument that tax incentives are not particularly suited for increasing the base of innovative companies (Bastos, 2004).

The study also suggests impact of the policy on innovation output. This is a particularly important finding, for the number of studies that analyzed such variables is still small. The main finding is that beneficiary firms had 12% higher chances of innovating. Bérubé and Mohnen (2009) also found firms receiving public support innovate more. This may be interpreted as evidence that, at a minimum, impact of tax incentives is not fully jeopardized by moral hazard, relabeling of activities and increase of input prices. In addition, it is interesting to note that this result is very similar to the average impact on the chances of a firm starting to invest in R&D (11,11%), reinforcing both the result and the role of R&D as a main source of innovation.

The ATT suggests beneficiary firms experienced a substantial employment growth because of the policy. Among the few studies that analyzed firm's performance, Czarnitzki et al. (2011) did not find any impact of government intervention. The impact relative to 2011 mean value (5%) is similar to the one found by Kannebley et al. (2013) - 5.7% to 8.5%. However, interpretation of this finding is challenging, especially considering that no positive impact on net revenue was found. The reason behind this employment raise may be a relevant subject for a survey or qualitative research on the policy.

Contrary to Czarnitzki et al. (2011), Aralica et al. (2013) and Bérubé and Mohnen (2009), this study does not present evidence of impact of the policy on new products sales and exports, although the sign of the ATT is consistently positive and it achieves statistical significance in alternative matching algorithms (as part of the robustness checks). Moreover, no evidence of effect on firms' labor productivity was found. The same result was obtained by Cappelen, Raknerud and Rybalka (2007) and Colombo, Grilli and Murtinu (2011).

Kannebley et al. (2013) found positive impact of the incentives of Law 11,196/05 on exports. However, such study used a different outcome variable: exports per employee. So, the results reported herein cannot be said to be inconsistent with their findings, although they suggest a deeper investigation on the exports of beneficiary firms.

These are particularly troubling results from an innovation policy perspective. The endogenous growth literature identifies as main drivers of economic growth the increase in factor productivity (Romer, 1990; and Grossman & Helpman, 1989, 1990) and design of new products (Aghion & Howitt, 1990; Grossman & Helpman, 1991). These should be crucial objectives of an innovation policy, and this study's findings suggest Brazilian tax incentives did not contribute to achieving these goals.

The treatment probability models (propensity score) also provide relevant information to understand which firms seek and obtain the tax incentives. Estimates confirm net revenue is a crucial factor determining participation in the policy, which is in accordance with the theoretical argument that tax incentives are more appropriate for large companies. It also provides grounds to the critique that the policy design disfavors small firms, whether because it requires adoption of the real profit tax regime or because deduction of expenses can only be carried out within the same fiscal year.

The models also suggest continuous R&D activities and exports are important factors explaining participation in the policy. These are expected results, for firms with such features are more likely to invest substantial resources on innovation, benefiting more from the incentives. Other variables significant for a meaningful group of estimates are foreign controlling capital and firm size.

The analyses and results described in this paper present relevant insights for discussing the policy and improvements of its design. First, they present sound evidence of positive impacts of these incentives, with additionallity effects on both input and output variables. In this sense, the tax benefits seem to constitute an important action for supporting entrepreneurial innovation in the country, although with limited range due to its strict requirements. This result is consistent with the increasing and spread use of tax incentives at the international level, as discussed in section 2.2.3. It is reasonable to conclude that the Brazilian experience confirms the role and relevance of tax incentives in a national innovation strategy.

Nevertheless, the share of government support through tax incentives is below the levels of several developed economies, as presented in Figure 2.3, suggesting there is room for a more intensive use of this policy tool in the country. For this reason, implementing measures to reduce participation barriers and raise the volume of tax breaks seems to constitute an important challenge for the development of the Brazilian innovation tax policy.

Besides the requirement of firms to operate under the real profit tax regime, two other points can be considered obstacles for firms to be entitled to the incentives. The first is the absence of any type of carryback or carryforward scheme, not allowing firms to deduct innovation expenses in fiscal years other than the ones they were actually incurred. And the second is the restrictions to outsource and deduct expenditures incurred by other firms of the same group: in both cases, firms without an internal R&D department cannot benefit from the incentives by transferring their innovation initiatives to other legal entities.

Another positive result identified in this study is the increased demand for R&D personnel. A higher number of researchers working on industrial innovation projects can raise overall qualification of the workforce and foster knowledge spillovers between firms. Raising incentives for firms willing to hire even more researchers may increase this effect of the policy.

On the other hand, the substantial level of crowding-out (estimated by comparing the estimated average policy impact on R&D expenditures with the mean tax break per firm) is a relevant problem to be addressed. The adoption of incremental based schemes for part of the incentives is a strategy to be considered, so firms are compelled to raise their R&D levels above a certain threshold.

This paper suggests that the main challenges of the policy currently are how to impact sales and exports of new goods, and increase labor productivity. Devising a strategy to meet these targets requires qualitative research with the beneficiary companies, including case studies and surveys, to better understand why the increase in R&D and research personnel was not followed by better results in these output indicators. Ayres and Kapczynski (2015) presented the idea of 'innovation sticks', meaning that the results of present innovation efforts are considered to determine incentives in the future, and that firms failing to meet certain targets are penalized according to a set of rules previously established.

## 2.7 Concluding Remarks

This paper presents an impact assessment of the tax incentives provided by Law 11,196/05. This policy represented an inflection point on the use of fiscal measures to foster industrial innovation in Brazil, both in terms of tax generosity, investment volume and number of beneficiary firms.

Following a branch of the international empirical literature on innovation policy, I applied the propensity score matching with difference-in-differences and estimated the average treatment effect on beneficiary firms using microdata from the PINTEC editions of 2008 and 2011 and other databases. Results suggest a causal impact of the policy on R&D expenditures (average of around five hundred thousand Brazilian *reais* in 2011) and number of research staff (average of five researchers), rejecting the hypothesis of full crowding-out. The average estimated impact, nevertheless, falls short of the volume of tax break per firm.

The policy also increases average chances of firms to start investing in innovation (on average, 23% for innovative activities and 11% for R&D) and actually innovating (average of 12%). Finally, there is also evidence of impact on company size: beneficiary firms hired on average 107 more employees because of the policy.

These findings provide empirical support in favor of tax incentives as a relevant part of the government strategy to boost entrepreneurial innovation in the country.

On the other hand, this study provides no evidence of impact on firms' productivity and new products' sales and exports. This is an important result for it may reveal shortcomings of the policy design, implying the need of reform to improve these indicators. This result also points to the importance of investigating more carefully how beneficiary companies have invested additional resources increased by public funding.

The study has limitations arising from the applied empirical strategy that may be object of future researches. The PSM does not account for knowledge spillovers between firms, considered a major side effect and source of growth caused by technological progress (Griffith et al., 1995).

Finally, this study is part and contributes to the recent development of the empirical economic literature on innovation policies, aiming at evaluating and providing empirical evidence for the debate and improvement of government action. Most of the observed results are consistent and in accordance with similar researches on tax incentives in other countries.

# 3 Effects of Tax Incentives on the Composition of Innovation Investments of Brazilian firms

Abstract

The objective of this paper is to investigate whether the tax incentives for innovation in Brazil established by Law 11,196/05 have altered the composition of firms' innovation investments. Using disaggregate data at the firm level from the PINTEC survey and other sources, the average treatment effect on the treated (ATT) is estimated through a propensity score matching with difference-in-differences procedure. Main findings of the study are: (a) incentives raised R&D intensity of beneficiary firms by 9.5%, causing them to increase R&D expenditures around eleven hundred thousand Brazilian *reais* or 17% of the mean value of these expenditures by beneficiary firms in 2011, while decreasing mean spending on acquisition of external knowledge and introduction of innovations into the market; (b) the policy also fostered additional hiring of 3.35 researchers with undergraduate university degree in 2011 (around 11% of the average research workforce in beneficiary firms that year), without significant impact on personnel with higher educational level; and (c) there is no evidence of impact on R&D outsourcing levels or on the balance between product and process innovation. A number of policy implications are drawn from the study: (a) incentives aiming innovative activities besides strict R&D may be important to reap the benefits of secondary innovation; (b) policy design should foster hiring of R&D personnel with graduate degree; (c) incentives aimed at fostering process innovation can help increasing productivity gains; and (d) repealing restrictions on R&D outsourcing should be considered.

Keywords: Tax incentives. Innovation. Investment composition.

## 3.1 Introduction

The economic literature and debate on public policies aimed at promoting technological innovation have experienced a substantial stride in the recent decades, driven by new models, evidence from different countries, new analytical tools of assessment and an increasing interest by researchers and policy-makers worldwide (for recent reviews and a summary of the international experience see Edler, Cunningham, Gök & Shapira, 2013; OECD, 2014a; and Hall & Lerner, 2009). Considering the multiplicity of tools and different industrial base of each country, results of such studies present significant variations. But, in general, most of them found evidence of some level of positive impact of government incentives, whether in the case of direct subsidies (Cunningham, Gök & Larédo, 2012; Aschhoof, 2009; Almus & Czarnitzki, 2003) or tax incentives (EC, 2014; Köhler, Laredo & Rammer, 2012).

Another strand of the innovation economics literature has dedicated its efforts to study the composition of firms' innovation investments (Link, 1982; Czarnitzki, Kraft & Thorwarth, 2009; Barge-Gil & López, 2014, among others).[64] These analyses considered different features of enterprises and business environment that may influence innovation strategy, including knowledge spillovers, technology base of the firm and range of activities and produced goods.

The intersection between these two subjects constitutes a more recent and unexplored field of research in economics. As argued by Zúñiga-Vicente, Alonso-Borrego, Forcadell and Galán (2014), most studies on innovation policy have considered research and development (R&D) as a homogeneous activity, not investigating whether and how government incentives affect the composition of private spending as a reflex of changes in their innovation strategies (the "behavioral additionality effect", as suggested by Buisseret, Cameron & Georghiou, 1995). By the same token, Afcha and López (2014) noted the subject did not receive enough attention in technology policy evaluation studies. OECD (2006b) and Neicu, Teirlinck and Kelchtermans (2014) confirmed this topic has been majorly ignored in economics. The literature commonly assesses the impact of innovation policies in broad terms or using aggregate indicators such as R&D expenditures or other innovation inputs.

This paper aims to contribute to the body of knowledge on this topic by presenting quantitative evidence of the Brazilian case. Since the last decade, the federal government has adopted different policies directed at fostering business innovation, including tax incentives for R&D spending and hiring of research personnel. The study presents an econometric assessment of how such fiscal benefits have affected the bundle of firms' innovation investments, according

[64] See section 3.2.

to four different criteria: (a) spending on each subcategory of innovative activities;[65] (b) R&D outsourcing; (c) educational level of R&D personnel; and (d) type of innovation (product or process).

This study uses disaggregate data at the firm level gathered by the Brazilian Institute of Geography and Statistics (IBGE) for the Brazilian Innovation Survey (PINTEC).[66] Policy impact is estimated through the propensity score matching and the average treatment effect on the treated, applying a difference-in-differences analysis for continuous variables to minimize selection bias.

The following section reviews the literature on private innovation investment composition and discusses the economic meaning and relevance of each broad classification of investments analyzed herein. The third part discusses the behavioral additionality effect of innovation policies, analyzing tax incentives' schemes in more detail. Section four describes the current industrial innovation landscape and the tax policy in place in Brazil, focusing on composition of investments. The fifth part describes the data and empirical strategy used for the empirical analysis. The sixth part exhibits and debates the results, and the last section summarizes and concludes the paper.

## 3.2 The Economic Debate on Composition of Business Innovation Investments

This section presents the main literature that debates the economic relevance of the composition of innovation investments for firms and the aggregate economy. The first subsection introduces the topic by providing a brief overview of the literature and discussing how expenditures composition have been used as an analytic tool in innovation studies. The second explains and describes the main broad categories used in the empirical analysis, and the third discusses their importance for economic development.

### 3.2.1 General literature on the topic.

The economic debate on how firms divide and allocate their limited resources for innovation has one of its main roots in Nelson's (1959) classic argument that a firm's investment in basic research increases with the size of its technological base and range of

[65] As defined in section 3.2.2.1.
[66] "*Pesquisa de Inovação Industrial*".

manufactured products ("fingers in many pies").[67] A subsequent literature tried to model firms` R&D investment composition to test Nelson`s hypothesis. Link (1982) presented one of the first and most influential papers on this topic; he found diversification of activities is indeed positively correlated with basic research spending. Other studies that achieved similar results are Mansfield (1980, 1981) and Griliches (1986); the only exception is Jaffe, Trajtenberg and Henderson (1993).

The categories of research (basic and applied) and development are expressly described in both the Oslo and Frascati Manuals (OECD, 2005 and 2015a).[68] The distinction was criticized by Mowery and Rosenberg (1989) as artificial, since new knowledge is often produced within development projects, meanwhile basic research may generate new inventions with immediate market use.

A number of studies used different classifications to analyze changes in the R&D expenditures' bundle as proxies for firms' innovation strategies or patterns. Saha (1999), Beladi, Marjit and Yang (2011), Aralica and Botrić (2013) and Cohen and Klepper (1996) investigated the division between product and process R&D; Beneito, Rochina-Barrachina and Sanchis (2015) distinguished between physical capital and labor (researchers' salaries); Minniti (2010) and Gil (2013) considered horizontal and vertical innovation; Afcha and López (2014), Den Hertog and Thurik (1993) and Tamayo and Huergo (2014) used the division between internal and external (outsourced) R&D; and Dumont, Spithoven and Teirlinck (2014) and Aggarwal, Hsu and Wu (2015) analyzed the education and technical expertise of research personnel.

As per the object of studies or how they address R&D composition, Barge-Gil and López (2014) and Aggarwal et al. (2015) considered such mix as a given input or independent variable, in order to assess what would be the most efficient or successful strategy to increase innovation output. Alternatively, others tried to identify determinants or relevant factors that affect R&D combination, including: market structure (Minniti, 2010; Den Hertog & Thurik, 1993); technological intensity (Barge-Gil & López, 2014); firm size (Mansfield, 1981; Cohen & Klepper, 1996); outsourcing (Beladi et al., 2011); animal spirits (Gil, 2013); business cycles (Rafferty, 2003); product life cycle (Saha, 1999); international experience (Tamayo & Huergo,

[67] "A broad technological base insures that, whatever direction the path of research may take, the results are likely to be of value to the sponsoring firm. It is for this reason that firms which support research toward the basic-science end of the spectrum are firms that have their fingers in many pies". (Nelson, 1959, p. 302).

[68] Following the definitions posed in the Frascati Manual, both basic and applied research refer to an original investigation (experimental or theoretical), but their main difference is that the former does not aim any particular use, while the later is directed to a practical purpose or application. Development, on the other hand, is based on a previous existing set of knowledge, and has the objective of creating new products or processes, or improving existing ones (OECD, 2015a).

2014); and innovation efficiency over time (Beneito et al., 2015). This literature reveals how different factors can influence firms' R&D strategy and the expenditure combination arising from it. It thus stresses the importance that studies on R&D composition be designed carefully and considering a comprehensive set of relevant control variables, in order to avoid endogeneity problems.

A related stream of literature arose from Pavitt's (1984) proposed taxonomy of four types of innovative firms (Evangelista, 2000; Evangelista, Perani, Rapiti & Archibugi, 1997; Veugelers & Cassiman, 1999; Mairesse & Mohnen, 2002; Castellacci, 2008). The author was interested in identifying sectoral patterns and their technological trajectories, but his classification also has implications for innovation composition: sectors dominated by suppliers or scale intensive are more focused on process and vertical[69] innovation, while specialized supplier industries rely more on product and concentric[70] innovation. Pavitt's categories have been applied in different investigations, also influencing data collection and policy design (Archibugi, 2001). The taxonomy also influenced the emergence of a management literature on innovation patterns and trajectories. Afcha and López (2014) pointed that heterogeneity of R&D has been widely acknowledged and received greater attention in these studies. Narula (2001) and Miotti and Sachwald (2003) analyzed the relevance of firm size on the decision of R&D outsourcing; Granstrand, Patel and Pavitt (1997) studied the relation between technological diversification and competences; and Arora and Gambardella (1990) looked into complementarity and external research linkages.

This literature review suggests that, despite being a specific topic, there is significant diversity in terms of theoretical frameworks and methodological approaches available to address innovation expenditures composition. Besides the classic division between research and development, different categories (and arguments) were developed and tested. These analyses both challenge and complement the standard homogeneous R&D approach (Link, 1982; Barge-Gil & López, 2014), evidencing the relevance of taking into consideration the composition of the bundle of innovation inputs.

[69] "The "vertical" figure is the percentage of the innovations produced by innovating firms, that are outside the innovating firms' principal sector of activity. but used within the innovating firms' sector: it reflects the relative importance of technological diversification into the equipment, materials and components for their own production". (Pavitt, 1984, p. 356).

[70] "The "concentric/conglomerate" figure is the percentage of the innovations that are both produced and used outside the principal sector of the innovating firms' activities: it reflects the relative importance of technological diversification into related and unrelated product markets". (Pavitt, 1984, p. 356).

### 3.2.2 Selected broad classifications of innovation investments' composition.

This part explains the innovation investment categories considered in this empirical study, summarizing the main arguments and economic reasoning presented by the literature.

#### *3.2.2.1 Distinct innovative activities.*

The main point of investigating the division of investments in different innovative activities is to acknowledge and consider in the analysis that firms choose between distinct strategies to acquire and apply information to increase productivity or design new products.

In this conceptual framework, R&D is but one strategy available to the firm. The Frascati Manual requires that, in order to fall under the category of R&D, the activity must be (a) novel; (b) creative; (c) uncertain; (d) systematic; and (e) transferable or reproducible (OECD, 2015a). It expressly excludes a series of ancillary activities such as technical services, standardization, testing and feasibility studies.

Innovative activity, on the other hand, is a broader concept. The Oslo Manual includes in this category any procedure aimed at implementing innovations, whether of scientific, technological, organizational, financial or commercial nature (OECD, 2005). Innovative activities encompass the following operations: (a) strict R&D, as defined; (b) acquisition of external knowledge; (c) purchase of machinery, equipment and other capital goods; (d) other arrangements for innovation, such as industrial design, engineering and set-up, trial production, patent and licensing, production start-up and testing; (e) market preparation; and (f) training.

These activities can positively impact the stock of knowledge and technological development of firms. Enterprises divide resources on these choices taking into consideration their marginal returns and other variables such as knowledge spillovers, personnel turnover and technological rate of obsolescence. The understanding of firms' technological behavior and strategies and how they respond to different factors by increasing or substituting between these activities is key not only to design policy intervention but also to better understand significant shifts in the structure of technological investments.

Firms' choices on which innovative activity to invest (and how much) matter for aggregate economic performance, for each one entails distinct levels of technological development and externalities, thus affecting country's output and welfare. Acquisition of machinery and equipment increase capital stock, while training positively influences human capital levels, and R&D expands knowledge frontier. In one of the few studies to consider the composition of the bundle of innovative activities, Zhu, Xu and Lundin (2006) argued R&D is more risky, costly and has a large maturation period than other categories.

Table 3.1 presents the distribution of firms investing in each type of innovative activity for a group of selected European countries,[71] according to the 2012 Community Innovation Survey (Eurostat, 2016). Purchase of machinery, equipment and software is the most frequent form of investment for majority of countries, followed by internal R&D and training. Acquisition of external knowledge, on the other hand, was not reported as a relevant innovation strategy for a great number of firms within the region.

Table 3.1

*Share of innovative firms investing in each innovative activity for selected (European) countries (2012)*

| Country | Share of innovative enterprises engaged in each innovative activity[a] | | | | | |
|---|---|---|---|---|---|---|
| | Machinery, equipment and software | Market introduction | External knowledge | Other activities | In-house R&D | Training |
| Belgium | 60.05 | 32.16 | 18.37 | 27.58 | 57.19 | 48.35 |
| Denmark | 46.15 | n/a | 43.57 | n/a | 55.31 | 30.36 |
| Germany | 64.48 | 33.04 | 21.96 | 78.53 | 48.01 | 56.89 |
| Ireland | 57.58 | n/a | 25.81 | n/a | 64.24 | n/a |
| Greece | 73.55 | 37.45 | 33.75 | 36.36 | 34.08 | 42.43 |
| Spain | 26.85 | 17.92 | 2.10 | 7.61 | 42.56 | 23.89 |
| France | 60.70 | 44.96 | 21.99 | 37.78 | 64.53 | 58.07 |
| Croatia | 80.02 | 39.67 | 31.61 | 37.02 | 55.56 | 60.22 |
| Italy | 71.01 | 32.36 | 15.06 | 18.13 | 37.33 | 33.47 |
| Hungary | 73.65 | 31.94 | 15.73 | 41.71 | 50.97 | 41.67 |
| Netherlands | 63.14 | 41.46 | 28.08 | 49.43 | 72.80 | 46.68 |
| Austria | 67.98 | 41.28 | 32.75 | 43.12 | 50.80 | 60.61 |
| Poland | 70.64 | 31.16 | 17.46 | 37.55 | 30.80 | 48.27 |
| Portugal | 61.12 | 29.19 | 17.09 | 27.25 | 35.14 | 53.74 |
| Romania | 68.72 | 19.38 | 10.13 | 30.56 | 24.53 | 24.42 |
| Slovenia | 72.77 | 42.27 | 38.34 | 37.84 | 78.07 | 42.12 |
| Finland | 65.23 | 43.78 | 39.89 | 38.45 | 75.24 | 39.52 |
| Sweden | 66.72 | 30.00 | 48.34 | 24.30 | 64.18 | 26.76 |
| Norway | 46.46 | 39.95 | 26.75 | 37.98 | 71.28 | 53.90 |
| Turkey | 74.14 | 42.76 | 28.62 | 42.47 | 40.50 | 37.37 |
| Average[b] | 64.43 | 36.09 | 26.21 | 37.98 | 47.53 | 45.77 |

n/a – not available
[a] Regardless of organizational or marketing innovation (including enterprises with abandoned/suspended).
[b] Number of enterprises not considered (all countries with available information have the same weight).
Source: Eurostat (2016).

[71] Data for Brazil are presented and discussed in sections 3.4 and 3.5.

***3.2.2.2 Internal and external R&D.***

This classification is useful to differentiate innovation efforts carried out internally by enterprises and those outsourced to third parties, such as other entities of the same economic group, specialized research firms or laboratories and non-profit institutions.

There is a large body of literature that tries to identify if and when companies outsource R&D. The main theoretical basis of this debate may be found in the theory of transaction costs (Coase, 1937; Williamson, 1989), according to which a firm outsources any activity when external costs (information asymmetry, bargaining, enforcement and coordination, among others) do not overcome internal ones.

Following this reasoning, Love and Rooper (2002) and Afcha and López (2014) argued there is a tradeoff between internal and external R&D that can be interpreted in terms of different types of costs. Internal R&D requires high early and sometimes irreversible costs (research equipment), but on the other hand it allows for economies of scale that reduce total cost in time. External R&D, alternatively, has less cost in the short run (for specialized research institutions also benefit from economies of scale), but it imposes a higher risk of competition, for a firm acquiring knowledge from third parties is less likely to have the property right to enforce monopoly on developed technology. By the same token, Den Hertog and Thurik (1993) maintained firms outsource R&D to overcome budget limitations, but with this choice comes the danger of outflow of information.

Mowery and Rosenberg (1989) and later Beneito (2006) presented the argument of specificity of the research project, maintaining the more complex and firm-specific the intended innovation, the higher the information exchange. This would increase the advantages of in-house R&D, both because internal staff is more likely to understand technical details of production and also to avoid disclosure of core technologies.

Internal and external R&D, however, do not need to be substitutes in a zero-sum game, as they may work as complements of each other (Mowery, 1983; Link & Rees, 1991; Lokshin, Belderbos, and Carree, 2015). Beneito (2003, 2006) studied the case of Spanish firms and found the relation between in-house and outsourced R&D may not be linear nor a discrete choice, and can be better comprehended as a combination strategy.

In order to have a first idea on how firms divide their R&D resources pursuant to these categories, in 2013 around 88% of total R&D by U.S. firms was undertaken in-house, and less than 12% was outsourced. This general picture, however, should be considered with caution, as it may overlook differences between sectors (petroleum and coal products industries outsourced more than half of their R&D) or firm size (companies with ten to 25 thousand employees had around 20% of external R&D - NSF, 2013b).

#### *3.2.2.3 Educational level of R&D personnel.*

Proper qualification of human resources is deemed essential for innovation-related projects (Dumont et al., 2014; Spithoven & Teirlinck, 2010), considering the complexity of activities and that they rely heavily on the knowledge of available research personnel. Formal education is considered one of the two basic or most important sources of new skills for firms' employees, along with on-the-job experience or 'learning-by-doing' (OECD, 1995).

Formal education degrees are relevant assets for industry researchers for a number of reasons. First, because of the tacit knowledge embedded in such training (Argote & Ingram, 2000). They are also necessary to sustain firms' core scientific bases and research network (Lam, 1995). Roach and Sauerman (2010) argued Ph.D. holders entering the market bring frontier scientific knowledge and ties with the academic community, increasing firms' 'absorptive capacity', defined by Cohen and Levinthal (1990) as the ability to find value in new information, and to assimilate and apply it to commercial ends. Cohen and Levinthal (1990) stated the absorptive capacity of an organization is a direct function of the capacity of its individual members, although it should not be comprehended as their sum.

Lee, Miozzo and Laredo (2010) suggested academic degrees have a relevant byproduct of providing students with skills, procedures and techniques to conduct high level research. These abilities are relevant and useful for industry R&D. Relying on this argument, Spithoven and Teirlinck's (2010) empirical research with Belgium firms concluded educational level of R&D personnel enables more collaboration and partnerships for knowledge exchange.

Akhmat, Zaman, Shukui, Javed and Khan (2014) found such positive relation between education and innovation can also be identified at the aggregate level. According to this study, higher educational indicators positively affect number of publications, R&D expenditure levels and patent citation.

Interestingly, these arguments do not make the case for highly academic trained researchers to be always firms' best choice for hiring. A group of studies have found that diversity in the composition of the research team is also important (Subramanian, 2016; Wang & Chen, 2010; Fernández-Ribas & Shapira, 2009). Garcia-Quevedo, Mas-Verdu, and Polo-Otero (2011) argued that demand for Ph.D. holders is not uniform across firms and depends positively on R&D effort and collaboration with universities.

Figure 3.1 presents the breakdown of educational level of aggregate R&D personnel for a group of countries. One can see majority of the human resources have first-stage theoretical tertiary education, but Ph.D. holders also represent a significant share of the workforce. The broad picture should again be taken with caution, as firm size and sector of activity plays important roles in determining the educational mix of firms' R&D staff.

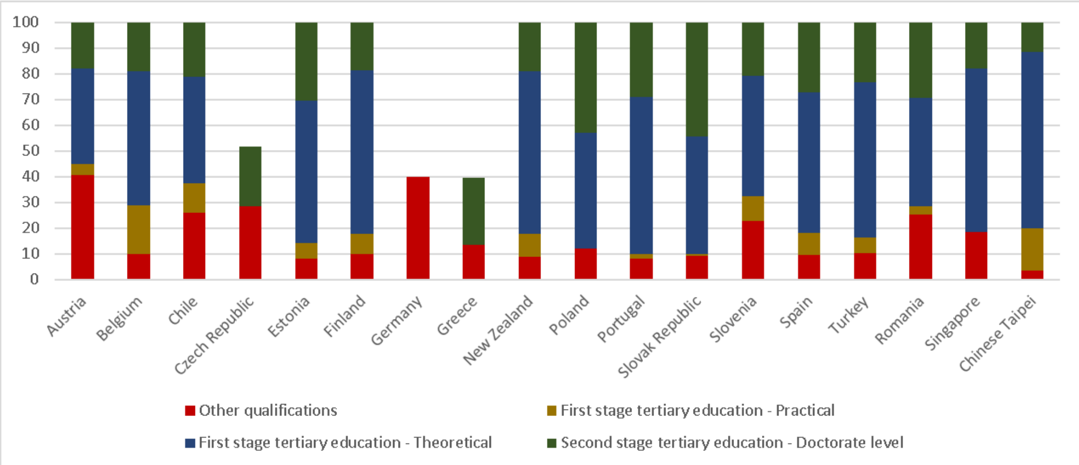


*Figure 3.1.* Percentage of total R&D personnel by educational level for selected countries. Source: OECD (2016).

***3.2.2.4 Product and process innovation.***

The empirical literature also distinguishes between product and process innovation (Saha, 1999; Beladi et al., 2011; Aralica & Botrić, 2013; and Cohen & Klepper, 1996). The main point is to understand whether firms' technological efforts focus on developing new or better-quality items for the market or improve production or productivity. But it is not uncommon that these two types of innovation are closely linked, being difficult to separate them (OECD, 2005, mentions the case of new products that requires modifications in the production process).

Both innovation types can positively impact firm's output, but some distinctions are drawn by the literature. In most cases, process R&D is related to productivity increase, by reducing production costs or elevating output; while product innovation generates new or better-quality goods (Saha, 1999). Cohen and Klepper (1996) maintained that product innovation is more likely to generate licensing income and rapidly increase output. In their model, they consider product innovation raises prices, as buyers are willing to pay more for new features and functionalities. In Beladi et al. (2011), process innovation reduces labor content in production. Lin and Saggi's (2002) duopolistic model suggests product and process

R&D might be complementary rather than substitutes. They show firms tend to invest more in product R&D when they also invest in process R&D, due to product differentiation.

Figure 3.2 below presents the percentage of innovative companies investing in product and process innovation in different European economies.[72] With few exceptions, it is possible to identify a balance between these groups, meaning both types of innovation seem relevant for firms within the region.

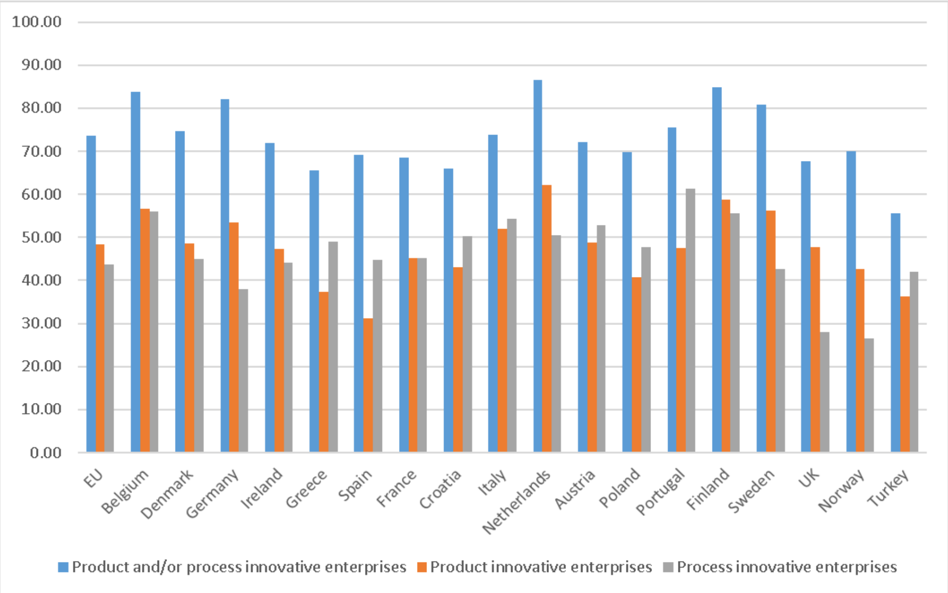


*Figure 3.2*. Product and Process innovative enterprises as percentage of total innovative firms, in 2012 for selected European countries. Source: Eurostat (2016).

### 3.2.3 Relevance of composition of innovation investment for economic development.

The importance of this debate is not limited to uncover how firms employ their resources and decide their information seeking strategies. To be relevant for the design and evaluation of policies, investment composition must also matter for innovation output and economic growth. A group of theoretical models - mostly from the endogenous or new growth theory - and empirical investigations have pointed to how these categories can be factors influencing the aggregate result of the economy.

[72] Data for Brazil is presented and discussed in sections 3.4 and 5.

The distinction between research and development carries immediate consequences for economic growth, mostly due to the difference of knowledge spillovers levels (U.S. J.E.C., 2010). Griliches (1986), Mansfield (1980) and Czarnitzki et al. (2009) identified a “premium” for basic research, meaning that it is more important for productivity increase than other types of R&D. Rafferty (2003) used such categories to study innovation strategies within the business cycle, and concluded that basic R&D tends to increase during recessions, suggesting stabilization policies might have a negative impact on long-run growth by reducing the expansion of the scientific frontier. On the other hand, Barge-Gil and López (2014) argued that development is more relevant than research for product innovation and sales of new products.

The choice between strict R&D and other types of innovative activities can be analyzed according to the models designed by Young (1992) and Aghion and Howitt (1998). They suggest innovations can be ‘fundamental’, which arise exclusively from the work of researchers doing strict R&D, or ‘secondary’, generated by production workers in a learning-by-doing process. Long-run growth is a concave function of the share of workers dedicated to each type of innovation. The maximum rate is achieved at a point ($g^*$) in which both fundamental and secondary innovation are positive. If the levels of fundamental research are below ($g^*$), further research can increase general knowledge and impact growth positively. However, after that point, reduction of feedback from experience makes more research sterile, reducing growth (Aghion & Howitt, 1998). Such reasoning was first developed by Young (1992) to explain the development of the Hong Kong and Singapore economies.

The case of R&D outsourcing has also been analyzed by different models and empirical investigations with conflicting results, although most of them acknowledge the existence of complementarity between internal and external R&D, and the positive effect of some level of innovation outsourcing (Lokshin, Belderbos & Carree, 2007). This is in accordance with the evidence of an upward trend of external R&D in most developed countries (UNCTAD, 2005b). Lokshin et al. (2015) used the ‘absorptive capacity’ argument (Cohen & Levinthal, 1990; Griffith, Redding & Van Reenen, 2003 and 2004) to suggest a dynamic model in which external R&D only has a positive impact on productivity once a minimum level of internal R&D is reached. Similar results were obtained by Bönte (2003) for German firms and by Beneito (2006), who found external R&D to be of incremental nature.

Challenging these results, Knott (2016) maintained that outsourced R&D is actually less productive, and its growing share is the explaining factor of the decline of total R&D productivity over the last decades. The main argument is that internal R&D generates ‘internal spillovers', which account for a substantial part of productivity increase. Bergman (2011) also found evidence of a negative impact of R&D outsourcing on productivity levels.

General population educational level can be considered an important element for economic growth because of skill acquisition and human capital accumulation (Lucas, 1988). More specifically, education affects firms' ability to innovate (Nelson & Phelps, 1966) or their absorptive capacity (Griffith et al., 2004; Castellacci, 2011), thus raising innovation levels and growth. Reeding (1996) presented an endogenous growth model in which human capital and R&D are complementary. Leiponen's (2005) panel analysis concluded firms in which employees do not present necessary skills benefit less from innovation, making human capital an "enabling factor in profitable innovation". Empirical confirmations of the positive relation between education and innovation are presented in Piva and Vivarelli (2009) and D'Este, Rentocchini and Vega-Jurado (2012).

In the case of product and process innovation, endogenous growth models provide theoretical support for both types to be growth inducing factors. Product innovation is the basis of variety expanding models (Romer, 1987 and 1990; Rivera-Batiz & Romer, 1991), where innovators counterbalance the tendency to decreasing returns of capital by developing new products. Process innovation, on the other hand, is the typical set-up of quality-ladder (Grossman & Helpman, 1991) and Schumpeterian theories (Aghion & Howitt, 1992), in which innovation generates growth by rendering used technology obsolete and replacing it by efficiency-enhancing methods.

Young (1998) distinguished between vertical (an improvement of existing intermediate products increasing productivity) and horizontal (new intermediate products) innovation. Such concepts are close to and may be used to analyze product and process innovation. The author suggested this dichotomy can explain why increasing R&D rates can be consistent with stagnant or decreasing growth (Jones, 1995). In summary, horizontal innovation can increase average consumer utility by expanding variety of available products, but, if excessive, it also dissipates rents of quality improvement of existing products, leading to less investment in vertical innovation, and, consequently, to a reduction of productivity increase and growth rate.[73]

Howitt (1999) used such framework to maintain R&D subsidies positively impact growth in the long run by fostering vertical innovation with constant returns. Similar or

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[73] "As the paper has argued, when product quality and variety are jointly determined, changes in the total pool of rents can lead to any number of outcomes, including cases in which increased entry leads to a decline in the long-run growth rate, since a rise in the number of available varieties lowers the return to product improvement". (Young, 1998, p. 61).

extended versions of this model are presented by Cozzi (2005) and Gil (2013) to analyze the influence of animal spirits; Segerstrom (2000) relaxed the assumptions on returns; and Li (2000) allowed for inter-R&D spillovers.

The literature discussed in this subsection presents strong arguments to maintain that the distribution of investments between the categories used in this empirical study is a relevant factor to be considered for policy design and evaluation, as it may influence innovation and growth. For this reason, investigating if and how indirect tax subsidies change firm's strategies and spending composition is important both from an academic and policy standpoint. The mentioned studies provide a relevant basis for the interpretation of results and to draw policy implications from them.

## 3.3 Public Incentives and Innovation Investments Composition

This section summarizes the main literature dedicated to evaluate the impact of policies on the composition of innovation investments and expenditures. The first part presents the theoretical models and arguments raised by the literature, while the second reviews the empirical evidence. The third part details studies that focused on tax benefits, considering the particularities of this type of government intervention.

### 3.3.1 Theoretical framework.

The effect of public policies on innovation strategies is known as the behavior additionality effect (Buisseret et al., 1995). Georghiou (1994) suggested policy impact had three different dimensions: input (usually interpreted as expenditure increase); behavioral (change in the firm's strategy); and output (modification of results). The OECD report on the subject stated this approach aims to "measure explicitly changes in the ways firms conduct R&D as a result of government policy instruments" (OECD, 2006b, p. 7), regardless of a significant impact on the bulk of total R&D. These analyses are supposed to complement (and not replace) the traditional approach of input additionality.

The importance of the behavioral approach lies in the fact that the traditional concepts of input and output additionality do not sufficiently describe the impact of public policies on the innovation process (Falk, 2007). The main idea is to open the "R&D black box" (David & Hall, 2000) to identify the channels through which government subsidies and incentives alter private innovation. Neicu et al. (2014) and Gök and Edler (2012) suggested the approach presents a rationale for government intervention that goes beyond the neoclassical concept of market failure. By assessing policy impact on firms' strategies, the behavioral additionality analysis comes closer to an evolutionary perspective.

An interesting feature of behavioral additionality is that it comprises multiple layers or dimensions of firms' innovation strategy, and for this reason it opens a wide range of subjects and methods that can be used for policy analysis and evaluation (for a review of the literature, see Gök & Edler, 2012). Falk (2007) listed four different perspectives for researchers to investigate: scope, scale, acceleration and cognitive capacity; Clarysse, Wright and Mustar (2009) focused on organizational learning; and OECD (2006b) summarized a series of country studies that analyzed project development.

Innovation expenditures composition may be deemed as one of the perspectives to analyze behavioral additionality. Zúñiga-Vicente et al. (2014) presented a literature survey on the topic, but their review is limited to the classic research or development dilemma. As a conclusion, they claim a higher weight of research activities should increase the crowding-in effect of public subsidies.

Most investigations on the effect of public incentives on the composition of innovation investments are eminently empirical, meaning they present an investment or demand model to back the econometric analysis with room for different interpretations or conclusions depending on the sign and significance of their estimation results. They do not, in this sense, rely on theoretical predictions based on maximization models (Link, 1982; Aerts & Thorwarth, 2008; Diamond, 1999, are some examples, among other studies mentioned in Table 3.2).

Nonetheless, the topic has received attention of theoreticians that developed models to explain such impact. Joglekar and Hamburg (1983) analyzed basic research incentives, and concluded they crowd industry investments out,[74] unless firms are required to match the same proportion of investments with their funds. This conclusion was challenged by Brockhoff and Warschkow (1993), that stated that results become unclear once applied research incentives are included in the model and certain behavioral assumptions are dropped. Robson (1993) hypothesized that R&D policies foster development projects but reduces private investment in basic research, in light of diminishing returns.

As per investment in each category of innovative activities, David, Hall and Toole (2000) maintained firms are more likely to invest extra funds in projects that generate greater

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[74] "In fact, we must say that the provision of seed money is counterproductive since it reduces the industry's investment. Intuitively, this occurs because as government increases its investment in basic research, firms feel freer to allocate their own funds primarily to activities whose benefits are more appropriable." (Joglekar & Hamburg, 1983, p. 1008).

profits in the short run.[75] Aghion and Howitt (1998) argued that any increase in research productivity (such as a subsidy policy financing part of its cost) should shift funds from secondary to fundamental innovation (that can be interpreted as strict R&D). They went as far as to state this result holds even if the subsidy is only applicable to secondary innovation activities, because of indirect impacts on research productivity.[76] Young (1992) maintained that targeting policies in Singapore caused a rapid industrial transformation and introduction of new industries, but at the same time did not allow for experience learning to occur. On the other hand, the *laissez-faire* oriented policies of the Hong Kong government did not alter the landscape of industrial sector but boosted firms' learning-by-doing, increasing productivity.

The internal-external R&D balance can be influenced by public policy mainly through two channels. First, in case innovation partnerships are costly or risky, firms may avert from outsourcing R&D because expected results do not pay off. When this is the case, public funding can subsidize part of the cost, thus fostering collaboration. Improvement of social welfare, however, depends on the magnitude of the cost (Vilasuso & Frascatori, 2000). Second, R&D cooperation may help internalizing part of positive externalities arising from knowledge spillovers. Hinlopen (2001) presented a model in which a cooperation policy is not as effective to raise R&D levels as a subsidy, and LaRiviere (2014) suggested subsidies reduce the size of R&D collaborations.

The impact of innovation policy on the educational level of R&D personnel has mainly been subject of empirical studies (Dumont et al., 2014; Afcha & Garcia-Quevedo, 2014). Georghiou and Clarysse (2006) noted that upgrading of education or qualification may constitute a byproduct of a public subsidy in the context of a funded project.[77]

In Howitt's (1999) model, although subsidies affect both horizontal (product) and vertical (process) innovation, only the later grows in the long run because of horizontal innovation's decreasing results, with positive effects on the growth rate. In Segerstrom's (2000) extension of such model, subsidies also influence the R&D composition balance, but the direction of impact depends on the parameters of decreasing returns of each type of innovation.

[75] The authors, however, do not develop a formal model nor detail the argument.
[76] "Another striking result is that any parameter change that raises the productivity of the innovation process will shift resources out of learning by doing and into research. This is even true of a parameter change whose only direct effect is to raise the productivity of *learning by doing*". (Aghion & Howitt, 1998, p. 175).
[77] The authors do not, nonetheless, present a formal model detailing such prediction, nor state the conditions or assumptions for such result should arise.

### 3.3.2 Review of the empirical literature.

Empirical evidence of the change caused by innovation policy in firms' investment composition is small (Zúñiga-Vicente et al., 2014; Afcha & López, 2014; Neicu, 2014; and OECD, 2006b) but growing. Econometric analyzes on this topic mostly date from the 2000s, and are not numerous. Table 3.2 presents a summary of a group of selected papers that addressed the issue, presenting the main methodological choices and results for comparison purposes.

Nearly all studies considered strictly R&D expenditures, not investigating other innovation activities, as suggested by OECD (2005). The only exceptions are Clausen (2007) and Zhu et al. (2006). Furthermore, one can see the 'research versus development' debate is still the most recurrent object of analysis, although recent papers (Dumont et al., 2014; Afcha & López, 2014; Jaffe & Lee, 2015) have considered other categories.

Most analyses focused on a single government program or policy instrument, commonly a grant or direct funding. The exceptions are Zhu et al. (2006), that considered a pool of R&D support programs that include tax incentives, Clausen (2007), with an analysis on "far from" and "close to" the market subsidies, and Afcha and Garcia-Quevedo (2014), that studied federal and regional incentives.

Methods and estimators also vary, but different papers acknowledge the importance of addressing the problem of self-selection bias, for companies with access to government support are likely to be inherently more innovative, which may render results inconsistent and not reliable.[78]

Most studies only found significant results for one or part of the variables, which means there is a change in the investment composition. This confirms the theoretical argument of behavioral additionality, in the sense that government funding and incentives alter not only the magnitude but also the strategic behavior of firms and their innovation plans.

[78] "Ordinary Least Squares estimation of the impact of public support on the R&D activities of firms may provide biased results, if the fact that the probability to receive a subsidy or tax benefit differs between companies is not taken into account" (Dumont, 2014, p. 14).

Table 3.2

*Summary of the literature on the impact of public policies on innovation investment composition*

| Study | Country/ region | Division of innovative or R&D activities | Public support considered | Method / estimator | Results |
|---|---|---|---|---|---|
| Higgins and Link (1981) | U.S. | Basic research, applied research and development | Federal R&D expenditures | OLS | Federal research subsidies displace research in favor of development projects |
| Link (1982) | U.S. | Basic research, applied research and development | Federal R&D expenditures | OLS | Incentives push R&D away from basic research towards development activities |
| Robson (1993) | U.S. | Basic research, applied research and development | Federal R&D expenditures | Aggregate time series; unit roots test | Federal incentives to basic research provide the strongest stimulus to private spending |
| Diamond (1999) | U.S. | Basic research | Federal R&D expenditures | Dickey-Fuller test for stationarity | Government funding of basic research does not crowd-out private funding |
| Zhu et al. (2006) | Shanghai | R&D; other Science and technology activities | Direct funding and tax incentives | Arellano-Bond GMM | Direct funding encourages firms to undertake more R&D and less other science and technology activities. The opposite result is found for tax incentives |
| Clausen (2007) | Norway | Private internal and external R&D; research and development; other innovation expenditures; educational level (Master and PhD) of workforce ("quality of R&D) | Subsidies and government grants ("far from" and "close to" the market | 2SLS | "Far from the market" subsidies increase internal R&D, research expenditures, number of R&D man labor years conducted by R&D staff with Master's or Ph.D. degree, but have no impact on other innovation expenditures. "Close to" the market subsidies crowd out internal R&D and development expenditures, and have a negative impact on R&D conducted by highly educated personnel. No significant impact on innovative expenditures. |
| Aerts and Thorwarth (2008) | Flanders (Belgium) | Research and development | Public R&D funding (direct) | Treatment effects models and IV methods | R&D subsidies increase development expenditure; crowding out effects for the research part cannot be rejected |

(continued)

| Study | Country/ region | Division of innovative or R&D activities | Public support considered | Method / estimator | Results |
|---|---|---|---|---|---|
| Czarnitzki et al. (2011a) | Flanders (Belgium) | Research and development | "Basic and strategic" research grants | Random effects Tobit | Subsidy recipients invest more in research than other firms. Effect on private development expenditures is positive but non-significant |
| Aralica and Botrić (2013) | Croatia | Product and process innovation | Tax incentives | PSM | Significant impact only on product innovation |
| Afcha and López (2014) | Spain | Internal and external R&D | Direct subsidies | Multinomial logit | Subsidies favor R&D conducted internally and externally simultaneously, and internal over external R&D |
| Dumont et al. (2014) | Belgium | Educational level of R&D employees (Ph.D.; higher education and other qualifications) | Tax incentives | Two-step: Multinomial logit followed by seemingly unrelated equations | Public support significantly increases the share of researchers holding a PhD |
| Neicu et al. (2014) | Belgium | Research and development | Tax credits | PSM | Incentivized firms exhibit more research orientation |
| Afcha and Garcia-Quevedo (2014) | Spain | Educational level of R&D employees | Federal and regional R&D subsidies | PSM; coarsened exact matching | No increase is found in the average level of qualification of R&D staff members in subsidized firms. |
| Jaffe and Le (2015) | New Zealand | Product and process innovation | R&D grants | PSM | Impact on process innovation and any product innovation are similar. Effect increases in the case of new goods and services to the world |

The distinction between the basic components of R&D was used for analysis since the beginning of this empirical literature. Link (1982) considered these variables in his seminal paper, and found federal subsidies tend to divert resources away from basic research and direct them to development activities, confirming the predictions later suggested by Joglekar and Hamburg's (1983) model (similar results were reported by Higgins and Link, 1981; and Aerts and Thorwarth, 2008). Such conclusion was later challenged by papers that found a positive impact of public funding on basic research (Robson, 1993; Diamond, 1999; Czarnitzki et al., 2011a).

Empirical analyses on different innovative activities (Zhu et al., 2006; Clausen, 2007) found that firms undertake more R&D when benefited from direct subsidies, a result consistent with the predictions of Aghion and Howitt's (1998) model. In the case of tax incentives, however, Zhu et al. (2006) found that enterprises tend to switch from R&D to other low-tech oriented innovation activities with quicker results in the short run, as hypothesized by David et al. (2000).

There is also evidence that direct subsidies impact the internal and external R&D balance. Clausen (2007) and Afcha and López (2014) found positive results for internal levels without significant effects on innovation outsourcing, meaning companies increase their share of in-house R&D. Once again, such findings are theoretically grounded, as they follow the predictions of the models of Vilasuso and Frascatori (2000) and LaRiviere (2014).

The educational level of R&D staff is positively impacted by 'far from the market subsidies' and tax incentives, according to Clausen (2007) and Dumont et al. (2014). Both studies found that beneficiary firms hired more highly qualified researchers, with a Master's or Ph.D. degree, confirming the intuition of Georghiou and Clarysse (2006) that this may be an indirect positive effect of innovation policies. Afcha and Garcia-Quevedo (2014), on the contrary, did not obtain any significant result for the educational mix of research personnel.

Results for the combination of product and process innovations are unclear, as the two studies on the subject reported opposite results. Aralica and Botrić (2013) found that only product innovation was benefited from innovation policies in Croatia, while New Zealand firms increased their results in both types in similar rates, according to Jaffe and Le (2015).

### 3.3.3 Tax incentives and behavioral additionality.

As discussed in Chapter 2, the use of tax incentives to foster innovation dates from the second half of the last century (Bloom, Griffith & Van Reenen, 2002). Since the 1980s, a growing group of countries have resorted to this policy tool, approving different schemes to reduce the tax cost of innovative initiatives.[79]

The main difference and advantage of the fiscal incentive approach is to be more market-oriented, meaning that firms retain the decision on which projects and ideas are financed and implemented, instead of a previous choice by government bureaucracy (David et al., 2000;[80] Hall e Van Reenen, 2000; OCDE, 2014). By keeping the decision-making process within the firm, these incentives minimize inefficiencies and the allocative distortions arising from government intervention.

On the other hand, tax incentives may bear an inherent contradiction in terms of social returns of funded projects. Pursuant to the market failure argument, public policies should focus on promoting innovation with higher levels of positive externalities or knowledge spillovers. However, as tax incentivized firms retain full control of their R&D portfolio, they would minimize such externalities by developing technologies that can be largely appropriated by means of internalized profits (Hall & Van Reenen, 2000). David et al. (2000) also mentioned that beneficiary companies most likely prefer projects with highest expected payoffs in the short run.

This debate provides different insights to maintain tax incentives should have different behavioral additionality effects than those arising from direct incentives. Both the market-oriented nature and bias towards projects with less knowledge spillovers should impact the nature of R&D performed by firms, and, consequently, their expenditures composition. Therefore, this literature provides a theoretical basis for empirical studies aimed at assessing the impact of tax incentives on the composition of innovation investments.

The theoretical arguments and models on innovation policy and composition of investments discussed in subsection 3.3.1, however, do not distinguish between different types of policies, and, more specifically, they do not expressly discuss tax incentives. For this reason, although their conclusions and predictions are a relevant starting point for interpreting results of the empirical analysis, they should be taken with caution. One must consider whether each argument makes sense and remains valid for the tax incentives case.[81] As pondered by Neicu et

[79] See Table 1.2 in Chapter 2.
[80] "Although not strictly necessary, the primary difference in execution between these two policy instruments [tax incentives and direct subsidies] is that the former [tax incentives] typically allows the private firms to choose projects, whereas the latter [direct subsidies] usually is accompanied by a government directed project choice, either because the government spends the funds directly or because the funds are distributed via grants to firms for specific projects or research areas". (David, Hall & Toole, 2000, p. 502).
[81] A formal extension of these models to the tax incentives case, although desirable, is beyond the scope of this study.

al. (2014), behavioral additionality effects are different because firms can freely spend the extra resources available through tax breaks.

The empirical literature on the evaluation of tax measures also provide useful but limited information for this study, as they mainly focus on input additionality, using R&D spending as a broad indicator of impact (Zúñiga-Vicente et al., 2014; OECD, 2006b). The low elasticity of tax incentives was particularly object of different analyzes (for recent reviews of this literature, see EC, 2014; Köhler et al., 2012; and Gaillard-Ladinska, Non & Straathof, 2014). According to EC (2014), most of these studies identify an elasticity inferior to one, but Hall (1995) and Köhler et al. (2012) stated these effects tend to increase with time.

In spite of recent developments of the empirical literature, there still appears to be little evidence on how tax incentives affect innovation composition. Four of the studies summarized in Table 3.2 consider fiscal measures, and all of them found some sort of behavioral additionality of the policy. The first one is Zhu et al. (2006), and the paper suggested that, in Shanghai, these benefits drove resources away from strict R&D and directed them to other science and technology activities, with lower “tech-orientation”. The reason for such outcome would be that companies prefer to invest in less costly and less risky projects with quicker returns, such as training or technical services.

The results of Neicu et al. (2014) pointed to the opposite direction. Belgian firms that benefited from the wage-related tax credits have increased their research orientation. The authors hypothesized that the reason may be a reduction in the wage cost of highly qualified R&D personnel, or that firms replaced low-skilled workers in light of the requirements of the policy.

Aralica and Botrić (2013) is one of the few studies that provided evidence from a non-developed country. They estimated the impact of a tax scheme introduced in 2007 in Croatia, and concluded it had a positive significant effect on product innovation, but in case of process innovation this effect was statistically insignificant.

Dumont et al. (2014) analyzed the exemption granted by the Belgian government to withholding tax that levy on the wage of workers. Positive and significant impact was found for Ph.D. degree holders. Moreover, the study did not reveal evidence of substitution of personnel, i.e., the additional hiring of Ph.D. researchers was not caused by a reduction of employees with less formal education.

## 3.4 The Brazilian Innovation Tax Policy and Investment Composition

This section complements the policy description presented in Chapter 2, suggesting how the design of the incentives may change the composition of innovation investments. The first subsection presents a brief overview of the industrial innovation scenario in Brazil, with aggregate data on the composition of innovation inputs. The second part details the innovation tax policy introduced in 2005, focusing on the incentives that may have an impact on the distribution of such investments.

### 3.4.1 Industrial innovation context.

As discussed in Chapter 2*,* since 2003 Brazil has experienced a substantial shift in the industrial policy paradigm at the federal government level. Fostering economic development became a primary policy target to be achieved by nurturing dynamic comparative advantages and competitiveness of national companies at the international level. Such was the message of the industrial policy plan announced by the government in 2003 (the Industrial, Technology, and Foreign Trade Policy[82] - PITCE), that had among its objectives "to enhance the economic efficiency, and to develop and disseminate technologies with potential to increase the levels of activity and competitiveness within the international trade" (Brasil, 2003, p. 2).

Figures 3.3 to 3.6 depict a group of indicators relevant to understand the development of the Brazilian innovation context since the 2003 policy. Figure 3.3 presents the evolution of public and private expenditures with R&D for the 2002-2013 period. It is clear that, in absolute terms, the investment in innovation increased substantially, around 20% per year on average. But, at the same time, spending as a share of the gross domestic product (GDP) rose at a much slower pace (around 2% per year), suggesting that much of the increase of resources allocated to innovation may be attributed to an overall upsurge in the economic activity, and not to higher R&D intensity. And, even considering such increase, the Brazilian R&D intensity (R&D expenditures per GDP) was around 1.7% in 2013, a proportion substantially lower than the average 2.4% of OECD countries (OECD, 2016). Furthermore, public expenditure was considerably superior than private after 2010, implying government support partially failed to act as a leverage for more business investment in innovation.

[82] "*Política Industrial, Tecnológica e de Comércio Exterior*".

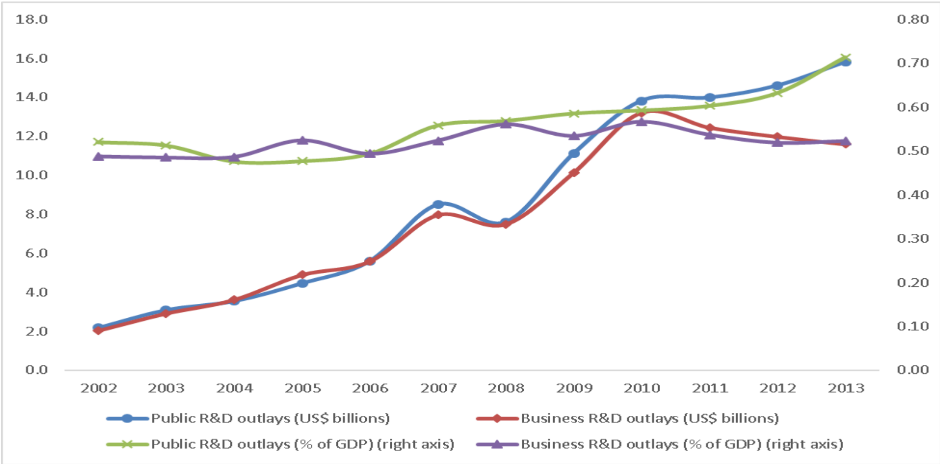


*Figure 3.3*. Public and private R&D outlays in Brazil: US$ 1,000,000.00 and as percentage of GDP (right axis). Source: MCTI (2015a).

Figures 3.4 to 3.6 present data on the composition of innovation expenditures for the entire manufacturing industry and selected industrial sectors. Figure 3.4 shows a small increase on the share of strict R&D in the bulk of innovative activities. The auto industry, chemicals and machinery experienced this rise on a larger scale, meaning a deeper modification of innovation strategies took place in these sectors. Figure 3.5 evidences the level of R&D outsourced by local firms is substantially low, and that its share has not changed significantly during the period. The share of innovative companies dedicated exclusively to product innovation has fallen in all series of Figure 3.6.

As per the educational level of R&D staff, an ABDI survey in 2013 reported that nearly 80% of large firms did not employ researchers with Ph.D. degree, and more than half did not employ researchers with a Master's degree (ABDI, 2013). These figures suggest the increase in R&D expenditures in the country in the last years may not have improved the quality of research undertaken by these enterprises (Clausen, 2007) nor enhanced their absorptive capacity.

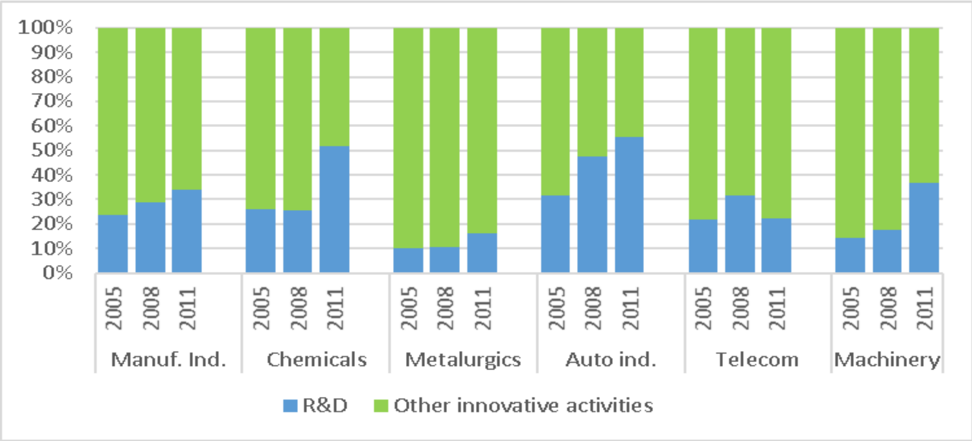


*Figure 3.4.* Percentage of innovation expenditures dedicated to R&D and other innovative activities (2005 - 2011). Source: (IBGE, 2007, 2010; 2013).

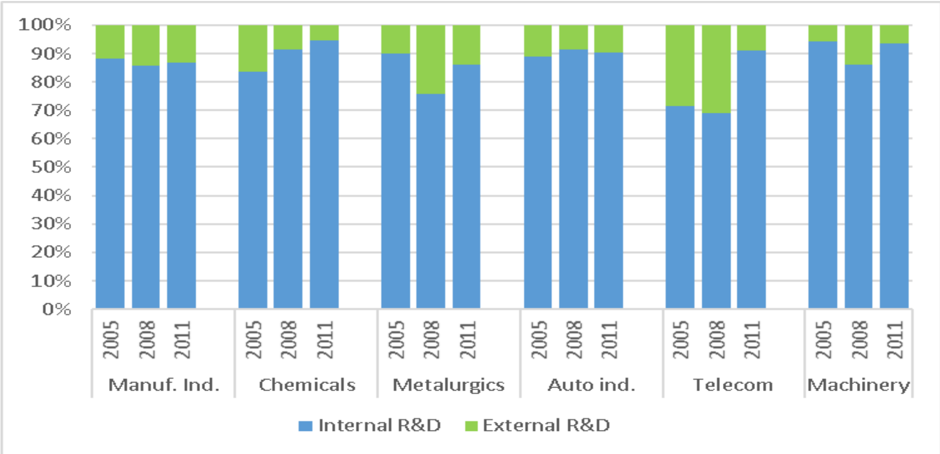


*Figure 3.5.* Percentage of in-house and outsourced R&D. Source: (IBGE, 2007, 2010; 2013).

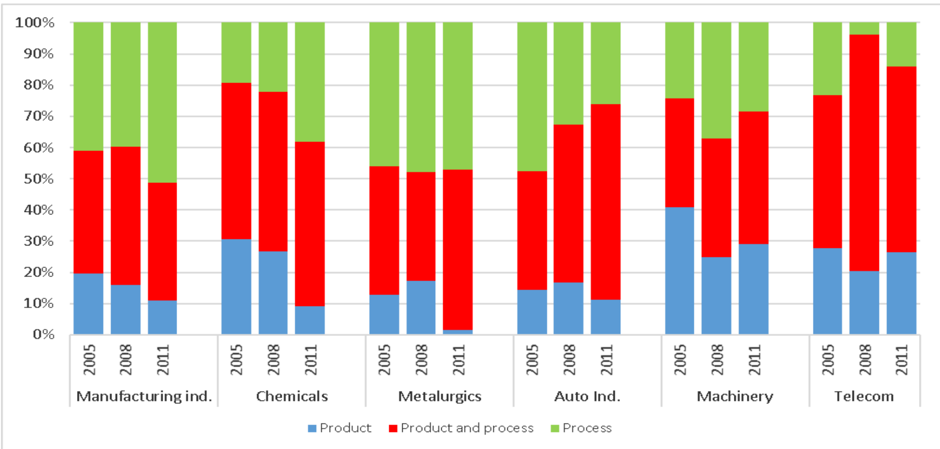


*Figure 3.6.* Evolution of percentage of innovative firms with product innovation, process innovation and both (2005 – 2011). Source: (IBGE, 2007, 2010; 2013).

### 3.4.2 Tax incentives for innovation: the Law 11.196/05.

As presented in Chapter 2, a new regulatory framework for innovation tax incentives was approved by Brazilian Congress in 2005, pursuant to the provisions of the Brazilian Innovation Law (10,973/04). The new Law (11,196/05) expanded previous incentives, reducing the cost of innovation projects. Following the experience and framework of other countries (see OECD, 2015b), the benefits mainly reduced or exempted companies from taxes that levied on innovation inputs and outputs, or allowed the deduction of expenditures from the base of income taxes.

The law initially provided for six tax incentives, but further amendments added others and modified existing ones. As the focus of this study is to discuss how these measures altered the distribution of firms' innovation expenditures, Table 3.3 summarizes the tax benefits according to the changes each introduced in the relative tax cost of different activities within a broad investment category, following the four classifications discussed in section 3.2.2.

The first and most relevant incentive provided by the law is the deduction of R&D expenditures from the taxable base of income tax and social contribution to the net profit (CSLL). In principle, this benefit would favor the development of strict R&D projects over other innovative activities, as the law uses the expression 'technological research and technological innovation development' to refer to the incentivized activities. However, the conceptual framework of the policy blurs the distinction between these activities. According to Decree 5,798/06,[83] for purposes of the law this expression encompasses not only the standard cases of research and experimental development (as suggested by OECD, 2015a), but also activities that the Oslo Manual (OECD, 2005) classify as 'other types of innovative activities', meaning: (a) testing, standardization, calibration of machinery and equipment and certification (labeled as 'industrial basic technology'); and (b) technical support services, including installation and maintenance of research equipment and facilities, and training of research personnel. Such definition makes it difficult to maintain the incentives create an advantage for strict R&D by reducing its relative tax cost.

The deduction of expenditures is mainly applicable to internal R&D. Outsourced R&D can only be deducted if the contracted organization falls into one of the categories expressly listed in the law (universities, research institutes, independent inventors and small firms). One may argue that, by restricting the cases of outsourced R&D, the law favors development of in-house R&D, thus influencing the composition of expenditures. On the other hand, art. 19-A

[83] Such statute details the rules applicable to the tax incentives of Law 11,196/05.

establishes a more favored treatment for projects outsourced to public research institutes with intellectual property sharing. In these cases, deduction of expenditures from the tax base is up to 250%.

Table 3.3

*Summary of the tax incentives of Law 11,196/05, arranged by categories of investments affected*

| Broad Investment categories | Incentivized activity or expenditure | Applicable tax | Incentive | Incentive rate or ceiling |
|---|---|---|---|---|
| R&D and other innovative activities | R&D expenditures | Income tax; CSLL[a] | Tax deduction | Up to 160% of expenditures[a] |
| R&D outsourcing level | Internal R&D | Income tax; CSLL[a] | Tax deduction | Up to 160% of expenditures[b] |
| | Outsourcing to universities, research institutes or independent inventors | Income tax; CSLL[a] | Tax deduction | Up to 160% of expenditures[b] |
| | Outsourcing to small enterprises | Income tax; CSLL[a] | Tax deduction | Up to 160% of expenditures[b] |
| | Projects outsourced to non-profit research institutes (with intellectual property sharing) | Income tax; CSLL[a] | Tax deduction | 50% to 250% of expenditures[c] |
| Educational Level of R&D personnel | Hiring of new research personnel (up to 5%) | Income tax; CSLL[a] | Tax deduction | 10% deduction of R&D expenditures[d] |
| | Hiring of new research personnel (above 5%)[d] | Income tax; CSLL[a] | Tax deduction | 20% deduction of R&D expenditures[d] |
| Process innovation; product innovation | R&D expenditures related to valid patent | Income tax; CSLL[a] | Additional tax deduction | 20% deduction[e] |
| | Filing and registration of patents and trademarks abroad | Withhold income tax | Tax reduction | Total exemption |
| Other incentives | Purchase of new equipment | Income tax; CSLL[f] | Accelerated depreciation | Full depreciation in the first year |
| | Purchase of new equipment | Tax on industrialized products (IPI) | Tax reduction | 50% of the tax |
| | Purchase of other capital goods | Income tax | Tax deduction | Deduction of non-depreciated capital |
| | Intangible goods | Income tax; | Accelerated amortization | Full amortization in the first year |

[a] Art. 17, I, and art. 19.
[b] Considered as part of total R&D expenditures, for purposes of calculating the standard 160% deduction provided in art. 19.
[c] Not cumulative with other incentives (art. 19-A).
[d] Additional to the standard 160% R&D expenditures deduction (art. 19, §1st).
[e] Additional to the standard 160% R&D expenditures deduction (art. 19, §3rd).
[f] CSLL - Social Contribution to Net Profit (*"Contribuição Social sobre Lucro Líquido"*).

The increase of research payroll raises the ceiling of expenses' deduction by 20% of total spending. The law does not distinguish or set any requirements for minimum academic degree of newly hired research personnel. Art. 2, III, of Decree 5,798/05 defines researcher as any graduate, undergraduate or technical high school level employee exclusively dedicated to R&D activities.[84] Although there is no change in the relative tax cost of researchers in terms of their educational level, such design can still impact the education mix of R&D staff. It may be more advantageous for firms to hire less qualified and less costly personnel to obtain the incentives rather than spend more resources with high-wage qualified researchers.

There is no distinction between product and process innovation, as both are included in the definition of technological innovation[85] and are therefore eligible for the incentives. Nonetheless, the law also provides for an additional benefit for expenditures related to patented technologies.[86] As there is evidence in the literature that patents are more suited for protection of product than process innovation (Carnegie Melon, 1994; López, 2009), one may argue this provision of the law creates a distinction in favor of the former type.

So far, only a few studies tried to assess the impact of tax incentives for innovation in the country. Three econometrics analyses concluded they had positive effects in firms R&D expenditures, technical personnel and export levels (Shimada, Kannebley Jr. e De Negri, 2013; Kannebley Jr. e Porto, 2012; Kannebley Jr., Araújo, Maffioli & Stucchi, 2013). None of these analyses have considered behavioral additionality effects of the policy, or how it has affected the mix of activities or input factors for innovation. This is the main novelty and purpose of the empirical analysis that follows.

### 3.5 Empirical Analysis: Data and Estimation Strategy

The objective of this empirical study is to test whether tax incentives provided by Law 11,196/05 have had a significant impact on the composition of innovation investments of beneficiary firms. The focus herein is on the behavioral additionality of the policy. Based on the literature review in section 3.3, the interest lies on finding if and how firms modified their innovation strategies – represented by the mix of investments and innovation choices – once they received indirect public funding.

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[84] Art. 21 of Law 11,196/05 establishes the government may direct subsidize hiring of graduate researchers (PhD and Master's degree).
[85] Art. 17, §1st of Law 11,196/05.
[86] Art. 19, §3rd of Law 11,196/05.

The broad categories of innovation investments or projects used in the analysis are the ones discussed previously: (a) different types of innovative activities; (b) R&D outsourcing; (c) educational level of R&D personnel; and (d) product and process innovation.

The study uses firm-level data on Brazilian innovative firms, as detailed in 3.5.1 below, and the variables considered for analysis are presented in subsection 3.5.2. Following recent empirical studies on behavioral additionality (Aralica & Botrić, 2013; Neicu et al., 2014; Afcha & Garcia-Quevedo, 2014; Jaffe & Le, 2015), a propensity score matching (PSM) is used to mitigate the selection bias problem arising from firms' different absorptive capacities. The method is described in Chapter 2 and briefly outlined in section 3.5.3; it aims to reduce heterogeneity in the sample and select an appropriate counterfactual for beneficiary firms, to estimate the impact of the incentives. Furthermore, non-dummy outcome variables are considered in a difference-in-differences framework, so as avoid endogeneity arising from firms' fixed effects.

This study presents several contributions to the existing literature. To the best of my knowledge, it is the first econometric assessment of the behavioral additionality of an innovation policy in Brazil. In this sense, the results should constitute an important basis to understand how government intervention affects private innovation strategies within the national context.

The analysis also sheds new light on the tax incentives of Law 11,196/05. Previous studies (Shimada, Kannebley Jr. e De Negri, 2013; Kannebley et al., 2013; Kannebley Jr. e Porto, 2012) focused exclusively on input and output additionalities, and have not considered how the policy affects the bundle of private innovation investments. This investigation provides more detailed information on how beneficiary firms reacted to the tax breaks, with relevant implications for the policy design.

In addition, the empirical literature on behavioral additionality of innovation policies is still limited and on development, as discussed in section 3.3. Existing studies refer almost exclusively to developed economies, and there are few investigations focusing on tax incentives. The present analysis adds to the existing body of knowledge at the international level by presenting an analysis in the context of a developing country, allowing for comparison of the results of the Brazilian case with other experiences.

### 3.5.1 Data.

Sources of data used in this study are the same as those described in Chapter 2. Firm level data from the Industrial Innovation Surveys (PINTEC) of 2008 and 2011 (IBGE, 2010 and 2013) were merged with the list of beneficiary firms of Law 11,196/05 (MCTI 2015b, 2013, 2012, 2011, 2010, 2009, 2008 and 2007), and the list of exporting and importing firms disclosed by the Brazilian Ministry of Development, Industry and Foreign Trade (MDIC, n.d.). The resulting dataset was organized in a panel format with two periods ($t$ = 2008, 2011). Nominal 2008 values were deflated to 2011 using the IGP-DI index.[87]

In order to reduce heterogeneity of firms, only those that innovated in the 2009-2011 period were considered[88]. Additionally, samples used in each analysis were narrowed considering the particularities of each group of outcome variables: in the analysis of distinct innovative activities, only firms with positive spending in at least one of the categories in 2011 were considered;[89] for the study of R&D outsourcing and of educational level of research personnel, firms should have had positive R&D spending in 2011;[90] and for the investigation of product and process innovation, the analysis was limited to firms that innovated in the 2009-2011 period.

To ensure the baseline and final values of the non-dummy outcome variables are not biased for the difference-in-differences estimation, it was further necessary to exclude from the dataset (a) all firms that benefited from the tax incentives before the baseline year (2008), and (b) all firms that did not benefit from the tax incentives at the specific year considered for analysis (see section 3.5.2), but did at any other point in time. In the cases of different categories of innovation activities, R&D outsourcing and educational level of personnel, as treatment impacts the outcome variables at the same period, it was also necessary to ignore all firms from the control group that accessed the benefits in 2008.

### 3.5.2 Variables and descriptive statistics.

Participation in the policy is considered a treatment binary dummy variable, based on which a probability model (the propensity score) is estimated. For the analysis of different categories of innovation activities, R&D outsourcing and educational level of personnel, tax incentives are assumed to affect innovation investments at the same year companies benefit from them (2011). Observations in 2008 provide the baseline values to analyze the evolution of outcome variables in a difference-in-differences framework.

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[87] We followed FAPESP, 2011 in the use of this index to deflate innovation expenditures.
[88] Questions V10, V11, V16_17_1, V16_17_2 and V16_17_3 of PINTEC 2011 (IBGE, 2013).
[89] Questions V31, V32, V33, V33_1, V34, V35, V36 and V37 of PINTEC 2011 (IBGE, 2013). PINTEC only collects information on expenditures for the last of the three years period.
[90] Questions V31 and V32 of PINTEC 2011 (IBGE, 2013).

In the case of product and process innovation, however, the impact is estimated not for inputs but for results of these investments, and, for this reason, a maturation period is necessary. In the PINTEC survey, firms state whether they have achieved any product or process innovation within the last three years.[91] Such is the information used to assess the effect of incentives on type of innovation. The year of participation in the policy considered for this analysis is 2008, and outcome is observed for the 2009-2011 period.

The outcome variables used in this study constitute part of one of the four broad categories of innovation investments mentioned previously. The complete list and definition of the variables are presented in Table 3.4. The PINTEC survey and database follow closely the Oslo Manual (OECD, 2005) on the group of expenditures included in the category of innovative activities, as discussed in section 3.2.2.1 above.

Table 3.4

*List and definition of outcome variables*

| Broad category or group | Nature of variables | Outcome variable | Definition |
|---|---|---|---|
| Innovative activities | Continuous - difference between 2011 and 2008 real values | *rd_tot* | Total R&D |
| | | *knowledge* | Acquisition of knowledge from third parties |
| | | *software* | Software license or acquisition |
| | | *machinery* | Acquisition of machinery and equipment |
| | | *training* | Training |
| | | *intro* | Introduction of innovations in the market |
| | | *project* | Industrial design and other measures for production and distribution |
| R&D outsourcing | Continuous - difference between 2011 and 2008 real U.S. dollar values | *rd_int* | Internal R&D expenditures |
| | | *rd_ext* | External R&D expenditures |
| Educational level of R&D personnel | Continuous - difference between number of researchers with the respective educational level in 2011 and 2008 | *phd* | PhD degree |
| | | *master* | Master's degree |
| | | *undergrad* | Undergraduate level[92] |
| | | *high* | High school level |
| | | *others* | Others |
| Type of innovation | Binary - firm achieved this type of innovation in the 2009-2011 period | *product* | Product innovation only |
| | | *process* | Process innovation only |
| | | *both* | Both product and process innovation |

[91] Questions V10, V11, V16_17_1, V16_17_2 and V16_17_3 of PINTEC 2011 (IBGE, 2013).
[92] First level or bachelor's degree. In Brazil, such degree is commonly referred to as '*graduação*' or '*bacharelado*'.

In the case of innovation activities and R&D outsourcing, variables represent the evolution of 2011 real value expenditures of firms for each item, and for the educational level of R&D personnel, they are the evolution on the number of employees with each degree[93]. For the type of innovation analysis, outcome variables are dummies that take the value of one if a firm has innovated in product, process or both in the 2009-2011 period; the binary nature of these variables does not allow the use of difference-in-differences for estimation.

Figures 3.7 to 3.14 and Table 3.5 provide a comprehensive picture of the distribution of these outcome variables for beneficiary (treated) and non-incentivized (control) firms. Descriptive statistics are summarized in three different ways: pie graphs present the average share of each expenditure, researcher's degree or type of innovation in 2011; column graphs depict the average difference between real values in 2011 and 2008 for continuous variables, and for the dummy outcomes the 2008 distribution is presented in a second pie graph; and Table 3.5 informs the number of observations, mean value and standard deviation for each outcome.

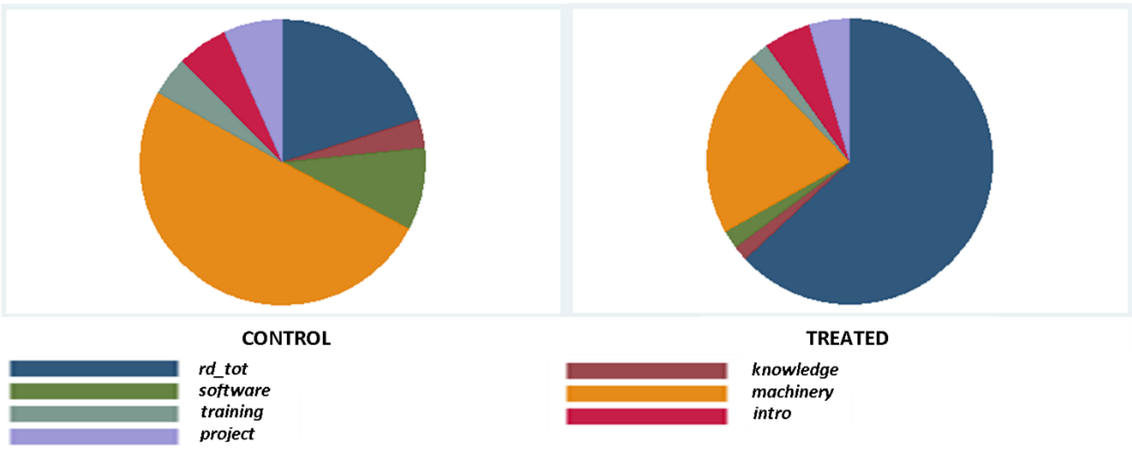


*Figure 3.7.* Average share of spending on each innovative activity in 2011 for treated and control groups. Source: IBGE (2013, confidential microdata).

[93] Workers with partial dedication are weighted according to the share of their time dedicated to the firm's research activities. Questions V51, V52, V53, V53_1, V54_1, V54_2 and V555 of PINTEC 2011 (IBGE, 2013) present the number of R&D personnel with partial dedication, and questions V56, V57, V58, V58_1, V59_1 and V59_2 and V60 the average share of time of each group dedicated to firms' R&D.

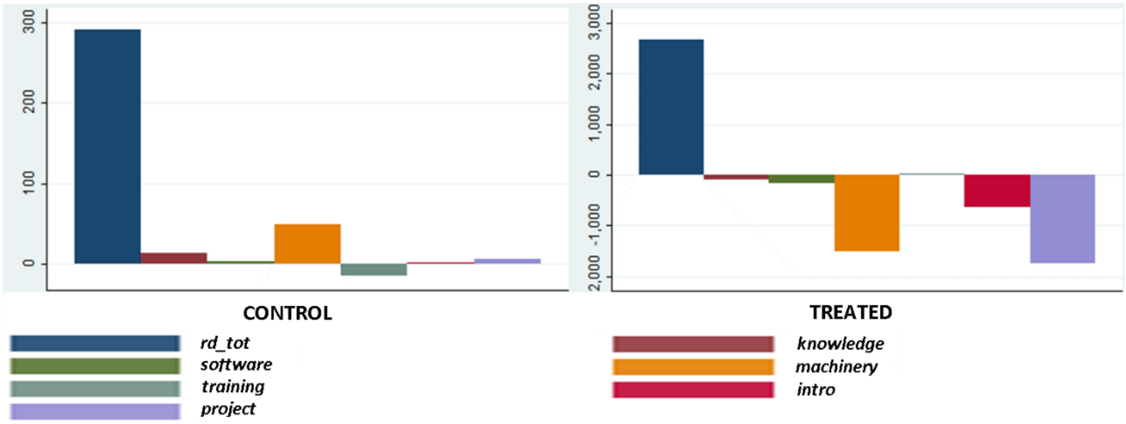


*Figure 3.8.* Evolution of average spending on each innovative activity in the 2008-2011 period. Brazilian R$ 1,000.00. Source: IBGE (2010 and 2013, confidential microdata).

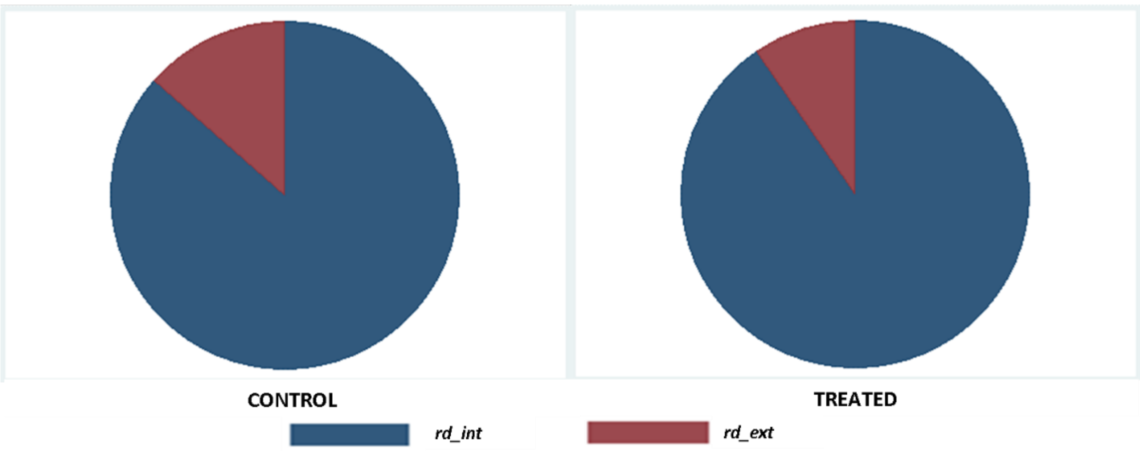


*Figure 3.9.* Average share of internal and external R&D spending in 2011. Source: IBGE (2013, confidential microdata).

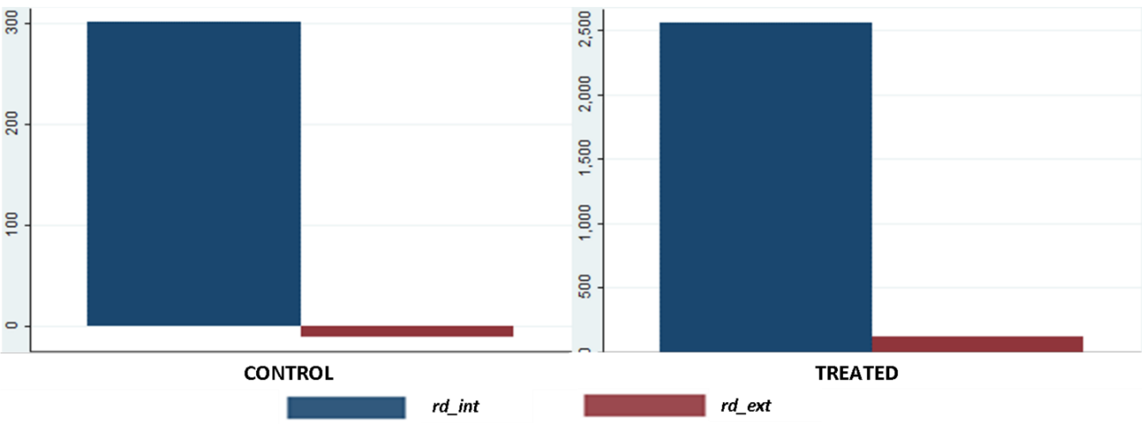


*Figure 3.10.* Evolution of average spending on internal and external R&D in the 2008-2011 period. Brazilian R$ 1,000.00. Source: IBGE (2010 and 2013, confidential microdata).

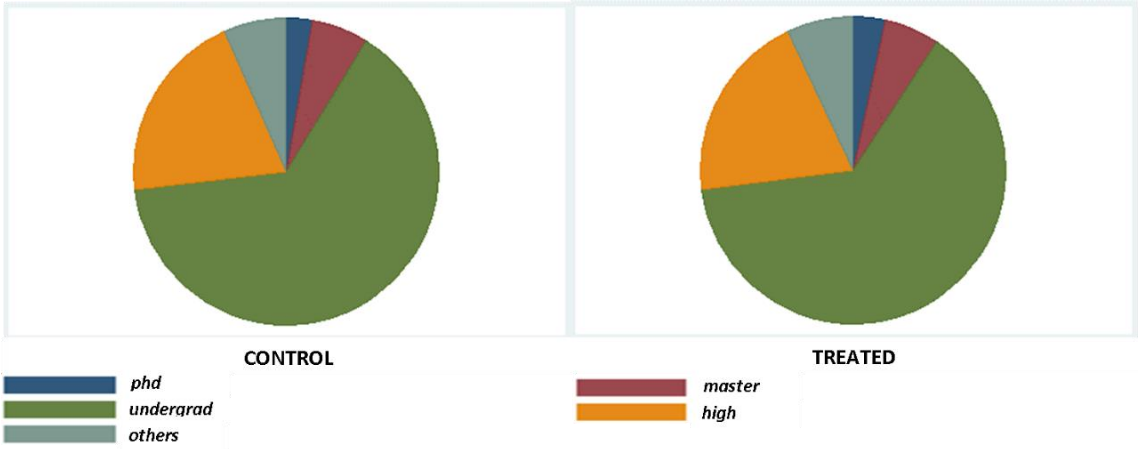


*Figure 3.11.* Average share of researchers by educational level in 2011. Source: IBGE (2013, confidential microdata).

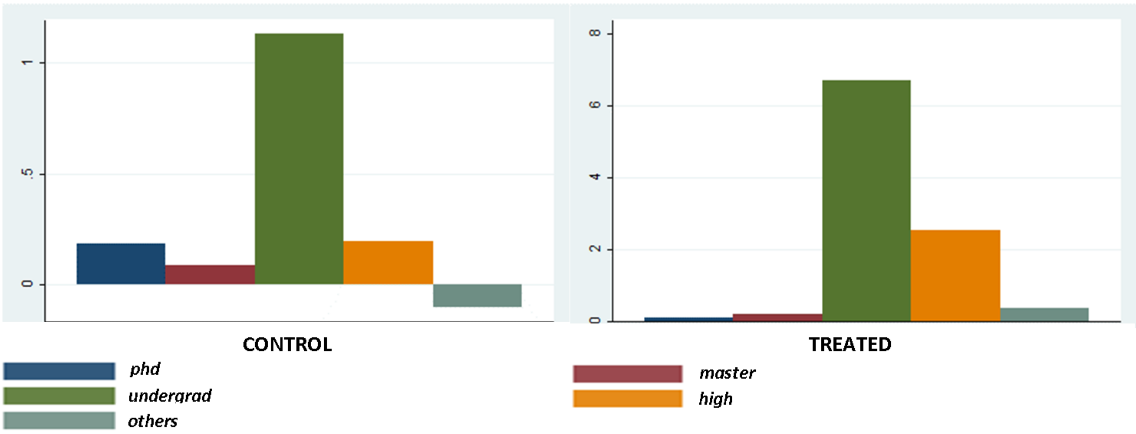


*Figure 3.12.* Evolution of the average number of researchers by educational level in the 2008-2011 period. Source: IBGE (2010 and 2013, confidential microdata).

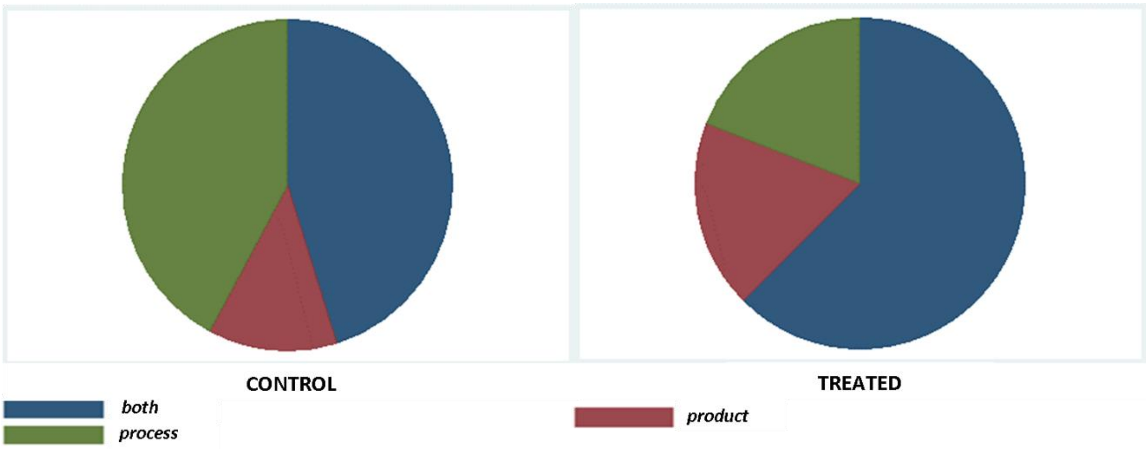


*Figure 3.13.* Share of innovative firms by type of innovation achieved in the 2009-2011 period. Source: IBGE (2013, confidential microdata).

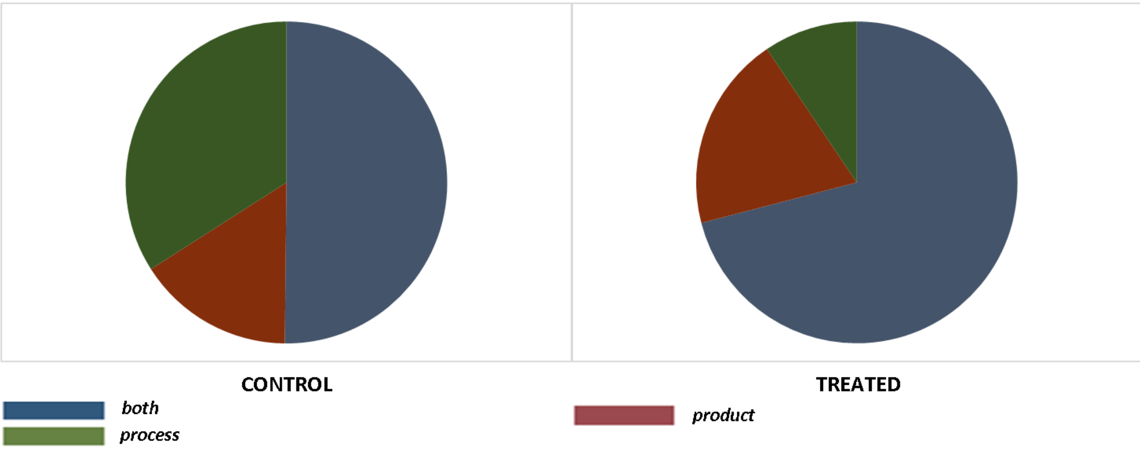


*Figure 3.14.* Share of innovative firms by type of innovation achieved in the 2005-2008 period. Source: IBGE (2013, confidential microdata).

The greatest difference observed for different categories of innovative activity is the share of total R&D. The direct comparison between groups shows beneficiary firms spent a substantial higher proportion of their resources in this activity than non-incentivized companies in 2011. Such difference seems in part to be consequence of a recent change in the composition of the investment bundle, as the average spending in total R&D in the 2009-2011 grew substantially more for beneficiary firms, as evidenced in Figure 3.8. It is also interesting to note these enterprises have a smaller share of investments in software, and that they actually decreased their expenditures in machinery and industrial design and other measures for production and distribution.

The picture of R&D outsourcing also seems to be different for both groups. On average, treated firms kept a higher part of their R&D in-house, and this type of investment grew around 8.5 times more from 2008 to 2011 among these companies than for the average of firms not benefited by the tax incentives.

The distribution of researchers by educational level, on the other hand, does not present a remarkable difference between the two groups, as suggested by Figure 3.11. It must be considered, however, that incentivized enterprises had an average increase of 6 researchers with an undergraduate degree in the three-years period considered, while the same indicator for the control group is slightly above one.

Finally, while the share of firms investing and succeeding exclusively in product innovation is practically the same for treated and control groups, ‘process innovation only’ firms represent a much smaller part for the later, while more treated companies dedicated their efforts to both types of innovation.

Table 3.5

*Outcome Variables - descriptive statistics*

| Broad Investment category | Unit | Outcome Variable | Treatment | N | Mean | Std. err. |
|---|---|---|---|---|---|---|
| Innovative activities expenditures | R$ 1,000 | *rd_tot* | 0 | 6412 | 290.46 | 15562.81 |
| | | | 1 | 260 | 2675.66 | 20468.64 |
| | | *knowledge* | 0 | 6412 | 12.82 | 1673.42 |
| | | | 1 | 260 | -103.33 | 733.51 |
| | | *software* | 0 | 6412 | 2.37 | 4898.28 |
| | | | 1 | 260 | -166.27 | 1380.23 |
| | | *machinery* | 0 | 6412 | 48.14 | 39610.41 |
| | | | 1 | 260 | -1515.65 | 18866.47 |
| | | *training* | 0 | 6412 | -14.55 | 579.13 |
| | | | 1 | 260 | -3.63 | 876.80 |
| | | *intro* | 0 | 6412 | -0.72 | 4281.54 |
| | | | 1 | 260 | -637.62 | 5240.06 |
| | | *project* | 0 | 6412 | 5.40 | 6736.65 |
| | | | 1 | 260 | -1758.34 | 19849.95 |
| R&D outsourcing | R$ 1,000 | *rd_int* | 0 | 6412 | 301.14 | 15352.41 |
| | | | 1 | 260 | 2558.05 | 19958.90 |
| | | *rd_ext* | 0 | 6412 | -10.67 | 2272.95 |
| | | | 1 | 260 | 117.61 | 1348.17 |
| Educational level of R&D personnel | Number of researchers | *phd* | 0 | 6412 | 0.18 | 13.58 |
| | | | 1 | 260 | 0.11 | 2.42 |
| | | *master* | 0 | 6412 | 0.09 | 5.92 |
| | | | 1 | 260 | 0.20 | 2.80 |
| | | *undergrad* | 0 | 6412 | 1.13 | 45.55 |
| | | | 1 | 260 | 6.70 | 25.30 |
| | | *high* | 0 | 6412 | 0.20 | 8.46 |
| | | | 1 | 260 | 2.53 | 14.11 |
| | | *others* | 0 | 6412 | -0.11 | 9.30 |
| | | | 1 | 260 | 0.38 | 4.29 |
| Type of innovation | Binary | *product* | 0 | 5901 | 0.13 | 0.33 |
| | | | 1 | 151 | 0.14 | 0.35 |
| | | *process* | 0 | 5901 | 0.42 | 0.49 |
| | | | 1 | 151 | 0.19 | 0.39 |
| | | *both* | 0 | 5901 | 0.45 | 0.50 |
| | | | 1 | 151 | 0.68 | 0.47 |

With the exception of the dummy variables for type of innovation, all variables represent the difference between real values in 2011 and 2008. Nominal values of 2008 were deflated to their real value on 2011 using the IGP-DI index. Source: IBGE (2010 and 2013, confidential disaggregate data).

In sum, the ‘naive estimators’ (Duguet, 2012) indicate the existence of relevant differences in the composition of innovation investments between firms benefited by the tax incentives and other companies. This first evidence suggests the possibility that part of these discrepancies is result of policy intervention, meaning tax incentives may have had a behavioral additionality worth analyzing through more rigorous estimation.

In this analysis, covariates ($X_i$) are the factors determining the probability of a firm to obtain the tax incentives, as estimated by the propensity score. For this reason, these variables are observed at the same period of treatment (2011 in the case of different innovative activities, R&D outsourcing and educational level of research personnel; and 2008 for type of innovation). Covariates used in this estimation are: (a) firm size (number of employees – log-linearized) (*personnel*); (b) firm age (*age*); (c) dummy for national controlling capital (*nac_control*); (d) dummy for foreign controlling capital (*for_control*); (e) dummy for continuous R&D activity in the last three years (*rd_cont*); (f) dummy for firms belonging to a corporate group (*group*); (g) net revenue; (log-linearized) (*revenue*); (h) dummy for importing firms in (*t-1*) (*imp*); (i) dummy for exporting firms in (*t-1*) (*exp*); (j) dummy for main firm market being international (*for_market*); (k) dummies for each of the five country regions (*North - N, Northeast - NE, Middle west - CO, Southeast - SE and South - S*), excluded firms from the state of São Paulo, to avoid perfect collinearity; and (l) industrial sector dummies, using the National Classification of Economic Activities.[94] Main descriptive statistics for these variables are shown in Tables A3.1 and A3.2 of the Appendix.

### 3.5.3 Identification strategy.

The research strategy implemented in this paper is the propensity score matching (PSM) with difference-in-differences for non-binary outcome variables. A more detailed explanation of the theoretical foundations of this method is presented in Chapter 2.

In practical terms, for each broad category of innovation investments (Table 3.4), it was estimated a propensity score predicting probability of treatment, using the covariates mentioned in the previous section and applying a logit functional distribution form (following Becker & Caliendo, 2007; and Yang, Huang & Hou, 2012). Both covariates and treatment are observed at the same period (with the exception of import and export variables, considered at *t-1*).

After excluding observations that do not comply with the common support assumption, treated units are matched with their control counterparts using the nearest neighbor with replacement algorithm.

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[94] CNAE 2 digits. The respective industrial sector is informed by the number after the prefix '*cnae_*' for each dummy variable.

A means test is performed to assess quality of the matching, checking if covariates are reasonably balanced between the matched units. Following Caliendo and Kopeinig (2005), the following tests' results and indicators are reported and considered: (a) t-test for differences in means of each covariate; (b) reduction on the standardized bias for each covariate; (c) reduction of the pseudo r-squared for the matched sample; (d) joint significance F-test; and (e) the mean and median bias for the matched sample.

The average treatment effect on the treated (ATT) is calculated by comparing the means of each outcome variable for treated and control groups. In order to obtain the confidence interval and significance value of the regressions, I use Abadie and Imbens' (2006) heteroskedasticity-consistent analytical standard errors with two neighbors.

For sensitivity analysis, the Rosenbaum bounds approach is applied. It calculates the maximum value of the odds of treatment ratio ($\Gamma$) for treated and control units that does not compromise the significance of the PSM results (Rosenbaum, 2010; Diprete & Gangl, 2004; Becker & Caliendo, 2007; and Aralica & Botrić, 2013). ($\Gamma$) intervals of ($0.1$) are applied up to the value of two.

Finally, for robustness checks, policy impact is estimated according to three different methods: (a) the ATT is calculated after two alternative matching algorithms (kernel and radius matching) are applied for estimating the propensity score; (b) the ATT is estimated for log-linearized transformations of the continuous outcome variables, after the nearest neighbor matching; and (c) policy effect is estimated through a Seemingly Unrelated Regression (SUR) framework for continuous outcome variables and logit regression for dummies, using exclusively the units selected in the propensity score and weighting the control observations in the case of repetition (Zelner, 1962; Wooldridge, 2002).[95]

### 3.6 Results

This section presents and discusses the results of the empirical analysis. The first subsection displays the estimated propensity scores and discusses the balancing of covariates; the second reports the estimated policy impact on the outcome variables; the third presents the sensitivity analysis and robustness checks; and the fourth discusses the results in light of the literature and policy description outlined in the previous sections.

[95] As replacement is allowed in the estimation of the propensity score, units are weighted accordingly in the case of repetition. It is not clear if SUR is more efficient than estimating OLS when all equations have the same regressors (Wooldridge, 2002).

### 3.6.1 Treatment probability models.

Table 3.6 presents the results of the estimated propensity score for each of the broad groups of outcome variables under study. In most of the cases, coefficients of the covariates have the same sign, supporting the specification of the treatment probability model. Pseudo r-square ranges from 0.17 to 0.35, and log-likelihood from -468 to -332.

The two covariates that present statistically significant coefficients at 95% confidence level for all models (not considering sector dummies) are net revenue and continuous R&D. In both cases, coefficients have the expected positive sign. These results inform that odds of participation in the policy increase with net revenue, and that firms developing R&D continuously are in a better position to obtain the tax incentives granted by the government. Covariates with statistically significant results in at least one of the models are firm size and import in (*t-1*), with a positive coefficient, and national controlling capital and primary market out of the country, with negative influence on policy participation.

Figures 3.15 to 3.18 present the kernel density plots for the propensity score of unmatched and matched samples. These graphs reveal that the propensity score, very different between control and treated groups when the whole sample is considered, becomes strongly balanced once the matching is applied, leading to an acceptable specification of the probability models.

Results of the means test for all covariates are presented in Tables A3.3 to A3.6 of the Appendix. None of the variables present significant differences (at a 95% confidence level) between treatment and control groups in any of the models, with the single exception of *'revenue'* in the probability model for the educational level analysis. Majority of the covariates present a substantial reduction of standardized bias in matched samples, and in all cases log-likelihood test ($p>chi^2$) does not reject joint insignificance hypothesis. Pseudo-$R^2$, mean and median bias also drop considerably for the matched groups. These results, along with the kernel density plots, provide good grounds to accept the propensity score specification and to consider the balancing condition met.

Table 3.6

*Estimated propensity score for each broad investment category*

| *Covariate* | Broad investment category | | | |
|---|---|---|---|---|
| | Innovative activities | R&D outsourcing | Educational level | Type of innovation |
| *personnel* | -0.076(0.15) | -0.04(0.166) | 0.004(0.148) | 0.43(0.193)** |
| *age* | -0.001(0.008) | 0.004(0.008) | 0.004(0.008) | 0.005(0.008) |
| *nac_control* | -0.643(0.513) | -1.357(0.679)** | -0.785(0.511) | -0.605(0.492) |
| *for_control* | -0.562(0.497) | -1.021(0.658) | -0.506(0.496) | -0.117(0.492) |
| *rd_cont* | 1.465(0.209)*** | 1.056(0.451)** | 0.908(0.385)** | 1.46(0.256)*** |
| *group* | 0.212(0.205) | 0.247(0.241) | 0.277(0.207) | 0.412(0.232)* |
| *revenue* | 0.714(0.137)*** | 0.513(0.152)*** | 0.509(0.133)*** | 0.344(0.162)** |
| *imp* | 0.85(0.388)** | 0.674(0.431) | 0.808(0.425)* | 1.168(0.624)* |
| *exp* | 0.432(0.268) | 0.462(0.325) | 0.271(0.29) | 0.553(0.409) |
| *for_market* | -0.888(0.422)** | -0.794(0.48)* | -0.73(0.371)** | -0.4(0.376) |
| *dummyN* | -0.11(0.712) | -1.225(1.102) | -1.216(0.765) | -0.348(0.606) |
| *dummyNE* | -0.44(0.443) | -0.428(0.485) | -0.501(0.458) | -0.254(0.574) |
| *dummySE*[b] | -0.025(0.272) | -0.078(0.306) | 0.127(0.268) | -0.371(0.391) |
| *dummyS* | 0.404(0.21)* | -0.03(0.245) | 0.13(0.229) | 1.022(0.255)*** |
| *dummyCO* | -0.985(0.785) | -1.393(1.099) | -0.6(0.707) | n/a[a] |
| *cnae_10* | -1.909(1.251) | -1.943(0.554)*** | -3.124(1.553)** | -4.181(1.533)*** |
| *cnae_11* | -1.756(1.444) | -1.647(0.906)* | -3.165(1.695)* | -5.331(1.931)*** |
| *cnae_12* | 1.434(2.709) | n/a[a] | n/a[a] | -2.533(2.185) |
| *cnae_13* | -2.71(1.365)*** | -2.221(0.807)*** | -3.434(1.653)** | -4.89(1.689)*** |
| *cnae_14* | -3.065(1.624)* | n/a[a] | -3.388(1.875)* | n/a[a] |
| *cnae_15* | -2.284(1.44) | -1.742(0.802)** | -2.779(1.661)* | -5.574(1.869)*** |
| cnae_16 | n/a[a] | n/a[a] | n/a[a] | n/a[a] |
| cnae_17 | -1.412(1.289) | -1.545(0.716)** | -2.874(1.593)* | -5.397(1.826)*** |
| cnae_18 | n/a[a] | n/a[a] | n/a[a] | n/a[a] |
| cnae_19 | n/a[a] | n/a[a] | n/a[a] | n/a[a] |
| cnae_20 | -1.768(1.256) | -1.657(0.575)*** | -2.757(1.54)* | -4.346(1.563)*** |
| cnae_21 | -1.052(1.298) | -0.887(0.678) | -2.141(1.569) | -3.395(1.586)** |
| cnae_22 | -2.788(1.336)** | -3.033(0.877)*** | -4.089(1.647)** | -4.218(1.591)*** |
| cnae_23 | -1.403(1.308) | -1.843(0.75)** | -2.929(1.608)* | -4.203(1.638)** |
| cnae_24 | -2.466(1.433)* | -1.939(0.861)** | -2.716(1.616)* | -3.74(1.574)** |
| cnae_25 | -1.772(1.282) | -1.58(0.646)** | -2.767(1.572)* | -3.993(1.59)** |
| cnae_26 | -1.985(1.3) | -2.547(0.768)*** | -2.846(1.56)* | -2.722(1.551)* |
| cnae_27 | -1.388(1.261) | -1.355(0.593)** | -2.352(1.551) | -3.827(1.579)** |
| cnae_28 | -1.679(1.258) | -1.821(0.6)*** | -2.785(1.554)* | -3.145(1.542)** |
| cnae_29 | -0.838(1.255) | -1.147(0.617)* | -1.967(1.551) | -2.584(1.54)* |
| cnae_30 | -0.278(1.362) | 0.278(1.045) | -0.974(1.659) | -3.531(1.762)** |
| cnae_31 | -1.311(1.299) | -1.17(0.715) | -2.245(1.616) | -4.009(1.687)** |
| cnae_32 | -1.515(1.344) | -1.516(0.808)* | -2.725(1.641)* | -3.2(1.659)* |
| cnae_33 | n/a[a] | n/a[a] | n/a[a] | n/a[a] |
| cnae_35 | n/a[a] | n/a[a] | n/a[a] | n/a[a] |
| cnae_38 | n/a[a] | n/a[a] | n/a[a] | n/a[a] |
| cnae_50 | n/a[a] | n/a[a] | n/a[a] | n/a[a] |
| cnae_58 | n/a[a] | n/a[a] | n/a[a] | n/a[a] |
| cnae_59 | n/a[a] | n/a[a] | n/a[a] | n/a[a] |
| cnae_60 | n/a[a] | n/a[a] | n/a[a] | n/a[a] |
| cnae_61 | -1.87(1.632) | -1.161(1.057) | -3.322(1.819)* | -5.546(1.793)*** |
| cnae_62 | 0.424(1.289) | n/a[a] | -1.189(1.588) | -3.109(1.568)** |
| cnae_63 | -0.754(1.665) | n/a[a] | n/a[a] | n/a[a] |
| cnae_71 | 0.031(3.554) | n/a[a] | -2.37(2.255) | n/a[a] |
| cnae_72 | n/a[a] | n/a[a] | n/a[a] | n/a[a] |
| cnae_81 | n/a[a] | n/a[a] | n/a[a] | n/a[a] |
| cnae_89 | -0.384(1.698) | n/a[a] | -0.182(2.298) | n/a[a] |
| cnae_91 | n/a[a] | n/a[a] | n/a[a] | n/a[a] |
| cnae_99 | n/a[a] | n/a[a] | n/a[a] | n/a[a] |
| *constant* | -9.745(1.755)*** | -6.435(1.304)*** | -6.116(2.013)*** | -8.263(1.868)*** |
| *N* | 2311 | 988 | 1144 | 2683 |
| *Loglikelihood* | -468.367 | -332.296 | -406.315 | -336.785 |
| *PseudoR2* | 0.268 | 0.165 | 0.170 | 0.356 |
| *Prob>chi2* | 0.000 | 0.000 | 0.000 | 0.000 |

Logit model. Standard error in parenthesis. * p<.10; ** p<.05; *** p<.01.
[a] Excluded due to collinearity.
[b] Not considered firms in the state of São Paulo.

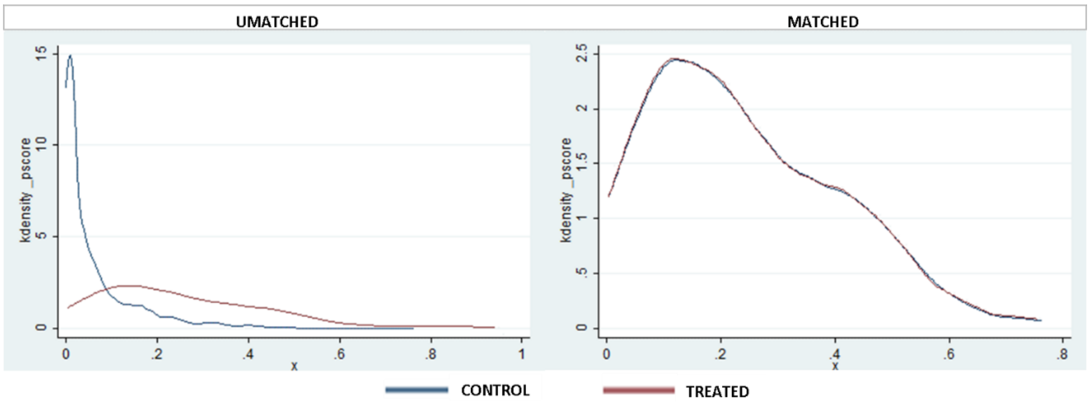


*Figure 3.15.* Kernel density plot for treated and control groups in the unmatched and matched samples. Broad category: different innovative activities.

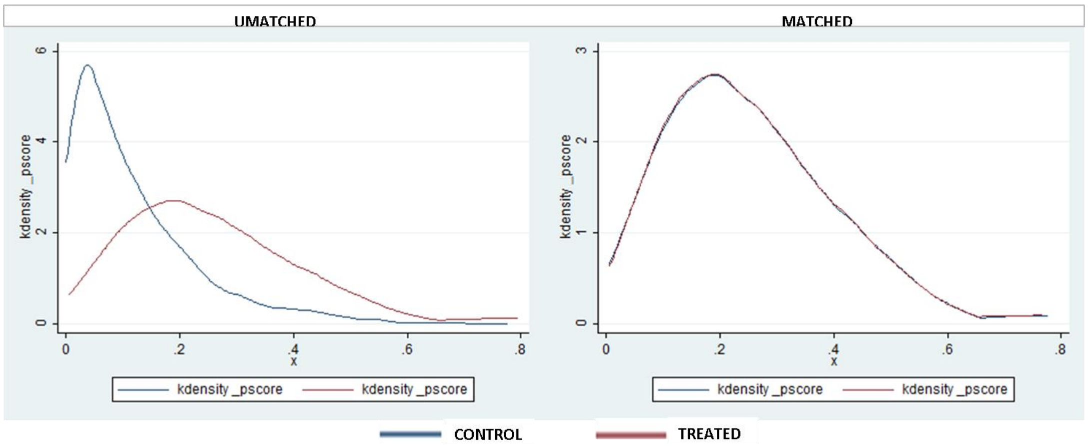


*Figure 3.16.* Kernel density plot for treated and control groups in the unmatched and matched samples. Broad category: R&D outsourcing.

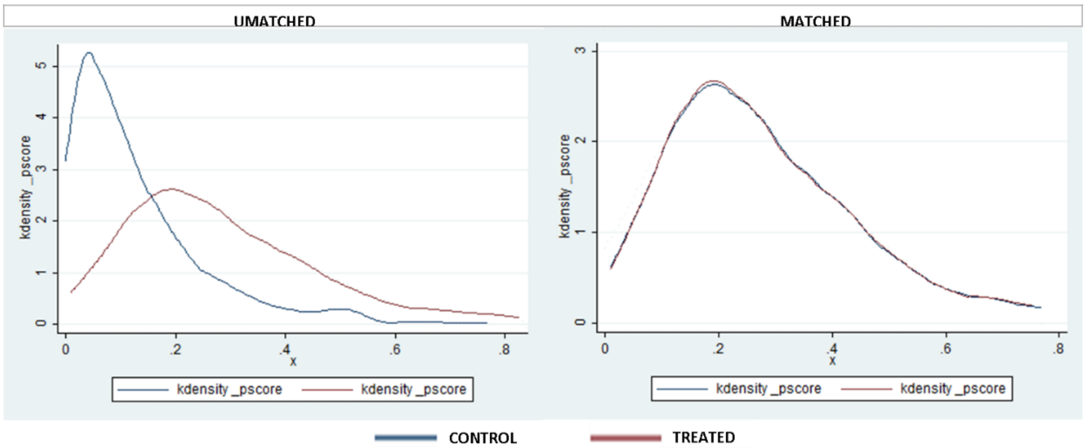


*Figure 3.17.* Kernel density plot for treated and control groups in the unmatched and matched samples. Broad category: Educational level of R&D staff.

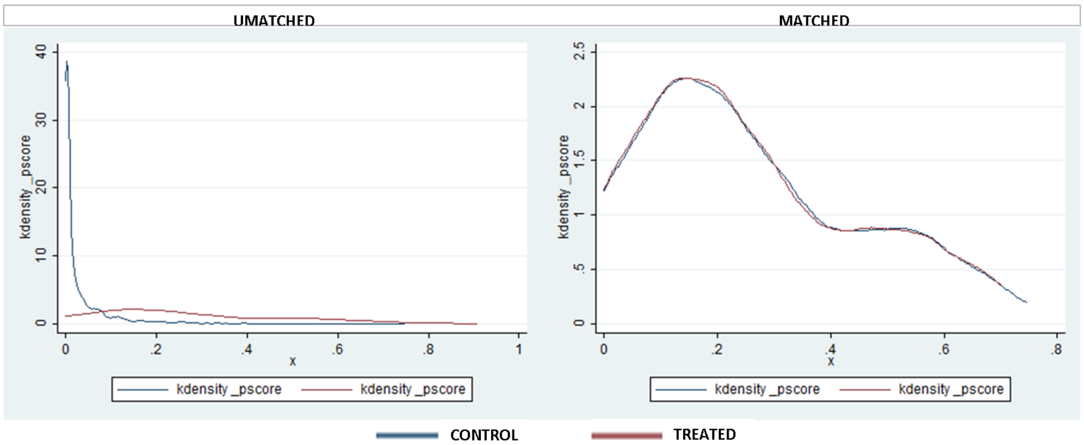


*Figure 3.18.* Kernel density plot for treated and control groups in the unmatched and matched samples. Broad category: Type of innovation.

### 3.6.2 Estimated impact.

The average treatment effect estimated for each outcome variable according to the procedure described in section 3.5 is displayed in Table 3.7, along with the respective standard errors, confidence level indicators and relative effects (considering the mean of the control group as the baseline value).

In the analysis of different categories of innovative activities, the most relevant and significant result is for total R&D expenditures. The average impact of the policy on R&D spending of beneficiary firms in 2011 was around eleven hundred thousand Brazilian *reais*[96] (around six hundred thousand dollars).[97] This value represents 17% of the mean R&D spending of beneficiary firms that year,[98] and an increase of the R&D intensity within the bundle of innovative activities[99] of 9.5%. None of the other categories had an impact close to this magnitude. The estimated effect is significant even at a 99% confidence level.

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[96] Around fifteen hundred thousand Brazilian *reais* readjusted to December, 2016, using the IGP-M/FGV index of the last month of each year.
[97] Value in U.S. dollars converted according to the exchange rate applicable on the last day of 2011.
[98] Mean nominal value in 2011: R$ 6,287.92. To calculate relative impact, this value is readjusted to 2011 using the IGP-M/FGV.
[99] R&D expenditures as a share of total innovative activities' spending.

Table 3.7

*Estimated Average Treatment Effect on the Treated (ATT)*

| Broad investment category | Unit | Variable | Sample | Mean | | Difference | Relative effect |
|---|---|---|---|---|---|---|---|
| | | | | Treated | Controls | | |
| Different innovative activities | R$ 1,000 | *rd_tot* | Unmatched | 1135.97 | 183.97 | 951.99(141.82)*** | 5.17 |
| | | | ATT | 1036.61 | -55.82 | 1092.43(377.9)*** | -19.57 |
| | | *knowledge* | Unmatched | -71.61 | 8.35 | -79.96(34.73)** | -9.58 |
| | | | ATT | -73.06 | 127.90 | -200.96(95.31)** | -1.57 |
| | | *software* | Unmatched | -60.04 | 32.78 | -92.82(53.7)* | -2.83 |
| | | | ATT | -47.62 | -98.68 | 51.06(122.54) | -0.52 |
| | | *machinery* | Unmatched | -337.83 | 142.50 | -480.34(184.84)*** | -3.37 |
| | | | ATT | -308.36 | 197.02 | -505.38(397.51) | -2.57 |
| | | *training* | Unmatched | 11.29 | -14.92 | 26.21(29.71) | -1.76 |
| | | | ATT | 18.42 | -7.78 | 26.21(78.87) | -3.37 |
| | | *intro* | Unmatched | -119.31 | 3.43 | -122.74(81.94) | -35.79 |
| | | | ATT | -109.07 | 271.34 | -380.41(187.72)** | -1.40 |
| | | *project* | Unmatched | -358.74 | -64.44 | -294.29(98.03)*** | 4.57 |
| | | | ATT | -160.99 | -155.74 | -5.25(179.5) | 0.03 |
| R&D outsourcing | R$ 1,000 | *rd_int* | Unmatched | 1040.05 | 614.68 | 425.37(104.03)*** | 0.69 |
| | | | ATT | 1040.32 | 786.42 | 253.9(217.74) | 0.32 |
| | | *rd_ext* | Unmatched | 109.26 | 31.38 | 77.88(57.73) | 2.48 |
| | | | ATT | 110.87 | -130.95 | 241.82(173.24) | -1.85 |
| Educational level | Number of researchers | *phd* | Unmatched | 0.00 | 0.11 | -0.11(0.08) | -1.00 |
| | | | ATT | 0.00 | 0.04 | -0.04(0.13) | -0.95 |
| | | *master* | Unmatched | 0.30 | 0.21 | 0.08(0.13) | 0.37 |
| | | | ATT | 0.31 | 0.29 | 0.01(0.24) | 0.03 |
| | | *undergrad* | Unmatched | 9.04 | 4.81 | 4.23(0.9)*** | 0.88 |
| | | | ATT | 9.17 | 5.82 | 3.35(1.61)** | 0.58 |
| | | *high* | Unmatched | 3.41 | 1.94 | 1.47(0.76)* | 0.76 |
| | | | ATT | 3.44 | 2.39 | 1.05(1.46) | 0.44 |
| | | *other* | Unmatched | 0.93 | 0.22 | 0.71(0.56) | 3.19 |
| | | | ATT | 0.96 | -0.43 | 1.39(1.08) | -3.22 |
| Type of innovation | Binary | *product* | Unmatched | 0.15 | 0.14 | 0(0.03) | 0.00 |
| | | | ATT | 0.15 | 0.15 | 0(0.05) | 0.00 |
| | | *process* | Unmatched | 0.15 | 0.35 | -0.21(0.04)*** | -0.60 |
| | | | ATT | 0.15 | 0.18 | -0.03(0.05) | -0.17 |
| | | *both* | Unmatched | 0.71 | 0.51 | 0.2(0.04)*** | 0.39 |
| | | | ATT | 0.70 | 0.67 | 0.03(0.07) | 0.04 |

Standard errors in parenthesis. * p<.10; ** p<.05; *** p<.01. Matching algorithm: nearest neighbor. Standard error estimated according to Abadie and Imbens (2006).

The estimation also informs that part of such increase was counterbalanced by a reduction of investments in other innovative activities. Firms benefited with tax incentives experienced an average reduction of expenditures on (a) acquisition of external knowledge (of around two hundred thousand Brazilian *reais*[100] or a hundred and ten thousand U.S. dollars), and (b) introduction of innovations in the market (of around three hundred and eighty thousand

[100] Around two hundred and eighty thousand Brazilian *reais* readjusted to December, 2016, using the IGP-M/FGV index of the last month of each year.

Brazilian *reais*[101] or two hundred thousand U.S. dollars). The average of the control group for these outcome variables is positive, meaning the policy can be considered the responsible factor for the decrease in these investments.

The estimation does not yield evidence of impact on other innovative activities, as the statistical significance does not achieve a minimum confidence level. The sign of the estimated effect for software and training investments is positive, but of small magnitude. The ATT for machinery and equipment, on the other hand, is substantial, but so is the respective standard error, and for this reason it is not possible to reject the null hypothesis of zero impact.

In terms of composition of the research staff, firms incentivized by the policy increased the number of researchers with undergraduate degree only. On average, these enterprises hired 3.35 more researchers with such background because of the policy. The effect is significant at a 95% confidence level, and it represents a 18.5% increase in the group of researchers with this educational level, and 11% of the average size of R&D staff in 2011[102]. It is relevant to note that, different from the case of innovative activities, none of the other categories of researchers experienced a decrease in their number as a result of the policy. Actually, all estimates of the educational level outcome variables are positive (though without statistical significance), with the exception of the PhD level, that presented a neglectable and non-significant value (less than 0.05). These results suggest the tax incentives increased the size besides modifying the educational mix of R&D staff, as companies on average did not lay off other personnel to hire undergraduate degree researchers.

The empirical study does not present evidence of policy impact on the levels of R&D outsourcing. Estimated coefficients are similar for internal and external R&D, and in both cases they are not statistically significant.[103] This result disproves the impression caused by Figures 3.9 and 3.10 that the policy could have favored internal R&D.

Finally, the estimation also indicates there is no effect of the incentives on the type of innovation pursued by beneficiary firms. Although Figures 3.13 and 3.14 suggest beneficiary firms did less 'process innovation only' and dedicated their efforts more to both types of innovation, the difference between treated and control groups does not withstand after the

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[101] Around five hundred and thirty thousand Brazilian *reais* readjusted to December, 2016, using the IGP-M/FGV index of the last month of each year.

[102] Mean value for beneficiary firms in 2011 is 15.66 researchers.

[103] It is important to stress that, as the interest lies on the composition of the R&D bundle, only firms with positive investment in one of the categories were considered. For this reason, the result should not be considered inconsistent with the significant result for total R&D in Chapter 2, where only firms with positive R&D spending were considered.

matching. In this sense, it is not possible to maintain the policy had any effect on the decision of firms on what type of innovation process to invest.

### 3.6.3 Robustness checks and sensitivity analysis.

Table 3.8 presents robustness checks results, including the estimated ATT using alternative matching algorithms (kernel and radius) and log-linearized outcome variables (continuous only) and impact assessment using SUR and logit regressions. In general, coefficient signs and statistical significance follow closely the results of the main model, suggesting they are not sensitive to the estimator applied. Estimated impacts using the alternative matching algorithms are generally smaller, most probably result of the increase in the heterogeneity of the comparison base, as more units are considered in the control group.

In the case of different categories of innovative activities, the impact on total R&D remains positive and significant in all cases, although the value varies substantially from the main estimation. In the case of acquisition of external knowledge, the magnitude of the negative result varies less, and is also significant for all robustness checks. Introduction of innovations in the market, on the other hand, only remains significant (at a 95% confidence level) for the log-linearized specification, suggesting this result may not be as robust as the others. The ATT or coefficient for the other outcome variables do not achieve statistical significance in any of the robustness checks, reinforcing that they are not affected by the tax incentives.

The impact of the policy on the hiring of research personnel with undergraduate degree is confirmed by two of the alternative models, but loses significance as the matching algorithm is changed. This result, therefore, is sensitive to the choice of the counterfactual method. Again, estimates do not indicate impact on none of the other groups of researchers.

Confirming the main estimation, the alternative models do not present evidence of impact on the levels of R&D outsourcing and type of innovation, with the exception of the internal R&D spending in the case of SUR estimation.

Table 3.8

*Estimated policy impact: robustness Checks results*

| Broad Investment category | Outcome Variable | Estimated effect - Robustness checks | | | |
|---|---|---|---|---|---|
| | | kernel matching[a] | radius matching[b] | Log-linearized[c] | SUR and logit[d] |
| Innovative activities expenditures | *rd_tot* | 835.45(220.77)*** | 543.37(223.69)** | 0.0014(0.0005)*** | 1186.5(342.61)*** |
| | *knowledge* | -154.05(59.35)*** | -138.07(60.94)** | -0.0027(0.0013)** | -180.23(80.01)** |
| | *software* | -80.28(58.18) | -45.51(60.4) | 0.0003(0.0006) | 51.58(142.1) |
| | *machinery* | -19.69(222.79) | -41.36(230.18) | -0.0007(0.0006) | -501.3(303.35) |
| | *training* | 66.27(45.33) | 89.11(46.58)* | 0.0002(0.0008) | 29.36(42.23) |
| | *intro* | -198.03(123.74) | -146(127.48) | -0.0011(0.0005)** | -320.13(177.24)* |
| | *project* | 149.01(84.67)* | 85.58(86.68) | 0(0.0006) | -33.42(116.69) |
| R&D outsourcing | *rd_int* | 194.45(130.14) | 133.95(132.28) | 0.0003(0.0003) | 356.85(151.94)** |
| | *rd_ext* | 72.23(45.08) | 54.66(45.78) | 0.0017(0.0012) | 164.09(88.47)* |
| Educational level | *phd* | -0.11(0.12) | -0.12(0.12) | -0.0015(0.0031) | -0.06(0.13) |
| | *master* | -0.06(0.18) | -0.04(0.18) | -0.0002(0.0053) | -0.05(0.23) |
| | *undergrad* | 1.78(1.31) | 1.87(1.33) | 0.0134(0.0065)** | 3.38(1.4)** |
| | *high* | 0.98(1.08) | 1.13(1.1) | 0.0019(0.0024) | 1.51(1.38) |
| | *other* | 0.9(0.48)* | 0.9(0.5)* | 0.0025(0.0019) | 1.47(1.18) |
| Type of innovation | *product* | -0.02(0.04) | 0.02(0.04) | | 0(0.39) |
| | *project* | -0.04(0.05) | -0.03(0.05) | | -0.23(0.4) |
| | *both* | 0.06(0.05) | 0(0.06) | | 0.15(0.32) |

Standard errors in parenthesis. * p<.10; ** p<.05; *** p<.01.
[a] Matching algorithm: kernel. Standard error estimated by 100 bootstrap iterations.
[b] Matching algorithm: radius within caliper (20% of the standard deviation of the propensity score). Standard error estimated by 100 bootstrap iterations.
[c] Continuous variables were log-linearized according to the following transformation equation: $\ln\_x_i = \ln(x_i + x_{min} + 1)$; where ($x_{min}$) means the minimum value observed for ($x_i$) in the sample. Matching algorithm: nearest neighbor. Standard error estimated according to Abadie and Imbens (2006).
[d] Estimated effect is the value of the coefficient of the treatment dummy independent variable. For continuous dependent variables, analysis was performed through a seemingly unrelated regressions estimator, and in the case of binary dependent variables a logistic regression was applied. In both cases, only observations used in the main propensity score model were used, weighted according to the number of repetitions for non-treated units.

Table 3.9 presents the results of the Rosenbaum bounds sensitivity analysis for the outcome variables with significant impact estimates in the main model. In the case of total R&D and external knowledge acquisition, coefficients lose significance at the ($1.2 < \Gamma < 1.3$) interval. This means a hidden variable not considered in the propensity score model should affect odds of treatment ratio at a minimum of 20% in order to render the estimation results spurious. Considering the large group of covariates used to estimate the propensity score and that the difference-in-difference estimators excluded any chance of endogeneity arising from fixed effects, the results may be considered moderately insensitive to hidden bias. An interval of ($\Gamma < 1.4$) was found and accepted by Aralica and Botrić (2013) for policy impact on R&D expenditures, and Diprete and Gangl (2004) obtained and ($\Gamma < 1.15$) for unemployment benefits effects on wage change.

Table 3.9

*Results of the sensitivity analysis of hidden bias due to omitted variables (Rosenbaum bounds)*

| Outcome Variable | $\Gamma$ | sig+ | sig- | t-hat+ | t-hat- | CI+ | CI- |
|---|---|---|---|---|---|---|---|
| | 1 | 0.0011 | 0.0011 | 451.0500 | 451.0500 | 154.1740 | 842.2120 |
| | 1.1 | 0.0057 | 0.0001 | 359.0780 | 552.5000 | 67.5165 | 959.5570 |
| | 1.2 | 0.0208 | 0.0000 | 287.1750 | 656.8300 | 1.9385 | 1078.6900 |
| | 1.3 | 0.0562 | 0.0000 | 218.0360 | 744.9500 | -42.0000 | 1187.2800 |
| | 1.4 | 0.1205 | 0.0000 | 158.5370 | 835.5930 | -110.6250 | 1306.3300 |
| *rd_tot* | 1.5 | 0.2152 | 0.0000 | 100.0000 | 907.1880 | -190.3430 | 1403.1600 |
| | 1.6 | 0.3337 | 0.0000 | 44.2325 | 999.7590 | -300.0000 | 1503.0400 |
| | 1.7 | 0.4629 | 0.0000 | 1.9385 | 1077.0000 | -375.6720 | 1619.3800 |
| | 1.8 | 0.5886 | 0.0000 | -22.0615 | 1138.4200 | -441.3260 | 1698.1000 |
| | 1.9 | 0.6999 | 0.0000 | -57.5000 | 1236.2300 | -512.4920 | 1823.1700 |
| | 2 | 0.7908 | 0.0000 | -109.5000 | 1303.8300 | -571.3720 | 1922.6800 |
| | 1 | 0.0011 | 0.0011 | 0.0006 | 0.0006 | 0.0002 | 0.0011 |
| | 1.1 | 0.0058 | 0.0001 | 0.0004 | 0.0007 | 0.0001 | 0.0012 |
| | 1.2 | 0.0210 | 0.0000 | 0.0004 | 0.0008 | 0.0000 | 0.0013 |
| | 1.3 | 0.0567 | 0.0000 | 0.0003 | 0.0009 | -0.0001 | 0.0015 |
| | 1.4 | 0.1212 | 0.0000 | 0.0002 | 0.0010 | -0.0001 | 0.0016 |
| *knowledge* | 1.5 | 0.2163 | 0.0000 | 0.0001 | 0.0011 | -0.0002 | 0.0018 |
| | 1.6 | 0.3351 | 0.0000 | 0.0001 | 0.0013 | -0.0004 | 0.0019 |
| | 1.7 | 0.4644 | 0.0000 | 0.0000 | 0.0013 | -0.0005 | 0.0020 |
| | 1.8 | 0.5901 | 0.0000 | 0.0000 | 0.0014 | -0.0006 | 0.0021 |
| | 1.9 | 0.7012 | 0.0000 | -0.0001 | 0.0015 | -0.0006 | 0.0023 |
| | 2 | 0.7919 | 0.0000 | -0.0001 | 0.0016 | -0.0007 | 0.0024 |
| | 1 | 0.0793 | 0.0793 | -2.3267 | -2.3267 | -6.2035 | 0.7197 |
| | 1.1 | 0.0289 | 0.1771 | -3.1240 | -1.4738 | -7.4549 | 1.4015 |
| | 1.2 | 0.0095 | 0.3131 | -3.9962 | -0.6686 | -8.4748 | 2.1775 |
| | 1.3 | 0.0029 | 0.4666 | -4.7354 | -0.0634 | -9.5999 | 2.9312 |
| | 1.4 | 0.0008 | 0.6139 | -5.6807 | 0.2720 | -10.6116 | 3.7912 |
| *intro* | 1.5 | 0.0002 | 0.7381 | -6.3769 | 0.7588 | -11.6235 | 4.4780 |
| | 1.6 | 0.0001 | 0.8324 | -7.2433 | 1.3005 | -12.5934 | 5.1309 |
| | 1.7 | 0.0000 | 0.8981 | -7.8894 | 1.6522 | -13.3530 | 5.8128 |
| | 1.8 | 0.0000 | 0.9408 | -8.5494 | 2.2328 | -14.1341 | 6.6436 |
| | 1.9 | 0.0000 | 0.9670 | -9.2593 | 2.7492 | -14.7766 | 7.3947 |
| | 2 | 0.0000 | 0.9822 | -9.9878 | 3.1584 | -15.5141 | 8.3672 |
| | 1 | 0.0124 | 0.0124 | 2.1250 | 2.1250 | 0.2500 | 4.1000 |
| | 1.1 | 0.0445 | 0.0026 | 1.6000 | 2.6500 | -0.3000 | 4.6750 |
| | 1.2 | 0.1135 | 0.0005 | 1.1000 | 3.1500 | -0.7500 | 5.2500 |
| | 1.3 | 0.2244 | 0.0001 | 0.7300 | 3.6000 | -1.2000 | 5.7500 |
| | 1.4 | 0.3665 | 0.0000 | 0.3000 | 4.0500 | -1.6500 | 6.2250 |
| *undergrad* | 1.5 | 0.5183 | 0.0000 | -0.0175 | 4.4250 | -2.0000 | 6.6500 |
| | 1.6 | 0.6583 | 0.0000 | -0.4500 | 4.8350 | -2.4500 | 7.0800 |
| | 1.7 | 0.7729 | 0.0000 | -0.7500 | 5.2250 | -2.8000 | 7.5500 |
| | 1.8 | 0.8577 | 0.0000 | -1.0250 | 5.5250 | -3.0750 | 8.0000 |
| | 1.9 | 0.9155 | 0.0000 | -1.3500 | 5.8600 | -3.4000 | 8.3000 |
| | 2 | 0.9521 | 0.0000 | -1.6000 | 6.1750 | -3.7000 | 8.7500 |

* gamma - log odds of differential assignment due to unobserved factors; sig+ - upper bound significance level; sig- - lower bound significance level; t-hat+ - upper bound Hodges-Lehmann point estimate; t-hat- - lower bound Hodges-Lehmann point estimate; CI+ - upper bound confidence interval (a= .95); CI- - lower bound confidence interval (a= .95).

The impact on expenditures with introduction of innovations in the market and hiring of researchers with undergraduate degree, on the other hand, is more sensitive to hidden bias, as statistical significance is not found for values of ($\Gamma$) above 1.2. This means these estimations should be taken with caution, although they should not be disregarded, as there is no indication of a non-observable variable that may potentially affect such results.

### 3.6.4 Discussion of the results.

The results of the empirical investigation may be analyzed in five different perspectives discussed along this study. I first consider the theoretical concept of tax incentives and its features.

As discussed in section 3.3.3, the main advantage of tax schemes to foster innovation is their 'market-oriented' nature, as firms retain the decision about their investments, with less interference from the public sector (OECD, 2014a). The fact that several outcome variables were not affected by the policy provides support to this argument. The results suggest that major shifts in firms' innovation strategies did not take place due to the tax policy. Firms did not alter their R&D outsourcing levels nor the type of innovation they pursue once they obtained the benefits. This result strengthens the idea that tax incentives reduce distortions arising from government intervention, as firms were not compelled to divert resources from other activities (presumably with smaller expected profit) because of policy requirements.

On the other hand, the study refutes one of main shortcomings of tax incentives raised by the literature, i.e., the potential conflict between public and private interests (Hall & Van Reenen, 2000). Firms, this argument goes, would try to focus their extra resources in activities with more internalized results. However, the innovative activity that presented highest impact in this estimation was total R&D. And the economic literature has acknowledged that R&D has substantial positive externalities, arising mainly from knowledge spillovers (Griliches, 1992; and Wieser, 2005).

Second, the results can be analyzed from the perspective of the theoretical literature on behavioral additionality, and the models or arguments on how government intervention affects each of the broad investment categories. The first point to stress in this regard is the confirmation of behavioral additionality effects of the policy. Although limited to a group of variables, the study provides evidence that firms had altered the composition of their investments, and this may be interpreted as evidence of changes in their innovation strategies. The study, in this sense, confirms the importance of the behavioral additionality approach to better understand the impact and dynamics of innovation policies.

In the case of different categories of innovative activities, the estimates support the conclusions of Aghion and Howitt's (1998) model that government funding increases investment in fundamental innovation, and they dispute the argument by David et al. (2000)

that beneficiary firms are more likely to seek short-run profit. The evidence presented herein indicates that incentivized firms on average increased their investments in strict R&D, while reducing or not changing their spending in other activities. One may conclude from this that the policy elevated the intensity of fundamental innovation for treated companies. According to the Aghion and Howitt, such outcome happens because fundamental innovation has a more ‘forward-looking’ nature, meaning it captures rents from future products, while secondary innovation is rewarded only by existing technology.

The increase in the number of researchers with an undergraduate degree is not explained by any of the theoretical models analyzed in the literature review. This outcome in part disputes Georghiou and Clarysse’s (2006) claim that government incentives could indirectly raise the educational level of the research team, as no impact on hiring of more qualified researchers was found. The empirical investigation of Garcia-Quevedo et al. (2011) suggested this might be explained by factors like R&D intensity and university collaboration. According to these authors’ findings, demand for researchers with a university degree comes from R&D intensive firms that outsource research to universities. More qualified personnel (with a PhD or Master’s degree) are needed by companies with a strong R&D infrastructure that have close collaboration with higher education institutions.

No measurable impact on R&D outsourcing levels is found in this analysis, contrary to the group of theoretical models that suggest public incentives impact such balance, whether to increase (Vilasuso & Frascatori, 2000) or reduce (LaRiviere, 2014) collaboration with third parties. Under the light of the transaction cost theory, this finding implies the incentives did not alter the ratio of internal and external costs of R&D, making companies indifferent to such choice when deciding on new investments. If the arguments by Mowery and Rosenberg (1989) and Beneito (2006) are considered, it may also be maintained that the incentives did not affect specificity of the research projects, as this is the main factor determining whether R&D is undertaken in-house.

Finally, the absence of impact on the ‘type of innovation’ outcome variables contradicts Howitt’s (1999) conclusions that both vertical and horizontal innovations are fostered by public incentives in the short run. The results, in this sense, seem closer to Segerstrom’s (2000) model, that suggests the outcome of government intervention is uncertain in terms of type of innovation.

Considering the empirical literature presented in section 3.3.2, this study presents novel results worth detailing. The increase in R&D intensity within the bundle of innovative activities contrasts with the findings of Zhu et al. (2006) for tax incentives, but it is in accordance with the results of Clausen (2007) and Zhu et al. (2006) for direct subsidies, as they also found that R&D intensity rises. Results for educational level of R&D staff also differs from previous studies considered. Clausen (2007) and Dumont et al. (2014) found evidence of impact on the number of qualified researchers with PhD or Master's degree, while Afcha and Garcia-Quevedo (2014) did not reach any significant results. Finally, while no significant impact was found herein for R&D outsourcing and type of innovation, Clausen (2007) and Afcha and López (2014) obtained positive results for internal R&D levels, and Aralica and Botrić (2013) found that the product-process innovation balance was affected by government policy.

The estimate results can also be analyzed in light of the policy design, as summarized in section 3.4.2. As mentioned previously, although Decree 5,798/05 uses the expression "technological research and technological innovation development", a group of additional activities besides strict R&D are included in such concept. For this reason, it is difficult to attribute the increased R&D intensity to the definition of incentivized activities. The negative impact on acquisition of external knowledge and introduction of innovations in the market, however, may have been caused by this normative provision. As such activities are not expressly listed as benefited by the enhanced deduction of expenses, firms may have chosen to dedicate their resources to other innovative strategies.

The policy does not distinguish between the educational level of new R&D personnel (art. 2, III, of Decree 5,798/05). Still, as argued in section 3.3.1, policy design might have had an impact on the composition of human resources. By establishing as the only requirement for the additional 20% deduction the increase in the number of researchers, regardless of their educational background, the law may have induced firms not to hire employees with higher qualification and greater wages in order to meet the minimum required number. This may explain why the measured impact is limited to researchers with undergraduate degree, without significant effect on workers with Master's and PhD degrees.

Despite restricting outsourcing R&D and providing a more favorable treatment of product innovation (by enhancing deduction of patented technologies and reducing the tax burden for patent protection), the estimations presented herein suggest these measures were not significant to affect the levels of in-house and external R&D nor the type of innovation pursued by firms.

Finally, in order to draw policy implications from the empirical study, the literature on innovation investments and economic growth (section 3.2.3) is used as the main theoretical background. The increase of R&D intensity in the bundle of innovative investments can in principle be considered a positive result of the policy to be preserved and fostered, as strict

R&D is generally related to innovation projects with higher technological levels (Zhu et al., 2006) and knowledge spillovers, besides employing more qualified (and better paid) personnel (Garcia-Quevedo et al., 2011).

Nonetheless, if the conclusions of Aghion and Howitt's (1998) model are considered, one must not assume that an increase in the levels of more fundamental innovation (herein considered as the case of strict R&D) necessarily leads to higher equilibrium growth levels, for secondary innovation may not follow such rise, reducing productivity gains and quality improvement arising from experience. As it is difficult to argue that Brazil presents excessive levels of R&D,[104] this argument serves as a caveat that the policy must also aim at other innovative activities, for they are also relevant to foster development, as Young's (1992) account of the Hong Kong case informs.

The absence of impact on the number of researchers with graduate training is an important negative result that needs to be addressed. The literature suggests highly qualified personnel is essential to firms' ability to innovate (Nelson & Phelps, 1966) and absorptive capacity (Castellacci, 2011), thus impacting innovation and growth levels. Establishing a system of incentives and cost reductions that stimulates demand for a more qualified research workforce seems particularly relevant to improve the policy. The Belgian case described and tested by Neicu et al. (2014) and Dumont et al. (2014) presents a viable option and first basis for policy design.

The case for R&D outsourcing levels is less clear, since the theoretical and empirical literature does not seem to have reached a consensus on whether higher proportions of external R&D is positive for innovation output and growth. Still, the restrictions imposed by the law to R&D outsourcing within the country is not justified by economic theory and may be a relevant point of reform, especially considering that a group of papers argued that internal and external R&D may be complementary in the firm's innovation strategy (Beneito, 2003, 2006).

At last, the design of incentives particularly suited to impact process innovation constitutes another challenge to be addressed. OECD (2015d) stressed that the weakness of Brazilian productivity rates is one of the main reasons to explain low GDP per capita levels compared to developed economies. Plus, a group of models (Young, 1998; Howitt, 1999) maintained that vertical or process innovation has a particularly important role for long-run economic growth due to its impact on productivity levels.

[104] See data for aggregate R&D levels in section 3.4.1.

### 3.7 Summary and Conclusions

This paper presents an empirical study on the impact of innovation tax incentives established in Brazil by the Law 11,196/05 on the composition of innovation investments. The behavioral additionality is a recent dimension of the evaluation of innovation policies at the international economic literature, and it is virtually unexplored in Brazil. This approach complements assessments on the effects of innovation policy on broad input indicators, such as R&D expenditures and research personnel, allowing a deeper understanding on firms' responses to government intervention and how they modify their strategies in light of the extra resources and policy design.

In order to design and interpret the results of the research, an extensive literature review on a variety of topics is presented. Besides the theoretical foundations of the behavioral additionality analysis, the main arguments and models that explain the economic relevance of the categories of innovation investment composition used in the study are discussed. It is also shown that there are solid economic arguments to maintain that the composition of the investments' bundle matters for firm's performance and economic growth, stressing the relevance of the study.

The empirical literature considered on the topic is exclusively international, addressing the impact of policies adopted by different countries on distinct innovation composition variables. Most of these studies found effect on only some of the variables, indicating that government measures indeed affect investment options differently, thus changing the bundle and behavior of firms towards innovation. There are few analyses dedicated to evaluate tax incentives, adding more relevance to this study.

The institutional design of the Brazilian innovation tax policy is considered in this perspective. It is argued that, although the policy encompasses a wide range of benefited activities, there are provisions that impact composition of investments by altering the relative tax cost of different options or establishing different restrictions or incentive rates for particular expenditures (as presented in Table 3.3).

The study uses firm level data from PINTEC and applies a matching procedure to generate a counterfactual for beneficiary companies and estimate the average treatment impact on them. The three main conclusions of the study are: (a) considering the entire group of innovative activities, there is a positive effect on total R&D expenditures of around 17%, raising the R&D intensity of the bulk of innovative activities by 9.5%; (b) there is also evidence of negative impact of the policy on expenditures for acquisition of external knowledge (of around two hundred thousand Brazilian *reais*) and introduction of innovations in the market (of around three hundred and eighty thousand Brazilian *reais*); (c) the policy also fostered additional hiring of 3.35 researchers with university level degree in 2011 (around 18.5% of the average number of researchers with this educational level working in beneficiary firms that year), without significant impact on personnel with higher educational level; and (d) there is no evidence that the policy affects R&D outsourcing levels or the balance between product and process innovation. Robustness checks and sensitivity analysis indicates the positive impact on total R&D is moderately robust, while increase in the number of undergraduate degree researchers is more sensitive to the chosen estimator or hidden bias. The research adds new findings so far not present on the empirical literature on the subject, especially concerning a positive effects of tax incentives on R&D intensity (as argued in section 3.6.4).

A number of policy implications are drawn from the study and suggest there is room for improvement on the policy design. At first, promoting other innovative activities besides strict R&D constitutes a necessary action to reap the benefits of secondary innovation. Increase the number of R&D personnel with graduate training is another important strategy to be pursued, especially considering the law does not make any distinction on the educational background of researchers for the additional incentive of 20% deduction of expenses. Establishing incentives or requirements aimed at fostering process innovation can help to increase productivity gains in industrial firms. And, finally, the law establishes restrictions on R&D outsourcing that do not find solid ground on economic theory, as there is no consensus on the literature on its impact on innovation output or firm's performance.

Three research agendas follow from the conclusions of this study. At first, the concept of behavioral additionality introduces new dimensions or layers of firms' responses to government intervention that can be addressed. Even narrowing the scope to expenditures, other categories or classifications can be considered, complementing the analysis presented herein. Moreover, this research strategy can be replicated for other innovation policies or measures implemented by the Brazilian government for comparison of results, allowing a better understanding of the differences between policy tools and how firms react to each one.

Finally, one point not addressed in this study but relevant for policy design is the issue of persistency, or whether the identified impacts are temporary or limited to the validity of the incentives (or to the first years in which firms obtain them). Gök and Edler (2012) maintained that the "the most durable" type of additionality is the behavioral one, although the empirical evidence supporting such idea is scarce. Considering the time dimension in the analysis constitutes an interesting point for future research, as there is no evidence that the impact estimated herein is permanent or just a brief change in firms' investment structure.

# 4 BRAZILIAN INNOVATION TAX POLICY AND INTERNATIONAL INVESTMENT: EVIDENCE FROM UNITED STATES ENTERPRISES AND INTERNATIONAL PATENT APPLICATIONS

Abstract

In the last decades, multinational enterprises (MNEs) have increased their internationalization levels of innovation activities, directing more resources to research and development (R&D) out of their home countries. Brazil has benefited from such changes and has received increasing investment from MNEs. In 2005, the federal government approved new tax incentives (Law 11,195/05) to foster business innovation in the country by reducing the tax cost of R&D projects. This paper presents the first quantitative assessment on whether these tax breaks have attracted ‘footloose R&D’, diverting international investment from other economies. After a literature review on locational factors for R&D attraction and an analysis of the Brazilian case, an econometric model is presented, using data on R&D investment by U.S. MNEs and priority patent applications. No evidence that Brazilian tax incentives have attracted international R&D from alternative host countries is found. This result is in accordance with previous research suggesting R&D performed in Brazil by MNEs is mainly adaptive and support-oriented and, for this reason, tax incentives are not of primary importance as an attraction factor. It also suggests that claims that international fiscal competition lead to a zero-sum game may be unfounded in the Brazilian case.

Keywords**:** Tax incentives. Innovation. International investment.

## 4.1 Introduction

Industrial investment in innovation has changed substantially in the last decades. Although a large portion of funding is still in the hands of multinational enterprises (MNEs) from developed countries (UNCTAD, 2005b; OECD, 2008b), the potential for offshore research has reshaped the strategy of these groups. Resources and projects are divided among several geographic areas either to exploit local competitive advantages or to support production and sales. So far Brazil has received a small share of these funds, but it has recently experienced an increasing inflow of international research and development (R&D) investment.[105]

As innovation generates positive externalities and knowledge spillovers, and may positively influence growth rates (Solow, 1959; Romer, 1990; Aghion & Howitt, 1992), governments have tried to develop and implement policies to increase and attract these investments. In this policy context, the use of tax incentives as a tool to foster innovation has particularly increased in the last decades. They tend to be more "market-friendly" than direct subsidies since the decision on the projects to be implemented remains within the firm (Hall & Van Reenen, 2000).[106]

In 2005, the Brazilian federal government enacted Law 11,196/05, consolidating and expanding tax incentives to companies willing to invest in scientific and technological development in the country. Although a descriptive presentation of the incentives and beneficiary companies is disclosed annually by the Ministry of Science, Technology and Innovation (MCTI, 2015b, 2016), to date the impact of the incentives on R&D investments by MNEs in Brazil has not been properly evaluated. Surveys have been conducted to assess to assess the relevance of these incentives to international groups[107] but no quantitative study or research was found that attempted to clarify whether the Brazilian tax policy has had any relevance or significant impact on attracting foreign innovation capital to the country.

The objective of this paper is to present a first investigation on the topic. Based on a review of the relevant literature and data on R&D internalization and its drivers, an econometric model is presented to test whether there is evidence that tax breaks granted by Brazilian authorities have diverted investment from other sources, attracting 'footloose R&D' (as defined by Bloom & Griffith, 2001) in a beggar-thy-neighbor scheme. Two distinct sets of panel data are used for estimation: R&D investment of United States (U.S.) MNEs abroad; and priority

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[105] See section 4.3.2.
[106] "A tax-based subsidy seems the market-oriented response as it leaves the choice of how to conduct and pursue R&D programs in the hands of the private sector". (Hall & Van Reenen, 2000, p. 449).
[107] See section 4.3.4.

patent applications in which at least one of the inventors is from a country different from at least one of the applicants.

The paper is structured as follows: the second section discusses R&D internationalization as a global trend, presenting the theoretical framework and relevant literature, identifying its main drivers and analyzing the role of tax policy in this context. The third section is dedicated to the Brazilian case, presenting data on international investment in the country and analyzing the innovation tax policy introduced by the government. The fourth section presents the econometric analysis, describing the empirical model and debating its results. The fifth and last section concludes the study by discussing the policy implications of its findings.

## 4.2 International Investment in Innovation

The data and most recent studies on internationalization of R&D depict a scenario in which MNEs are the main drivers of the process and emerging countries are entering the competition for funds. In this section, the most important trends and features described by this literature are presented, along with an analysis on the locational factors that determine where these investments take place, and the relevance of fiscal incentives in this context.

### 4.2.1 Current trends.

R&D was one of the last activities of the value chain to be internationalized by multinational groups after distribution, sales and production (OECD, 2011b). Although exceptional examples do exist, the main trend until the 1980s was centralization of technology development in the parent company`s domestic facilities. The main explanation for this, as presented in the literature, is the vital importance of technology for business, along with its tacit nature, economies of scale for laboratory equipment and research, difficulty of knowledge transfer and the risk of information leaks (OECD, 2008b).

Starting in the 1990s, international competition drove MNEs to decentralize their research efforts to other countries. At a slow but growing pace, part of these activities was outsourced to foreign affiliates or subcontracted to specialized firms abroad. Studies identified a group of “centrifugal forces” that counterbalance R&D centralization: support for production and adaptation of products to foreign markets; development or customization of technology for natural resource extraction; technology seeking the capture of spillovers; access to low cost or highly skilled personnel; and proximity to customers or partners (Thomson, 2009; OECD, 2008b).

In spite of these drivers, the majority of MNEs' R&D is still performed in the home country (OECD, 2014a). Internationalization is growing, but it is still far behind other value adding activities. The UNCTAD`s World Investment Prospects Survey informed that, in 2016, 43% of the respondent MNEs planned to spend more than one-fifth of their R&D budget abroad. In comparison, for the same lower limit, the percentage of respondents rises to 68% when it refers to asset internationalization, 70% for investment and 88% for sales (UNCTAD, 2014). The figures for R&D should nonetheless be considered an improvement. Earlier versions of the same survey indicate a smooth upward trend of internationalization, with less than 35% of respondents with at least 20% of international R&D for 2011 and 2013 (UNCTAD, 2012 and 2013).

The trend identified in the UNCTAD surveys matches the trajectory of R&D funds of U.S. MNEs spent out of the U.S., as portrayed in Figure 4.1. Although irregular, it is possible to identify a growth pattern over the years, achieving around 20% of the total value in 2012.

MNEs offshoring R&D are mostly from a few countries, with a high predominance of parent companies from the U.S., United Kingdom, Japan, Germany and France (UNCTAD, 2005b). The level of internationalization also varies with geography: Western European groups presented higher levels of R&D offshoring in 2005, while Japanese and South Korean enterprises had higher expectations of internationalizing such activities in the future (UNCTAD, 2005b). As per sectorial differences, the chemical and pharmaceutical industries are the ones that most internationalized their innovation efforts (UNCTAD, 2005a and 2005b). Pharmaceuticals is also indicated as the leading industry for R&D internationalization by a more recent report of the European Commission (EC, 2012).

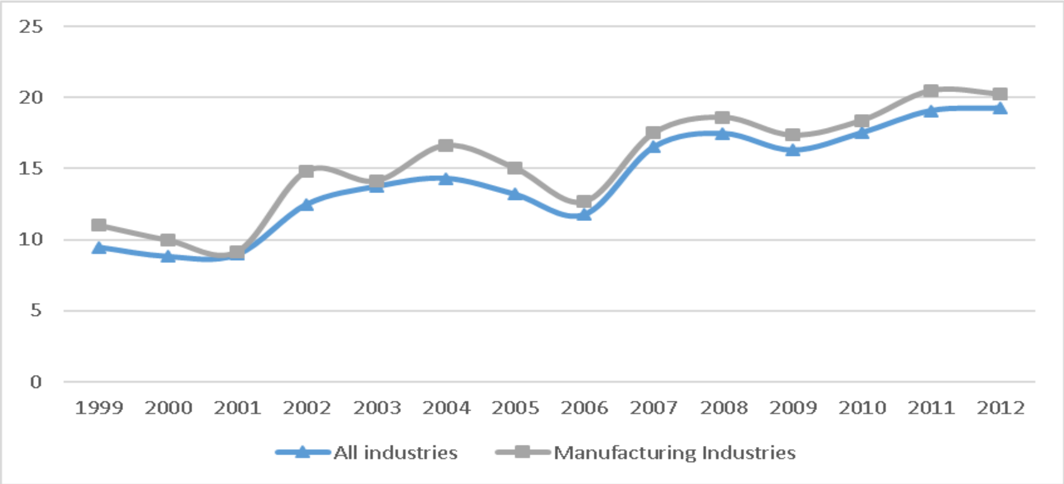


*Figure 4.1.* Percentage of R&D resources spent by U.S. MNEs (including affiliates) out of the country. Source: NSF (2015, 2014, 2013a, 2011, 2010, 2009, 2007, 2006, 2005, 2003, 2002).

The largest part of internationalized R&D is directed to developed countries (OECD, 2008b). According to the aforementioned European Commission Report, “the linkage between the U.S. and the E.U. is the single most important bilateral relationship in the internationalization of business R&D” (EC, 2012, p. 28). The relevance of emerging countries in this field is still limited. Figure 4.2 shows that investments in Latin America, Africa, Eastern Europe, the Middle East and Asia-Pacific (excluding Japan, China and South Korea) only account for a small percentage of the total R&D internationalized by U.S. MNEs.

Nonetheless, all revised studies and reports were unanimous in stating that emerging countries are becoming relevant players in this field, attracting a growing share of resources. However, as this is a recent trend, and one which requires a minimum level of qualified labor and infrastructure, only a few developing countries are truly attractive and receive a significant portion of investments. In 2005, the World Investment Report (UNCTAD, 2005b) limited this group to five nations: China, Singapore, Brazil, Mexico and Korea.

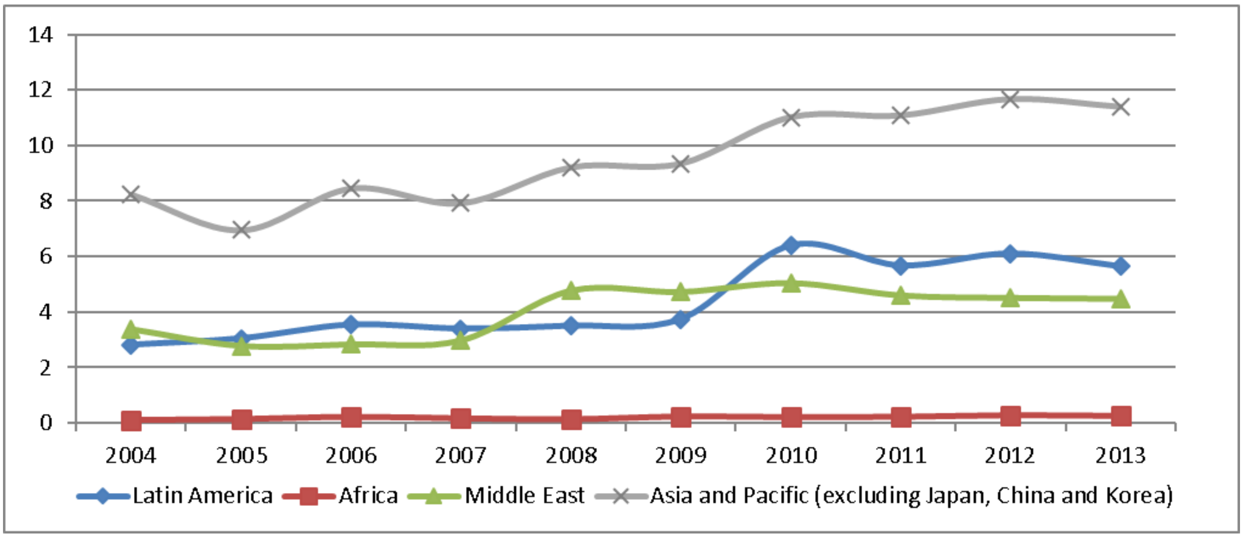


*Figure 4.2.* Percentage of international R&D directed to developing countries by U.S. MNEs (per region). Source: U.S. B.E.A. (n.d.). Available Data up to 2008 account for U.S. Direct Investment to majority-owned Nonbank Foreign Affiliates. As from 2009, data includes all U.S. majority-owned foreign affiliates.

It is relevant to discuss not only the extent but also the nature of R&D performed in these countries. This is a difficult question to address due to the lack of available data. In OECD (2011b), it was argued that a large proportion refers to non-core development such as product design, software development and high-tech manufacturing, although there are cases where MNEs installed research-focused facilities in developing economies. In the same sense, UNCTAD (2005b) stated that “in developing countries, while most R&D has traditionally been of an adaptive nature, recent trends suggest that more sophisticated activities are also expanding” (UNCTAD, 2005b, p. 138).

A last recent development is that developing countries are not only attracting foreign capital, but their MNEs are starting to internationalize R&D. This new trend is led mostly by Chinese multinationals, followed by a small number of Indian, Korean and Brazilian groups (UNCTAD, 2005b). OECD (2008b) stated that the motives of these companies are slightly different from developed countries’ MNEs, as they are more interested in complying with requirements to enter foreign markets and obtaining new technologies and skills.

### 4.2.2 Types of international R&D and drivers of investment location.

Considering the portrayed scenario of rising internationalization, the purpose of this subsection is to review the literature and relevant data on country features and factors influencing MNEs' decisions on the location of their R&D facilities or the destination for their resources.

The pioneer works on the subject date from the 1960s and 1970s and include Dunning (1958), Brash (1966), Safarian (1966) and the U.S. Tariff Commission (1973). In general, though, R&D was a minor topic within a broader discussion on foreign direct investment (FDI). However, it later became clear that technology superiority was too important to be treated as ordinary investment (Lall, 1979), and specific studies were developed, such as Creamer (1976), Ronstadt (1977), Lall (1979), and Behrman and Fischer (1980). The proliferation of literature on the subject, however, followed the rise of international R&D in the 1990s (EC, 2012), including both theoretical contributions and empirical assessments (Dunning, 1988, 1994 and 1998; UNCTAD, 2005a and 2005b; Thursby & Thursby, 2006; Criscuolo, 2004; and Sachwald, 2008, among others).

Within this debate, different theoretical and analytical building blocks were suggested to try to explain the reasons behind MNEs` choices of location for R&D facilities, and the features necessary to attract such investments. Relevant characteristics studied and assessed in this literature are income and market size, human capital, knowledge spillovers, labor costs, geographical proximity, public policy and economic fundamentals (EC, 2012).

One particular influential framework was proposed by Dunning (1988, 1994 and 1998) and used (with minor changes) in Thomson (2009), UNCTAD (2005b), OECD (2008b) and EC (2012).[108] The author argued that firms engage in different types of R&D abroad when they intend to acquire competitive advantages "which are best exploited internationally from a foreign location" (Dunning, 1994, p. 75).

There are four main categories of technological innovation undertaken by MNEs in other countries. The first is the adaptation of products, materials or processes to the local market. The second is research on basic materials (mainly natural resources or immobile inputs) or products, due to the constant need for testing and interaction with the customer. In some cases, these two types are considered jointly under the label of adaptive or asset-exploiting R&D (EC, 2005; Thompson, 2009). The third type is rationalized research or "innovative

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[108] Reference is also made to the works of Sapelak and Ricalde (2008), that distinguished between firms' different policies on research or development, and Sachwald (2008), that identified types of R&D units based on their role in the international innovation network.

R&D" (UNCTAD, 2005b), turning the local site into a technology exporter for other labs in the R&D network. Finally, MNEs may establish "monitoring posts" in specific places with the purpose of keeping track of the latest technological developments and benefit from knowledge spillovers.

Relevant country features attracting investment vary for each type of international R&D. Table 4.1 summarizes the main arguments presented in the literature, relating each type with the respective attraction factors and expected or common destinations.

Table 4.1

*International R&D types, locational attracting factors and common destinations, according to the relevant literature*

| Type of R&D | Main purpose | Common location | Primary country attracting factors |
|---|---|---|---|
| Adaptive | Support for production; adaptation to local market; asset-exploiting | Widely spread; dominant form in emerging countries | Demand oriented factors: market size or income; market growth potential; export base. Supply-side: minimum base of qualified R&D personnel; natural resources. |
| Innovative | Development of new technologies. Capable of independent innovation aimed at the international market | Developed economies; South-East Asia; exceptional in emerging economies | Availability of highly skilled R&D personnel; quality of scientific environment; strength of the National Innovation System; protection of intellectual property rights; physical capital stock. |
| Technology monitoring | Scan and access technological developments, and capture knowledge spillovers | Developed economies | Innovative and dynamic clusters of high-tech industries. |

Source: Dunning (1994), EC (2012), UNCTAD (2005b), OECD (2011b) and Thursby and Thursby (2006).

The main type of R&D received by the majority of emerging economies is adaptive. This is regarded as the most common or 'traditional' form of R&D internationalization (UNCTAD, 2005b), and it is meant to adapt products to local regulations or consumer preferences, preparing them to be manufactured or sold in the local market. Internationalization drivers in this case are weak, and development should be limited, local and demand-oriented, not affecting core business technology or the innovation strategy of the group at the international level. As a consequence, the main variable for determining the R&D level should be market size or level of sales of the respective affiliate or local representative. In some cases, economies of scale may dictate that one facility works as a base for an entire region, so export levels might well be significant. On the supply-side, the availability of a minimally qualified workforce is also a relevant factor, although it should be more a requirement than an attraction force.

In more recent and limited cases, MNEs have identified competitive advantages in undertaking R&D not only for market exploitation, but also to supplement or expand technology development in the home country. Supply-side factors play a more pivotal role, and the critical one is the presence of a substantial pool of highly qualified scientists and engineers in specific areas. This directs this type of investment to developed economies, although South-East Asia has attracted a group of facilities, and there are special cases of innovative R&D in other countries, such as the automotive industry in Latin America (UNCTAD, 2005b) and, more recently, the case of pharmaceutical companies in Brazil (Dias, Teixeira, Queiroz & Galina, 2013). Presence in, and interaction with, universities is also a relevant feature, as it may boost innovation efforts. In addition, as the technology developed in these centers may have a strategic competitive advantage, an institutional framework protecting intellectual property rights is crucial.

The last type is a very specific case of R&D offshoring, mainly used by companies as monitoring outposts to access innovation externalities from clusters and regions with a concentration of innovative firms (Cantwell & Janne, 1999;[109] Le Bas & Sierra, 2002; and, more recently, Jindra, Hassan & Cantner, 2016; and Siedschlaga, Smith, Turcu & Zhang, 2013). It is "mainly drawn to countries boasting world class clusters of technological and industrial activity" (UNCTAD, 2005b, p. 165), and, for this reason, it happens almost exclusively in developed economies. The attraction factor, in this case, is merely the presence of the cluster. The main examples are the Silicon Valley electronics/information technology and Boston pharmaceuticals industries.

Some factors seem to be applicable to all cases. The most important one is market size. In spite of carrying a more vital role in adaptive and non-central R&D, demand-orientation is usually mentioned as the most important investment attraction aspect regardless of the type of R&D (EC, 2012; OECD, 2011b; Hall, 2011). Labor costs and wages, on the other hand, are not identified as determinant factors, although they may be influential in the case of innovative R&D in emerging countries (UNCTAD, 2005b; OECD, 2011b).

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[109] "When foreign research does become more exploratory in character, usually in the main centers to take advantage of the local expertise and technological spillovers available there, then it is generally as a means of directly facilitating the main lines of development already established at home". (Cantwell & Janne, 1999, p. 123).

Another issue particularly relevant for this analysis is the role of government action and public policy for investment attraction.[110] However, consulted studies paid little attention to the subject, with unclear conclusions. UNCTAD (2005b) stated that, although incentives may help to reduce costs and attract funds, they are not determinants by themselves. EC (2012) went even further by arguing that specific incentives for foreign firms do not seem to present proper results, and stresses the relevance of economic fundamentals and broader policies for R&D support.

#### *4.2.2.1 Empirical assessments.*

As previously mentioned, since the advance of international R&D in the 1990s, several studies tried to identify and empirically test the strength of locational attraction factors. Such studies vary both in their methods, units of analysis, period, and regions studied. Results, as expected, are not unanimous, although patterns may be found that can provide important insights. Three surveys of this literature that cover different periods are EC (1998, focused on the European case), Hatem and Py (2008), and Hall (2011).

Methods applied to evaluate the relevance of country features were essentially surveys, econometrics modeling, data analysis and, to a minor degree, case studies (Mechin, 2006; Sapelak & Ricalde, 2008). Surveys are generally used for assessing future trends or gaining insights into the motive and rationale of the decision-making process of innovation strategies. Particularly influential research studies that followed this strategy are Edler, Meyer-Krahmer and Reger (2002), UNCTAD (2005a), and Thursby and Thursby (2006). The first was based on a survey with around two hundred companies in the triad (North America, Western Europe and Japan), and its main findings are interesting for describing a less developed stage of R&D globalization. The main driver is demand-oriented (adaptation of products)[111], and internationalization is mostly restricted to developed countries, with European firms leading the process.

The other two surveys pointed to a different scenario, with an accelerating pace of innovation offshoring and emerging countries rising as competitive alternatives, especially the developing Asian countries. UNCTAD (2005a) confirmed that European countries are more advanced in this process and that industry differences apply, with chemicals and

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[110] Section 4.2.3 discusses tax incentives are discussed in further detail.

[111] "The North American and especially the Japanese corporations investigated still follow a more 'traditional' concept of R&D internationalization which is characterized by adapting products developed in the home country to the local market and regional technical support activities". (Edler, Meyer-Krahmer & Reger, 2002, p. 160). European countries appeared to be more open to decentralize strategic R&D to their foreign centers.

pharmaceuticals being the most internationalized ones. The Thursby and Thursby (2006) survey was more detailed on locational factors, finding that MNEs look for different features if they are investing in developing or developed countries: in the first case, as expected, demand plays a more significant role, represented by market growth potential, although quality and cost of R&D personnel and collaboration with universities also count; in the case of developed nations, supply-side factors are dominant, high costs may be compensated by better infrastructure and more qualified personnel, and institutional factors such as intellectual property regimes are also considered.

The second set of studies uses econometric models to test if country features influence the innovation investment of international groups and other variables. According to Hatem and Py (2008), discrete choice location models have been used recently due to the availability of microeconomic databases on individual projects. The main relevant characteristics stressed in these studies are: market size or affiliates` sales levels, which was confirmed in nearly all studies reviewed (Hatem, 2009; Kumar, 2001; Cantwell & Piscitello, 2002; Jones & Teegen, 2003; Athukorala & Kohpaiboon, 2001), agglomeration economies (Hatem, 2009; Jindra et al., 2016; Siedschlag et al., 2013), knowledge externalities (Jindra et al., 2016), human capital (Siedschlag et al., 2013, Cantwell & Piscitello, 2002; Jones & Teegen, 2003) and R&D intensity in the region (Siedschlag et al., 2013, Shimizutani & Todo, 2008; Belderbos, Lykogianni & Veugellers, 2008; Athukorala & Kohpaiboon, 2001). Alkemade, Keimeriks, Schoen, Villard and Laurens (2015), on the other hand, emphasized the relevance of country origin and industrial sector.

Data analysis studies and reports (OECD, 2008b, 2011b, 2014a and 2015b; UNCTAD, 2005b; EC, 2012) rely mainly on country data, descriptive statistics and time series along with literature surveys, presenting a comprehensive and updated description of the situation and future trends for companies` investments policies. In general, findings in these empirical studies matched predictions of the theoretical framework presented in section 4.2.2. Relevant factors may rank differently, but the picture remains unchanged: with the exception of very developed clusters, demand is still the main attraction feature, although it plays a more significant role for emerging countries, in light of the nature of the majority of R&D activities developed therein. On the supply side, research cost factors are at most of secondary importance, and may be overridden by the excellence of the national innovation system and pool of qualified personnel; these elements gain more importance as foreign facilities take responsibility for the development of core technologies. Finally, institutional factors seem dependent on the nature of R&D – they are not mentioned as relevant for adaptive research, as technology generated in this case is not central to the group's business, and, therefore, intellectual property is not of primary importance.

### 4.2.3 Tax incentives and foreign R&D attraction - the 'footloose R&D' argument.

The analysis on the relevance of tax incentives as factors of attraction of international R&D may be deemed to be a recent development of and the intersection point between two important contemporary debates in economics: (a) the impact of these policies on private R&D (as analyzed in Chapter 2); and (b) the main drivers of innovation investment location, as presented in section 4.2.2.

Empirical evidence provided by companies` surveys do not grant these incentives primary importance in the attraction of new investment (Thursby & Thursby, 2006). They seem to matter more in developed nations, but are still less relevant than several other factors, such as intellectual property protection, collaboration with universities and quality of R&D systems. Governments, nonetheless, have been using this instrument to attract innovation activities to their territories due to their positive externalities.[112]

Another point that has received considerable attention in empirical reports is the corporate strategy of reallocating money from one country to another to take advantage of fiscal benefits without raising global expenditure. This was called by Bloom and Griffith (2001) as 'footloose R&D', and the issue was discussed in OECD (2013a). This report presented a quantitative model to analyze the effective value and impact of tax measures on the location of expenditure and knowledge-based capital. One of the findings was that international competition for R&D may lead to overall loss of tax revenues without the corresponding increase in innovation, calling therefore for international cooperation and consistency between national policies. In OECD (2014), the topic was once again highlighted, observing that individual tax alleviation policies can generate a zero-sum game at the international level, which may be considerably costly considering that around 90% of the total R&D worldwide is in MNEs` hands. Similar conclusions were reached by Köhler et al. (2011) and in the report of the French *Assemblée Nationale* (2010).

In the academic literature, however, this topic has not yet been extensively discussed (Thomson, 2009 described it as being "at a nascent stage"). Pioneer studies on the subject date from the 1990s (Hines Jr., 1993, 1994 and 1995). The main problems this literature has tried to

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[112] "While increasing the volume of R&D activities is the primary objective of R&D tax incentives, Governments also often expect impacts on the competitiveness of their industry, and regard fiscal incentives as a tool to improve the international attractiveness of their country as a location for innovation." (Köhler et al., 2001, p. 4).

tackle are (a) whether incentives actually present any positive impact, i.e. if new or more international investments are directed to the country granting benefits; and, if so, (b) to what extent attracted investments represent an increase in global R&D of international groups, and how much of it is mere reallocation of funds. The first question has been discussed above and, at least at the national level, the literature seems to present relative consensus on the existence of positive outcomes. The second problem is discussed hereinafter.

Table 4.2 summarizes the most influential studies found on the subject, displaying dependent variables, methodological choices and most important findings. In order to present a clear picture of the status of the debate, papers were grouped into three categories, according to the results obtained. Studies in the first group found a certain degree of substitutability between R&D performed in different locations, and also that MNEs respond to shifts in fiscal provisions by relocating their resources according to the relative tax cost of each country. The most influential of these papers is Bloom and Griffith (2001), that developed the 'footloose R&D' argument. By analyzing a panel of countries, the authors found that business R&D in the United Kingdom was attracted to other countries by tax incentives. Wilson (2009) conducted a similar study focusing on the competition between U.S. states, and found that "nearly all" R&D augmentation caused by tax reductions was caused by relocation between states.

Table 4.2

*Summary of the main literature on tax incentives and international R&D relocation*

| Result Group | Study | Main dependent variables | Main tax provision / incentive considered | Econometric model or estimator | Main conclusions |
|---|---|---|---|---|---|
| R&D relocation; substitutability | Hines Jr. (1995) | Royalties paid by U.S. MNEs` affiliates to the parent company; R&D expenditure of foreign affiliates per labor compensation | Withholding tax on royalty payments to another country | Tobit | Local R&D and imported technology are substitutes. MNEs respond to an increase in royalty tax rates by increasing local R&D. |
| | Bloom and Griffith (2001) | R&D expenditure | User cost of R&D | Within groups IV | R&D undertaken in one country responds to tax cost changes abroad (‘footloose R&D’). |
| | Wilson (2009) | R&D expenditure | State tax credits | Within groups regression | “Nearly all” R&D increase in one U.S. state is due to relocation from another state. |
| | McKenzie and Sershun (2010) | R&D expenditure | Tax rate on marginal production costs | OLS, FGLS, Difference GMM, Panel Corrected Standard Errors | Both R&D tax incentives and overall competitiveness of the production tax regime affect international R&D flow |
| | Dischinger and Riedel (2010) | Intangible assets ownership | Statutory corporate tax rate | OLS, FE, 2SLS, Difference GMM | Decrease of tax rate imposed to a subsidiary impacts positively the level of intangible investment received. |
| | Baumann, Knoll and Riedel (2014) | Patent applications | ‘b-index’ | FE, Poisson | Around 80% of R&D increase caused by tax incentives is due to relocation. |

(continued)

| Result Group | Study | Main dependent variables | Main tax provision / incentive considered | Econometric model or estimator | Main conclusions |
|---|---|---|---|---|---|
| No relevant relocation | Hines Jr. (1993) | R&D stock; R&D flow | R&D expense deductibility; foreign tax credit | OLS<br>IV | Domestic (U.S.) R&D directed at foreign markets has small response to tax changes. |
| | Hines Jr. (1994) | R&D stock; R&D flow | R&D expense deductibility<br>Foreign tax credit | OLS<br>IV | Tax rises in the U.S. in the 1980s did not cause MNEs to transfer R&D abroad. |
| | Athukorala and Kohpaiboon (2006) | R&D expenditure as share of sales | Tax incentives index | RE | R&D tax incentives do not seem to be an important explanatory variable once other controls are included. |
| | Thomson (2009) | R&D expenditure of U.S. MNEs` affiliates; R&D financed from abroad | ‘b-index’ | RE, FE, Difference-GMM | Host country tax policy is not a relevant factor to attract cross-border R&D. |
| Complementarity | Hines Jr. and Jaffe (2001) | Number of new patents deposited at home and abroad | R&D expense deductibility; estimate of foreign average tax rate | OLS | Home and foreign R&D are complements and not substitutes. Tax incentives at home or abroad increase rate of innovation in both locations. |

These results were challenged by the second group of studies that, in essence, followed the empirical literature of drivers of internationalization of R&D. Their main arguments are: (a) that once an adequate number of country features are added as controls, tax costs or incentives lose statistical significance, meaning that other factors are more relevant for location of innovation activities; and (b) that fierce international competition does not allow substantial relocation results to emerge or be sustainable, as tax incentives granted by one country are counterbalanced by similar provisions abroad (OECD, 2014a; Köhler et al., 2011). Athukorala and Kohpaiboon (2006) defended the first point by running two groups of estimates: the first one with a full set of control variables that did not find significance for tax incentives; and a second reducing the number of controls that generated significant results similar to Hines Jr. (1995) and Bloom and Griffith (2001). Based on such analyzes, they argue that the specification used in such studies was actually biased by omitted variables. In the same sense, Thomson`s (2009) results were that "no evidence was found to support the hypothesis that tax incentives are effective in either inducing MNEs' affiliates to undertake additional R&D or to encourage additional international R&D contracts" (Thomson, 2009, p. 40).

There is only one study in the third group, one of the pioneer papers by Hines Jr. and Jaffe (2001). Focusing exclusively on the firm`s dilemma of local versus foreign R&D, the study concludes that these two activities are actually complementary, and therefore a tax decrease in either country is more likely to increase the levels of innovation in both locations. Such result, however, was not discussed or even considered by later analyses.

The two most frequent indicators for innovation activities are R&D expenditure by country or state (as a measure of input), and location of intellectual property application or ownership, which works as a proxy for innovation generated locally. The latter is challenged as a reliable indicator, on the basis that patent protection is heterogeneous among sectors and corporate tax planning may affect location selection (EC, 2014).

Studies also differ on the measure of tax costs or incentives considered. While the majority use tax rates or values extracted directly from tax laws or regulations, a smaller group considers the abovementioned user cost of capital and the '*b-index'*.

The first conclusion taken from this literature review is that it remains an open debate that has not yet reached a level of consensus. Diversity of methods, data and variables lead to different conclusions and interpretations of the behavior of international groups when pursuing technological development worldwide.

A second relevant point is that these studies focused on developed countries, and there is little (if any) discussion on whether and to what extent their results apply to emerging economies. As mentioned previously, the type of R&D MNEs undertaken in each nation may differ drastically depending on the level of the wealth of the nation, and it is not obvious whether the attraction of fiscal measures would be stronger or weaker in either one.

## 4.3 Analysis of the Brazilian Case

This section presents and discusses the main features and available data on international innovation investment directed to Brazil. The first subsection discusses FDI and the national innovation system; the second analyzes the R&D developed by international groups in the country; the third discusses the country`s advantages and factors attracting innovation investments from abroad, highlighting the results of the existing empirical literature; and the fourth briefly describes the fiscal policy implemented by the Brazilian government to foster innovation and discuss possible implications for foreign R&D attraction, thus providing the factual basis for the empirical study in the next section.

### 4.3.1 Landscape of FDI and innovation in Brazil.

R&D offshoring forms part of the investments made by international business groups in a country. For this reason, it is important to comprehend the broad picture of how receptive and attractive Brazil has been to FDI in general, for it is a relevant channel for attracting innovation funds.

From the time of the commercial liberalization and institutional reforms in the 1990s (along with a massive privatization program), Brazil became more appealing to international investors (Ruiz, 2015; Hiratuka, 2008)[113] although serious challenges remained to be solved. Such evolution can be clearly seen in Figure 4.3, which shows that until 1994 international investment directed to the country was stagnant, growing substantially thereafter (although dropping at certain intervals). The services sector has usually led the FDI entering the country, with an average of 50% of equity participation in the 2001-2014 period, followed by the industrial sector, with an average of 37% (BACEN, n.d.).[114]

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[113] "During the 1990s, particularly in the second half of the decade, there was a boom in foreign direct investment (FDI) flows to the Brazilian economy, which translated into an increase in the already large role of foreign corporations in the Brazilian productive structure. Despite some decline in FDI flows to Brazil in the first years of the twenty-first century, inflows remain high". (Hirakuta, 2008, p. 1).

[114] Excludes intercompany loans.

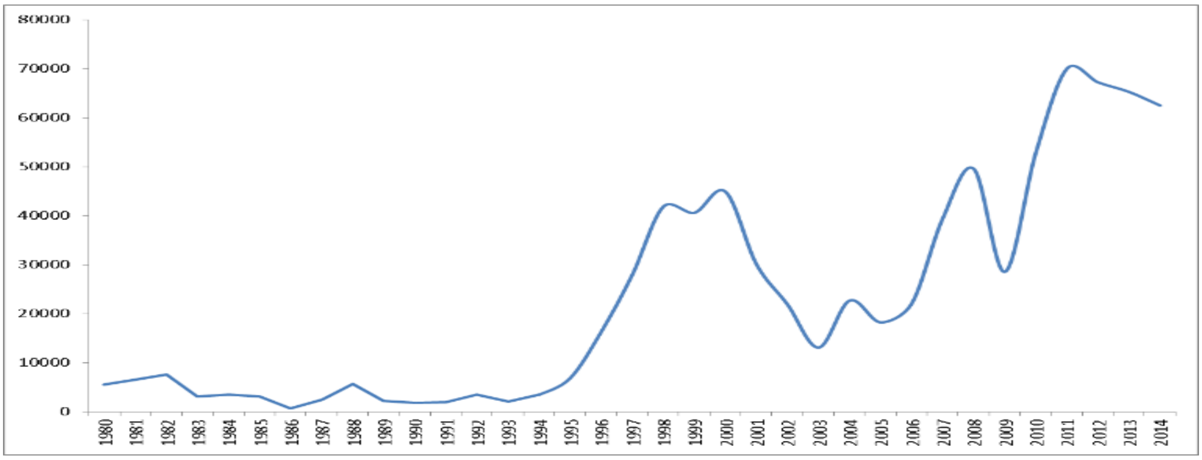


*Figure 4.3.* FDI entering Brazil (US$ millions). US$ values adjusted according to the Consumer Price Index of the U.S. Bureau of Labor Statistics. Source: BACEN (n.d.).

Industrial FDI may be considered spread among different sectors, as none of them achieves more than 36% of the total during the 2006-2014 period, as presented in Figure 4.4. Metallurgics has been the leading industrial sector to attract foreign capital during this time span, with food industries and chemicals also having significant shares. It is interesting to point out that the auto industry, once a very important sector for Brazilian industrialization during the second half of the 20th century, did not achieve a substantial share of manufacturing FDI.

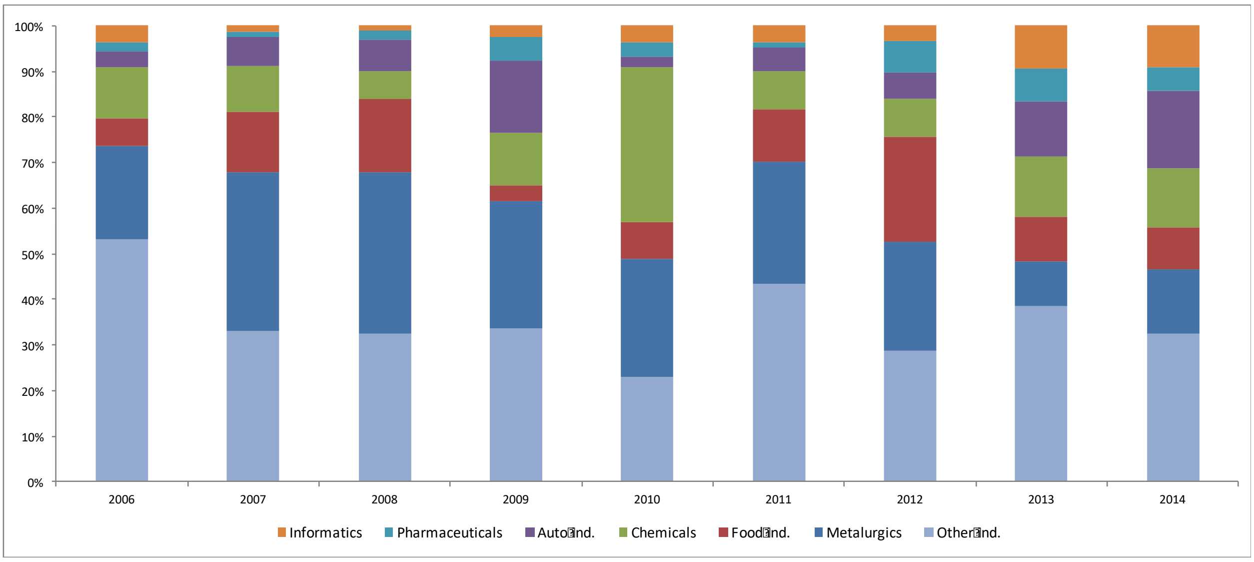


*Figure 4.4.* Industrial FDI composition (equity participation). Source: BACEN (n.d.).

In terms of capital origin, as with most emerging markets, Brazil receives the bulk of its FDI from developed OECD nations. Table 4.3 below presents the share of each major investor country for the 2001-2014 period.

Table 4.3

*Country of origin of FDI directed to Brazil (equity participation) – Percentage per year*

| Country | Year | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
| Netherlands | 9.0 | 17.8 | 11.0 | 37.5 | 14.6 | 15.4 | 23.7 | 10.4 | 20.6 | 12.7 | 25.3 | 20.2 | 21.3 | 15.7 |
| U.S. | 21.2 | 13.8 | 18.2 | 19.4 | 21.1 | 19.9 | 17.7 | 15.9 | 15.5 | 11.7 | 12.8 | 20.3 | 18.3 | 15.2 |
| Luxembourg | 1.3 | 5.3 | 1.8 | 3.6 | 0.6 | 3.3 | 8.3 | 13.4 | 1.7 | 16.8 | 2.7 | 9.9 | 10.3 | 11.9 |
| Spain | 13.1 | 3.1 | 5.4 | 5.1 | 5.5 | 6.9 | 6.4 | 8.7 | 10.8 | 2.9 | 12.4 | 4.2 | 4.6 | 10.6 |
| Japan | 3.9 | 2.7 | 10.4 | 1.2 | 3.5 | 2.9 | 1.5 | 9.2 | 5.3 | 4.8 | 10.8 | 2.4 | 5.1 | 6.7 |
| Portugal | 8.0 | 5.4 | 1.5 | 2.8 | 1.5 | 1.5 | 1.5 | 2.4 | 1.2 | 2.3 | 0.7 | 0.9 | 1.2 | 5.6 |
| France | 9.1 | 9.6 | 6.3 | 2.4 | 6.6 | 3.3 | 3.6 | 6.5 | 6.8 | 6.6 | 4.4 | 3.6 | 3.0 | 5.3 |
| Switzerland | 0.9 | 1.8 | 2.6 | 1.8 | 1.6 | 7.3 | 2.6 | 1.8 | 1.2 | 12.3 | 1.7 | 7.2 | 4.7 | 3.5 |
| U.K. | 2.0 | 2.5 | 1.9 | 1.3 | 0.7 | 1.9 | 3.1 | 1.6 | 3.3 | 2.0 | 4.0 | 3.3 | 2.4 | 3.1 |
| Germany | 5.0 | 3.3 | 3.9 | 3.9 | 6.3 | 3.8 | 5.2 | 2.4 | 7.8 | 1.0 | 1.6 | 1.4 | 2.0 | 2.8 |
| Canada | 2.1 | 5.2 | 0.9 | 2.9 | 6.5 | 5.7 | 2.4 | 3.2 | 4.3 | 1.4 | 2.6 | 3.2 | 2.5 | 1.6 |
| Others | 13.3 | 13.6 | 16.6 | 9.7 | 26.4 | 17.3 | 15.0 | 18.7 | 17.0 | 23.2 | 19.0 | 22.3 | 23.9 | 17.9 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

Source: BACEN (n.d.).

The figures for the Brazilian innovation system, on the other hand, do not show a positive picture. Brazilian gross expenditure on science and technology in 2013 was around 1.7% of the country`s GDP, below the OECD average (around 2.4%) and far from some of its most innovative economies such as South Korea (4.15%), Israel (4.09%) and Japan (3.47%) – OECD (n.d.). Figure 4.5 shows that most of this gap refers to private investment in innovation, as public R&D expenditure in Brazil is on a similar level to that of developed countries.

Queiroz (2011) pointed out that the difference in business R&D is commonly interpreted as the result of two main forces: a non-competitive business environment that does not stimulate firms to pursue technological development; and a non-technology intensive industrial sector. The latter argument should be considered carefully since Brazil currently hosts firms in some of the most technologically advanced industrial sectors, such as pharmaceuticals, information technology, biofuels and nanotechnology. Figure 4.6 presents the R&D intensity for selected industries in the country, measured as a share of the expenditure on total sales.

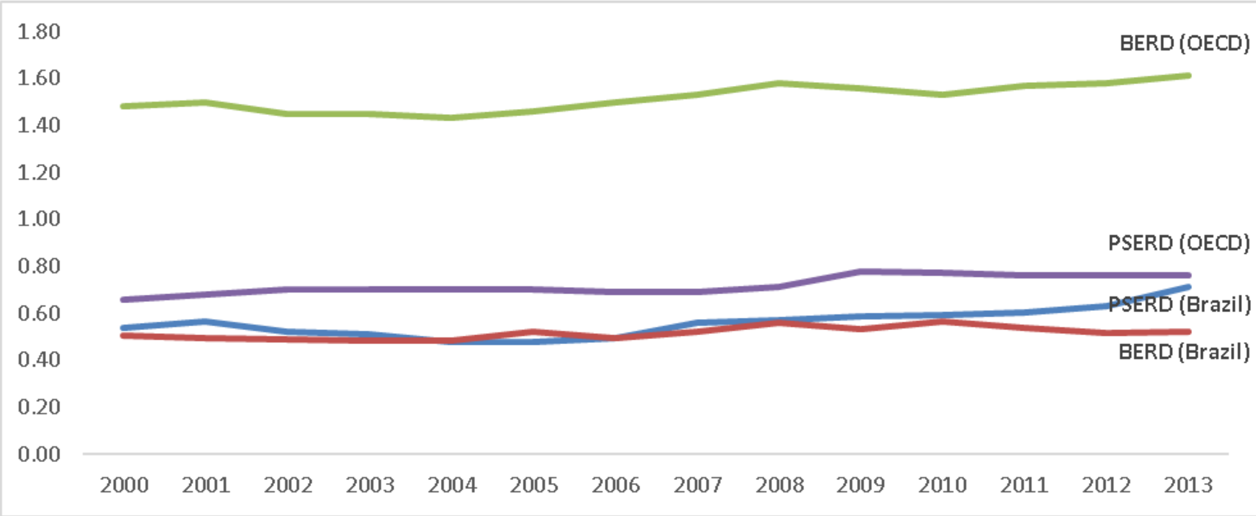


*Figure 4.5.* Public Sector (PSERD) and Business (BERD) Expenditure in R&D, as percentage of GDP: OECD countries and Brazil. Source: OECD (n.d.) and MCTI (2015a).

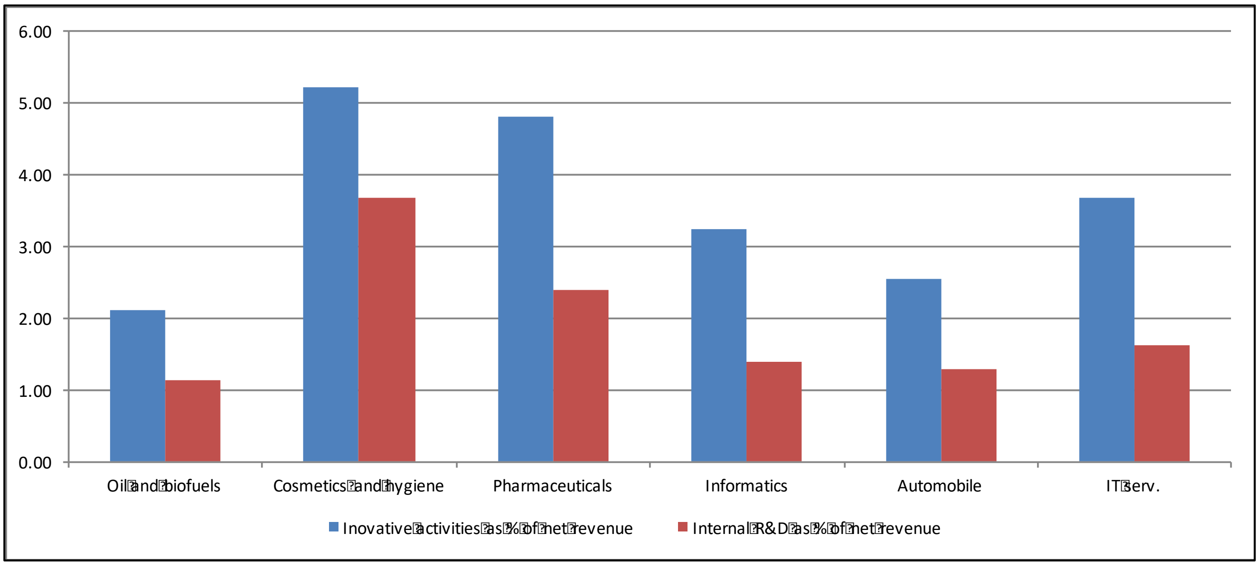


*Figure 4.6.* R&D intensity of selected industries in Brazil. Source: IBGE (2013).[115]

The challenge to increase the technological efforts of Brazilian industry involves the attraction of international capital. Although foreign companies represent only a small number of the total of industrial firms, their R&D spending is usually higher (Arbache, Goldstein & Marques, 2011; Costa, 2005; Queiroz, 2011). Figure 4.7 evidences such argument by presenting

[115] Innovative activities include: internal and external R&D; acquisition of knowledge from third parties; software license or acquisition; acquisition of machinery and equipment; training; introduction of innovations in the market; and industrial design and other measures for production and distribution (IBGE, 2013).

the average R&D and innovative activities expenditures of firms present at the 2011 edition of the Industrial Innovation Survey (PINTEC - IBGE, 2013) by origin of controlling capital. Although firms owned by nationals represent the great majority of the survey sample, it is clear that their innovation outlays are substantially smaller than those of firms controlled by foreign capital. For this reason, the identification of local factors that can attract foreign innovation funds, along with the discussion of the role of public policies, is of great importance.

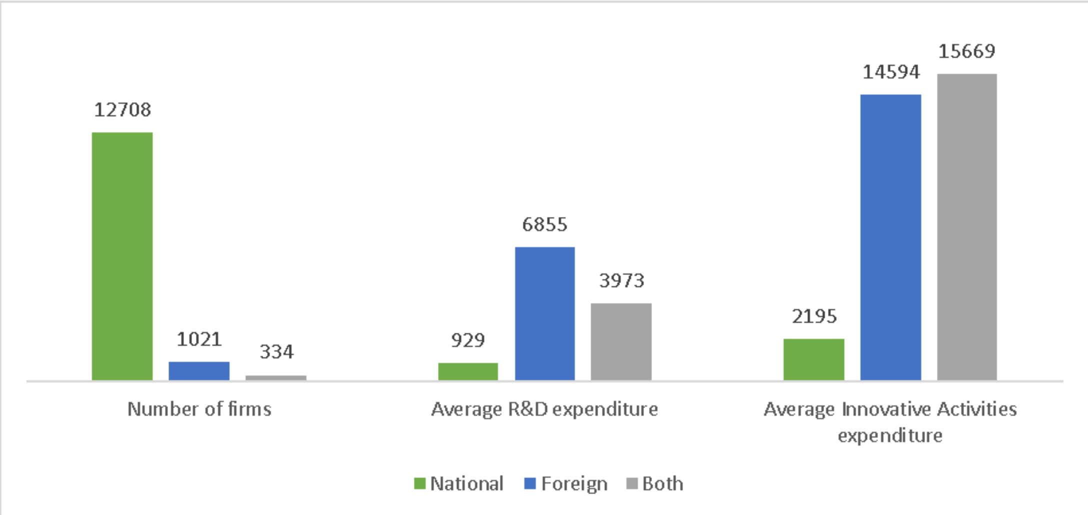


*Figure 4.7.* Number of firms, and average R&D and innovative activities expenditure by origin of controlling capital. Brazilian R$ 1,000.00. Source: IBGE (2013, confidential microdata)

### 4.3.2 Business innovation by MNEs in Brazil.

Costa (2005) identified three stages of the development of innovation activities by international groups in Brazil. From the 1950s until the end of the 1980s, the country passed through the import substitution period. At this phase, nearly all technology was imported, and residual development was carried out for adaptive purposes only. From the 1990s, the increase in FDI and international competition brought new investment that led to technological upgrading and efficiency gains. However, it was only in the late 1990s that MNEs started to include Brazilian facilities and affiliates in their global R&D strategies.

As is the case in almost every developing country, Brazil attracts a small fraction of the total of international resources for R&D that leave MNEs` headquarters. In the case of U.S. MNEs, Brazilian affiliates receive an annual share of less than 4% of total R&D offshoring, as depicted in Figure 4.8. The time series is also informative in the sense that the situation has improved in the last decade. Following the FDI trend discussed previously, the share of U.S. R&D offshored to Brazil has risen from around 1% to more than 2.5%, reaching a top value of 3.5% in 2010. While total international R&D by U.S. groups grew on average around 5% during this period, investment directed to Brazil doubled that rate. Narrowing the focus to the manufacturing sector, investment in Brazil grew by more than 9%, bringing the share of funds to 3.3% of the total.

Figure 4.9 presents the participation of Brazilian inventors in patent applications worldwide, using the fractional indicator suggested by Thomson (2013) and de Rassenfosse, Dernis, Guellec, Picci & Van Pottelsbergue de la Potterie (2013).[116] This index confirms and repeats the previous results, i.e., Brazil is responsible for a small share of international innovation worldwide (no more than 0.5% in 2013), but its participation has increased in the last decades.

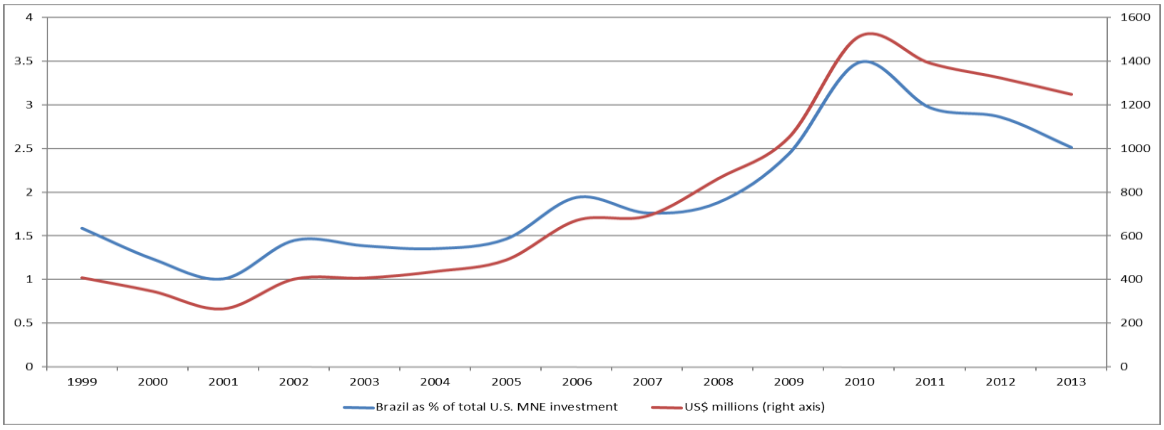


*Figure 4.8.* Total amount and share of R&D invested by U.S. MNEs in Brazil. Real 2014 values readjusted according to the CPI index. Source: U.S. B.E.A. (n.d.).

[116] See section 4.4.1.3 for a detailed explanation.

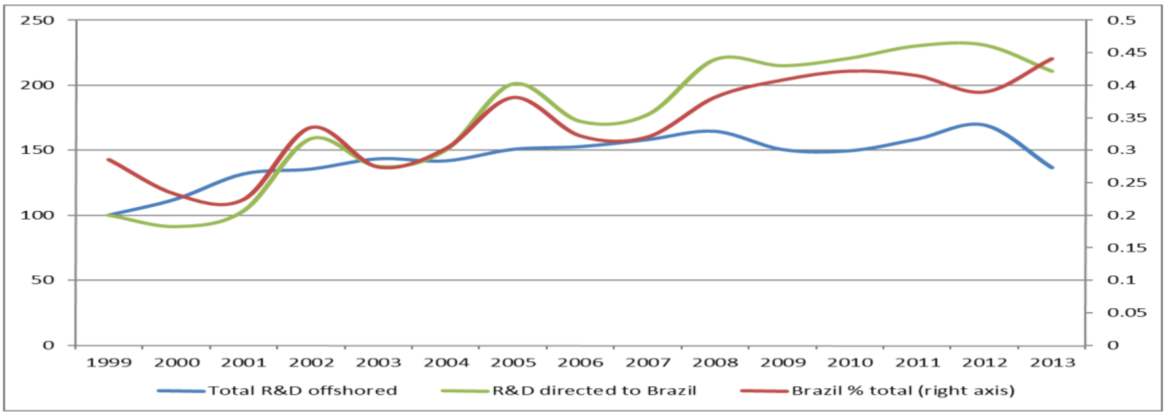


*Figure 4.9.* Total R&D offshored worldwide and R&D directed to Brazil: fractional patent proxy indicator. 1999 = 100 (Total R&D and R&D directed to Brazil). Source: E.P.O. (2015).

Ruiz (2015) reported that a great part of R&D directed to Brazil refers to transportation equipment, or more specifically, to flex-fuel technologies. Arruda, Barcellos and Tumelero (2014) identified 'current or potential' sectors in which the country has knowledge advantages that may attract foreign capital - agribusiness, information technology, energy, nanotechnology, biotechnology, chemicals, aeronautics, aerospace and defense. Figure 4.10 presents the most relevant sectors in which U.S. MNEs invest in R&D in Brazil. Manufacturing sectors that have led innovation investment in Brazil are transportation equipment, chemicals and machinery. These sectors are also high FDI investors in the country, as shown in Figure 4.4 above.

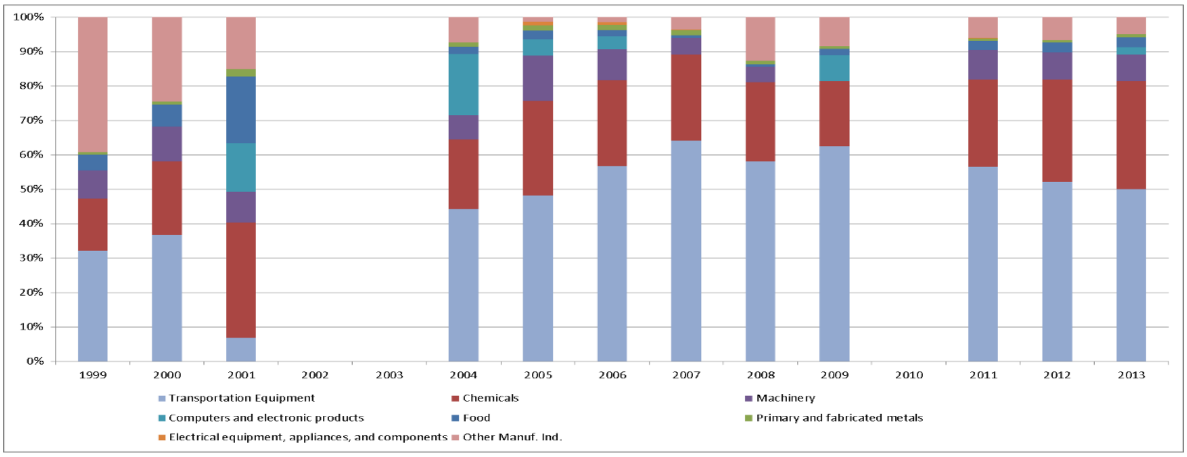


*Figure 4.10.* Share of R&D funds by U.S. manufacturing MNEs' directed to Brazil. Values for 2002, 2003 and 2010 were excluded due to missing data. Source: U.S. B.E.A. (n.d.).

With respect to the investing countries, Ruiz (2015) used patent data and concluded that, during 1980-2010, the major firms were from the U.S., Germany, Switzerland, Netherlands, France and Italy. This scenario is confirmed by the data displayed in Table 4.4, that details the location of foreign controlling capital reported by Brazilian firms in 2011 for the PINTEC survey (IBGE, 2013). Firms controlled by U.S. and European capital represent the great majority of the reporting sample, and they also account for the greatest part of expenditures in R&D and innovative activities.

Table 4.4

*Number of firms and total spending on R&D and innovative activities, by location of foreign controlling capital*

| Location of foreign controlling capital | Number of firms | Total spending | |
|---|---|---|---|
| | | R&D | Innovative Activities |
| Mercosur (other than Brazil) | 60 | 115725.3 | 222076.3 |
| U.S. | 333 | 2921754.0 | 7428914.0 |
| Canada and Mexico | 38 | 359420.4 | 879047.9 |
| Other American countries | 36 | 48164.3 | 89403.5 |
| Asia | 133 | 428592.3 | 1725303.0 |
| Europe | 740 | 4450849.0 | 9766945.0 |
| Oceania or Africa | 15 | 1000.0 | 9262.0 |

Not included firms controlled exclusively by Brazilian capital.
Source: IBGE (2013, confidential microdata).

The data presented in this section suggests that, in spite of being an important market for foreign firms, Brazil does not attract technology-intensive investment. This is in accordance with the conclusions of the literature for developing countries, as discussed in section 4.2.2. Nonetheless, attractiveness for innovation activities has increased and gained momentum, following a more general trend of FDI inflow.

### 4.3.3 Factors of attraction of international R&D.

To better understand the described scenario, the main drivers or factors of attraction of R&D investment in Brazil should be considered, including the challenges or barriers for further expansion. As an emerging economy with a non-developed innovation system, Brazil should attract more adaptive and support focused R&D, which makes market size and potential growth the most important assets to sustain and increase investment levels, leaving a secondary role for technological capabilities and other supply-side factors. Costa (2005) stressed the importance of market size, although she also identifies the relevance of investment trajectories, as companies with long-term local presence have more easily transitioned their technological developments up to the global strategic R&D level.

In the case of U.S. MNEs, the available data makes a compelling case for demand-pull factors, as affiliates sales and R&D expenditure are a case of almost perfect collinearity for the 1999-2013 period, as displayed in Figure 4.11 (although the high correlation is not specific to the Brazilian case. The number is very similar - 0.98 - if all affiliates out of the U.S are considered).

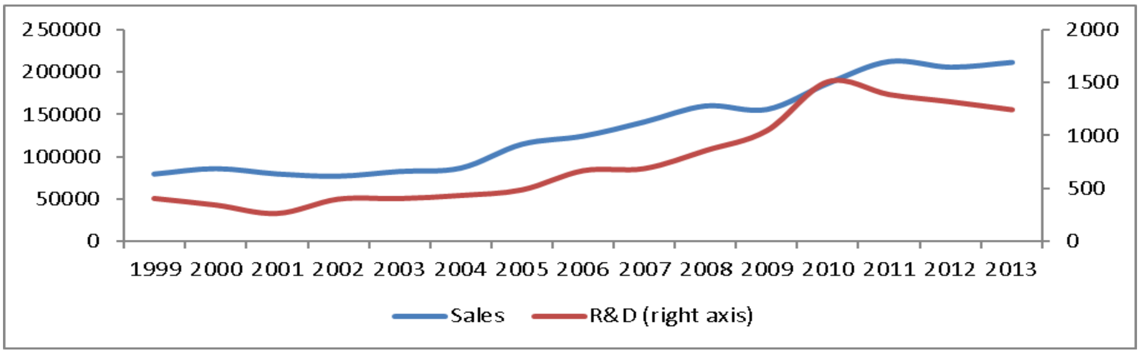


*Figure 4.11*. Sales and R&D expenditure levels of U.S. MNEs in Brazil (US$ millions). Correlation = 0.96. Real 2014 values readjusted according to the CPI index. Source: U.S. B.E.A. (n.d.).

The R&D intensity of Brazilian affiliates grew slightly in the period (from 0.51% to 0.59%), but it is still smaller than the total for the entire group of host countries (0.81). This reinforces the previous argument that Brazil is receiving more resources but it still lags behind as an attractive location for international innovation.

Relevant empirical literature that tried to track and measure attraction factors for international R&D in the country mainly comprised surveys of local affiliates' staff. Most of the studies found results consistent with the theoretical literature and the innovation investment scenario discussed previously, emphasizing the relevance of market size, minimum availability of research personnel and science and technology institutions. In a 2007 survey with 48 affiliates of foreign groups, respondents identified good opportunities to invest in R&D in Brazil. Although attraction factors were not ranked, the most relevant ones were: perspective of market growth, competitive costs and presence of high quality professionals, universities and research centers (Engenhar, 2007).

A similar study (described in Queiroz, 2011) also concluded that market size and workforce were the main factors attracting R&D projects to the country. The quality and educational level of human resources were described as adequate, but shortage of professionals was shown to be a factor hindering further investment.

The predominance of demand-side factors was better evidenced in Arbache et al. (2011). In a survey with more than 70 companies, the growth of both local and regional markets was ranked as the primary motivator for implementing R&D in Brazil. The presence of a qualified pool of researchers was also mentioned as an advantage, although its limited size was considered a challenge. The research also found out that for the majority of the affiliates (83%) R&D strictly followed headquarters` agenda, and that independent high-order R&D was conducted by less than half of the affiliates.

Similar results were found by Arruda et al. (2014). According to the study, a great number of multinationals that developed R&D in Brazil still focused on adaptation and product support. Such affiliates had to present a strong case to convince their parent companies to transfer substantial research to their facilities because of high costs and the bureaucratic requirements they faced. The study confirmed that the national and Latin American markets were usually the main factors of attraction, but other features such as geography and specific technological clusters were also important.

Finally, Galina, Camillo and Consoni (2011) presented conclusions that differed from the previous studies and the international literature. They surveyed 54 MNEs and found that, as the complexity of technological activities increased, the market size and demand-side factors actually gained importance, while qualified workforce, infrastructure and local science and technology systems became less relevant. The authors justified their findings through firms' trajectory in the country. Older affiliates, they argued, had managed to develop a network of suppliers, partners and professionals to overcome local technological deficiencies, up to the point where these were no longer key factors. For this reason, market expansion had more value for these firms than solutions to the country's innovation bottlenecks. On the other hand, international groups newer to the country paid more attention to these problems, requiring greater persuasion that the local economy could provide supply factors for their R&D projects, even on a simpler scale.

The above-mentioned studies converge in terms of challenges and negative features that hinder investment. High costs, taxes and excessive bureaucracy are relevant aspects taken into consideration by MNEs, affecting the competitiveness of the economy (Arruda et al., 2014; Galina et al., 2011, and Arbache et al., 2011). These studies also agree that the insufficient number of scientists, engineers and qualified personnel for conducting high level R&D still remains the most relevant restriction for increasing the complexity of innovation projects and introducing local laboratories and facilities into the global strategic innovation plans of these multinational groups. The same problem is illustrated by the Human Capital Report by the World Economic Forum, that ranks Brazil 78th out of 124 countries in terms of the quality of the workforce. The country presents particularly poor indicators in the quality of science and math education, and primary schools. In 2015, around seventy-five thousand students graduated in engineering, manufacturing and construction, in comparison to more than four hundred and fifty thousand in Russia, two hundred and thirty-seven thousand in the U.S. and one hundred and forty-seven thousand in South Korea (WEF, 2015).

#### 4.3.4 Innovation tax policy and attraction of international R&D.

In the last decades, the debate on appropriate policies to foster entrepreneurial innovation has regained strength in Brazil. The challenge of creating a business environment that encourages R&D without protectionism but enhancing firms' international competitiveness has been the subject of great discussion among scholars and policy-makers. Evidences of this paradigm shift are the three major industrial policy plans issued by the federal government, along with a National Strategy for Science, Technology and Innovation in 2012 (MCTI, 2012a).

In this new policy context, tax incentives are one of the strategies that have gained momentum. As discussed in detail in Chapter 2, in 2005 the federal government enacted Law 11,196/05 (also known as "*Law of Goodness"*), which consolidated and expanded tax incentives to companies willing to invest in scientific and technological development. The objective was to reduce the cost of performing R&D activities within national territory, thus encouraging firms to increase their expenditure in innovation and generating knowledge spillovers and positive externalities. The structure of the benefits was similar to the practice in other countries, deducting expenditure from taxable income or reducing tax rates that are levied on R&D inputs and outputs.

The main objective of the policy was to reduce the tax cost of performing R&D in the country. Araujo (2010) estimated the magnitude of such change through the '*b-index*', used by OECD to measure the fiscal burden on innovation. His estimates are depicted in Figure 4.12 using the "implied subsidy rate" or the '*1-(b-index)'* (OECD, 2013a), along with the average for the OECD countries as calculated by Warda (2013). One can see the policy approved in 2005 reduced the tax burden of R&D in Brazil, and that such benefits are consistently higher than the average of OECD, although it is similar to or even lower than some of its economies, such as Spain, France and Canada (Warda, 2013).

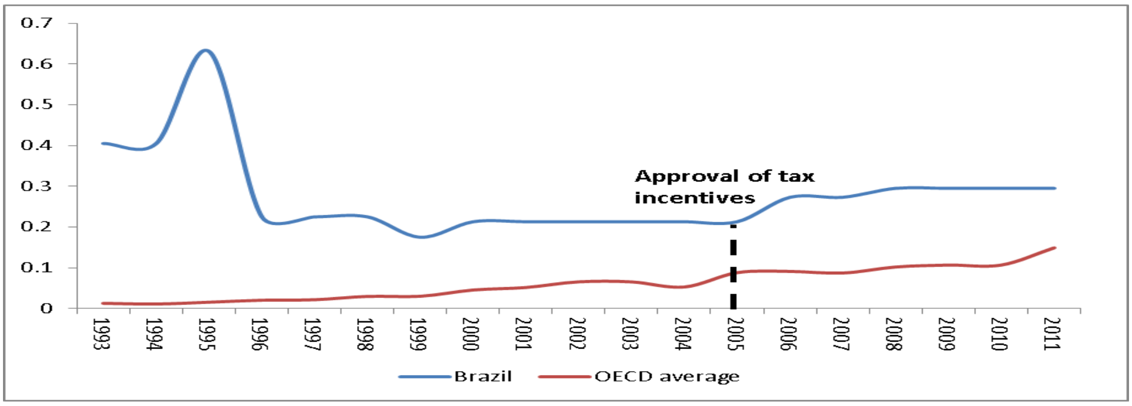


*Figure 4.12.* Evolution of the '*1-(b-index)*' – Brazil and OECD average. The indicator increases with the tax generosity of the policy. Source: Araujo (2010) and Warda (2013).

The law does not establish any requirement for capital ownership, and therefore does not distinguish between locally-owned companies and affiliates of multinational groups. Table 4.5 below presents the total number and percentage of potentially innovative firms present in the 2011 PINTEC survey (IBGE, 2013), indicating how many participated in the policy and dividing them by capital origin. Although local firms represent the majority of the sample, the percentage of those that obtained tax benefits is substantially lower than in the foreign-owned group.

Table 4.5

*Distribution of potentially innovative companies, according to origin of controlling capital and participation in the tax policy in 2011*

| Did the firm benefit from tax incentives in 2011 | No. of firms - Controlling Capital Origin | |
|---|---|---|
| | Local | Foreign |
| Yes | 322 (2.53%) | 166 (16.26%) |
| No | 12,386 (97.47%) | 855 (83.74%) |

Percentage of firms by participation in the policy in parentheses. Firms with both national and foreign controlling capital represented a very small share and were excluded. Source: IBGE (2013, confidential microdata).

These numbers suggest firms with international capital may be in a better position to benefit from the incentives provided by the Brazilian tax policy. They do not mean, however, that such companies or additional innovation funds were necessarily attracted to the country by the incentives. Galina, Camillo and Consoni (2011) reported that innovation policies did not rank as a primary factor for R&D attraction in their survey. Queiroz (2011) also concluded that such incentives are of secondary importance, and argued that, as more countries approve similar measures, they lose relevance as a decisive factor for new projects or funds. In Arbache et al. (2011), fiscal incentives again received low frequency of responses when MNEs were questioned about their motivation to perform R&D in Brazil.

The survey by Arruda et al. (2014) specifically referred to the incentives of Law 11,196/05. They reported that, from the MNEs` perspective, the tax policy is a positive and attractive feature of the local innovation system. However, the excessive bureaucracy and accounting requirements, along with the legal uncertainty (firms do not know beforehand whether the reported expenditure will be accepted by the authorities), reduces positive impacts.

The discussion presented along this section gives inconclusive results on the relevance of tax policy for attraction of funds for business technology. The country certainly improved its participation in the international map of innovation, as evidenced by the increasing share of resources directed to it. Qualitative evidence provided by the reviewed literature, however, suggests that Brazil still has problems in attracting R&D above the adaptive level. It is difficult to assess whether the observed increase in R&D inflow is an exclusive result of market factors, following the trend of FDI increase in the last two decades, or if policies designed to boost innovation expenditure are also a relevant explanatory factor. No quantitative studies that tried to test the impact of such policies in this type of investment were found. The empirical study described in the next section is a first attempt to fill this gap.

## 4.4 Empirical Analysis

This section presents the research to assess whether the Brazilian tax policy has had a measurable impact on the flow of international R&D investment directed to the country. Due to data availability, investigation is limited to whether the Brazilian policy was a relevant factor in attracting investment from other locations in a 'beggar-thy-neighbor' scheme, thus contributing to the entrance of 'footloose R&D' in the country above and beyond global average trends.

To illustrate this point, the time series presented in Figure 4.13 shows that the increase in the subsidy rate granted by the Brazilian tax policy was followed by a drop in the share of offshored R&D investment directed to all other countries, with a high negative correlation between variables. The main idea of the study is to assess if, after a set of control variables are included and appropriate econometric estimators are applied, such correlation remains negative and significant, providing evidence that the change in the innovation tax burden in Brazil may have caused relocation of innovation resources by MNEs from elsewhere.

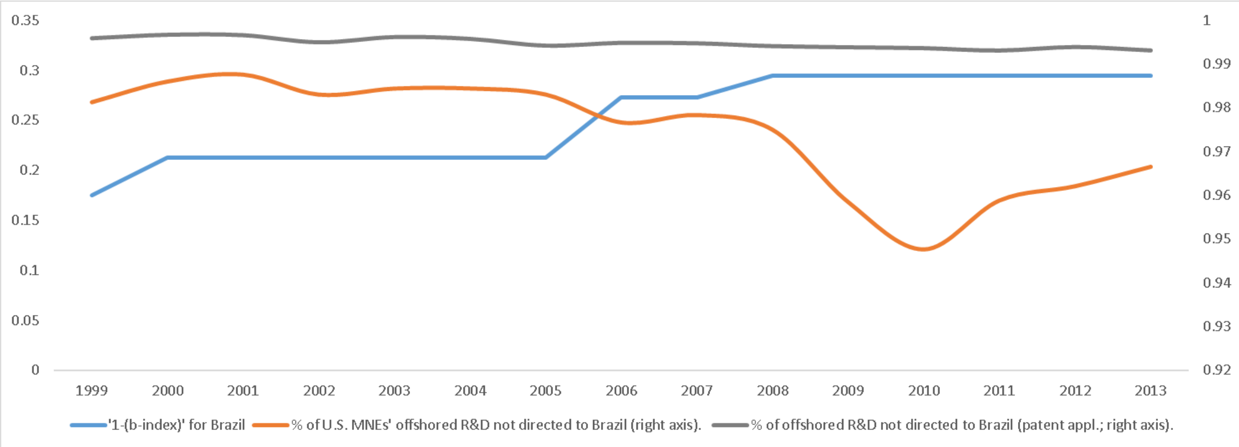


*Figure 4.13.* Implied subsidy rate for Brazil and share of international innovation investment directed to other countries. Correlation between '*1-(b-index*)' for Brazil and offshored R&D is -0.81 and -0.85 for the U.S. MNEs and fractional patent application, respectively. Offshored R&D indicators defined in section 4.4.1. Source: Araujo (2010), U.S. B.E.A. (n.d.) and E.P.O. (2015).

Unlike other econometric studies mentioned in Table 4.2, the objective is not to test the relevance of tax policies in general, but only the one implemented in Brazil. The main motivations for this choice of research are the intrinsic features of tax incentives and the nature of their expected impacts. Part of the controversy and absence of consensus in the literature (section 4.2.3) can be explained by particularities of the different institutional frameworks and economic incentives of stakeholders present in each economic system. The design of each policy is also country specific and subject to the political influence of relevant players who may try to shape it according to their own interests. Furthermore, the type of R&D investment directed to each country and the relevant factors that attract them may also vary, and be affected by tax cost changes in different ways. From all this, one can expect that it would be difficult for such incentives to have a uniform impact in all cases.

For this reason, studies that aggregate policies from different countries and try to extract a single coefficient for elasticity of R&D expenditure with respect to tax benefits are likely to achieve diverse results, depending on the countries, period and incentives considered. The conclusions of such analyses should not be taken as automatically valid or applicable to each individual case or policy, as specific conditions may change the results. Country specific studies (such as this one) are then necessary to assess the effects of national policies, even if their conclusions cannot be generalized to other situations.

### 4.4.1 The data.

For this analysis, a group of different datasets on several countries were merged. They refer to (a) tax costs and incentives to R&D in different countries; (b) activities and innovation investment of U.S. MNEs` international affiliates, (c) priority patent applications from different patent offices worldwide, including the country of origin of their respective applicants and inventors; and (d) specific features of each nation, including market, institutional, and science and technology systems. The data were arranged in an unbalanced panel format, covering the period from 1999 to 2013. As the interest lies on the effects of Brazilian policy in other countries, data for Brazil were excluded from all regressions.

#### *4.4.1.1 Indicator of tax costs and incentives.*

Two main measures of tax costs and generosity of incentives have been used by the literature. Bloom and Griffith (2001) and Wilson (2009) adopt the concept of user cost of capital (Hall & Jorgenson, 1967), while Baumann, Knoll and Riedel (2014) and OECD (2013a) apply the '*b-index*'[117] (Warda, 2001). A transformed version of the latter indicator is used herein: the '*1-(b-index)*' constitutes a more direct measure of tax generosity or "implied subsidy rate" (OECD, 2013a). Index values used in this analysis were estimated by Warda (2013), Stewart, Warda and Atkinson (2012), OECD (2014a),[118] and, for the Brazilian case, Araujo (2010).[119]

It is important to consider that if firms respond to tax benefits, they do so comparatively. Or, as suggested by Wilson (2009), both in-country and out-of-country tax costs are relevant.

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[117] "The b-index is a measure of the level of pre-tax profit a "representative" company needs to generate to break even on a marginal, unitary outlay on R&D" (OECD, 2013a, p.1).

[118] Missing data was extrapolated linearly for short intervals with no significant change in the index.

[119] Contrary to the author's estimates, I only reflected the changes of Law 11,196/05 in 2006, the first year in which firms could benefit from the incentives.

Therefore, a correct model specification should take into account not only Brazilian incentives, but how they compare to the ones granted by foreign governments.

However, the simultaneous introduction of separate variables representing tax incentives in Brazil and in other countries is not a feasible specification for the adopted identification strategy, for the Brazilian policy variable does not vary between countries at each time period, and therefore it cannot be included along with time dummies, due to perfect collinearity or violation of the full rank assumption of panel data estimators. For this reason, the difference between the index for Brazil and for each other country is used as the variable of interest:[120]

1. '*1-(b-index)':* implied subsidy rate ('*1-(b-index)'*) in place in Brazil minus the one for each other country (*i*) at time (*t*).

#### *4.4.1.2 Data for U.S. MNEs' affiliates.*

The study is limited to manufacturing U.S. MNEs with affiliates operating out of the U.S. and positive R&D expenditure abroad. The following data were extracted from the U.S. Bureau of Economic Analysis (B.E.A.) database on Activities of U.S. Affiliates of Foreign Multinational Enterprises (U.S. B.E.A., n.d.):

2. $r\&d^{MNE}$: R&D expenditure by manufacturing affiliates in each country per year, in million dollars US, log-linearized.

3. *sales:* total value of sales of the respective affiliates in each country per year, in million dollars US, log-linearized. This variable should account for the level and size of activities of local affiliates.

4. *exp:* export rate of affiliates, or the percentage of total sales to elsewhere other than the host country. The objective of this variable is to control for export orientation or the affiliates` capacity to serve other markets.

#### *4.4.1.3 Fractional Patent Indicator.*

Data on patents were extracted from the European Patent Office Statistical Database (E.P.O., 2015). Following the approach developed and described in Thomson (2013) and de

[120] This specification is appropriate for it captures the relevance of the Brazilian policy controlling for the tax generosity adopted by each country, and it can be used in a panel dataset analysis along with fixed effects and time dummies as covariates.

Rassenfosse et al. (2013), the information from the country of residence of applicants and inventors is used to obtain a proxy for R&D performed or contracted abroad.

A priority application is the first filing aimed at protecting a particular patent. Pursuant to Article 4 of the Paris Convention for the Protection of Industrial Property, once an application has been submitted to any national patent office worldwide, the applicant has 12 months to apply for protection in any other country which is part of the convention, claiming priority over any applications filed after the original submission. De Rassenfosse et al. (2013) maintained that priority applications are a valid and important indicator of innovation because they eliminate the geographic bias and are the closest measure to the date of the invention.

The basic idea of the indicator is to consider the applicant as the owner of the intellectual property and funding party of the innovation project. The inventor, on the other hand, is assumed to be the party that effectively carried out the research project, with resources provided by the applicant. Therefore, if the applicant is resident in one country and the inventor in another, it is assumed that the former has transferred resources and implementation of the project to the latter, regardless of whether a corporate or contract structure was used. As pointed out by Thomson (2013), this measure should be understood to be the subset of all offshored innovative activities of MNEs that comply with three basic requirements: (a) patentable technologies, (b) above a minimum inventive level, and (c) not invented by and assigned to the same affiliate.

As patent applications may have more than one applicant or inventor from different countries, a "fractional counting methodology" (de Rassenfosse et al., 2013) is used, meaning each applicant is assigned with an equal share of each patent filing, and the same procedure is applied for inventors.

Based on these guidelines, fractional patent application data were extracted and grouped according to the country of origin of applicants and inventors.[121] The cases where these two coincide represent around 90% of the sample for the year 2013, very similar to the result reported by Thomson (2013) and consistent with the literature that reports that the bulk of innovation does not actually leave headquarters' country. These cases were excluded, as this investigation focus exclusively on offshored R&D. Moreover, only patent applications were retrieved, excluding utility models and new designs.

For the purposes of this analysis, only data for the 100 countries with the highest number of priority applications in 2013 were considered. As Brazil mainly receives innovation

[121] MySQL Code used available upon request to the author.

investment from a limited group of nations, origin of applicants was limited to six countries (U.S., Germany, China, France, United Kingdom and Netherlands) responsible for 80% to 90% of the yearly innovation investment directed to Brazil.

Finally, patent application count was grouped by receiving country, thus reaching the following indicator:

5. *pat:* fractional number of priority patent applications invented by residents of each country per year and with applicants in another country, log-linearized. This should constitute a proxy for global innovation offshoring.

#### *4.4.1.4 Country features.*

Data on specific features of invested countries were gathered from different sources with the objective of controlling for factors that, according to the reviewed literature, may influence the decision of MNEs to invest in innovation there. These may be divided into three main groups. The first refers to data on the institutional and policy framework.

6. *pr:* the “legal system and property rights” index[122] of the Economic Freedom of the World annual reports (Gwartney, Lawson and Hall, 2015), that provides an indicator of the level of institutional development of each country.

The second group of country specific variables refers to the economic activity level or size of the economy.

7. *gdp:* gross domestic product, in million dollars US, log-linearized (nominal value - World Bank, n.d.).

8. *hc:* level of human capital, considered as number of researchers per 1,000 people in the work force (OECD, n.d.).

9. *ind:* level of industrialization of the economy, measured as the industrial sector`s added value as a share of GDP (World Bank, n.d.).

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[122] This index is comprised of the following items: judicial independence, impartial courts, protection of property rights, military interference in rule of law and politics, integrity of the legal system, legal enforcement of contracts, regulatory restrictions on the sale of real property, reliability of police and business costs of crime (Gwartney et al., 2015).

Indicators on the technological development or innovation system of host nations are also considered.

10. $r\&d^c$: total R&D expenditure as a share of GDP per country. The variable provides a measure of the nation`s research effort or strength of the innovation system (World Bank, n.d.; OECD, n.d.).

11. *ht_exp:* exports of high technology goods as a share of the country`s GDP (World Bank, n.d.).

12. *patstock*: stock of patents filed by residents in each local patent office, log-linearized (WIPO, n.d.). This indicator is the result of the sum of all patent files deposited in each country by residents since 1980 up to each year in the dataset, with a depreciation rate of 15%.

Descriptive statistics for all variables described in this section are presented in Table 4.6.

Table 4.6

*Descriptive statistics of variables used in the empirical analysis*

| Variable | Obs | groups | T-bar[a] | Mean | Std. Dev. | | | Min | Max |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Overall | Between | within | | |
| $r\&d^{MNE}$ | 643 | 50 | 12.86 | 4.28 | 2.56 | 2.38 | 0.69 | -0.92 | 8.88 |
| *pat* | 749 | 50 | 14.98 | 4.96 | 2.04 | 2.01 | 0.47 | 0.00 | 8.73 |
| $1\text{-}(b\text{-}index)_{it}$ | 418 | 37 | 11.3 | 0.15 | 0.12 | 0.11 | 0.06 | -0.23 | 0.32 |
| *gdp* | 750 | 50 | 15 | 12.67 | 1.27 | 1.21 | 0.42 | 9.35 | 16.07 |
| *sales* | 750 | 50 | 15 | 9.39 | 1.63 | 1.56 | 0.51 | 4.6 | 12.55 |
| *exp* | 613 | 50 | 12.26 | 41.41 | 21.12 | 21.4 | 6.25 | 0.00 | 92.55 |
| *pr* | 739 | 50 | 14.78 | 6.62 | 1.66 | 1.61 | 0.42 | 1.88 | 9.62 |
| *hc* | 543 | 47 | 11.55 | 5.28 | 3.84 | 4.14 | 0.97 | 0.09 | 17.94 |
| *ind* | 716 | 49 | 14.61 | 31.75 | 9.57 | 9.42 | 2.34 | 6.97 | 66.76 |
| $r\&d^c$ | 574 | 49 | 11.71 | 1.49 | 1.06 | 1.06 | 0.2 | 0.04 | 4.52 |
| *ht_exp* | 745 | 50 | 14.9 | 5.42 | 10.99 | 10.56 | 3.28 | .00 | 84.4 |
| *patstock* | 750 | 50 | 15 | 9.4 | 2.42 | 2.39 | 0.49 | 3.06 | 14.97 |

[a] average number of years under observation.

### 4.4.2 Estimation strategy.

The model specifications are presented in the subsections below. Coefficients are estimated using a number of panel data parametric models. The existence of fixed effects is assessed through the Hausman test, and upon confirmation, fixed effects estimator is applied.

For comparison purposes, results of the random effects model (Wooldridge, 2002) are also depicted. For the dynamic specifications, three classes of estimators are used: (a) the fixed effects; (b) Arelano-Bond difference-GMM (Arelano & Bond, 1991); and (c) bias-corrected least squares dummy variables estimator (LSDVC) (Bruno, 2005; Bun & Kiviet, 2003).[123]

#### *4.4.2.1 R&D investments by U.S. MNEs.*

The first empirical analysis uses aggregate data from U.S. MNEs. It is assumed that parent companies, at the beginning of each period, analyze the sales performance of each international affiliate on the last period ($sales_{i,t-1}$), along with a series of economic, institutional and technological indicators of each country ($c_{i,t-1}$). Based on such analysis, they decide how much to invest in each international affiliate ($r\&d^{MNE}{}_{it}$).

They also study and compare tax incentives for locally performed R&D granted by each government in different locations, including the Brazilian tax policy in place each year ($1\text{-}(b\text{-}index)_{it}$). It is further assumed that companies know the rate of incentives applicable in each country when they make their decision, as such benefits are in general approved or announced by the government before companies can apply or benefit from them. For this reason, this variable is considered at the same time period as the dependent variable.

This leads to the static investment equation (1), which captures the described process. All variables are described in section 4.4.1. ($f_i$) accounts for countries\` fixed effects, ($f_t$) are time dummies that capture the possible influence of year effects, and ($v_{it}$) is the error term. All control variables ($c_{it}$) are included in the equation with one lagged period.

$$r\&d_{it}^{MNE} = \beta_0 + \beta_1[1-(b-index)]_{it} + c_{i,t-1} + f_i + f_t + v_{it} \quad ;$$

$$c_{it} = \beta_2 sales_{it} + \beta_3 exp_{it} + \beta_4 pr_{it} + \beta_5 hc_{it} + \beta_6 ind_{it} + \beta_7 r\&\mathrm{d}_{it}^{C} + \beta_8 patstock_{it}. \qquad (1)$$

Wilson (2009) suggested adjustment costs may play a pivotal role in the definition of investments directed to each affiliate. This means parent companies take into consideration the value invested in previous years, in order to avoid discontinuing ongoing projects or in light of multi-year planning. To test such argument, a dynamic version of the above model is estimated, including the lagged value of the dependent variable as one of the controls.

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[123] Judson and Owen (1999) suggested LSDVC is more appropriate for unbalanced panels with small group numbers as in this case, outperforming other estimators as system GMM.

$$r\&d_{it}^{MNE} = \beta_0 + \beta_1[1-(b-index)]_{it} + c_{i,t-1} + \beta_9 r\&d_{i,t-1}^{MNE} + f_i + f_t + v_{it}. \qquad (2)$$

#### *4.4.2.2 Fractional patent application.*

The investment model of the second analysis is similar to the one represented by equations (1) and (2) above. Three changes are necessary to adapt it to the case of patent applications. First, the market size is measured by GDP level per year, as there is no data on the value of sales of these companies' affiliates in each country, (data for U.S. MNEs reveal such variables are highly correlated). Similarly, data on export orientation is replaced by exports of high technology goods as a share of the country`s GDP (*ht_exp*). This should provide a measure of the export orientation of high technology industrial sectors of each nation.

Finally, the investment equation must take into account that patent filings are outputs of the innovation process, and not inputs as is the case in R&D expenditure. To deal with such feature, at time (*t-1)*, parent firms observe tax incentives for innovation in place in different countries, as well as last period (*t-2*) variables for potential demand (market size and export orientation), supply factors (human capital, knowledge stock, industry share of GDP and total country R&D expenditure) and institutional features (protection of property rights). Making the investment decision in (*t-1*), innovation projects take on average one period to mature and result in a priority patent filing. Therefore, the dependent variable should be considered in period (*t*).

This proposal is represented in equations (3) and (4) below for the static and dynamic models, respectively.

$$pat_{it} = \beta_0 + \beta_1[1-(b-index)]_{i,t-1} + c_{i,t-2} + f_i + f_t + v_{it} \quad ;$$

$$c_{it} = \beta_2 GDP_{it} + \beta_3 ht\_exp_{it} + \beta_4 pr_{it} + \beta_5 hc_{it} + \beta_6 ind_{it} + \beta_7 r\&d_{it}^{C} + \beta_8 patstock_{it}. \qquad (3)$$

$$pat_{it} = \beta_0 + \beta_1[1-(b-index)]_{i,t-1} + c_{i,t-2} + \beta_{10} pat_{i,t-1} + f_i + f_t + v_{it}. \qquad (4)$$

### 4.4.3 Presentation of results.

Table 4.7 presents the estimated coefficients and other results for the U.S. MNEs' investment model, both for static and dynamic versions. The Hausman test suggests the presence of fixed effects, confirming the relevance of the country's time invariant features for investment decisions, and rendering the random effects estimator inconsistent.

The variable for the level of sales of the respective affiliate presents the strongest and most consistent result in all models. Estimation results suggest the elasticity of R&D investment to sales ranges from 0.41 to 0.86, and the coefficient is significant at a 95% confidence level for all estimators. The lagged version of the dependent variable also influences the present outcome, and the positive coefficient is significant in all dynamic estimators applied.

The variable for Brazilian policy, on the other hand, did not reach a significant result in any of the estimations, suggesting the country incentives do not influence the decision of these enterprises on how much to invest in other countries. This result implies that the Brazilian policy is not successful in attracting ‘footloose R&D’, and the increase in the incentives rates does not divert resources from other destination options.

The majority of the other control variables presents a coefficient with the expected positive sign, but without statistical significance on the 95% confidence level.

Table 4.7

*Results of the main U.S. MNE model. Dependent Variable: $r\&d_{it}^{MNE}$*

| Variables | Estimator | | | | |
|---|---|---|---|---|---|
| | Random Effects | Fixed Effects | Fixed Effects | Arelano-Bond | LSDVC |
| $r\&d_{i,t-1}^{MNE}$ | | | 0.345*** | 0.484*** | 0.417*** |
| | | | (0.095) | (0.143) | (0.117) |
| *1-(b-index)$_{it}$* | -0.524 | -0.912 | -1.137 | -1.427 | -1.084 |
| | (0.462) | (0.592) | (0.694) | (0.926) | (1.222) |
| $sales_{i,t-1}$ | 1.048*** | 0.860*** | 0.576*** | 0.411*** | 0.542** |
| | (0.055) | (0.196) | (0.117) | (0.139) | (0.270) |
| $pr_{i,t-1}$ | 0.054 | 0.049 | 0.046 | 0.034 | 0.036 |
| | (0.059) | (0.080) | (0.057) | (0.066) | (0.139) |
| $ind_{i,t-1}$ | -0.010 | 0.028 | 0.050*** | 0.049** | 0.048 |
| | (0.011) | (0.017) | (0.013) | (0.018) | (0.062) |
| $patstock_{i,t-1}$ | 0.058 | 0.081 | 0.007 | -0.046 | -0.004 |
| | (0.076) | (0.276) | (0.207) | (0.233) | (0.487) |
| $hc_{i,t-1}$ | -0.031 | 0.037 | 0.041 | 0.029 | 0.038 |
| | (0.045) | (0.057) | (0.055) | (0.067) | (0.090) |
| $r\&d^{c}_{i,t-1}$ | 0.734*** | 0.328 | 0.223 | 0.229 | 0.194 |
| | (0.145) | (0.267) | (0.203) | (0.233) | (0.436) |
| $exp_{i,t-1}$ | -0.001 | 0.004 | -0.003 | -0.003 | -0.003 |
| | (0.003) | (0.007) | (0.005) | (0.006) | (0.009) |
| Observations | 241 | 241 | 218 | 218 | 218 |
| R-squared | 0.93 | 0.653 | 0.750 | | |
| Number of id | 31 | 31 | 31 | 31 | 31 |
| Country FE | Yes | Yes | Yes | Yes | Yes |
| Year dummy | Yes | Yes | Yes | Yes | Yes |
| Hausman Test | $X^2 = 50.23$; $P > X^2 = 0.0002$ | | | | |

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Coefficient of the constant variable not presented.

Estimation results for the fractional patent application models are displayed in Table 4.8. In this case, the Hausman test did not confirm the presence of country fixed effects, so the random effects estimator can be considered consistent and efficient. The variable representing market size is again a chief explanatory factor. The GDP coefficient is positive and statistically significant in nearly all models at a 90% confidence level. The elasticity of innovation investment to GDP is estimated to range from 0.25 to 0.84.

Table 4.8

*Results of the main fractional patent application model. Dependent Variable: $pat_{it}$*

| Variables | Estimator | | | | |
|---|---|---|---|---|---|
| | Random Effects | Fixed Effects | Fixed Effects | Arelano-Bond | LSDVC |
| $pat_{i,t-1}$ | | | 0.583*** | 0.632*** | 0.687*** |
| | | | (0.057) | (0.053) | (0.085) |
| $1\text{-}(b\text{-}index)_{i,t-1}$ | 0.180 | 0.143 | 0.204 | 0.126 | 0.195 |
| | (0.183) | (0.164) | (0.165) | (0.238) | (0.215) |
| $gdp_{i,t-2}$ | 0.840*** | 0.819** | 0.325* | 0.290 | 0.251** |
| | (0.240) | (0.307) | (0.191) | (0.199) | (0.121) |
| $pr_{i,t-2}$ | 0.098 | 0.054 | -0.020 | -0.027 | -0.029 |
| | (0.063) | (0.059) | (0.043) | (0.044) | (0.036) |
| $ht\_exp_{i,t-2}$ | 0.004 | -0.001 | -0.003 | -0.003 | -0.003 |
| | (0.005) | (0.007) | (0.003) | (0.003) | (0.005) |
| $ind_{i,t-2}$ | 0.006 | 0.017 | 0.007 | 0.006 | 0.007 |
| | (0.012) | (0.019) | (0.010) | (0.012) | (0.010) |
| $rd\_gdp_{i,t-2}$ | 0.075 | 0.062 | 0.059 | 0.080 | 0.033 |
| | (0.115) | (0.121) | (0.078) | (0.084) | (0.116) |
| $patstock_{i,t-2}$ | 0.131 | -0.009 | -0.042 | -0.056 | -0.024 |
| | (0.191) | (0.299) | (0.131) | (0.128) | (0.093) |
| $hc_{i,t-2}$ | 0.032 | 0.044 | 0.017 | 0.007 | 0.015 |
| | (0.027) | (0.027) | (0.017) | (0.016) | (0.032) |
| Observations | 296 | 296 | 296 | 296 | 296 |
| R-squared | 0.7945 | 0.338 | 0.561 | | |
| Number of id | 33 | 33 | 33 | 33 | 33 |
| Country FE | Yes | Yes | Yes | Yes | Yes |
| Year dummy | Yes | Yes | Yes | Yes | Yes |
| Hausman Test | $X^2 = 24.83$; $P> X^2 = 0.0983$ | | | | |

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Coefficient of the constant variable not presented.

The lagged version of the dependent variable is also positive and statistically significant in all models, confirming the influence of past decisions in the definition of current values.

Brazilian tax incentives again do not seem to be a relevant factor, as the respective variable did not achieve significance in any of the models. Other variables do not achieve statistical significance in most of the regressions, which seems to confirm the results of the previous model.

### 4.4.4 Robustness checks.

Two alternative versions of the main models are estimated to test robustness of the results. The LSDVC dynamic models are estimated multiple times, gradually excluding each of the control variables, to check if results are sensitive to the models' specifications.

Secondly, it may be the case that only a part of alternative host countries may be affected by the Brazilian tax policy. In particular, nations with a low volume of funds are less likely to perceive any impact since they probably are not strong competitors for 'footloose R&D' funds. Therefore, the main models are estimated taking resources directed to Brazil as a lower limit on the countries to be included in the regressions.

Estimated results are presented in Tables A4.1 to A4.4 of the Appendix. Confirming the main model's findings, in none of these cases is the coefficient related to the Brazilian policy or investments received by the country a statistically significant explanatory variable of the innovation resources directed by MNEs to other nations. Robustness checks also follow the main model's results in showing the relevance of market size and past investment, as coefficients of sales levels. GDP and lagged dependent variables are positive and have statistical significance in almost all tested specifications.

### 4.4.5 Discussion of the results.

Based on the quantitative study described in this section, the answer to the initial question is negative, i.e. no evidence was found suggesting that tax incentives established by the Brazilian government has attracted international 'footloose R&D' from alternative host countries. Results indicate that the Brazilian tax policy has no significant correlation with investments directed to other countries, thus leaving no empirical basis to maintain that MNEs took funds from alternative destinations to invest in innovation in Brazil because of the beneficial fiscal treatment. The fact that regressions using two distinct indicators of R&D investment (along with a group of robustness checks) point to the same direction substantially strengthen such conclusion.

Data discussed in sections 4.2 and 0 indicate that cross-border innovation has been on the rise in the last decades as multinational groups have been internationalizing a greater part of their R&D activities. Additionally, the Brazilian market became more attractive and has gained importance in the international economy during this period, as suggested by the increasing FDI inflow and sales levels of MNEs' affiliates in the country. It is more likely that the increase in foreign innovation funds directed to Brazil (displayed in Figure 4.8 and Figure 4.9) is explained by these general trends rather than by corporate tax planning.

These findings provide interesting insights in light of the literature discussed throughout this paper; they are in accordance with the findings of surveys of Brazilian MNEs` affiliates that indicate tax incentives are not really of primary importance in attracting resources for R&D from parent companies (Galina et al., 2011; Queiroz, 2011; Arbache et al., 2011; Arruda et al., 2014). This is an important result as this is the first quantitative confirmation of such hypothesis.

'Footloose R&D' is just a part of the total innovation investment of MNEs abroad. The positive and significant coefficient of the tax policy variable in the U.S. MNE model suggests that, at the international level, such measures may have a role in raising R&D investment levels, although it is not possible to say whether this represents a global increase or an international transfer of funds. This result is not robust, and should be further confirmed by future studies.

Focusing on the economic literature on impact of innovation tax policies, this study does not provide support to the argument that these incentives work as 'beggar-thy-neighbor' schemes. It should be stressed that these results are case specific and not applicable to all countries. Loss of generality, however, is the cost to consider the conclusions fairly robust for the Brazilian case.

The positive signs and statistical significance of the coefficients of variables representing demand-side factors (total sales or GDP levels) of the host countries are also noteworthy. They confirm previous results that the majority of R&D is mainly attracted by the market potential. The consulted literature on internationalization of R&D takes these features as typical of adaptive or "market seeking" R&D (OECD, 2011b; UNCTAD, 2005b; Dunning, 1994). This is still the dominant type of innovation transferred by multinational groups to affiliates or contractors in other countries. It is largely driven by market proximity, and its purpose is mainly production support and adaptation to local conditions, consumers' preferences or existing regulations.

Different signs for the export orientation coefficient were found, depending on the model specification. Interestingly, the literature is also ambiguous on this point, and not conclusive on whether this should constitute an attraction factor. In none of the cases, however, has this variable reached statistical significance.

The absence of statistical significance in nearly all the other variables is also a point of interest. This may be explained by the fact that sales levels (or market size) are indeed major explanatory factors, leaving little room for other features to influence. However, this certainly casts doubt on some of the conclusions present in the literature that emphasize supply-side and institutional factors.

The presence of fixed effects detected by the Hausman test informs that country specific features are relevant and taken into consideration by parent companies. In contrast, it is noteworthy that the coefficient of the institutional variable does not appear to be a significant explanation of investment.

Results of the dynamic models suggest that there are indeed considerable adjustment costs in international R&D funds, as suggested by Wilson (2009). Firms do not seem inclined to make radical changes in their investment policies in each country, smoothing such path to avoid discontinuances. It may also be the case that firms make multi-year plans to take advantage of economies of scale in research or which are necessary for the maturing of new technologies.

## 4.5 Policy Implications

The main point of the study is that, in the case of Brazil, fiscal benefits do not seem to be the most appropriate policy tool for attracting ‘footloose R&D’ or for competing at the international level for innovation funds that are not specific to supporting local activities. This study provides solid grounds for maintaining that, up to this point, the reduction of tax costs was not a driver to pull investment from other sources towards facilities and affiliates in the country.

The literature suggests that, in the case of more central or technology-complex R&D, supply-side factors play a more relevant role than the availability of a highly qualified workforce, research infrastructure or technology clusters. Policies aiming to foster investment in these areas seem to be a more promising choice for making the country more attractive for this type of R&D. Such a conclusion is in accordance with previously mentioned surveys (Arruda et al., 2014; Galina et al., 2011, and Arbache et al., 2011) and the available data on the poor quality of the country’s human capital, especially the pool of workforce specialized in engineering related areas (WEF, 2015).

The adaptive orientation of R&D performed in the country, as discussed in section 4.3.2, also suggests that measures to boost the local market seem to be the most straight-forward way to bring more innovation funds to local affiliates, although they may not change its main objective or nature. The positive and significant coefficients for sales levels and market size provide empirical support for this conclusion.

The fact that the fiscal policy did not attract “footloose” R&D does not mean that it is meaningless or without impact. As mentioned, recent studies for the Brazilian policy (following the conclusions of international research) identified the positive impact of these incentives, increasing the amount of R&D investment, although with different levels of elasticities (Shimada, Kannebley Jr. & De Negri, 2014; and Kannebley Jr. & Porto, 2012).

The results are also relevant from an international cooperation perspective. They suggest the worries expressed by the OECD (2013a, 2014a) that international competition should lead to a zero-sum game and overall reduction of revenues may be unfounded for the Brazilian case. This study is more aligned with the branch of literature that emphasizes macroeconomic and market size variables as attraction factors for international R&D (Thomson, 2009; Athukorala & Kohpaiboon, 2006). I conclude that claims for coordination rules at the international level (OECD, 2013) should be considered carefully, as they may inefficiently hinder countries in adopting tax incentives that increase their international R&D levels with no negative impact on the flow to other economies.

Finally, Hines Jr. and Jaffe’s (2001) conclusions that tax measures may have a complementary effect at the international level are challenging and may provide important insights for this discussion. Multinational coordination may encourage countries to devise and apply tax provisions that strengthen such complementarity, including special tax provisions in the case of technology transfer for development purposes and protection of intellectual property cross borders.

# 5 Conclusion

The objective of this thesis is to analyze the effects of tax incentives for innovation in Brazil established by Law 11,196/05, assessing the impact of this policy on industrial innovation. This is one of the most important instruments of horizontal industrial policy currently in place in the country. Up to 2014, the amount of tax breaks reached around seventeen billion Brazilian *reais*[124] (around six billion U.S. dollars)[125].

To reach this general aim, I present three research questions that are addressed in each of the papers that comprise this thesis. Chapter 2 is dedicated to the estimation of the impact of the policy on private innovation investment, innovation outputs and firms' performance. Chapter 3 analyzes the effect on composition of investment and type of innovation pursued by beneficiary enterprises. Finally, Chapter 4 investigates whether the Brazilian tax policy has attracted international R&D investment by diverting them from alternative countries, thus testing the applicability of the 'footloose R&D' argument for the Brazilian case.

In this concluding chapter, the findings of these investigations are jointly summarized and discussed, along with their contribution to the literature, further research agendas and policy implications.

## 5.1 Main Findings

Chapter 2 presents evidence that the policy positively impacted different innovation inputs in beneficiary firms. On average, the estimated annual impact on R&D expenditure is around five hundred thousand Brazilian *reais* (around two hundred and sixty-four thousand U.S. dollars)[126] or 6.8% of the mean R&D spending of beneficiary firms in 2011. The incentives also positively affected the size of R&D personnel, with an average increase of five researchers per beneficiary firm (16% of the average number of R&D staff of beneficiary firms in 2011). In both cases, previous studies have also found a positive impact for these variables.[127] Finally, the policy had an effect on the base of firms investing in innovation: the estimates suggest

[124] Real value in December, 2016, adjusted using the IGP-M/FGV index of the last month of each year. Sum of nominal values is around twelve billion Brazilian *reais.*
[125] According to the exchange rate applicable on the last day of the year.
[126] According to the exchange rate applicable on the last day of 2011.
[127] See Chapter 2, section 2.6.4 for a discussion of the results.

participating in the policy increased the chances of a firm beginning to invest in any innovative activities by 23%, and specifically in R&D by 11%.

These findings are of great importance, for they reject the full crowding-out hypothesis. In addition, the investigation shows that the tax breaks reduced entrance barriers and improved the likelihood of a firm to start investing in R&D, a novel result that has not been addressed in previous studies on the Brazilian policy, and that matches the findings of papers that assessed similar incentives in other countries.[128]

The magnitude of the impact on expenditures, however, is below the average benefit per firm in 2011. This suggests the existence of some level of crowding-out in the short run, in accordance with previous empirical literature (Van Pottelsberghe, 2003; EC, 2014).

The same empirical study also finds the policy increased the likelihood of firms innovating by an average of 12%, following the conclusions of Czarnitzki, Hanel and Rosa (2011), and Bérubé and Mohnen (2009) for the Canadian case. There is also evidence that the incentives positively impacted companies' growth by around a hundred and ten employees on average, or 5% of the mean size of treated units in 2011, a similar relative effect found by Kannebley Jr., Araújo, Maffioli and Stucchi (2013). These results constitute new and relevant evidence of how these tax benefits fostered innovation and industrial development. Such findings also contribute to the debate on industrial policy, for they suggest that public support can have an overall positive impact and that, in this particular case, government failures were not so strong as to completely cancel advantageous effects. This supports the argument that there is a role for the public sector in promoting innovation through efficiency-improving intervention.

Chapter 3 is the first quantitative study in Brazilian economic literature to discuss the composition of investment and behavioral additionality of the country's innovation tax policy, and constitutes a relevant contribution to the literature and to the understanding of these incentives. The most important result is that the policy caused beneficiary firms to raise their R&D intensity within the bundle of innovative activities. On average, this impact was around one point one million Brazilian *reais* (around six hundred thousand U.S. dollars)[129], which represents 17% of the mean spending of beneficiary firms in 2011, and an increase of the R&D intensity within the bundle of innovative activities of 9.5%. This may be considered a positive

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[128] See Table 2.4 in Chapter 2.

[129] According to the exchange rate applicable on the last day of 2011. This estimate was based on a sample that included companies with no R&D expenditure, as long as they had positive spending in any of the other categories of innovative activities. For this reason, the estimated impact on R&D is higher than the one found in the input analysis (Chapter 2), where only enterprises with positive R&D were considered.

effect, as strict R&D is regarded as more technologically advanced and riskier than the alternative choices (Zhu, Xu & Lundin, 2006). This finding is in accordance with the results of previous studies (Clausen, 2007; Zhu et al., 2006, for direct subsidies only), and it challenges the theoretical argument that firms benefiting from tax breaks direct their efforts to less risky projects with higher expected returns in the short run (David, Hall & Toole, 2000). Part of the R&D increase was counterbalanced by a reduction effect on spending with the acquisition of external knowledge (around two hundred thousand Brazilian *reais* or one hundred and ten thousand U.S. dollars)[130] and introduction of innovations in the market (around three hundred and eighty thousand Brazilian *reais* or one hundred and ninety U.S. dollars).[131]

The second most relevant impact found on investment composition is the average increase of 3.35 on the number of researchers with an undergraduate degree (18.5% of the average number of researchers with this educational level working in beneficiary firms in 2011). No evidence of impact on graduate researchers was found, such as in Clausen (2007) and Dumont, Spithoven and Teirlinck (2014). As none of the other categories of researchers has had a negative result, this confirms the results of the input analysis that an increase in the total size of innovation personnel took place because of the incentives.

The empirical analysis in Chapter 3 also indicate that the policy had no significant effect on R&D outsourcing levels and on the balance between product and process innovation. The reasons for these results should be object of further investigations, as previous studies in other countries have found evidence of impact on these variables (Clausen, 2007; Afcha & López, 2014; Aralica & Botrić, 2013), and theoretical models conclude they should be affected by public support (Vilasuso & Frascatori, 2000; LaRiviere, 2014; Howitt, 1999; Segerstrom, 2000).

The models that estimated the probability of a firm benefitting from the tax incentives (Chapter 2 and 3)[132] also provide relevant insights about the factors and features that influence such decisions. The most important covariate is firms' net revenues, with positive and statistically significant coefficients in all propensity score estimates. This result is relevant for it provides empirical support to the arguments that volume-based incentives are more suited to large corporations (OECD, 2011a; Bastos, 2004) and that policies with a single rule for different business situations may be detrimental to small firms (OECD, 2014a). Considering the policy

[130] According to the exchange rate applicable on the last day of 2011.
[131] According to the exchange rate applicable on the last day of 2011.
[132] Tables 2.12 and 2.14 in Chapter 2 and Table 3.6 in Chapter 3.

design, this finding strongly suggests that the requirement of beneficiary firms to operate under the real profit tax regime biases the incentives in favor of large companies.

Two other variables with significant coefficients in most estimations are the continuous development of R&D activities and at least one of the international trade dummies (export or import in the previous year and foreign markets as the most important to the firm). Both factors present the expected positive coefficient. Finally, it is interesting to note that, contrary to the argument that young firms may not benefit as much from tax incentives because of their reduced or inexistent taxable income (OECD, 2011), the age factor does not seem to play a relevant role in determining participation in the Brazilian policy.

Chapter 4 investigates whether the 'tax generosity' of the Brazilian innovation system has attracted foreign investment by diverting it from alternative destinations. This is the first investigation that tested the 'footloose R&D' argument for the Brazilian tax policy, and it is another original contribution of this thesis. The result matches part of the literature on the topic that did not find significant results for the tax policy variable in the attraction of foreign innovation investment, emphasizing the role of macroeconomic and market size variables (Thomson, 2009; Athukorala & Kohpaiboon, 2006). Plus, this finding is in accordance with a group of studies that argued that R&D undertaken by MNEs in developing countries is mainly for adaptive purposes, and therefore not very sensitive to public support (UNCTAD, 2005b; EC, 2012).

Summarizing these main findings, this thesis presents the following picture of the tax incentives of Law 11,196/05 for innovation: (a) the benefits have caused firms to increase their investment in innovation, both in terms of expenditure and research personnel, (b) in the case of MNEs, such increase was not caused by the diversion of investment from other countries; (c) incentives positively affected the chances of firms starting to invest in R&D and other innovative activities; (d) the policy also increased R&D intensity of innovation efforts and research staff with university degrees; and (e) beneficiary firms innovated more and experienced higher growth. These findings imply that the tax incentives are relevant for private investment in R&D in the country.

A general conclusion of this thesis implied in the findings is the comprehensiveness of the impact of the Brazilian innovation tax policy on the group of beneficiary firms. The empirical investigations present clear evidence of the three dimensions of policy impact (input, output and behavioral additionality - Georghiou, 1994); and that the incentives do not divert investment from alternative destinations, and thus that they may not be criticized as a beggar-thy-neighbor scheme. This means that not only have companies increased their efforts to improve technology as a result of government support, but they also modified their innovation strategies and spending composition, and obtained better results.

## 5.2 Future Research Agenda

The main research agenda arising from the findings of Chapter 2 is the assessment of positive externalities generated by beneficiary firms. As discussed therein, the propensity score matching is based on the stable unit treatment value assumption (Wooldridge, 2002), which means secondary impacts on non-beneficiary firms arising from knowledge spillovers are not considered in the estimates. These positive externalities, however, constitute a relevant part of the outcome of innovation projects, and they can be as high as twice the size of internalized results (Bloom, Schankerman & Van Reenen, 2015). Therefore, studies specifically designed to measure policy impact on knowledge spillovers can supplement the findings of this thesis.

Three agendas are discussed in Chapter 3 as future research prospects on composition of investment and type of innovation. The first is the study of other dimensions of behavioral additionality or other categories of innovation expenditure. The second is the use of this research strategy to evaluate other innovation policies implemented by the Brazilian government, to compare with the results for tax incentives presented herein. Finally, the third is the analysis of the persistency of the effects, investigating if they represent temporary or more enduring changes in firms' strategies (Gök & Edler, 2012).

Chapter 4 analyzes international R&D investment by focusing solely on resources attracted from alternative countries, negatively impacting foreign funds directed to them. It does not estimate the impact of the tax breaks on overall international innovation investment attracted to the country. Such analysis would supplement the findings of this study and present a valuable contribution to the understanding of the effects of tax policies at the international level.

This thesis also sheds important light on the challenges and shortcomings currently faced by the economic literature on innovation policy. As shown in Chapter 2, most of this literature investigated policies implemented in developed countries. There are few empirical studies that consider the situation in developing economies and try to investigate and explain if these measures affect firms differently in these cases. This seems a fruitful research agenda for the design of policy instruments that are specific for non-developed nations.

Additionally, most of the studies on innovation policy - this thesis included - refer exclusively to one instrument or government measure, without considering the fact that firms can and often do benefit from multiple incentives or supports granted by the public sector. The policy mix concept is recent and opens new possibilities for research on economics of innovation, constituting a relevant prospect for the development of this literature. (for a review, see Cunningham, Edler, Flanagan & Larédo, 2013; Nauwelaers, 2009).

## 5.3 Main Policy Implications

Several suggestions for the improvement of the policy are drawn from the empirical investigations and presented in the papers. First, three main factors are identified as obstacles for more firms to benefit from the incentives: (a) the requirement that companies operate under the real profit tax regime; (b) the absence of carryforward or carryback schemes; and (c) the restrictions to outsource innovation projects, or to transfer them to other legal entities of the same group.

The second policy implication is to have the reduction of crowding-out, innovation outputs and firms' performance as core elements of the policy design. Even considering the typical uncertainty and non-predictability of the outcome of innovation projects, the absence of evidence of the impact on new products and productivity is troubling from a policy perspective, as the channels through which the incentives affect firms' performance and generate economic growth remain unclear. It seems a relevant point of improvement to make beneficiary firms accountable for raising their R&D levels above an initial threshold, and also for the results of their projects, justifying the indirect funding and the cost of incentives to the government budget. Ayres and Kapczynski (2015) discussed and presented examples of 'innovation sticks' in the U.S., i.e., penalties applied to companies that fail to improve technology and to mitigate certain problems, such as vehicles' consumption of fossil fuels and the cost of the treatment of hospital patients.

The fact that no significant impact on the number of graduate researchers was found is another challenge that needs to be addressed. As argued in Chapter 3, there are solid grounds to maintain that policy design affects such results, as firms can obtain an additional 20% deduction of R&D expenditure only by increasing the number of researchers, regardless of their educational background. The introduction of incentives rates that require firms to hire additional graduate researchers or that increase the demand for this workforce is a relevant agenda for policy improvement.

Chapter 2 suggests this policy may not be significantly contributing to the increase in industrial productivity in the country. Besides, no evidence of impact on process innovation was found, as presented in Chapter 3. Such results, however, should be considered in light of a broader context. As argued in OECD (2015d), the low productivity of Brazilian industry is majorly due to structural factors, such as a fragmented tax system and insufficient infrastructure. For this reason, these findings are better interpreted as an indication that innovation policies alone are not sufficient to meet the productivity challenge in Brazil. That should be addressed through major institutional reforms or policies.

The absence of impact of the policy on the diversion of international investment from alternative destinations has two main implications from a policy perspective. Considering the national policy standpoint, the study evidences that fiscal benefits are not an appropriate policy tool for competing at the international level for the development of more technology-complex projects that are not dedicated to supporting the local activities of MNEs' affiliates. Policies targeting supply-side factors, as stressed in the literature, seem a more promising path for making the country more attractive to this type of R&D. The second implication refers to the international coordination of innovation policies. The argument of OECD (2013a, 2014a) that gains arising from tax policies are majorly from international reallocation of capital does not seem to hold for the Brazilian case. The findings of Chapter 4 suggest the adaptive R&D developed in the country does not follow this reasoning, as the tax break is not negatively correlated with the flow of investment to other countries. Coordination rules that restrict the Brazilian government from implementing tax incentives to foster innovation may reduce the positive effects of this policy without any benefit to other nations.

## 5.4 Recommendations on the Brazilian Innovation Policy

Besides specific recommendations for the improvement of the design and structure of tax incentives, the studies that comprise this thesis also present implications related to the current challenges and further development of the Brazilian system of innovation. During most of the last decade, the promotion of innovation was central to the industrial and development policies adopted by the federal government,[133] and several measures were taken to encourage firms to invest more (including the tax incentives analyzed herein). However, at least since 2014, the international trend of rationalization of innovation policies[134] arrived in Brazil, with

[133] See Chapters 1 and 2.
[134] See Chapter 1.

a negative impact on the government support in this area.[135] The scientific community in Brazil has described such movement as the ‘interruption of a cycle’, referring to the expansion of the science and technology base in the last decade (SBPC & ABC, 2016).

This thesis provides empirical support to maintain that the tax incentives of Law 11,196/05 are a success case of innovation policy, thus presenting an argument for their continuance. The general picture that arises from the findings is that the incentives have contributed substantially to the development of private R&D in the country. Applying rigorous econometric analysis, the studies present clear evidence that these benefits have positively impacted entrepreneurial innovation. In light of these findings, there seems to be little room for doubt about the positive effects of the policy. This conclusion is valid regardless of the theoretical framework adopted, for there is evidence that the tax breaks compensated for positive externalities, as suggested by the market failure literature, and that they modified firms' innovation behavior and strategies, making them a suitable tool from a neoschumpeterian perspective. Although improvements can help to rationalize efforts and enhance results, the policy in general has been effective. Its dismantling would most probably mean a reduction in the already low levels of private innovation investment in the country, with negative consequences on the competitiveness and productivity of the industry.

The second main implication refers to the evaluation of innovation policies in general. This thesis can be considered as part of an effort of Brazilian economics academia to apply quantitative methods and econometric estimators to assess the impact of innovation and other policies. The rapid advance these methods have experienced in the last decades is partially responsible for such development, along with the efforts of Brazilian scholars to improve their analyses. But it is important to acknowledge that this is also due to the microdata recently made available by different government bodies such as the Brazilian Institute of Geography and Statistics (IBGE).

As discussed in Chapter 2, the government reports on the tax policy mainly assess these incentives by analyzing the number of beneficiary firms and the total volume of investment and tax breaks. It is not an overstatement to generalize such conclusions to most innovation policies

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[135] Three facts may be called to attention to evidence this paradigm shift: the first is the evolution of the budget of the Ministry of Science, Technology and Innovation (MCTI), that experienced a reduction of around 22% from 2013 to 2016 (Annual Budget Laws 12,798/13 and 13.255/16, values readjusted by the IGP-DI/FGV index, without considering later budget cuts), after years of real growth (around 53% from 2003 to 2010 - Annual Budget Laws 10.640/03 and 12.214/10, values readjusted by the IGP-DI/FGV index, without considering later budget cuts). The second is the failed attempt of the federal government to suspend the tax incentives analyzed in this thesis for one year, according to Provisional Measure 694/15. Finally, the third is the merger of the MCTI with the Ministry of Communications in 2016.

carried out at the federal and sub-national levels of government in Brazil. The studies presented in this thesis denote the primary importance of advanced policy analysis to understand and estimate the benefits of government support, pinpointing where it has succeeded and where it has failed. It is of great importance to develop a culture of evaluation and accountability of innovation policies in the country, with the adoption of quantitative and other methods that can guide policy decisions and provide clear information to policy-makers and to the civil society about the benefits (or absence thereof) that arise from public spending and tax breaks.

# REFERENCES


Abadie, A., & Imbens, G. W. (2006). Large sample properties of matching estimators for average treatment effects. *Econometrica*, *74*(1), 235–267. doi:10.1111/j.1468-0262.2006.00655.

Aerts, K., & Thorwarth, S. (2008). *Additionality Effects of Public R&D Funding: 'R' versus 'D'.* FBE Research Report MSI_0811, 1-19. Retrieved from https://lirias.kuleuven.be/handle/123456789/216618.

Afcha, S. M. (2011). Behavioural additionality in the context of regional innovation policy in Spain. *Innovation*, *13*(1), 95-110. doi:10.5172/impp.2011.13.1.95.

Afcha, S., & García-Quevedo, J. (2014). *The Impact of R&D Subsidies on R&D Employment Composition*. Institut d'Economia de Barcelona Documents de Treball de l'IEB 2014/22. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2471050.

Afcha, S., & López, G. L. (2014). Public funding of R&D and its effect on the composition of business R&D expenditure. *BRQ Business Research Quarterly*, *17*(1), 22-30. doi:10.1016/j.cede.2013.01.001

Aggarwal, V. A., Hsu, D. H., & Wu, A. (2015). *R&D production team organization and firm-level innovation*. INSEAD Working Paper No. 2015/03/EFE/ACGRE.

Aghion, P., & Howitt, P. (1992). A model of growth through creative destruction. *Econometrica, 60*(2), 323. doi:10.2307/2951599.

Aghion, P., & Howitt, P. (1998). *Endogenous Growth Theory.* Cambridge: MIT Press.

Akhmat, G., Zaman, K., Shukui, T., Javed, Y., & Khan, M. M. (2014). Relationship between educational indicators and research outcomes in a panel of top twenty nations: Windows of opportunity. *Journal of Informetrics,8*(2), 349-361. doi:10.1016/j.joi.2014.01.007

Alkemade, F., Heimeriks, G., Schoen, A., Villard, L., & Laurens, P. (2015). Tracking the internationalization of multinational corporate inventive activity: national and sectoral characteristics. *Research Policy*, *44*(9), 1763-1772. doi:10.1016/j.respol.2015.01.007.

Almus, M., & Czarnitzki, D. (2003). The Effects of Public R&D Subsidies on Firms' Innovation Activities. *Journal of Business & Economic Statistics,21*(2), 226-236. doi:10.1198/073500103288618918.

Angrist, J. D., & Pischke, J. (2008). *Mostly harmless econometrics: an empiricist's companion*. Princeton: Princeton University Press.

ANPEI (2015). *Comunicado Oficial ANPEI: Novo Acordo pela Lei do Bem - MP 694* [Official Statement ANPEI: New Agreement on the Goodness Law - Provisionary Measyre 694]. Retrieved from http://www.educanpei.org.br/novo-acordo-pela-lei-do-bem.

Aralica, Z., & Botrić, V. (2013). Ievaluation of Research and Development Tax Incentives Scheme in Croatia. *Economic Research-Ekonomska Istraživanja,26*(3), 63-80. doi:10.1080/1331677x.2013.11517622.

Araújo, B. C. (2010). Incentivos fiscais à pesquisa e desenvolvimento e custos de inovação no Brasil [Tax incentives to research and development and innovation costs in Brazil]. *Radar: tecnologia, produção e comércio exterior*, IPEA, *9*, 3-11.

Araújo, B. C., Pianto, D., De Negri, F., Cavalcante, L. R., & Alves, P. (2012). Impactos dos fundos setoriais nas empresas [Impacts of sector funds on firms]. *Revista Brasileira de Inovação, 11*, 85-112.

Arbache, J., Goldstein, A., & Marques, F. (2011). *Attractiveness for Innovation: The Case of Brazil*. Retrieved from http://www.bndes.gov.br/SiteBNDES/export/sites/default/bndes_pt/Galerias/Arquivos/empresa/download/inovacao_presentation_07.pdf.

Archibugi, D. (2001). Pavitt's Taxonomy Sixteen Years On: A Review Article. *Economics of Innovation and New Technology,10*(5), 415-425. doi:10.1080/10438590100000016.

Arellano, M., & S. Bond. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies, 58*, 277-297.

Argote L, & Ingram P. (2000). Knowledge transfer in organizations: learning from the experience of others. *Organizational Behavior and Human Decision Processes*, *82*(1), 1-8.

Arora, A., & Gambardella, A. (1990). Complementarity and External Linkages: The Strategies of the Large Firms in Biotechnology. *The Journal of Industrial Economics, 38*(4), 361-379.

Arrow, K. J. (1962). Economic Welfare and the Allocation of Resources for Invention. In *The Rate of Direction of Inventive Activity*: Economic and Social Factors. Princeton: National Bureau of Economic Research, Princeton University Press.

Arruda, C., Barcellos, E., & Tumelero, C. (2014). *Relatório do projeto "Centro de Referência em Inovação (CRI) Multinacionais"* [Report of Project "Innovation Reference Centers Multinationals]. Fundação Dom Cabral (FDC), Núcleo de Inovação e Empreendedorismo.

Aschhoff, B. (2009). The effect of subsidies on R&D investment and success – do subsidy history and size matter?, *SSRN Electronic Journal*. doi: 10.2139/ssrn.1433275.

Athukorala, P., & Kohpaiboon, A. (2006). *Multinational Enterprises and Globalization of R&D: A Study of U.S-based Firms*. Departmental Working Papers from the Australian

National University. Retrieved from https://crawford.anu.edu.au/acde/publications/publish/papers/wp2006/wp-econ-2006-06.pdf.

Auerbach, A. J. (1982). *Taxation, Corporate Financial Ilicy And The Cost Of Capital*. NBER Working Paper Series, Working Paper No. 1026.

Austin, P. C. (2011). Optimal caliper widths for propensity-score matching when estimating differences in means and differences in proportions in observational studies. *Pharmaceutical Statistics,10*(2), 150-161. doi:10.1002/pst.433.

Avellar, A. P. (2008). Avaliação do Impacto do PDTI sobre o gasto em atividades de inovação e em P&D das empresas industriais [Impact Assessment of PDTI on inovative expenditures and R&D of industrial firms]. In J. A. De Negri, J. A., L. C. Kubota (eds), *Políticas de Incentivo à Inovação Tecnológica* (pp. 323-358). Brasília: IPEA.

Ayres, I., & Kapczynski, A. (2015). Innovation Sticks: The Limited Case for Penalizing Failures to Innovate. *The University of Chicago Law Review, 82*(4), 1781-1852.

Azurmendi, B. B., Aramburu, A. A., & Amozarrain, A. E. (2008). The Neo-Schumpeterian Model of Economic Development in the Basque Country: The role of Social Economy. *Revista de Economía Pública, Social y Cooperativa*, CIRIEC-España, *62* (Special Issue), 121-145.

BACEN (n.d.). *Time series* [Dataset]. Retrieved from http://www.bcb.gov.br/?SERIE TEMP.

Barge-Gil, A., & Lopez, A. (2014). R versus D: estimating the differentiated effect of research and development on innovation results. *Industrial and Corporate Change*, *24*(1), 93-129.

Bastos, V. D. (2004). Incentivos à Inovação: Tendências Internacionais e no Brasil e o Papel do BNDES junto às Grandes Empresas [International and Brazilian Trends and the Role of BNDES for Large Firms]. *Revista do BNDES*, Rio de Janeiro, 11(21), 107-138.

Baumann, R. (1999). O Brasil nos anos 1990: uma economia em transição [Brazil in the 1990s: a transition economy]. In R. Baumann (org.), *Brasil: uma década em transição*. Rio de Janeiro: Campos.

Becker, S., & Caliendo, M. (2007). Sensitivity Analysis for Average Treatment Effects. *The Stata Journal*, *7*(1), 71-83.

Behrman, J. N., Fischer W. A. (1980). *Overseas R&D Activities of Transnational Companies*. Cambridge: Oelgesclagert, Gunn & Hein.

Beladi, H., Marjit, S., & Yang, L. (2011). *Outsourcing: Volume and Composition of R&D*. The University of Texas at San Antonio, College Of Business Working Paper Series, WP# 0001ECO-414-2011.

Belderbos, R., Lykogianni, E., & Veugelers, R. (2008). Strategic R&D Location by Multinational Firms: Spillovers, Technology Sourcing, and Competition. *Journal of Economics & Management Strategy*, *17*(3), 759-779.

Benavente, J. M., Crespi, G., & Maffioli, A. (2012). Public support to firm level innovation: an evaluation of the FONTEC Program. *Revista Brasileira de Inovação, 11*, 113-152.

Beneito, P. (2003). Choosing among alternative technological strategies: an empirical analysis of formal sources of innovation. *Research Policy,32*(4), 693-713. doi:10.1016/s0048-7333(02)00079-3.

Beneito, P. (2006). The innovative performance of in-house and contracted R&D in terms of patents and utility models. *Research Policy,35*(4), 502-517. doi:10.1016/j.respol.2006.01.007.

Beneito, P., Rochina-Barrachina, M. E., & Sanchis, A. (2015). The path of R&D efficiency over time. *International Journal of Industrial Organization*, *42*, 57–69.

Berger, P. G. (1993). Explicit and Implicit Tax Effects of the R & D Tax Credit. *Journal of Accounting Research,31*(2), 131. doi:10.2307/2491268.

Bergman, K. (2011). *Internal and External R&D and Productivity – Evidence from Swedish Firm-Level Data*. Lund University Working Paper 2011:27.

Berman, E., Bound, J., & Griliches, Z. (1993). Changes in the Demand for Skilled Labor within U.S. Manufacturing Industries: Evidence from the Annual Survey of Manufacturing. doi:10.3386/w4255.

Bernstein, J. I. (1986). The Effect of Direct and Indirect Tax Incentives on Canadian Industrial R&D Expenditures. *Canadian Public Policy / Analyse de Politiques,12*(3), 438. doi:10.2307/3550607.

Bérubé, C., & Mohnen, P. (2009). Are firms that receive R&D subsidies more innovative? *Canadian Journal of Economics/Revue canadienne d'économique,42*(1), 206-225. doi:10.1111/j.1540-5982.2008.01505.x.

B.I.S. (2011). *The Plan for Growth.* Department for Business Innovation & Skills. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/31584/2011budget_growth.pdf.

Bloom, N., Chennells, L., Griffith, R., & Van Reenen, J. (1997). *How has tax affected the changing cost of R&D? Evidence from eight countries*. Institute for Fiscal Studies, WP 97-3.

Bloom, N., & Griffith, R. (2001). The internationalisation of UK R&D. *Fiscal Studies, 22,* 337-355.

Bloom, N., Schankerman, M., & Van Reenen, J. (2015). *Identifying Technology Spillovers and Product Market Rivalry*. CEP Discussion Paper No. 675.

Blundell, R., & Dias, M. C. (2000). Evaluation Methods for Non-Experimental Data. *Fiscal Studies, 21*(4), 427–468.

Bönte, W. (2003). R&D and productivity: Internal vs. external R&D - evidence from west german manufacturing industries. *Economics of Innovation and New Technology,12*(4), 343-360. doi:10.1080/10438590290018415.

Brash, D. (1996). *American Investment in Australian Industry*. Cambridge, Mass: Harvard University Press.

Brasil (2003). *Diretrizes de Política Industrial, Tecnológica e de Comércio Exterior* [Guidelines of Industrial, Technological and Trade Policy]. Brasília.

Brasil (2004). *Exposição de Motivos Interministerial 28 - MCTI/MDIC/MF/Casa Civil* [Interministerial Explanatory Memorandum 28 - MCTI/MDIC/MF/Casa Civil]. Retrieved from http://www.camara.gov.br/proposicoesWeb/prop_mostrarintegra;jsessionid=662FCF1420A0F131AE37C9B333546A04.proposicoesWebExterno1?codteor=215493&filename=Tramitacao-PL+3476/2004.

Brown, K. M. (1985). *The R&D tax credit: an evaluation of evidence on its effectiveness*. A staff study prepared for the use of the Joint Economic Committee Congress of the United States. Washington: U.S. Government Printing Office.

Bruno, G. S. F. (2005). *Estimation and inference in dynamic unbalanced panel data models with a small number of individuals*. CESPRI WP n.165 Università Bocconi-CESPRI, Milan.

Buisseret, T. J., Cameron, H., & Georghiou, L. (1995). What Difference Does It Make? Additionality in the Public Support of R&D in Large Firms. *International Journal of Technology Management*, *10*, (s4/5/6).

Bun, M. J., & Kiviet, J. F. (2003). On the diminishing returns of higher-order terms in asymptotic expansions of bias. *Economics Letters,79*(2), 145-152. doi:10.1016/s0165-1765(02)00299-9.

Caliendo, M., & Kopeinig, S. (2005). *Some Practical Guidance for the Implementation of Propensity Score Matching.* IZA Discussion Paper No. 1588.

Calzolaio, A. E., & Dathein, R. (2012). *Políticas fiscais de incentivo à inovação: uma avaliação da Lei do Bem* [Tax Incentives Policies for Innovation: an assessment of the Goodness Law ]. Porto Alegre : UFRGS/FCE/DERI.

Cameron, A. C., & Trivedi, P. K. (2009). *Microeconometrics Using Stata*. College Station: Stata Press.

Campanário, M. A., Silva, M. M., & Costa, T. R. (2005). *Política Industrial, Tecnológica e de Comércio Exterior (PITCE)*: análise de fundamentos e arranjos institucionais [Industrial, Technological and Trade Policy (PITCE): analysis of fundamentals and institutional arrangements]. XI Seminário Latino-Iberoamericano de Gestión Tecnológica ALTEC.

Cantwell, J., & Janne, O. (1999). Technological globalisation and innovative centres: the role of corporate technological leadership and locational hierarchy. *Research Policy,28*(2-3), 119-144. doi:10.1016/s0048-7333(98)00118-8.

Cantwell, J., & Piscitello, L. (2002). The location of technological activities of MNCs in European regions. *Journal of International Management,8*(1), 69-96. doi:10.1016/s1075-4253(01)00056-4.

Cappelen, A., Raknerud, A., & Rybalka, M. (2007). *The effect of R&D tax credits on firm performance*. Statistics Norway Report 2007/22. Retrieved from https://www.ssb.no/a/publikasjoner/pdf/rapp_200722/rapp_200722.pdf.

Castellacci, F. (2008). Technological paradigms, regimes and trajectories: Manufacturing and service industries in a new taxonomy of sectoral patterns of innovation. *Research Policy,37*(6-7), 978-994. doi:10.1016/j.respol.2008.03.011.

Castellacci, F. (2011). Closing the Technology Gap? *Review of Development Economics,15*(1), 180-197. doi:10.1111/j.1467-9361.2010.00601.x.

Castellacci, F., & Lie, C. (2013). *Do the effects of R&D tax credits vary across industries? A meta-regression analysis*. MPRA Paper No. 47937.

Castro, L. B. (2011). Privatização, Abertura e Desindexação: a Primeira Metade dos Anos 90 (1990-1994) [Privatization, Opening and Deindexation: the first half of the 1990s (1990-1994)]. In F. Giambiagi, A. Villela, L. B. Castro, & J. Hermann (eds.), *Economia brasileira contemporânea: 1945-2010*. Rio de Janeiro: Elsevier.

CD (Câmara dos Deputados) (n.d.). *MPV 252/2005* [Provisional Measure 252/2005]. Retrieved from http://www.camara.gov.br/proposicoesWeb/fichadetramitacao?idProposicao=290460.

Chang, H. J. (1994). *The political economy of industrial policy*. New York: St. Martin's Press.

Clarysse, B., Wright, M., & Mustar, P. (2009). Behavioural additionality of R&D subsidies: A learning perspective. *Research Policy,38*(10), 1517-1533. doi:10.1016/j.respol.2009.09.003.

Clausen, T. H. (2007). Do subsidies have positive impacts on R&D and innovation activities at the firm level? *Structural Change and Economic Dynamics,20*(4), 239-253. doi:10.1016/j.strueco.2009.09.004

Coase, R. H. (1937). The nature of the firm. *Economica, 4,* 386-405.

Cohen, W. M., & Klepper, S. (1996). Firm Size and the Nature of Innovation within Industries: The Case of Process and Product R&D. *The Review of Economics and Statistics,78*(2), 232. doi:10.2307/2109925.

Cohen, W. M., & Levinthal, D. A. (1989). Innovation and Learning: The Two Faces of R & D. *The Economic Journal,99*(397), 569. doi:10.2307/2233763.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly,35*(1), 128. doi:10.2307/2393553.

Colombo, M. G., Grilli, L., & Murtinu, S. (2011). R&D subsidies and the performance of high-tech start-ups. *Economics Letters,112*(1), 97-99. doi:10.1016/j.econlet.2011.03.007.

Corchuelo, B., & Martinez-Ros, E. (2009) *The Effects of Fiscal Incentives for R&D in Spain.* Business Economics Working Papers wb092302.

Corder, S., Salles-Filho, S. (2004). Financiamento e incentivos ao Sistema Nacional de Inovação [Financing and incentives to the National System of Innovation]. *Parcerias Estratégicas*, *19*.

Costa, I. (2005). *Technological learning, R&D and foreign affiliates in Brazil*. Globalization Of R&D and Developing Countries - Proceedings of the Expert Meeting Geneva 24-26 January 2005 (UNCTAD). New York and Geneva: United Nations, 2005.

Cozzi, G. (2005). Animal spirits and the composition of innovation. *European Economic Review,49*(3), 627-637. doi:10.1016/j.euroecorev.2003.08.003.

Creamer, D. B. (1976). *Overseas Research and Development by United States Multinationals, 1966-1975*: Estimates of Expenditures and a Statistical Profile. Conference Board report no. 685. The Conference Board, New York.

Crespi, G., Giuliodori, D., Giuliodori, R., & Rodriguez, A. (2016). The effectiveness of tax incentives for R&D+I in developing countries: The case of Argentina. *Research Policy*, http://dx.doi.org/10.1016/j.respol.2016.07.006.

Criscuolo, P. (2004). *R&D internationalization and knowledge transfer:* Impact on MNEs and their home countries. Ph.D thesis, MERIT, Maastricht.

Cruz, H. N., & Fasti de Souza, R. (2014). Sistema Nacional de Inovação e a Lei da Inovação: análise comparativa entre o Bayh-Dole Act e a lei da inovação tecnológica [The national system of innovation and the innovation law: comparative analysis with Bayh-Dole Act and technological innovation law]. *Revista de Administração e Inovação*, *11*(4), 329-354.

Cunningham, P., Gök, A, & Larédo, P. (2012). The Impact of Direct Support to R&D and Innovation in Firms. In J. Edler (org.), *Compendium of Evidence on the Effectiveness of Innovation Policy Intervention*. Manchester Institute of Innovation Research (MIoIR).

Czarnitzki, D., Hanel, P., & Rosa, J. M. (2011). Evaluating the impact of R&D tax credits on innovation: A microeconometric study on Canadian firms. *Research Policy,40*(2), 217-229. doi:10.1016/j.respol.2010.09.017.

Czarnitzki, D., Kraft, K., & Thorwarth, S. (2009). The knowledge production of 'R' and 'D', *Economics Letters*, 105(1), 141–3.

Dagenais, M., Mohnen, P., & Therrien, P. (1997). *Do Canadian Firms Respond to Fiscal Incentives to Research and Development?* CIRANO Scientific Series 97s-34.

David, P. A., & Hall, B. H. (2000). Heart of darkness: modeling public–private funding interactions inside the R&D black box. *Research Policy,29*(9), 1165-1183. doi:10.1016/s0048-7333(00)00085-8.

David, P. A., Hall, B. H., & Toole, A. A. (2000). Is public R&D a complement or substitute for private R&D? A review of the econometric evidence. *Research Policy,29*(4-5), 497-529. doi:10.1016/s0048-7333(99)00087-6.

De Negri, F., De Negri, J. A., & Lemos, M. B. (2009). Impactos do ADTEN e do FNDCT sobre o Desempenho e os Esforços Tecnológicos das Firmas Industriais Brasileiras [Impacts of ADTEN and FNDCT on the performance and technological efforts of Brazilian industrial firms]. *Revista Brasileira de Inovação, 8*(1), 211-254.

De Rassenfosse, G., Dernis, H., Guellec, D., Picci, L., & Bruno Van Pottelsberghe De La Potterie. (2013). The worldwide count of priority patents: A new indicator of inventive activity. *Research Policy,42*(3), 720-737. doi:10.1016/j.respol.2012.11.002.

Dehejia, R. H., & Wahba, S. (1999). Causal Effects in Nonexperimental Studies: Reevaluating the Evaluation of Training Programs. *Journal of the American Statistical Association,94*(448), 1053. doi:10.2307/2669919.

Dehejia, R. H., & Wahba, S. (2002). Propensity Score-Matching Methods for Nonexperimental Causal Studies. *Review of Economics and Statistics,84*(1), 151-161. doi:10.1162/003465302317331982.

Delloite (2014). *2014 Global Survey of R&D Tax Incentives*. Retrieved from http://www2.deloitte.com/content/dam/Deloitte/global/Documents/Tax/dttl-tax-global-rd-survey-aug-2014.pdf.

Den Hertog, R. G. J., & Thurik, A. R. (1993). *Determinants of internal and external R&D: Some Dutch evidence*. *De Economist*, *141*(2), 279–289. doi: 10.1007/bf01717384.

D'este, P., & Vega-Jurado, J. (2012). *The role of human capital in lowering the barriers to engaging in innovation: evidence from the Spanish innovation survey*. INGENIO (CSIC-UPV) Working Paper Series 201206.

Diamond, A. (1999). Does federal funding "crowd in" private funding of science? *Contemporary Economic Policy*, *17*(4), 423-431.

Dias, A. A., Teixeira, I. G. R., Queiroz, S. R. R., & Galina, S. V. R. (2013). Atividades de P&D das Multinacionais Farmacêuticas no Brasil [R&D activities of pharmaceutical multinationals in Brazil]. *Sistemas & Gestão, 8*, 458-468.

Diprete, T. A., & Gangl, M. (2004). *Assessing bias in the estimation of causal effects: Rosenbaum bounds on matching estimators and instrumental variables estimation with imperfect instruments*. Discussion Papers / Wissenschaftszentrum Berlin für Sozialforschung, Forschungsschwerpunkt Arbeit, Sozialstruktur und Sozialstaat, Abteilung Arbeitsmarktpolitik und Beschäftigung 2004-101.

Domingue, B., & Briggs, D. C. (2009). *Using Linear Regression and Propensity Score Matching to Estimate the Effect of Coaching on the SAT*. Retrieved from University of Colorado http://www.colorado.edu/education/sites/default/files/attached-files/Domingue_Briggs _Using%20Propensity%20Score%20Matching.pdf.

Dosi, G., & Marengo, L. (2007). *On the convergence of evolutionary and behavioral theories of organizations: a tentative roadmap*. LEM Working Paper Series, 2007.

Duguet, E. (2012). The effect of the incremental R&D tax credit on the private funding of R&D an econometric evaluation on French firm level data. *Revue d'économie politique*,*122*(3), 405-435.

Dumont, M. (2013). *The impact of subsidies and fiscal incentives on corporate R&D expenditures in Belgium (2001-2009)*. Federal Planning Bureau Working Paper 1-13.

Dumont, M., Spithoven, A., & Teirlinck, P. (2014). *Public support for R&D and the educational mix of R&D employees*. Federal Planning Bureau Working Paper 8-14.

Dunning, J. H. (1958). *American investment in British manufacturing industry*. London: George Allen and Unwin.

Dunning, J. H. (1988a). The Eclectic Paradigm of International Production: A Restatement and Some Possible Extensions. *Journal of International Business Studies,19*(1), 1-31. doi:10.1057/palgrave.jibs.8490372.

Dunning, J. H. (1994). Multinational enterprises and the globalization of innovatory capacity. *Research Policy,23*(1), 67-88. doi:10.1016/0048-7333(94)90027-2.

Dunning, J. H. (1998). Location and the Multinational Enterprise: A Neglected Factor? *Journal of International Business Studies,29*(1), 45-66. doi:10.1057/palgrave.jibs.8490024.

EC (1998). *Internationalisation of Research and Technology: Trends, Issues and Implications for S&T Policies in Europe*. ETAN Working Paper.

EC (2010). *Lisbon Strategy evaluation document.* Commission Staff Working Document. Retrieved from http://ec.europa.eu/europe2020/pdf/lisbon_strategy_evaluation_en.pdf.

EC (2012). *Internationalisation of business investments in R&D and analysis of their economic impact*. Luxembourg: Publications Office of the European Union.

EC (2013). *Europe 2020 Flagship Initiative Innovation Union.* Luxembourg: Publications Office of the European Union.

EC (2014). *A Study on R&D Tax Incentives: Final Report*. Hague: : Publications Office of the European Union.

Edler, J. (2013). Review of Policy Measures to Stimulate Private Demand for Innovation. Concepts and Effects. In J. Edler (org.), *Compendium of Evidence on the Effectiveness of Innovation Policy Intervention*. Manchester Institute of Innovation Research (MIoIR).

Edler, J., Cunningham, P., Gök, A., & Shapira, P. (2013). Impacts of Innovation Policy: Synthesis and Conclusions. In J. Edler (org.), *Compendium of Evidence on the Effectiveness of Innovation Policy Intervention*. Manchester Institute of Innovation Research (MIoIR).

Edler, J., Meyer-Krahmer, F., & Reger, G. (2002). Changes in the strategic management of technology: results of a global benchmarking study. *R and D Management,32*(2), 149-164. doi:10.1111/1467-9310.00247.

Eisner, R., Albert, S. H., & Sullivan, M. A. (1984). The new incremental tax credit for R&D: Incentive or disincentive? *National Tax Journal*,*37*, 171-185.

Engenhar (2007). *Brasil é bom para P&D mundial*? [Is Brazil good for global R&D?] 5, 10-12.

E.P.O. (2015). *PATSTAT Online* [Dataset]. Retrieved from https://www.epo.org/searching-for-patents/business/patstat.html#tab1. Code used available upon request to the author.

Erber, F. & Vermulm, R. (1993). *Ajuste Estrutural e Estratégias Empresariais* [Structural Adjustment and Firms' Strategies]. Brasília: IPEA.

Eurostat (2016). *Innovation activities and expenditures in 2012 in the enterprises by NACE Rev. 2 activity and size class [inn_cis8_exp]* [Data file]. Retrieved from http://ec.europa.eu/eurostat/web/products-datasets/-/inn_cis8_exp.

Evangelista, R. (2000). Sectoral Patterns Of Technological Change In Services. *Economics of Innovation and New Technology,9*(3), 183-222. doi:10.1080/10438590000000008.

Evangelista, R., Perani, G., Rapiti, F., & Archibugi, D. (1997). Nature and impact of innovation in manufacturing industry: some evidence from the Italian innovation survey. *Research Policy,26*(4-5), 521-536. doi:10.1016/s0048-7333(97)00028-0.

Evans, P. B. (2008). In Search of the 21st Century Developmental State. *CGPE Working Paper*. University of Sussex: Brighton.

Falk, R. (2007). *Measuring the Effects of Public Support Schemes on Firms' Innovation Activities*. Survey Evidence from Austria. WIFO Working Papers, No. 267.

FAPESP (2011). *Indicadores de ciência, tecnologia e inovação em São Paulo 2010* [Indicators of Science, Technology and Innovation in São Paulo]. São Paulo: FAPESP.

Fabiani, S., & Sbragia, R. (2014). Tax Incentives for Technological Business Innovation in Brazil: The Use of the Good Law - Lei do Bem (Law No. 11196/2005). *Journal of technology management & innovation,9*(4), 53-63. doi:10.4067/s0718-27242014000400004.

Fernández-Ribas, A., & Shapira, P. (2009). Technological diversity, scientific excellence and the location of inventive activities abroad: the case of nanotechnology. *The Journal of Technology Transfer,34*(3), 286-303. doi:10.1007/s10961-008-9090-2.

French Assemblée Nationale (2010). *Rapport d`information en conclusion des travaux de la mission d`évaluation et de contrôle sur le credit d`impôt recherché* [Report on the works of the evaluation and control mission on research tax credit]. Rapport n. 2.686, 30 de juin 2010, Paris.

Freeman, C. (1988). Japan: A New National System of Innovation. In Dosi, G. (ed.), *Technical change and economic theory*. London: Pinter, 330-348.

Gaillard-Ladinska, E., Non, M., & Straathof, B. (2014). *More R&D with tax incentives? A meta-analysis*. CPB Discussion Paper 309.

Galina, S. V., Camillo, E., & Consoni, F. (2011). *Por que empresas Multinacionais Investem em P&D em Países em Desenvolvimento?* Uma análise entre Fatores de Atração *versus* Tipo de P&D realizada no Brasil. [Why multinationals invest in R&D in developing countries? An analysis of Attraction factors versus type of R&D performed in Brazil] XXXV Encontro da ANPAD, Rio de Janeiro.

Gangl, M. (2004). *RBOUNDS*: *Stata module to perform Rosenbaum sensitivity analysis for average treatment effects on the treated*. Retrieved from http://econpapers.repec.org/software/bocbocode/s438301.htm.

Garcia-Quevedo, J., Mas-Verdú, F., & Polo-Otero, J. (2011). R&D human resources in firms: What determines the educational level required? *Applied Economics Letters,18*(16), 1537-1540. doi:10.1080/13504851.2010.548774.

Georghiou, L. (1994). *Impact of the Framework Programme on European Industry*. Brussels: European Commission.

Georghiou, L., & Clarysse, B. (2006). Introduction and Synthesis. In OECD(ed.) *Government R&D Funding and Company Behaviour - Measuring Behavioural Additionality*. Paris: OECD Publishing.

Gil, P. M. (2013). Animal spirits and the composition of innovation in a lab-equipment R&D model with transition. *Journal of Economics,108*(1), 1-33. doi:10.1007/s00712-012-0266-8.

Gok, A., & Edler, J. (2012). The use of behavioural additionality evaluation in innovation policy making. *Research Evaluation,21*(4), 306-318. doi:10.1093/reseval/rvs015.

Granstrand, O., Patel, P., & Pavitt, K. (1997). Multi-Technology Corporations: Why They Have “Distributed” Rather Than “Distinctive Core” Competencies. *California Management Review,39*(4), 8-25. doi:10.2307/41165908.

Greene,W. H. (2012). *Econometric analysis*. 7ed. Prentice Hall: Upper Saddle River.

Griffith T., Miller, H., & O’Connell, M. (2010). *The UK will introduce a patent box, but to whose benefit?* IFS working paper 5362, London: Institute for Fiscal Studies.

Griffith, R., Redding, S., & Reenen, J. V. (2004). Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries. *Review of Economics and Statistics,86*(4), 883-895. doi:10.1162/0034653043125194.

Griffith, R., Sandler, D., & Van Reenen, J. (1995). Tax Incentives for R&D. *Fiscal Studies*, 16(2), 21-44.

Griliches, Z. (1958). Research Costs and Social Returns: Hybrid Corn and Related Innovations. *Journal of Political Economy,66*(5), 419-431. doi:10.1086/258077.

Griliches, Z. (1984). *R&D, Patents, and Productivity*. Chicago: University of Chicago Press.

Griliches, Z. (1986) .*Productivity, R&D, and basic research at the firm level in the 1970s*. NBER working paper no. 1547.

Griliches, Z. (1992). The search for R&D spillovers. *Scandinavian Journal of Economics,94*, 29-47.

Grossman, G. M., & Helpman, E. (1991). Quality Ladders in the Theory of Growth. *The Review of Economic Studies,58*(1), 43. doi:10.2307/2298044.

Guceri, I. (2015). Tax incentives and R&D: an evaluation of the 2002 UK reform using micro data. *Oxford University Center for Business Taxation Working Paper Series WP15/11*.

Gwartney, J., Lawson, R., & Hall, J. (2015). *Economic Freedom of the World: 2015 Annual Report* [Dataset]. Fraser Institute, 2015. Retrieved from http://www.freetheworld.com/release.html.

Hægeland, T., & Møen, J. (2007). *Input additionality in the Norwegian R&D tax credit scheme.* Reports 2007/47 Statistics Norway.

Hall, B. H. (1990). *Investment and Research and Development at the firm level: Does the source of financing matter*? NBER Working Papers, n. 4096.

Hall, B. H. (1993). R&D Tax Policy During the 1980s: Success or Failure? In J. Poterba (ed.) *Tax Policy and the Economy*. Cambridge: MIT Press.

Hall, B. H. (1995). *Effectiveness of Research and Experimentation Tax Credits: Critical Literature Review and Research Design*. Report prepared for the Office of Technology Assessment, Congress of the United States. Retrieved from https://pdfs.semanticscholar.org/fa70/6c596661037fbb8bde299afc5dac73b49fbb.pdf.

Hall, B. H. (2011). The Internationalization of R&D. *SSRN Electronic Journal*. doi:10.2139/ssrn.2179941.

Hall, R., & Jorgenson, D. (1967). Tax policy and investment behaviour. *American Economic Review*, 57, 391–414.

Hall, B. H., & Lerner, J. (2009). *The Financing of R&D and Innovation*. NBER Working Paper Series. doi:10.3386/w15325.

Hall, B., & Reenen, J. V. (2000). How effective are fiscal incentives for R&D? A review of the evidence. *Research Policy, 29*(4-5), 449-469. doi:10.1016/s0048-7333(99)00085-2.

Hartmann, D. (2007). Understanding the Lisbon Strategy and policies from a Neo-Schumpeterian point of view. *Revista Universitaria Europea*, 7, 15-40.

Hatem, F. (2009). *Location Criteria of Activities related to Innovation: an econometric study on OECD AFA and FATS Data Bases*. OECD DSTI/IND/WPGI.

Hatem, F., & Py, L. (2008). *Location Factors in the Activities Related to Innovation of Multinationals:* A literature review. OECD DSTI/IND/WPGI(2008)6.

Higgins, R. S., & Link, A. N. (1981). Federal support of technological growth in industry: Some evidence of crowding out. *IEEE Transactions on Engineering Management,EM-28*(4), 86-88. doi:10.1109/tem.1981.6447450.

Himmelberg, C. P., & Petersen, B. C. (1994). R & D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries. *The Review of Economics and Statistics,76*(1), 38. doi:10.2307/2109824.

Hines Jr., J. R. (1993). On the sensitivity of R&D to delicate tax changes: the behavior of U.S. Multinationals in the 1980s. In A. Giovannini, R. G. Hubbard, & J. Slemrod (eds.), *Studies in International Taxation*. Chicago: University of Chicago.

Hines Jr., J. R. (1994). No Place like Home: Tax Incentives and the Location of R&D by American Multinationals. In J. M. Poterba (ed.), *Tax Policy and the Economy*, 8, Cambridge: MIT Press.

Hines Jr., J. R. (1995). Taxes, Technology Transfer, and the R&D Activities of Multinational Firms. In M. Feldstein, J. R. Hines Jr., & R. G. Hubbard (eds.), *The Effects of Taxation on Multinational Corporations.* Chicago: University of Chicago.

Hiratuka, C. (2008). *Foreign Direct Investment and Transnational Corporations in Brazil: Recent Trends and Impacts on Economic Development*. Working Group on Development and Environment in the Americas Discussion Paper Number 10. Retrieved from http://ase.tufts.edu/gdae/WGOverview.htm.

Ho, Y. (2006). *Evaluating the effectiveness of state R&D tax credits*, University of Pittsburgh.

Howitt, P. (1999). Steady Endogenous Growth with Population and R. & D. Inputs Growing. *Journal of Political Economy,107*(4), 715-730. doi:10.1086/250076.

IBGE (2007). *Pesquisa de inovação tecnológica: 2005* [Technological Innovation Survey: 2005]. Rio de Janeiro: IBGE.

IBGE (2010). *Pesquisa de inovação tecnológica: 2008* [Technological Innovation Survey: 2008]. Rio de Janeiro: IBGE.

IBGE (2013). *Pesquisa de inovação tecnológica: 2011* [Technological Innovation Survey: 2011]. Rio de Janeiro: IBGE.

Ientile, D., & Mairesse, J. (2009). A policy to boost R&D: Does the R&D tax credit work? *EIB Papers, 14*(1), 144-169.

Izsak, K., Markianidou, P., Lukach, R., & Wastyn, A. (2013). *The impact of the crisis on research and innovation policies*. Study for the European Commission DG Research by Technopolis Group Belgium and Idea Consult.

Jaffe, A. B., Trajtenberg, M., & Henderson, R. (1993). Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. *The Quarterly Journal of Economics,108*(3), 577-598. doi:10.2307/2118401.

Jaffe, A. B., & Le, T. (2015). *The Impact of R&D Subsidy on Innovation: A Study of New Zealand Firms.* NBER working paper series, working paper 21479.

Jindra, B., Hassan, S. S., & Cantner, U. (2016). What does location choice reveal about knowledge-seeking strategies of emerging market multinationals in the EU? *International Business Review,25*(1), 204-220. doi:10.1016/j.ibusrev.2014.11.008.

Jones, C. I. (1995). R & D-Based Models of Economic Growth. *Journal of Political Economy, 103*(4), 759-784. doi:10.1086/262002.

Jones, G. K., & Teegen, H. J. (2003). Factors affecting foreign R&D location decisions: management and host policy implications. *International Journal of Technology Management,25*(8), 791. doi:10.1504/ijtm.2003.003138.

Jones, C. I., & Williams, J. C. (1998). Measuring the Social Return to R&D. *The Quarterly Journal of Economics,113*(4), 1119-1135. doi:10.1162/003355398555856.

Jones C. I. (2005). Growth and Ideas. In P. Aghion, S. & Durlauf (eds.), *Handbook of Economic Growth*, volume 1B: 1064-1111. Amsterdam: North Holland.

Judson, R. A., & Owen, A. L. (1999). Estimating dynamic panel data models: a guide for macroeconomists. *Economics Letters,65*, 9–15.

Kannebley Jr., S., & Porto, G. (2012). *Incentivos Fiscais à Pesquisa, Desenvolvimento e Inovação no Brasil: Uma avaliação das políticas recentes* [Tax incentives to Research, Development and Innovation in Brazil: an assessment of recente policies]. Banco Interamericano de Desenvolvimento. Documento para discussão # IDB-DP-236.

Kannebley Jr., S., Araújo, B. C., Maffioli, A., & Stucchi, R. (2013). *Productive Development Policies and Innovation Spillovers through Labor Force Mobility: The Case of the Brazilian Innovation Support System*. IDB Working Paper Series No. IDB-WP-459.

King, M. A., & Fullerton, D. (eds.). (1984). *The taxation of income from capital: a comparative study of the United States, the United Kingdom, Sweden, and West Germany*. Chicago: University of Chicago Press.

Klassen, K. J., Pittmann, J. A., & Reed, M. P. (2004). *A Cross-National Comparison of R&D Expenditure Decisions: Tax Incentives and Financial Constraints*. Discussion Paper, University of Waterloo.

Klette, T. J., Møen, J., & Griliches, Z. (2000). Do subsidies to commercial R&D reduce market failures? Microeconometric evaluation studies. *Research Policy,29*(4-5), 471-495. doi:10.1016/s0048-7333(99)00086-4.

Knoll, B., Baumann, M., & Riedel, N. (2014). *The Global Effects of R&D Tax Incentives: Evidence from Micro-Data*. Beiträge zur Jahrestagung des Vereins für Socialpolitik 2014: Evidenzbasierte Wirtschaftspolitik - Session: Taxation II, No. B15-V2.

Knott, A. M. (2016). *Outsourced R&D and GDP.* U.S. CES Working Paper 16-19. Retrieved from https://www2.census.gov/ces/wp/2016/CES-WP-16-19.pdf.

Köler, C., Laredo, P., & Rammer, C. (2012). The Impact and Effectiveness of Fiscal Incentives for R&D. In J. Edler (org.), *Compendium of Evidence on the Effectiveness of Innovation Policy Intervention*. Manchester Institute of Innovation Research (MIoIR).

Kumar, N. (2001). Determinants of location of overseas R&D activity of multinational enterprises: the case of US and Japanese corporations. *Research Policy,30*(1), 159-174. doi:10.1016/s0048-7333(99)00102-x.

Lall, S. (1979). The International Allocation of Research Activity by US Multinationals. *Oxford Bulletin of Economics and Statistics,41*(4), 313-331.

Lam, A. (2005). Work Roles and Careers of R&D Scientists in Network Organizations. *Industrial Relations: A Journal of Economy and Society,44*(2), 242-275. doi:10.1111/j.0019-8676.2005.00383.x.

LaRiviere, J. (2014). *Government Subsidies and Incentives for R&D Collaboration Jacob LaRiviere*. Retrieved from http://web.utk.edu/~jlarivi1/docs/LaRiviere_RJV.pdf.

Le Bas, C., & Sierra, C. (2002). 'Location versus home country advantages' in R&D activities: some further results on multinationals' locational strategies. *Research Policy,31*(4), 589-609. doi:10.1016/s0048-7333(01)00128-7.

Lee, H., Miozzo, M., & Laredo, P. (2010). Career patterns and competences of PhDs in science and engineering in the knowledge economy: The case of graduates from a UK research-based university. *Research Policy,39*(7), 869-881. doi:10.1016/j.respol.2010.05.001.

Leiponen, A. (2005). Skills and innovation. *International Journal of Industrial Organization,23*(5-6), 303-323. doi:10.1016/j.ijindorg.2005.03.005.

Li, C. (2000). Endogenous vs. Semi-endogenous Growth in a Two-R&D-Sector Model. *The Economic Journal,110*(462), 109-122. doi:10.1111/1468-0297.00524.

Lin, P., & Saggi, K. (2002). Product differentiation, process R&D, and the nature of market competition. *European Economic Review,46*(1), 201-211. doi:10.1016/s0014-2921(00)00090-8.

Link, A. N. (1982). An Analysis of the Composition of R&D Spending. *Southern Economic Journal,49*(2), 342. doi:10.2307/1058486.

Link, A. N., & Rees, J. (1991). Firm Size, University-based Research and Returns to R&D. In Z. J. Acs, & D. B. Audretsch (eds.), *Innovation and Technological Change: An International Comparison*, 60-70.

Lokshin, B., Belderbos, R., & Carree, M. (2007). *The productivity effects of internal and external R&D: Evidence from a dynamic panel data model.* UNU-MERIT Working Paper Series, #2007-26.

Lokshin, B., Belderbos, R., & Carree, M. (2015). *Internal and external R&D: complements or substitutes? Evidence from a dynamic panel data model. Katholieke Universiteit Leuven*, Faculty of Economics and Applied Economics. OR 0604.

Love, J. H., & Roper, S. (2002). Internal Versus External R&D: A Study of R&D Choice with Sample Selection. *International Journal of the Economics of Business,9*(2), 239-255. doi:10.1080/13571510210134998.

Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics,22*(1), 3-42. doi:10.1016/0304-3932(88)90168-7.

Mairesse, J., & Mohnen, P. (2002). Accounting for Innovation and Measuring Innovativeness: An Illustrative Framework and an Application. *American Economic Review,92*(2), 226-230. doi:10.1257/000282802320189302.

Malerba, F., Mancusi, M. L., & Montobbio, F. (2013). Innovation, international R&D spillovers and the sectoral heterogeneity of knowledge flows. *Review of World Economics,149*(4), 697-722. doi:10.1007/s10290-013-0167-0.

Mansfield, E. (1980). Basic Research and Productivity Increase in Manufacturing. *American Economic Review*, *70*, 863-873.

Mansfield, E. (1981). Composition of R and D Expenditures: Relationship to Size of Firm, Concentration, and Innovative Output. *The Review of Economics and Statistics,63*(4), 610. doi:10.2307/1935857.

Martin, S., & Scott, J. T. (1998). *Market Failures and the Design of Innovation Policy*. Report prepared for the Working Group on Technology and Innovation Policy, Division of Science and Technology, OECD.

Matias-Pereira, J. (2015). Uma avaliação das políticas públicas de incentivo a inovação tecnológica no Brasil: a Lei do Bem [An assessment of innovation policies in Brazil: the Goodness Law]. *Parcerias Estratégicas*, 18(36), 221-250.

Matias-Pereira, J., & Kruglianskas, I. (2005). Gestão de Inovação: a Lei de Inovação Tecnológica como ferramenta de apoio às políticas industrial e tecnológica do Brasil [Innovation management: the technological innovation law as an instrument of industrial and technology policy in Brazil]. *RAE-eletrônica*, 4(2).

Mazzucato, M. (2011). *The Entrepreneurial State*. Londres: Demos.

Mazzucato, M. (2015). *From Market Fixing to Market-Creating: A new framework for economic policy*. ISIGrowth Working Paper 2/2015.

Mckenzie, K. J., & Sershun, N. (2010). Taxation and R&D: An Investigation of the Push and Pull Effects. *Canadian Public Policy,36*(3), 307-324. doi:10.1353/cpp.2010.0005.

MCTI (2007). *Relatório Anual da Utilização dos Incentivos Fiscais – Ano Base 2006:* Capítulo III da Lei do Bem – Lei Nº 11.196/05 [Annual Report on the use of Tax Incentives: Fiscal Year 2006: Chapter III of Law 11,196/05]. Retrieved from http://leidobem.net.br/wp-content/uploads/2013/06/Relat%C3%B3rio_Anual_ Incentivos_Fiscais_MCTI_2006.pdf.

MCTI (2008). *Relatório Anual da Utilização dos Incentivos Fiscais – Ano Base 2007:* Capítulo III da Lei do Bem – Lei Nº 11.196/05 [Annual Report on the use of Tax Incentives: Fiscal Year 2007: Chapter III of Law 11,196/05]. Retrieved from http://inei.org.br/inovateca/mct-relatorio-anual-do-uso-de-incentivos-fiscais/MCT%20-%20Relatorio%20Anual%20da%20Utilizacao%20dos%20Incentivos%20 Fiscais-%20 Ano%20Base%202007%20-27866.pdf/view.

MCTI (2009). *Relatório Anual da Utilização dos Incentivos Fiscais – Ano Base 2008:* Capítulo III da Lei do Bem – Lei Nº 11.196/05 [Annual Report on the use of Tax Incentives: Fiscal Year 2008: Chapter III of Law 11,196/05]. Retrieved from http://inei.org.br/inovateca/mct-relatorio-anual-do-uso-de-incentivos-fiscais/MCT%20-%20Relatorio%20Anual%20da%20Utilizacao%20dos%20Incentivos%20Fiscais-%20Ano%20Base%202008.pdf/view.

MCTI (2010). *Relatório Anual da Utilização dos Incentivos Fiscais – Ano Base 2009:* Capítulo III da Lei do Bem – Lei Nº 11.196/05 [Annual Report on the use of Tax Incentives: Fiscal Year 2009: Chapter III of Law 11,196/05]. Retrieved from http://inei.org.br/inovateca/mct-relatorio-anual-do-uso-de-incentivos-fiscais/MCT%20-%20Relatorio%20Anual%20da%20Utilizacao%20dos%20 Incentivos%20Fiscais-%20 Ano%20Base%202009%20-%2093B2Ad01.pdf/view.

MCTI (2011). *Relatório Anual da Utilização dos Incentivos Fiscais – Ano Base 2010:* Capítulo III da Lei do Bem – Lei Nº 11.196/05 [Annual Report on the use of Tax Incentives: Fiscal Year 2010: Chapter III of Law 11,196/05]. Retrieved from http://inei.org.br/inovateca/mct-relatorio-anual-do-uso-de-incentivos-fiscais/MCT-Relatorio_Anual_da_Utilizacao_dos_Incentivos_Fiscais-Ano_Base_2010-218612.pdf/view.

MCTI (2012a). *Estratégia Nacional de Ciência, Tecnologia e Inovação: balanço das atividades estruturantes 2011* [National Strategy of Science, Technology and Innovation: analysis of structural activities 2011]. Brasília: MCTI. Retrieved from http://www.mcti.gov.br/index.php/content/view/336399/Estrategia_Nacional_de_Ciencia_Tecnologia_e_Inovacao_2012_2015_e_Balanco_das_Atividades_Estruturantes_2011.html.

MCTI (2012b). *Relatório Anual da Utilização dos Incentivos Fiscais – Ano Base 2011:* Capítulo III da Lei do Bem – Lei Nº 11.196/05 [Annual Report on the use of Tax Incentives: Fiscal Year 2011: Chapter III of Law 11,196/05]. Retrieved from http://inei.org.br/inovateca/mct-relatorio-anual-do-uso-de-incentivos-fiscais/Relatorio%20Incentivos%20Fiscais%20-%20Ano%202011.pdf/view.

MCTI (2013). *Relatório Anual da Utilização dos Incentivos Fiscais – Ano Base 2012:* Capítulo III da Lei do Bem – Lei Nº 11.196/05 [Annual Report on the use of Tax Incentives: Fiscal Year 2012: Chapter III of Law 11,196/05]. Retrieved from http://www.mct.gov.br/upd_blob/0229/229781.pdf.

MCTI (2015a). *Brasil: Dispêndio nacional em pesquisa e desenvolvimento (P&D) em valores correntes, em relação ao total de P&D e ao produto interno bruto (PIB), por setor institucional, 2000-2013* [Brazil: National spending on R&D in current values, as a share of total R&D and GDP, per institutional sector, 2000-2013 - Data file]. Retrieved from http://www.mct.gov.br/index.php/content/view/29144/Brasil_Dispendio_nacional_em_pesquisa_e_desenvolvimento_P_D_em_valores_correntes_em_relacao_ao_total_de_P_D_e_ao_produto_interno_bruto_PIB_por_setor_institucional.html.

MCTI (2015b). *Lei do Bem - Utilização dos Incentivos Fiscais à Inovação Tecnológica – Ano Base 2013*: Capítulo III da Lei do Bem – Lei Nº 11.196/05 [Annual Report of the use of tax incentives - base year 2013: chapter III of Law 11,196/05]. Brasília.

MCTI (2016). *Lei do Bem - Utilização dos Incentivos Fiscais à Inovação Tecnológica – Ano Base 2014:* Capítulo III da Lei do Bem – Lei Nº 11.196/05 [Annual Report on the use of Tax Incentives: Fiscal Year 2014: Chapter III of Law 11,196/05]. Retrieved from http://www.mct.gov.br/upd_blob/0239/239671.pdf.

MDIC (n.d.). *Empresas Brasileiras Importadoras e Exportadoras* [Brazilian Importing and Exporting Firms] [Data file]. Retrieved from http://www.mdic.gov.br/index.php/comercio-exterior/estatisticas-de-comercio-exterior/empresas-brasileiras-exportadoras-e-importadoras.

Mechin A. (2006). *Une perspective relationnelle de la territorialité des firmes: le cas d'extension du site caennais de recherche-développement de Philips semi-conducteurs*. Roneo, école de management de Normandie. Retrieved from http://www.ecole-management-normandie.fr/metis/images/rapportsactivite/attractiviteterritoriale 2006.pdf.

Metcalfe, J. S. (1994). Evolutionary Economics and Technology Policy. *The Economic Journal,104*(425), 931. doi:10.2307/2234988.

Minniti, A. (2010). Product market competition, R&D composition and growth. *Economic Modelling,27*(1), 417-421. doi:10.1016/j.econmod.2009.10.008.

Miotti, L., & Sachwald, F. (2003). Co-operative R&D: why and with whom? *Research Policy,32*(8), 1481-1499. doi:10.1016/s0048-7333(02)00159-2.

Mohnen, P. (1999). Tax Incentives: Issue and Evidence. *CIRANO Scientific Series 99s-32*.

Mowery, D. C. (1983). The relationship between intrafirm and contractual forms of industrial research in American manufacturing, 1900–1940. *Explorations in Economic History,20*(4), 351-374. doi:10.1016/0014-4983(83)90024-4.

Mowery, D. C. (1992). The U.S. national innovation system: Origins and prospects for change. *Research Policy,21*(2), 125-144. doi:10.1016/0048-7333(92)90037-5.

Mowery, D. C., & Rosenberg, N. (1989). *Technology and the pursuit of economic growth*. Cambridge: Cambridge University Press.

Nadiri, M. I. (1993). *Innovations and Technological Spillovers.* Economic Research Report 93-31, New York University, Department of Economics.

Narula, R. (2001). Choosing Between Internal and Non-internal R&D Activities: Some Technological and Economic Factors. *Technology Analysis & Strategic Management,13*(3), 365-387. doi:10.1080/09537320120088183.

Nauwelaers, C (2009). *Policy Mixes for R&D in Europe. A study commissioned by the European Commission*. Directorate-General for Research. UNU-MERIT. Retrieved from http://www.eurosfaire.prd.fr/7pc/doc/1249471847_policy_mixes_rd_ue_2009.pdf.

Neicu, D., Teirlinck, P., & Kelchtermans, S. (2014). *Dipping in the policy mix: do R&D subsidies foster behavioral additionality effects of R&D tax credits?* KU Leuven MSI_1409.

Nelson, R. R. (1959). The Simple Economics of Basic Scientific Research. *Journal of Political Economy,67*(3), 297-306. doi:10.1086/258177.

Nelson, R. R. (1993). A Retrospective. In R. R. Nelson (ed), *National Innovation Systems: a Comparative Analysis*. New York, Oxford: Oxford University.

Nelson, R. R., & Phelps, E. S. (1966). Investment in Humans, Technological Diffusion, and Economic Growth. *The American Economic Review*, *56*(1/2), 69-75.

Nelson, R. R., & Winter, S. G. (1974). Neoclassical vs. Evolutionary Theories of Economic Growth: Critique and Prospectus. *The Economic Journal,84*(336), 886. doi:10.2307/2230572.

Nelson, R. R., & Winter, S. G. (2005). *Uma Teoria Evolucionária da Mudança Econômica* [An Evolutionary Theory of Economic Change]. Campinas: UNICAMP.

NSF (2002). *R&D in Industry: 1999* [Dataset]. Retrieved from https://www.nsf.gov/statistics/srvyindustry/.

NSF (2003). *R&D in Industry: 2000* [Dataset]. Retrieved from https://www.nsf.gov/statistics/srvyindustry/.

NSF (2005). *R&D in Industry: 2001* [Dataset]. Retrieved from https://www.nsf.gov/statistics/srvyindustry/.

NSF (2006). *Research and Development in Industry: 2002* [Dataset]. Retrieved from https://www.nsf.gov/statistics/srvyindustry/.

NSF (2007). *Research and Development in Industry: 2003* [Dataset]. Retrieved from https://www.nsf.gov/statistics/srvyindustry/.

NSF (2009). *Research and Development in Industry: 2004* [Dataset]. Retrieved from https://www.nsf.gov/statistics/srvyindustry/.

NSF (2010). *Research and Development in Industry: 2005* [Dataset]. Retrieved from https://www.nsf.gov/statistics/srvyindustry/.

NSF (2013a). *Business Research and Development and Innovation: 2008-2010* [Dataset]. Retrieved from https://www.nsf.gov/statistics/srvyindustry/.

NSF (2013b). *Business R&D and Innovation Survey, 2013* [Data file]. Retrieved from http://www.nsf.gov/statistics/srvyindustry/.

NSF (2014). *Business Research and Development and Innovation: 2011* [Dataset]. Retrieved from https://www.nsf.gov/statistics/srvyindustry/.

NSF (2015). *Business Research and Development and Innovation: 2012* [Dataset]. Retrieved from https://www.nsf.gov/statistics/srvyindustry/.

OCDE (1994). *Patent Manual 1994:* The measurement of scientific and technological activities - using patent data as science and technology indicators. Paris: OECD Publishing.

OECD (1995). *Manual on the Measurement of Human Resources devoted to S&T*. Paris: OECD Publishing.

OCDE (1997). *Oslo Manual* - Guidelines for Collecting and Interpreting Innovation Data. 2nd ed. Paris: OECD Publishing.

OCDE (2005). *Oslo Manual* - Guidelines for Collecting and Interpreting Innovation Data. 3rd ed. Paris: OECD Publishing.

OECD (2006a). *OECD Science, Technology and Industry Outlook 2006.* Paris: OECD Publishing.

OECD (2006b). *Government R&D Funding and Company Behaviour - Measuring Behavioural Additionality*. Paris: OECD Publishing.

OCDE (2008a). *OECD Science, Technology and Industry Outlook 2008*. OECD Publishing.

OECD (2008b). *The internationalization of Business R&D: evidence, impacts and implications*. Paris: OECD Publishing.

OECD (2009). *Policy Responses to the Economic Crisis: Investing in Innovation for Long-Term Growth*. Paris: OECD Publishing.

OCDE (2011a). *The International Experience with R&D Tax Incentives*. Testimony by the Organization for Economic Cooperation and Development - United States Senate Committee on Finance. Retrieved from http://www.finance.senate.gov/imo/media/doc/OECD%20SFC%20Hearing%20testimony%209%2020%2011.pdf.

OECD (2011b). *Attractiveness for Innovation: Location Factors for International Investment*. Paris: OECD Publishing.

OCDE (2013a). *Supporting Investment in Knowledge Capital, Growth and Innovation.* Paris: OECD Publishing.

OCDE (2013b). *Main features of R&D tax incentives provisions in selected OECD and non OECD countries, 2013*. Retrieved from http://www.oecd.org/sti/rd-tax-stats.htm.

OCDE (2014a). *OECD Science, Technology and Industry Outlook 2014*. Paris: OECD Publishing.

OCDE (2014b). *Direct government funding of business R&D and tax incentives for R&D, 2012 and 2006*. Retrieved from http://www.oecd.org/sti/rd-tax-stats.htm.

OECD (2015a). *Frascati Manual 2015:* Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities. Paris: OECD publishing.

OCDE (2015b). *OECD Science, Technology and Industry Scoreboard 2015:* Innovation for growth and society. Paris: OECD Publishing.

OECD (2015c). *The Innovation Imperative: Contributing to Productivity, Growth and Well-Being.* Paris: OECD Publishing. DOI: http://dx.doi.org/10.1787/9789264239814-en.

OECD (2015d). *OECD Economic Surveys: Brazil*. Paris: OECD Publishing.

OECD (2016). *OECD Science, Technology and Industry Outlook 2016.* Paris: OECD Publishing.

OECD (n.d.). *Main Science and Technology Indicators. MSTI 2016-1*. [Data file]. http://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB.

Pacheco, C. A. (2007). As reformas da política nacional de ciência, tecnologia e inovação no Brasil (1999-2002) [The reforms on the national policy of science, technology and innovation in Brazil (1999-2002)]. In *Manual de Políticas Públicas,* CEPAL.

Pavitt, K. (1984). Sectoral patterns of technical change: Towards a taxonomy and a theory. *Research Policy,13*(6), 343-373. doi:10.1016/0048-7333(84)90018-0.

Peri, G. (2005). Determinants of Knowledge Flows and Their Effect on Innovation. *Review of Economics and Statistics,87*(2), 308-322. doi:10.1162/0034653053970258.

Pinheiro, A. C., Gill, I. S., Servén, L., & Thomas, M. R. (2004). Brazilian Economic Growth, 1900-2000: Lessons and Policy Implications. *Interamerican Development Bank. Economic and Social Study Series RE1-04-011*.

Piva, M., & Vivarelli, M. (2009). The role of skills as a major driver of corporate R&D. *International Journal of Manpower,30*(8), 835-852. doi:10.1108/01437720911004452.

Queiroz, S. (2011). Obstáculos ao investimento em P&D de empresas estrangeiras no Brasil [Obstacles to the investment in R&D of foreign firms in Brazil]. *Revista USP*, *89,* 244-255.

Rafferty, M. (2003). Do Business Cycles Alter the Composition of Research and Development Expenditures? *Contemporary Economic Policy,21*(3), 394-405. doi:10.1093/cep/byg020.

Rao, N. (2013). *Do Tax Credits Stimulate R&D Spending? The Effect of the R&D Tax Credit in its First Decade*. NYU Wagner Research Paper 2272174.

Receita Federal (2015). Dados Setoriais 2009/2013 [Sector data 2009/2013] [Data file]. Retrieved from http://idg. receita.fazenda.gov.br/dados/receitadata/estudos-e-tributarios-e-aduaneiros/estudos-e-estatisticas/estudos-diversos/dados-setoriais-2009-2013.pdf.

Redding, S. (1996). The Low-Skill, Low-Quality Trap: Strategic Complementarities between Human Capital and R & D. *The Economic Journal,106*(435), 458. doi:10.2307/2235260.

Rivera-Batiz, L., & Romer, P. (1990). Economic Integration and Endogenous Growth. doi:10.3386/w3528.

Roach, M., & Sauermann, H. (2010). A taste for science? PhD scientists' academic orientation and self-selection into research careers in industry. *Research Policy,39*(3), 422-434. doi:10.1016/j.respol.2010.01.004.

Robson, M. T. (1993). Federal Funding and the Level of Private Expenditure on Basic Research. *Southern Economic Journal,60*(1), 63. doi:10.2307/1059931.

Rodrik, D. (2008). The New Development Economics: We Shall Experiment, but How Shall We Learn? *SSRN Electronic Journal*. doi:10.2139/ssrn.1296115.

Romer, P. (1987). Growth Based on Increasing Returns Due to Specialization. *American Economic Review*, 77, 56–62.

Romer, P. M. (1990). Endogenous Technological Change. *Journal of Political Economy,98*(5, Part 2). doi:10.1086/261725.

Ronstadt, R. C. (1977). *Research and Development Abroad by U.S. Multinationals*. New York: Praeger.

Rosenbaum, P. R., & Rubin, D. B. (1983). The Central Role of the Propensity Score in Observational Studies for Causal Effects. *Biometrika,70*(1), 41. doi:10.2307/2335942.

Rosenbaum, P. R. (2010). *Design of Observational Studies*. New York: Springer-Verlag.

Rosenberg, N. (1994). *Exploring the Black Box: Technology, Economics, and History.* Cambridge: Cambridge University Press.

Rubin, D. B. (1980). Bias Reduction Using Mahalanobis-Metric Matching. *Biometrics,36*(2), 293. doi:10.2307/2529981.

Rubin, D. B. (2006). The designversus the analysis of observational studies for causal effects: parallels with the design of randomized trials. *Statistics in Medicine,26*(1), 20-36. doi:10.1002/sim.2739.

Ruiz, A. U. (2015). Motivações do P&D transnacional no Brasil e efeitos locais de absorção de conhecimento [Motives of transnational R&D in Brazil and local effects of knowledge absorption]. *Revista Brasileira de Inovação*, 14(2), 415-442.

Russo, B. (2004). A cost-benefit analysis of R&D tax incentives. *Canadian Journal of Economics/Revue Canadienne d`Economique,37*(2), 313-335. doi:10.1111/j.0008-4085.2004.854954554284.x.

Sachwald, F. (2007). Location choices within global innovation networks: the case of Europe. *The Journal of Technology Transfer,33*(4), 364-378. doi:10.1007/s10961-007-9057-8.

Safarian, A. E. (1966). *Foreign Ownership of Canadian Industry,* Toronto, McGraw Hill.

Saha, S. (1999). *R&D composition over the product life cycle*. Center For Economic Research Discussion Paper No. 309. University of Minessota.

Sala-I-Martin, X. (1990). Lecture Notes on Economic Growth. *NEER Working Paper No. 3563*.

Sapelak, A., & Ricalde, L. O. (2008). *Market versus technology drive in R&D internationalization:* four different patterns of managing research and development – As relates to Pfizer Inc. ULB – Solvay Business School GEST-D-425.

SBPC, & ABC (2016). *Em defesa de uma política de estado para a ciência, a tecnologia e a inovação* [For a state policy on science, technology and innovation]. Retrieved from http://www.abc.org.br/IMG/pdf/doc-6852.pdf.

Schumpeter, J. A. (2008). *The Theory of Economic Development:* An Inquiry into Profits, Capital, Credit, Interest and the Business Cycle. New Brunswick (U.S.A) and London (U.K.): Transaction Publishers.

Segerstrom, P. (2000). The Long-Run Growth Effects of R&D Subsidies. *Journal of Economic Growth,5*(3), 277-305. doi:10.1023/a:1009881717993.

Shimada, E., Kannebley Jr., S., & De Negri, F. (2013). Efetividade da Lei do Bem no Estímulo ao Investimento em P&D: uma análise com dados em painel [Effect of the Goodness Law on Fostering R&D Investment: an analysis with panel data]. ANPEC. Retrieved from http://www.anpec.org.br/encontro/2013/files_I/i9-10d0885d8e8543656887a8a4cb6c4466.pdf.

Shimizutani, S., & Todo, Y. (2008). What determines overseas R&D activities? The case of Japanese multinational firms. *Research Policy,37*(3), 530-544. doi:10.1016/j.respol.2007.11.010.

Servalli, G. (2009). *Competitive European regions through research and innovation1 Different theoretical approaches to innovation policies*. European Commission. Retrieved from http://ec.europa.eu/regional_policy/archive/policy/future/pdf/5_seravalli_final_formatted.pdf.

Siedschlag, I., Smith, D., Turcu, C., & Zhang, X. (2013). What determines the location choice of R&D activities by multinational firms? *Research Policy,42*(8), 1420-1430. doi:10.1016/j.respol.2013.06.003.

Solow, R. M. (1957). Technical Change and the Aggregate Production Function. *The Review of Economics and Statistics,39*(3), 312. doi:10.2307/1926047.

Spithoven, A., & Teirlinck, P. (2010). External R&d: Exploring The Functions And Qualifications Of R&d Personnel. *International Journal of Innovation Management,14*(06), 967-987. doi:10.1142/s1363919610002969.

Stewart, L. A., Warda, J., & Atkinson, R. D. (2012). *We're #27!: The United States Lags Far Behind in R&D Tax Incentive Generosity*. The Information Technology and Innovation Foundation. Retrieved from http://www2.itif.org/2012-were-27-b-index-tax.pdf.

Subramanian, A. M., Choi, Y. R., Lee, S., & Hang, C. (2015). Linking technological and educational level diversities to innovation performance. *The Journal of Technology Transfer,41*(2), 182-204. doi:10.1007/s10961-015-9413-z.

Tamayo, M.P. & Huergo, E. (2014). Determinants of internal versus external R&D Offshoring: Evidence from Spanish firms. *SSRN Electronic Journal*. doi: 10.2139/ssrn.2554147.

Teubal, M. (1997). A catalytic and evolutionary approach to horizontal technology policies (HTPs). *Research Policy,25*(8), 1161-1188. doi:10.1016/s0048-7333(96)00886-4.

Thomson, R. (2009). Tax Policy and the Globalisation of R&D. *The Australian National University Working Papers in Trade and Development*. Retrieved from http://rspas.anu.edu.au/economics/publications.php.

Thomson, R. (2013). National scientific capacity and R&D offshoring. *Research Policy,42*(2), 517-528. doi:10.1016/j.respol.2012.07.003.

Thursby, J., & Thursby, M. (2006). *Here or There? A Survey of Factors in Multinational R&D Location*. Washington DC: National Academies Press.

Tigre, P. B., Cassiolato, J. E., Szapiro, M. H. S., & Ferraz, J. C. (1999). Mudanças Instituticionais e Tecnologia: Impactos da Liberalização sobre o Sistema Nacional de Inovações [Institutional and Technological Change: Impacts of Liberalization on the National System of Innovation]. In R. Baumann (org.). Brasil: uma década em transição. Rio de Janeiro: Campos.

Trubek, D. (2009). *Developmental States and the Legal Order: Towards a New Political Economy of Development and Law*. Wisconsin Law School Legal Studies Research Paper Series Paper No. 1075.

Tullock, G., Seldon, A., & Brady, G. L. (2005). *Government failure: a primer in public choice.* Washington, D.C.: Cato Institute.

UNCTAD (2005a). *UNCTAD survey on the internationalization of R&D: current patterns and prospects on the internationalization of R&D*. New York and Geneva: United Nations.

UNCTAD (2005b). *World Investment Report 2005*: Transnational Corporations and the Internationalization of R&D. New York and Geneva: United Nations.

UNCTAD (2012). *World Investment Prospects Survey 2012–2014*. New York and Geneva: United Nations.

UNCTAD (2013). *World Investment Prospects Survey 2013–2015*. New York and Geneva: United Nations.

UNCTAD (2014). *World Investment Prospects Survey 2014–2016*. New York and Geneva: United Nations.

U.S. (2011). *A Strategy for American Innovation*: Securing Our Economic Growth and Prosperity. National Economic Council and Office of Science and Technology Policy. Retrieved from https://www.whitehouse.gov/sites/default/files/uploads/Innovation Strategy.pdf.

U.S. (2015). *A Strategy for American Innovation*. National Economic Council and Office of Science and Technology Policy. Retrieved from https://www.whitehouse.gov/sites/default/files/strategy_for_american_innovation_october_2015.pdf.

U.S. B.E.A. (n.d.). *Database on Activities of U.S. Affiliates of Foreign Multinational Enterprises* [Data file]. Retrieved from http://www.bea.gov/international/di1fdiop.htm.

U.S. GAO (1989). *Tax Policy and Administration: The Research Tax Credit has Stimulated Some Additional Research Spending*. GAO/GGD-89-114. Washington, DC: GAO.

U.S. JEC (2010). *The 2010 Joint Economic Report. Report 111-XXX*. Washington, D.C.: U.S. Government Printing Office.

U.S. Tariff Commission (1973). *Implications of Multinational Firms for World Trade and Investment for US Trade and Labor*. Washington, D.C.: U.S. Government Printing Office.

Van Pottelsberghe, B. (2003). *Raising EU R&D Intensity - Improving the Effectiveness of Public Support - Mechanisms for Private Sector Research and Development: Fiscal Measures*. Report to the European Commission by an Independent Expert Group. Retrieved from http://ec.europa.eu/invest-in-research/pdf/download_en/report_ fiscalmeasures.pdf.

Verspagen, B. (1992). Endogenous innovation in neoclassical growth models: A survey. *Journal of Macroeconomics,14*(4), 631-662. doi:10.1016/0164-0704(92)90004-r.

Verspagen, B., & Loo, I. D. (1999). Technology Spillovers between Sectors. *Technological Forecasting and Social Change,60*(3), 215-235. doi:10.1016/s0040-1625(98)00046-8.

Veugelers, R., & Cassiman, B. (1999). Make and buy in innovation strategies: evidence from Belgian manufacturing firms. *Research Policy,28*(1), 63-80. doi:10.1016/s0048-7333(98)00106-1.

Vilasuso, J., & Frascatore, M. R. (2000). Public policy and R&D when research joint ventures are costly. *Canadian Journal of Economics/Revue Canadienne d`Economique,33*(3), 818-839. doi:10.1111/0008-4085.00043.

Vonortas, N. S., & Aridi, A. (2012). *Innovation Policy Handbook*. Washington D.C.: The George Washington University, Center for International Science and Technology Policy.

Wang, H., & Chen, W. (2010). Is firm-specific innovation associated with greater value appropriation? The roles of environmental dynamism and technological diversity. *Research Policy,39*(1), 141-154. doi:10.1016/j.respol.2009.09.015.

Warda, J. (2013). *B-index time series 1981-2011* [Data file]. Retrieved from http://www.oecd-ilibrary.org / science-and-technology/oecd-science-technology-and-industry-outlook-2014/tax-incentives-for-r-amp-d-and-innovation_sti_outlook-2014-18-en.

WEF (2015). *The Human Capital Report 2015*. World Economic Forum.

Wieser, R. (2005). Research And Development Productivity And Spillovers: Empirical Evidence At The Firm Level. *Journal of Economic Surveys,19*(4), 587-621. doi:10.1111/j.0950-0804.2005.00260.x.

Williamson, O. (1989). Transaction cost economics. In R. Schmalensee, & Willig (eds.) *Handbook of Industrial Organization*. NorthHolland, Amsterdam, 136-182.

Wilson, D. J. (2009). Beggar Thy Neighbor? The In-State, Out-of-State, and Aggregate Effects of R&D Tax Credits. *Review of Economics and Statistics,91*(2), 431-436. doi:10.1162/rest.91.2.431.

WIPO (n.d.). *IP Statistics Data Center* [dataset]. Retrieved from http://ipstats.wipo.int/ipstatv2/index.htm?tab=patent.

Wolf, C., Jr. (1986). *Markets or Governments: Choosing Between Imperfect Alternatives.* A Rand Note, N2505-SF. Santa Monica: Rand Corporation. Retrieved from http://www.rand.org/content/dam/rand/pubs/notes/2006/N2505.pdf.

Wooldridge, J. M. (2002). *Econometric Analysis Of Cross Section And Panel Data*. MIT Press: Massachusetts.

World Bank (2010). *Innovation policy: a guide for developing countries*. Washington: World Bank.

World Bank (n.d.). *World Bank Indicators Database* [Dataset]. Retrieved from http://data.worldbank.org/indicator/NY.GDP.MKTP.CD.

Yang, C., Huang, C., & Hou, T. C. (2012). Tax incentives and R&D activity: Firm-level evidence from Taiwan. *Research Policy,41*(9), 1578-1588. doi:10.1016/j.respol.2012.04.006.

Yohei, K. (2011). *Effect of R&D Tax Credits for Small and Medium-sized Enterprises in Japan: Evidence from firm-level data*. RIETI Discussion Paper Series 11-E-066.

Young, A. (1992). A Tale of Two Cities: Factor Accumulation and Technical Change in Hong Kong and Singapore. *NBER Macroeconomics Annual,7*, 13. doi:10.2307/3584993.

Young, A. (1998). Growth without Scale Effects. *Journal of Political Economy,106*(1), 41-63. doi:10.1086/250002.

Zanutto, E. L. (2006). A Comparison of Propensity Score and Linear Regression Analysis of Complex Survey Data. *Journal of Data Science,4*, 67-91.

Zellner, A. (1962). An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias. *Journal of the American Statistical Association,57*(298), 348. doi:10.2307/2281644.

Zhu, P., Xu, W., & Lundin, N. (2006). The impact of government's fundings and tax incentives on industrial R&D investments—Empirical evidences from industrial sectors in Shanghai. *China Economic Review,17*(1), 51-69. doi:10.1016/j.chieco.2005.04.002.

Zúñiga-Vicente, J., Alonso-Borrego, C., Forcadell, F. J., & Galán, J. I. (2012). Assessing The Effect Of Public Subsidies On Firm R&d Investment: A Survey. *Journal of Economic Surveys,28*(1), 36-67. doi:10.1111/j.1467-6419.2012.00738.x.

# APPENDICES

## Appendix to Chapter 2

Table A2.1

*List of Covariates used in Studies applying the Direct Approach*

| Study | Firm size[a] | Part of Corporate group | Economic sector | Year | Export | Financial constraint | R&D intensity | Other public funding | Previous R&D spending | Age | Capital | Profita-bility | Indebt-edness | Location | Others |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Guceri (2015) | X | X | X | X | | | | | | | | | | | X |
| Aralica et al. (2013) | X | X | | | X | | | | | | | | | | X |
| Dumont (2013) | X | | X | X | | | | | | | | | | X | X |
| Yang et al. (2012) | X | | X | X | | | | | X | X | X | X | | | |
| Duguet (2012) | | | X | X | X | | X | X | | | | | | | |
| Czarnitzki et al. (2011) | X | | | | X | X | X | X | | | | | | | X |
| Carboni (2011) | X | | X | | X | X | | X | | | X | | X | | |
| Yohei (2011) | X | | X | | | X | | | | X | | X | X | X | X |
| Bérubé e Mohnen (2009) | X | | X | | | X | | | | | | | | X | X |
| Corchuelo e Martinez-Ros (2009) | X | | X | | | X | | X | X | | | | | | X |
| Hægeland e Møen (2007) | | | | X | | | | X | | | | | | | X |
| Ho (2006) | X | | | | | | | | | | | | | | |
| Avellar (2008) | X | | X | | X | | | | | X | | | X | X | X |
| Kannebley Jr. e Porto (2012) | X | | X | X | | | | | | X | | | | X | X |
| Kannebley Jr. et al (2013) | X | | X | X | X | | | | | X | | | | X | X |
| Shimada et al. (2014) | X | | X | | X | | | | | X | X | | | | X |

[a] Measured by total employment.

Table A2.2

*Descriptive Statistics for independent variables (input analysis)*

| Statistics | | Variable | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *personnel* | *age* | *nac_control* | *for_control* | *rd_cont* | *group* | *revenue* | *imp* | *exp* | *for_market* | *dummyN* | *dummyNE* | *dummySE* | *dummyS* | *dummyCO* |
| N | | 13706 | 6670 | 13706 | 13706 | 13564 | 13706 | 13704 | 13706 | 13706 | 13706 | 13706 | 13706 | 13706 | 13706 | 13706 |
| Mean | | 4.59 | 26.23 | 0.94 | 0.09 | 0.12 | 0.14 | 9.20 | 0.39 | 0.32 | 0.04 | 0.04 | 0.10 | 0.18 | 0.28 | 0.05 |
| std.dv. | | 1.43 | 12.89 | 0.25 | 0.28 | 0.33 | 0.35 | 2.30 | 0.49 | 0.46 | 0.21 | 0.19 | 0.30 | 0.38 | 0.45 | 0.22 |
| Percentil | 5% | 2.56 | 8.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.88 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 25% | 3.76 | 15.00 | 1.00 | 0.00 | 0.00 | 0.00 | 7.73 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 50% | 4.57 | 25.00 | 1.00 | 0.00 | 0.00 | 0.00 | 9.43 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 75% | 5.42 | 38.00 | 1.00 | 0.00 | 0.00 | 0.00 | 10.62 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 |
| | 95% | 6.94 | 45.00 | 1.00 | 1.00 | 1.00 | 1.00 | 12.49 | 1.00 | 1.00 | 0.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 |

Real 2011 values for whole PINTEC sample. Source: PINTEC 2011 (confidential disaggregate data).

Table A2.3

*Descriptive Statistics for independent variables (output and performance analysis)*

| Statistics | | Variable | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *personnel* | *age* | *nac_control* | *for_control* | *rd_cont* | *group* | *revenue* | *imp* | *exp* | *for_market* | *dummyN* | *dummyNE* | *dummySE* | *dummyS* | *dummyCO* |
| N | | 6567 | 6565 | 6567 | 6567 | 6526 | 6566 | 6562 | 13580 | 13580 | 6565 | 13580 | 13580 | 13580 | 13580 | 13580 |
| Mean | | 5.27 | 23.22 | 0.90 | 0.13 | 0.14 | 0.25 | 10.23 | 0.31 | 0.31 | 0.07 | 0.04 | 0.10 | 0.17 | 0.28 | 0.05 |
| std.dv. | | 1.14 | 12.90 | 0.31 | 0.34 | 0.35 | 0.43 | 1.74 | 0.46 | 0.46 | 0.25 | 0.20 | 0.30 | 0.38 | 0.45 | 0.22 |
| Percentil | 5% | 3.61 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 25% | 4.54 | 12.00 | 1.00 | 0.00 | 0.00 | 0.00 | 9.28 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 50% | 5.18 | 22.00 | 1.00 | 0.00 | 0.00 | 0.00 | 10.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 75% | 5.91 | 35.00 | 1.00 | 0.00 | 0.00 | 1.00 | 11.29 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 |
| | 95% | 7.34 | 42.00 | 1.00 | 1.00 | 1.00 | 1.00 | 12.96 | 1.00 | 1.00 | 1.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 |

Real 2008 values for whole PINTEC sample. Source: PINTEC 2008 (confidential disaggregate data).

Table A2.4

*Results of the Means Test for the estimated propensity score. Outcome Variable: in_exp*

| Variable | Mean | | %bias | %reduct | t-test | | V(T)/ |
|---|---|---|---|---|---|---|---|
| | Treated | Control | | \|bias\| | t | p>\|t\| | V(C) |
| *revenue* | 1.80E+05 | 2.80E+05 | -11.4 | 65 | -1.55 | 0.122 | 0.07 |
| *personnel* | 5.9526 | 6.0015 | -4.6 | 94.1 | -0.42 | 0.674 | 0.65 |
| *nac_control* | 0.7551 | 0.82993 | -20.1 | 56.3 | -1.58 | 0.114 | . |
| *for_control* | 0.27211 | 0.19048 | 20.8 | 51.8 | 1.66 | 0.098 | . |
| *rd_cont* | 0.7551 | 0.72109 | 7.5 | 91.9 | 0.66 | 0.509 | . |
| *group* | 0.31293 | 0.30612 | 1.6 | 96.1 | 0.13 | 0.9 | . |
| *imp* | 0.85034 | 0.87075 | -4.8 | 91.6 | -0.5 | 0.615 | . |
| *exp* | 0.77551 | 0.79592 | -4.4 | 92.9 | -0.43 | 0.671 | . |
| *for_market* | 0.04762 | 0.02041 | 12.6 | -237.2 | 1.29 | 0.199 | . |
| *dummyN* | 0.01361 | 0.02041 | -5 | 42.2 | -0.45 | 0.653 | . |
| *dummyNE* | 0.04082 | 0.06803 | -11.3 | 43.9 | -1.03 | 0.305 | . |
| *dummySE* | 0.13605 | 0.11565 | 5.7 | 8.8 | 0.53 | 0.599 | . |
| *dummyS* | 0.34694 | 0.36735 | -4.4 | 47.6 | -0.36 | 0.716 | . |
| *dummyCO* | 0.01361 | 0.0068 | 4.5 | 68.7 | 0.58 | 0.563 | . |
| *cnae_10* | 0.10204 | 0.10884 | -2.2 | 36.2 | -0.19 | 0.85 | . |
| *cnae_11* | 0.01361 | 0.01361 | 0 | 100 | 0 | 1 | . |
| *cnae_12* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_13* | 0.02041 | 0.02721 | -3.8 | 76.9 | -0.38 | 0.703 | . |
| *cnae_14* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_15* | 0.01361 | 0.0068 | 4.7 | 62.5 | 0.58 | 0.563 | . |
| *cnae_16* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_17* | 0.04762 | 0.05442 | -3.4 | 64.5 | -0.26 | 0.792 | . |
| *cnae_18* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_19* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_20* | 0.12925 | 0.10884 | 6.8 | 73.7 | 0.54 | 0.591 | . |
| *cnae_21* | 0.04762 | 0.02721 | 11.5 | 44.7 | 0.92 | 0.358 | . |
| *cnae_22* | 0.02721 | 0.02041 | 3.2 | 85.4 | 0.38 | 0.703 | . |
| *cnae_23* | 0.04082 | 0.04762 | -3.7 | -22.9 | -0.28 | 0.778 | . |
| *cnae_24* | 0.01361 | 0.03401 | -15.8 | -137.4 | -1.15 | 0.253 | . |
| *cnae_25* | 0.04082 | 0.04762 | -3.1 | 73.1 | -0.28 | 0.778 | . |
| *cnae_26* | 0.02721 | 0.05442 | -14.2 | -5.4 | -1.18 | 0.24 | . |
| *cnae_27* | 0.08163 | 0.08163 | 0 | 100 | 0 | 1 | . |
| *cnae_28* | 0.08844 | 0.06803 | 7.3 | -188.5 | 0.65 | 0.516 | . |
| *cnae_29* | 0.08844 | 0.08844 | 0 | 100 | 0 | 1 | . |
| *cnae_30* | 0.02041 | 0 | 17.4 | -94.7 | 1.74 | 0.082 | . |
| *cnae_31* | 0.04762 | 0.04762 | 0 | 100 | 0 | 1 | . |
| *cnae_32* | 0.02041 | 0.02721 | -4.7 | -37.4 | -0.38 | 0.703 | . |
| *cnae_33* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_35* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_38* | 0 | 0 | . | . | . | . | . |
| *cnae_50* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_58* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_59* | 0 | 0 | . | . | . | . | . |
| *cnae_60* | 0 | 0 | . | . | . | . | . |
| *cnae_61* | 0.0068 | 0.0068 | 0 | 100 | 0 | 1 | . |
| *cnae_62* | 0.11565 | 0.12925 | -4.8 | 68.6 | -0.35 | 0.723 | . |
| *cnae_63* | 0.0068 | 0 | 6.7 | -48.9 | 1 | 0.318 | . |
| *cnae_71* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_72* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_81* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_89* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_91* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_99* | 0 | 0 | . | . | . | . | . |

| Sample | Ps R2 | LR chi2 | p>chi2 | MeanBias | MedBias |
|---|---|---|---|---|---|
| Unmatched | 0.228 | 251.05 | 0 | 18.2 | 12.6 |
| Matched | 0.057 | 22.71 | 0.911 | 4.7 | 3.5 |

Variables' results for matched sample only.

Table A2.5

*Results of the Means Test for the estimated propensity score. Outcome Variable: rd_exp*

| Variable | Mean | | %bias | %reduct | t-test | | V(T)/ |
|---|---|---|---|---|---|---|---|
| | Treated | Control | | \|bias\| | t | p>\|t\| | V(C) |
| *revenue* | 3.60E+05 | 5.60E+05 | -23.6 | 4.7 | -1.17 | 0.244 | 0.21* |
| *personnel* | 6.1754 | 6.1979 | -2 | 97.1 | -0.17 | 0.868 | 0.73 |
| *age* | 28.341 | 28.719 | -2.9 | 82 | -0.25 | 0.804 | 1.36 |
| *nac_control* | 0.73333 | 0.76296 | -7.7 | 82.5 | -0.56 | 0.577 | . |
| *for_control* | 0.28889 | 0.25926 | 7.2 | 80.2 | 0.54 | 0.587 | . |
| *rd_cont* | 0.95556 | 0.91852 | 12.8 | 64.5 | 1.25 | 0.212 | . |
| *group* | 0.37037 | 0.37037 | 0 | 100 | 0 | 1 | . |
| *imp* | 0.86667 | 0.82222 | 11 | 73.2 | 1.01 | 0.315 | . |
| *exp* | 0.79259 | 0.77037 | 4.9 | 87.9 | 0.44 | 0.66 | . |
| *for_market* | 0.05185 | 0.02222 | 13 | -242.7 | 1.29 | 0.199 | . |
| *dummyN* | 0.01481 | 0 | 12.1 | -682.9 | 1.42 | 0.157 | . |
| *dummyNE* | 0.04444 | 0.02222 | 9.4 | 32.6 | 1.02 | 0.311 | . |
| *dummySE* | 0.15556 | 0.14074 | 4.1 | -120.3 | 0.34 | 0.733 | . |
| *dummyS* | 0.2963 | 0.34074 | -9.6 | -66.7 | -0.78 | 0.435 | . |
| *dummyCO* | 0.00741 | 0.01481 | -5 | 75.5 | -0.58 | 0.563 | . |
| *cnae_10* | 0.12593 | 0.08889 | 11.7 | -91.8 | 0.98 | 0.328 | . |
| *cnae_11* | 0.02222 | 0.02963 | -5.8 | 20.3 | -0.38 | 0.703 | . |
| *cnae_12* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_13* | 0.02222 | 0.02222 | 0 | 100 | 0 | 1 | . |
| *cnae_14* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_15* | 0.02222 | 0.02222 | 0 | 100 | 0 | 1 | . |
| *cnae_16* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_17* | 0.03704 | 0.04444 | -4 | 55.3 | -0.31 | 0.759 | . |
| *cnae_18* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_19* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_20* | 0.14815 | 0.11111 | 11.5 | 27.2 | 0.9 | 0.367 | . |
| *cnae_21* | 0.05185 | 0.06667 | -7.8 | 40.1 | -0.51 | 0.608 | . |
| *cnae_22* | 0.01481 | 0.01481 | 0 | 100 | 0 | 1 | . |
| *cnae_23* | 0.02963 | 0.03704 | -4.4 | -320.3 | -0.34 | 0.736 | . |
| *cnae_24* | 0.02222 | 0.03704 | -10.5 | -568.2 | -0.72 | 0.475 | . |
| *cnae_25* | 0.05185 | 0.05185 | 0 | 100 | 0 | 1 | . |
| *cnae_26* | 0.02222 | 0.00741 | 6.6 | 77.7 | 1.01 | 0.315 | . |
| *cnae_27* | 0.08889 | 0.08889 | 0 | 100 | 0 | 1 | . |
| *cnae_28* | 0.07407 | 0.07407 | 0 | 100 | 0 | 1 | . |
| *cnae_29* | 0.07407 | 0.08148 | -3.2 | 76.8 | -0.23 | 0.821 | . |
| *cnae_30* | 0.02222 | 0.00741 | 12.7 | 3.6 | 1.01 | 0.315 | . |
| *cnae_31* | 0.03704 | 0.03704 | 0 | 100 | 0 | 1 | . |
| *cnae_32* | 0.02222 | 0.01481 | 4.8 | -26.2 | 0.45 | 0.653 | . |
| *cnae_33* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_35* | 0 | 0 | . | . | . | . | . |
| *cnae_38* | 0 | 0 | . | . | . | . | .* |
| *cnae_50* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_58* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_59* | 0 | 0 | . | . | . | . | . |
| *cnae_60* | 0 | 0 | . | . | . | . | . |
| *cnae_61* | 0.00741 | 0.02963 | -21.1 | -258.6 | -1.35 | 0.177 | . |
| *cnae_62* | 0.1037 | 0.13333 | -9.9 | -95.8 | -0.75 | 0.453 | . |
| *cnae_63* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_71* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_72* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_81* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_89* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_91* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_99* | 0 | 0 | . | . | . | . | . |

| Sample | Ps R2 | LR chi2 | p>chi2 | MeanBias | MedBias |
|---|---|---|---|---|---|
| Unmatched | 0.155 | 123.41 | 0 | 14.5 | 9.6 |
| Matched | 0.048 | 17.78 | 0.986 | 4.9 | 3.2 |

Variables' results for matched sample only.

Table A2.6

*Results of the Means Test for the estimated propensity score. Outcome Variable: researcher*

| Variable | Mean | | %bias | %reduct | t-test | | V(T)/ |
|---|---|---|---|---|---|---|---|
| | Treated | Control | | \|bias\| | t | p>\|t\| | V(C) |
| *revenue* | 6.60E+05 | 1.00E+06 | -24.1 | 16.1 | -1.37 | 0.172 | 0.36* |
| *personnel* | 6.423 | 6.3647 | 4.8 | 93.6 | 0.45 | 0.649 | 0.69* |
| *age* | 28.731 | 30.183 | -10.9 | 38.7 | -0.94 | 0.346 | 0.79 |
| *nac_control* | 0.69714 | 0.70857 | -2.8 | 93.6 | -0.23 | 0.816 | . |
| *for_control* | 0.34286 | 0.33714 | 1.3 | 96.7 | 0.11 | 0.91 | . |
| *rd_cont* | 0.94857 | 0.96 | -3.9 | 87.3 | -0.51 | 0.61 | . |
| *group* | 0.41714 | 0.37714 | 8.7 | 78.2 | 0.76 | 0.446 | . |
| *imp* | 0.89714 | 0.88571 | 3 | 93.6 | 0.34 | 0.732 | . |
| *exp* | 0.80571 | 0.82286 | -3.9 | 90.8 | -0.41 | 0.681 | . |
| *for_market* | 0.07429 | 0.06857 | 2.2 | 19.6 | 0.21 | 0.836 | . |
| *dummyN* | 0.01714 | 0.02857 | -8.5 | -250.7 | -0.71 | 0.476 | . |
| *dummyNE* | 0.04 | 0.02286 | 7.4 | 51.7 | 0.92 | 0.359 | . |
| *dummySE* | 0.17143 | 0.15429 | 4.7 | -32.8 | 0.43 | 0.665 | . |
| *dummyS* | 0.26286 | 0.30857 | -10.1 | -15.7 | -0.95 | 0.345 | . |
| *dummyCO* | 0.01714 | 0.00571 | 6.9 | 48.9 | 1 | 0.316 | . |
| *cnae_10* | 0.10286 | 0.13143 | -9.5 - | 6009.3 | -0.83 | 0.407 | . |
| *cnae_11* | 0.01714 | 0.00571 | 9.5 | -184.2 | 1 | 0.316 | . |
| *cnae_12* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_13* | 0.01714 | 0.00571 | 7.4 | 24.3 | 1 | 0.316 | . |
| *cnae_14* | 0.00571 | 0 | 5.7 | 36.3 | 1 | 0.318 | . |
| *cnae_15* | 0.01714 | 0.01714 | 0 | 100 | 0 | 1 | . |
| *cnae_16* | 0.00571 | 0.00571 | 0 | 100 | 0 | 1 | . |
| *cnae_17* | 0.03429 | 0.02286 | 6.3 | -14.4 | 0.64 | 0.522 | . |
| *cnae_18* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_19* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_20* | 0.13143 | 0.16 | -9.1 | 17.8 | -0.76 | 0.45 | . |
| *cnae_21* | 0.06857 | 0.07429 | -2.7 | 84.9 | -0.21 | 0.836 | . |
| *cnae_22* | 0.01714 | 0.01143 | 3 | 86.5 | 0.45 | 0.654 | . |
| *cnae_23* | 0.02857 | 0.01143 | 10.1 | -470.6 | 1.14 | 0.253 | . |
| *cnae_24* | 0.02857 | 0.01714 | 7.3 | -87.5 | 0.71 | 0.476 | . |
| *cnae_25* | 0.04571 | 0.08571 | -18.1 - | 2422.1 | -1.51 | 0.132 | . |
| *cnae_26* | 0.04571 | 0.01714 | 11.6 | 30 | 1.53 | 0.126 | . |
| *cnae_27* | 0.08571 | 0.09714 | -4.4 | 50 | -0.37 | 0.712 | . |
| *cnae_28* | 0.06857 | 0.05714 | 4.3 | 27.5 | 0.44 | 0.661 | . |
| *cnae_29* | 0.09714 | 0.09143 | 2.2 | 90.6 | 0.18 | 0.855 | . |
| *cnae_30* | 0.02286 | 0.02857 | -4.7 | 62.1 | -0.34 | 0.736 | . |
| *cnae_31* | 0.02857 | 0.04571 | -10.8 | -301 | -0.85 | 0.398 | . |
| *cnae_32* | 0.01714 | 0.00571 | 7.9 | -18.7 | 1 | 0.316 | . |
| *cnae_33* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_35* | 0 | 0 | . | . | . | . | . |
| *cnae_38* | 0 | 0 | . | . | . | . | .* |
| *cnae_50* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_58* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_59* | 0 | 0 | . | . | . | . | . |
| *cnae_60* | 0 | 0 | . | . | . | . | . |
| *cnae_61* | 0.01143 | 0.01143 | 0 | 100 | 0 | 1 | . |
| *cnae_62* | 0.08571 | 0.09143 | -2 | -28 | -0.19 | 0.851 | . |
| *cnae_63* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_71* | 0.00571 | 0 | 9.4 | -51.7 | 1 | 0.318 | . |
| *cnae_72* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_81* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_89* | 0.00571 | 0.00571 | 0 | 100 | 0 | 1 | . |
| *cnae_91* | 0.00571 | 0 | 10 | -22.2 | 1 | 0.318 | . |
| *cnae_99* | 0 | 0 | . | . | . | . | . |
| Sample | Ps R2 | LR chi2 | p>chi2 | MeanBias | MedBias | | |
| Unmatched | 0.162 | 159.32 | 0 | 14.2 | 8.8 | | |
| Matched | 0.05 | 24.23 | 0.932 | 5.3 | 4.4 | | |

Variables' results for matched sample only.

Table A2.7

*Results of the Means Test for the estimated propensity score. Outcome Variable: in_dummy*

| Variable | Mean | | %bias | %reduct | t-test | | V(T)/ |
|---|---|---|---|---|---|---|---|
| | Treated | Control | | \|bias\| | t | p>\|t\| | V(C) |
| *revenue* | 3.00E+05 | 1.50E+06 | -41.8 | -65 | -1.99 | 0.049 | 0.02* |
| *personnel* | 6.0075 | 6.1027 | -7.1 | 94.3 | -0.43 | 0.671 | 0.55* |
| *age* | 25.459 | 22.23 | 24.6 | -58.9 | 1.44 | 0.152 | 1.38 |
| *nac_control* | 0.70492 | 0.72131 | -4.6 | 92.2 | -0.2 | 0.843 | . |
| *for_control* | 0.39344 | 0.39344 | 0 | 100 | 0 | 1 | . |
| *rd_cont* | 0.57377 | 0.54098 | 8.4 | 94.5 | 0.36 | 0.718 | . |
| *group* | 0.36066 | 0.40984 | -11.7 | 81.1 | -0.55 | 0.58 | . |
| *imp* | 0.86885 | 0.78689 | 19.3 | 82.6 | 1.2 | 0.234 | . |
| *exp* | 0.80328 | 0.72131 | 18.5 | 82 | 1.06 | 0.291 | . |
| *for_market* | 0.11475 | 0.04918 | 26.8 | -53.4 | 1.32 | 0.19 | . |
| *dummyN* | 0 | 0 | 0 | 100 | . | . | . |
| *dummyNE* | 0.06557 | 0.08197 | -6.6 | 76.3 | -0.34 | 0.732 | . |
| *dummySE* | 0.13115 | 0.18033 | -13.2 | -183.2 | -0.74 | 0.458 | . |
| *dummyS* | 0.36066 | 0.37705 | -3.6 | 54.4 | -0.19 | 0.853 | . |
| *dummyCO* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_10* | 0.04918 | 0.01639 | 11.4 | -13.4 | 1.01 | 0.313 | . |
| *cnae_11* | 0.03279 | 0 | 27 | -942 | 1.43 | 0.156 | . |
| *cnae_12* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_13* | 0.03279 | 0.04918 | -10.2 | 39.1 | -0.45 | 0.651 | . |
| *cnae_14* | 0.01639 | 0 | 8.5 | 75.2 | 1 | 0.319 | . |
| *cnae_15* | 0.01639 | 0 | 10.3 | 36.9 | 1 | 0.319 | . |
| *cnae_16* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_17* | 0.06557 | 0.04918 | 9.8 | -90.5 | 0.39 | 0.7 | . |
| *cnae_18* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_19* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_20* | 0.04918 | 0.01639 | 12.1 | 56.7 | 1.01 | 0.313 | . |
| *cnae_21* | 0.04918 | 0.06557 | -9.8 | 52.8 | -0.39 | 0.7 | . |
| *cnae_22* | 0.04918 | 0.08197 | -15.6 | -21.8 | -0.73 | 0.469 | . |
| *cnae_23* | 0.08197 | 0.14754 | -32.1 | -209.8 | -1.13 | 0.26 | . |
| *cnae_24* | 0.01639 | 0.03279 | -10.1 | -200.5 | -0.58 | 0.563 | . |
| *cnae_25* | 0.01639 | 0 | 7.2 | 58.1 | 1 | 0.319 | . |
| *cnae_26* | 0.01639 | 0.01639 | 0 | 100 | 0 | 1 | . |
| *cnae_27* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_28* | 0.16393 | 0.13115 | 12 | -17.2 | 0.51 | 0.613 | . |
| *cnae_29* | 0.14754 | 0.16393 | -6.5 | 77.5 | -0.25 | 0.805 | . |
| *cnae_30* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_31* | 0.04918 | 0.01639 | 17.9 | -980.9 | 1.01 | 0.313 | . |
| *cnae_32* | 0.01639 | 0.03279 | -11.5 | -8.2 | -0.58 | 0.563 | . |
| *cnae_33* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_35* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_38* | 0 | 0 | . | . | . | . | .* |
| *cnae_50* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_58* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_59* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_60* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_61* | 0.01639 | 0.06557 | -56.8 - | 2481.8 | -1.37 | 0.173 | . |
| *cnae_62* | 0.09836 | 0.08197 | 6.6 | 74.7 | 0.31 | 0.754 | . |
| *cnae_63* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_71* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_72* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_81* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_89* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_91* | 0.01639 | 0.03279 | -33.5 | -806.7 | -0.58 | 0.563 | . |
| *cnae_99* | 0 | 0 | 0 | 100 | . | . | . |
| Sample | LR chi2 | p>chi2 | MeanBias | MedBias | R | %Var | |
| Unmatched | 634.18 | 0 | 23.2 | 13.1 | 0.62 | 50 | |
| Matched | 21.99 | 0.782 | 9.3 | 6.6 | 0.41* | 75 | |

Variables' results for matched sample only.

Table A2.8

*Results of the Means Test for the estimated propensity score. Outcome Variable: rd_dummy*

| Variable | Mean | | %bias | %reduct | t-test | | V(T)/ |
|---|---|---|---|---|---|---|---|
| | Treated | Control | | \|bias\| | t | p>\|t\| | V(C) |
| *revenue* | 2.90E+05 | 3.70E+05 | -3 | 88.4 | -1 | 0.32 | 0.95 |
| *personnel* | 6.0663 | 6.2573 | -14.2 | 88.6 | -1.59 | 0.113 | 1.02 |
| *age* | 27.778 | 28.896 | -8.5 | 45 | -0.7 | 0.487 | 1.1 |
| *nac_control* | 0.77778 | 0.71852 | 16.6 | 71.9 | 1.12 | 0.264 | . |
| *for_control* | 0.2963 | 0.37037 | -19.1 | 70.9 | -1.29 | 0.198 | . |
| *rd_cont* | 0.62963 | 0.53333 | 24.7 | 83.9 | 1.61 | 0.11 | . |
| *group* | 0.37037 | 0.35556 | 3.5 | 94.3 | 0.25 | 0.801 | . |
| *imp* | 0.85185 | 0.88148 | -7 | 93.7 | -0.71 | 0.476 | . |
| *exp* | 0.76296 | 0.74815 | 3.3 | 96.8 | 0.28 | 0.778 | . |
| *for_market* | 0.06667 | 0.1037 | -15.1 | 13.4 | -1.09 | 0.277 | . |
| *dummyN* | 0.01481 | 0.01481 | 0 | 100 | 0 | 1 | . |
| *dummyNE* | 0.05926 | 0.02222 | 14.9 | 46.5 | 1.54 | 0.125 | . |
| *dummySE* | 0.16296 | 0.11852 | 11.9 | -155.9 | 1.05 | 0.295 | . |
| *dummyS* | 0.34815 | 0.34815 | 0 | 100 | 0 | 1 | . |
| *dummyCO* | 0.00741 | 0 | 4.1 | 79.4 | 1 | 0.318 | . |
| *cnae_10* | 0.05926 | 0.05926 | 0 | 100 | 0 | 1 | . |
| *cnae_11* | 0.02963 | 0.06667 | -30.5 - | 1077.1 | -1.42 | 0.156 | . |
| *cnae_12* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_13* | 0.01481 | 0.00741 | 4.6 | 72.5 | 0.58 | 0.563 | . |
| *cnae_14* | 0.00741 | 0.00741 | 0 | 100 | 0 | 1 | . |
| *cnae_15* | 0.01481 | 0.01481 | 0 | 100 | 0 | 1 | . |
| *cnae_16* | 0.00741 | 0.00741 | 0 | 100 | 0 | 1 | . |
| *cnae_17* | 0.02963 | 0.00741 | 13.3 | -158.2 | 1.35 | 0.177 | . |
| *cnae_18* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_19* | 0.00741 | 0.00741 | 0 | 100 | 0 | 1 | . |
| *cnae_20* | 0.08148 | 0.06667 | 5.5 | 80.4 | 0.46 | 0.644 | . |
| *cnae_21* | 0.05185 | 0.07407 | -13.3 | 36 | -0.75 | 0.454 | . |
| *cnae_22* | 0.03704 | 0.01481 | 10.6 | 17.4 | 1.15 | 0.252 | . |
| *cnae_23* | 0.03704 | 0.02222 | 7.3 | 30 | 0.72 | 0.475 | . |
| *cnae_24* | 0.04444 | 0.05185 | -4.6 | -35.8 | -0.28 | 0.777 | . |
| *cnae_25* | 0.03704 | 0.02963 | 3.2 | 81.1 | 0.34 | 0.736 | . |
| *cnae_26* | 0.02963 | 0.03704 | -3.9 | 54.7 | -0.34 | 0.736 | . |
| *cnae_27* | 0.06667 | 0.08148 | -7.1 | 45.8 | -0.46 | 0.644 | . |
| *cnae_28* | 0.12593 | 0.11852 | 2.7 | 73.5 | 0.19 | 0.853 | . |
| *cnae_29* | 0.11111 | 0.12593 | -5.9 | 79.6 | -0.38 | 0.708 | . |
| *cnae_30* | 0.02222 | 0.02963 | -6.6 | -0.1 | -0.38 | 0.703 | . |
| *cnae_31* | 0.05926 | 0.06667 | -4.1 | -144.2 | -0.25 | 0.803 | . |
| *cnae_32* | 0.01481 | 0.00741 | 5.2 | 51.1 | 0.58 | 0.563 | . |
| *cnae_33* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_35* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_38* | 0 | 0 | . | . | . | . | .* |
| *cnae_50* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_58* | 0.01481 | 0.01481 | 0 | 100 | 0 | 1 | . |
| *cnae_59* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_60* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_61* | 0.00741 | 0 | 8.5 | -288.9 | 1 | 0.318 | . |
| *cnae_62* | 0.08148 | 0.08148 | 0 | 100 | 0 | 1 | . |
| *cnae_63* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_71* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_72* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_81* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_89* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_91* | 0.00741 | 0 | 15.1 | -309.7 | 1 | 0.318 | . |
| *cnae_99* | 0 | 0 | 0 | 100 | . | . | . |
| Sample | Ps R2 | LR chi2 | p>chi2 | MeanBias | MedBias | | |
| Unmatched | 0.297 | 634.18 | 0 | 23.2 | 13.1 | | |
| Matched | 0.078 | 28.97 | 0.791 | 5.6 | 3.5 | | |

Variables' results for matched sample only.

Table A2.9

*Results of the Means Test for the estimated propensity score. Outcome Variable: innovator*

| Variable | Mean | | %bias | %reduct | t-test | | V(T)/ |
|---|---|---|---|---|---|---|---|
| | Treated | Control | | \|bias\| | t | p>\|t\| | V(C) |
| *personnel* | 6.717 | 6.8591 | -12 | 91.1 | -0.99 | 0.322 | 0.87 |
| *age* | 26.607 | 27.248 | -4.8 | 79.5 | -0.41 | 0.685 | 1.11 |
| *nac_control* | 0.61379 | 0.66207 | -11.8 | 85.1 | -0.85 | 0.394 | . |
| *for_control* | 0.46897 | 0.44138 | 6.5 | 92.6 | 0.47 | 0.639 | . |
| *rd_cont* | 0.73793 | 0.73793 | 0 | 100 | 0 | 1 | . |
| *group* | 0.53793 | 0.6 | -13.3 | 80 | -1.07 | 0.287 | . |
| *revenue* | 12.602 | 12.769 | -10.1 | 93.5 | -0.87 | 0.384 | 0.74 |
| *imp* | 0.75862 | 0.86207 | -22.7 | 75.2 | -2.26 | 0.025 | . |
| *exp* | 0.90345 | 0.91034 | -1.7 | 98.7 | -0.2 | 0.841 | . |
| *For_market* | 0.09655 | 0.07586 | 7.6 | 34.1 | 0.63 | 0.532 | . |
| *dummyN* | 0.04138 | 0.03448 | 3.5 | -9756 | 0.31 | 0.76 | . |
| *dummyNE* | 0.03448 | 0.04828 | -5.1 | 69.8 | -0.59 | 0.557 | . |
| *dummySE* | 0.09655 | 0.08276 | 4 | 79.8 | 0.41 | 0.682 | . |
| *dummyS* | 0.3931 | 0.42069 | -5.9 | 71.7 | -0.48 | 0.634 | . |
| *dummyCO* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_10* | 0.12414 | 0.14483 | -6.6 | -153.3 | -0.51 | 0.607 | . |
| *cnae_11* | 0.0069 | 0.02069 | -11.3 | -283.8 | -1.01 | 0.316 | . |
| *cnae_12* | 0.0069 | 0.01379 | -10.8 | -121.5 | -0.58 | 0.563 | . |
| *cnae_13* | 0.01379 | 0.01379 | 0 | 100 | 0 | 1 | . |
| *cnae_14* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_15* | 0.01379 | 0.0069 | 4.4 | 75.3 | 0.58 | 0.563 | . |
| *cnae_16* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_17* | 0.01379 | 0.02759 | -10.4 | -5.3 | -0.82 | 0.411 | . |
| *cnae_18* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_19* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_20* | 0.07586 | 0.05517 | 8.6 | 42.5 | 0.71 | 0.478 | . |
| *cnae_21* | 0.04828 | 0.04138 | 4.4 | 75.4 | 0.28 | 0.778 | . |
| *cnae_22* | 0.04138 | 0.10345 | -29.4 | -138.6 | -2.05 | 0.042 | . |
| *cnae_23* | 0.02069 | 0.04828 | -14.4 | 12.6 | -1.29 | 0.199 | . |
| *cnae_24* | 0.04138 | 0.06207 | -11.8 | -35.2 | -0.79 | 0.428 | . |
| *cnae_25* | 0.02759 | 0.03448 | -3.1 | 85.4 | -0.34 | 0.736 | . |
| *cnae_26* | 0.11724 | 0.13103 | -5.6 | 80.8 | -0.36 | 0.723 | . |
| *cnae_27* | 0.05517 | 0.06207 | -3.5 | 63.2 | -0.25 | 0.803 | . |
| *cnae_28* | 0.13793 | 0.11034 | 9.1 | 62.5 | 0.71 | 0.478 | . |
| *cnae_29* | 0.15172 | 0.05517 | 33.5 | 22.9 | 2.72 | 0.007 | . |
| *cnae_30* | 0.01379 | 0 | 13.7 | -527.8 | 1.42 | 0.157 | . |
| *cnae_31* | 0.02069 | 0.02069 | 0 | 100 | 0 | 1 | . |
| *cnae_32* | 0.02759 | 0.01379 | 8.7 | -139.8 | 0.82 | 0.411 | . |
| *cnae_33* | 0.0069 | 0 | 6.4 | 43.4 | 1 | 0.318 | . |
| *cnae_35* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_38* | 0 | 0 | . | . | . | . | .* |
| *cnae_50* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_58* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_59* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_60* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_61* | 0.01379 | 0.0069 | 7 | -146.8 | 0.58 | 0.563 | . |
| *cnae_62* | 0.01379 | 0.02069 | -4.4 | 60 | -0.45 | 0.653 | . |
| *cnae_63* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_71* | 0.0069 | 0.0069 | 0 | 100 | 0 | 1 | . |
| *cnae_72* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_81* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_89* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_91* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_99* | 0 | 0 | 0 | 100 | . | . | . |
| Sample | Ps R2 | LR chi2 | p>chi2 | MeanBias | MedBias | | |
| Unmatched | 0.411 | 569 | 0 | 29 | 16.4 | | |
| Matched | 0.079 | 31.43 | 0.594 | 6 | 4.4 | | |

Variables' results for matched sample only.

Table A2.10

*Results of the Means Test for the estimated propensity score. Outcome Variable: new_sales*

| Variable | Mean | | %bias | %reduct | t-test | | V(T)/ |
|---|---|---|---|---|---|---|---|
| | Treated | Control | | \|bias\| | t | p>\|t\| | V(C) |
| *personnel* | 6.826 | 6.7916 | 2.9 | 97.8 | 0.21 | 0.836 | 0.77 |
| *age* | 27.795 | 26.098 | 12.7 | 45.9 | 1.02 | 0.309 | 1.18 |
| *nac_control* | 0.62295 | 0.62295 | 0 | 100 | 0 | 1 | . |
| *for_control* | 0.45902 | 0.46721 | -1.9 | 97.8 | -0.13 | 0.898 | . |
| *rd_cont* | 0.77869 | 0.80328 | -6.4 | 96.1 | -0.47 | 0.638 | . |
| *group* | 0.52459 | 0.57377 | -10.6 | 84.2 | -0.77 | 0.442 | . |
| *revenue* | 12.719 | 12.792 | -4.4 | 97.2 | -0.33 | 0.745 | 0.61* |
| *imp* | 0.79508 | 0.7541 | 9 | 90.2 | 0.76 | 0.446 | . |
| *exp* | 0.93443 | 0.93443 | 0 | 100 | 0 | 1 | . |
| *personnel* | 0.10656 | 0.13115 | -9 | 21.7 | -0.59 | 0.555 | . |
| *dummyN* | 0.04098 | 0 | 21 | -58470.3 | 2.27 | 0.024 | . |
| *dummyNE* | 0.04098 | 0.03279 | 3 | 82.1 | 0.34 | 0.735 | . |
| *dummySE* | 0.10656 | 0.10656 | 0 | 100 | 0 | 1 | . |
| *dummyS* | 0.39344 | 0.42623 | -7 | 66.4 | -0.52 | 0.604 | . |
| *dummyCO* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_10* | 0.10656 | 0.11475 | -2.6 | -0.4 | -0.2 | 0.839 | . |
| *cnae_11* | 0.0082 | 0.01639 | -6.7 | -128.1 | -0.58 | 0.563 | . |
| *cnae_12* | 0.0082 | 0.02459 | -25.6 | -426.6 | -1.01 | 0.315 | . |
| *cnae_13* | 0.01639 | 0.01639 | 0 | 100 | 0 | 1 | . |
| *cnae_14* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_15* | 0.01639 | 0 | 10.5 | 41.2 | 1.42 | 0.157 | . |
| *cnae_16* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_17* | 0.01639 | 0.02459 | -6.2 | 37.4 | -0.45 | 0.653 | . |
| *cnae_18* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_19* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_20* | 0.06557 | 0.08197 | -6.9 | 54.4 | -0.49 | 0.626 | . |
| *cnae_21* | 0.05738 | 0.0082 | 31.2 | -75.3 | 2.17 | 0.031 | . |
| *cnae_22* | 0.03279 | 0.05738 | -11.6 | 5.5 | -0.92 | 0.357 | . |
| *cnae_23* | 0.01639 | 0.01639 | 0 | 100 | 0 | 1 | . |
| *cnae_24* | 0.04098 | 0.08197 | -23.3 | -167.9 | -1.33 | 0.184 | . |
| *cnae_25* | 0.03279 | 0.03279 | 0 | 100 | 0 | 1 | . |
| *cnae_26* | 0.13115 | 0.09836 | 13.3 | 54.4 | 0.8 | 0.424 | . |
| *cnae_27* | 0.05738 | 0.04098 | 8.2 | 12.6 | 0.59 | 0.556 | . |
| *cnae_28* | 0.15574 | 0.17213 | -5.4 | 77.7 | -0.34 | 0.731 | . |
| *cnae_29* | 0.15574 | 0.13115 | 8.5 | 80.4 | 0.55 | 0.586 | . |
| *cnae_30* | 0.01639 | 0.01639 | 0 | 100 | 0 | 1 | . |
| *cnae_31* | 0.0082 | 0.0082 | 0 | 100 | 0 | 1 | . |
| *cnae_32* | 0.02459 | 0 | 15.6 | -327.4 | 1.75 | 0.082 | . |
| *cnae_33* | 0.0082 | 0.01639 | -7.6 | 32.7 | -0.58 | 0.563 | . |
| *cnae_35* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_38* | 0 | 0 | . | . | . | . | .* |
| *cnae_50* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_58* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_59* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_60* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_61* | 0.0082 | 0.0082 | 0 | 100 | 0 | 1 | . |
| *cnae_62* | 0.01639 | 0.03279 | -10.4 | 4.8 | -0.82 | 0.41 | . |
| *cnae_63* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_71* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_72* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_81* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_89* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_91* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_99* | 0 | 0 | 0 | 100 | . | . | . |

| Sample | Ps R2 | LR chi2 | p>chi2 | MeanBias | MedBias |
|---|---|---|---|---|---|
| Unmatched | 0.411 | 569 | 0 | 29 | 16.4 |
| Matched | 0.055 | 17.78 | 0.98 | 5.3 | 1.9 |

Variables' results for matched sample only.

Table A2.11

*Results of the Means Test for the estimated propensity score. Outcome Variable: new_exp*

| Variable | Mean | | %bias | %reduct | t-test | | V(T)/ |
|---|---|---|---|---|---|---|---|
| | Treated | Control | | \|bias\| | t | p>\|t\| | V(C) |
| *personnel* | 6.826 | 6.8148 | 0.9 | 99.3 | 0.07 | 0.946 | 0.79 |
| *age* | 27.795 | 26.287 | 11.3 | 51.9 | 0.91 | 0.362 | 1.21 |
| *nac_control* | 0.62295 | 0.60656 | 4 | 94.9 | 0.26 | 0.794 | . |
| *for_control* | 0.45902 | 0.48361 | -5.8 | 93.4 | -0.38 | 0.702 | . |
| *rd_cont* | 0.77869 | 0.80328 | -6.4 | 96.1 | -0.47 | 0.638 | . |
| *group* | 0.52459 | 0.56557 | -8.8 | 86.8 | -0.64 | 0.522 | . |
| *revenue* | 12.719 | 12.733 | -0.9 | 99.4 | -0.06 | 0.949 | 0.64* |
| *imp* | 0.79508 | 0.7459 | 10.8 | 88.2 | 0.91 | 0.363 | . |
| *exp* | 0.93443 | 0.95082 | -3.9 | 97 | -0.55 | 0.584 | . |
| *personnel* | 0.10656 | 0.09836 | 3 | 73.9 | 0.21 | 0.834 | . |
| *dummyN* | 0.04098 | 0.0082 | 16.8 | -46756.2 | 1.66 | 0.099 | . |
| *dummyNE* | 0.04098 | 0.02459 | 6.1 | 64.1 | 0.72 | 0.474 | . |
| *dummySE* | 0.10656 | 0.12295 | -4.7 | 76 | -0.4 | 0.689 | . |
| *dummyS* | 0.39344 | 0.40164 | -1.8 | 91.6 | -0.13 | 0.896 | . |
| *dummyCO* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_10* | 0.10656 | 0.11475 | -2.6 | -0.4 | -0.2 | 0.839 | . |
| *cnae_11* | 0.0082 | 0.0082 | 0 | 100 | 0 | 1 | . |
| *cnae_12* | 0.0082 | 0.0082 | 0 | 100 | 0 | 1 | . |
| *cnae_13* | 0.01639 | 0 | 10.4 | 43.2 | 1.42 | 0.157 | . |
| *cnae_14* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_15* | 0.01639 | 0.0082 | 5.2 | 70.6 | 0.58 | 0.563 | . |
| *cnae_16* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_17* | 0.01639 | 0.02459 | -6.2 | 37.4 | -0.45 | 0.653 | . |
| *cnae_18* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_19* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_20* | 0.06557 | 0.07377 | -3.4 | 77.2 | -0.25 | 0.802 | . |
| *cnae_21* | 0.05738 | 0.01639 | 26 | -46.1 | 1.7 | 0.09 | . |
| *cnae_22* | 0.03279 | 0.06557 | -15.5 | -26 | -1.18 | 0.238 | . |
| *cnae_23* | 0.01639 | 0.01639 | 0 | 100 | 0 | 1 | . |
| *cnae_24* | 0.04098 | 0.06557 | -14 | -60.7 | -0.85 | 0.395 | . |
| *cnae_25* | 0.03279 | 0.03279 | 0 | 100 | 0 | 1 | . |
| *cnae_26* | 0.13115 | 0.09836 | 13.3 | 54.4 | 0.8 | 0.424 | . |
| *cnae_27* | 0.05738 | 0.04918 | 4.1 | 56.3 | 0.28 | 0.777 | . |
| *cnae_28* | 0.15574 | 0.17213 | -5.4 | 77.7 | -0.34 | 0.731 | . |
| *cnae_29* | 0.15574 | 0.13115 | 8.5 | 80.4 | 0.55 | 0.586 | . |
| *cnae_30* | 0.01639 | 0.02459 | -8.1 | -273.1 | -0.45 | 0.653 | . |
| *cnae_31* | 0.0082 | 0.0082 | 0 | 100 | 0 | 1 | . |
| *cnae_32* | 0.02459 | 0.01639 | 5.2 | -42.5 | 0.45 | 0.653 | . |
| *cnae_33* | 0.0082 | 0.02459 | -15.2 | -34.6 | -1.01 | 0.315 | . |
| *cnae_35* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_38* | 0 | 0 | . | . | . | . | .* |
| *cnae_50* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_58* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_59* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_60* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_61* | 0.0082 | 0.01639 | -8.3 | -193.4 | -0.58 | 0.563 | . |
| *cnae_62* | 0.01639 | 0.02459 | -5.2 | 52.4 | -0.45 | 0.653 | . |
| *cnae_63* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_71* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_72* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_81* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_89* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_91* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_99* | 0 | 0 | 0 | 100 | . | . | . |
| Sample | Ps R2 | LR chi2 | p>chi2 | MeanBias | MedBias | | |
| Unmatched | 0.411 | 569 | 0 | 29 | 16.4 | | |
| Matched | 0.057 | 19.03 | 0.982 | 4.6 | 3 | | |

Variables' results for matched sample only.

Table A2.12

*Results of the Means Test for the estimated propensity score. Outcome Variable: revenue*

| Variable | Mean | | %bias | %reduct | t-test | | V(T)/ |
|---|---|---|---|---|---|---|---|
| | Treated | Control | | \|bias\| | t | p>\|t\| | V(C) |
| *personnel* | 6.4889 | 6.4586 | 2.8 | 97.7 | 0.22 | 0.829 | 0.93 |
| *age* | 26.82 | 28.074 | -9.6 | 67.6 | -0.78 | 0.438 | 1.21 |
| *nac_control* | 0.63934 | 0.7623 | -30.7 | 57.7 | -2.11 | 0.036 | . |
| *for_control* | 0.41803 | 0.28689 | 31.3 | 59.1 | 2.16 | 0.032 | . |
| *rd_cont* | 0.70492 | 0.70492 | 0 | 100 | 0 | 1 | . |
| *group* | 0.5 | 0.43443 | 14.1 | 75.3 | 1.02 | 0.307 | . |
| *revenue* | 12.244 | 12.06 | 12.3 | 91.7 | 1.07 | 0.284 | 0.94 |
| *imp* | 0.72951 | 0.63115 | 20.9 | 66 | 1.65 | 0.1 | . |
| *exp* | 0.89344 | 0.86066 | 7.9 | 92.5 | 0.78 | 0.438 | . |
| *personnel* | 0.06557 | 0.07377 | -3.4 | -457.5 | -0.25 | 0.802 | . |
| *dummyN* | 0.04098 | 0.02459 | 8.6 | -390.5 | 0.72 | 0.474 | . |
| *dummyNE* | 0.04098 | 0.04098 | 0 | 100 | 0 | 1 | . |
| *dummySE* | 0.09016 | 0.06557 | 7.5 | 66.6 | 0.71 | 0.476 | . |
| *dummyS* | 0.42623 | 0.54918 | -26.1 | 18.1 | -1.93 | 0.055 | . |
| *dummyCO* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_10* | 0.12295 | 0.13115 | -2.5 | -2354.4 | -0.19 | 0.848 | . |
| *cnae_11* | 0.0082 | 0.01639 | -7.8 | -27.9 | -0.58 | 0.563 | . |
| *cnae_12* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_13* | 0.01639 | 0.0082 | 4.6 | 76.6 | 0.58 | 0.563 | . |
| *cnae_14* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_15* | 0.0082 | 0.0082 | 0 | 100 | 0 | 1 | . |
| *cnae_16* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_17* | 0.01639 | 0 | 10.8 | -3.5 | 1.42 | 0.157 | . |
| *cnae_18* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_19* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_20* | 0.07377 | 0.0082 | 27.8 | -163.5 | 2.61 | 0.01 | . |
| *cnae_21* | 0.04918 | 0.04098 | 4.8 | 76.1 | 0.31 | 0.759 | . |
| *cnae_22* | 0.04918 | 0.03279 | 7 | 22.8 | 0.64 | 0.52 | . |
| *cnae_23* | 0.01639 | 0.02459 | -4.7 | 74.5 | -0.45 | 0.653 | . |
| *cnae_24* | 0.02459 | 0.05738 | -21.1 | -2038.5 | -1.29 | 0.198 | . |
| *cnae_25* | 0.03279 | 0.04098 | -3.6 | 70.8 | -0.34 | 0.735 | . |
| *cnae_26* | 0.13115 | 0.17213 | -15.2 | 55.3 | -0.89 | 0.374 | . |
| *cnae_27* | 0.06557 | 0.03279 | 15.4 | -2.7 | 1.18 | 0.238 | . |
| *cnae_28* | 0.15574 | 0.21311 | -18.2 | 36 | -1.15 | 0.25 | . |
| *cnae_29* | 0.12295 | 0.09836 | 8.8 | 74.1 | 0.61 | 0.542 | . |
| *cnae_30* | 0.0082 | 0 | 8.7 | -321.3 | 1 | 0.318 | . |
| *cnae_31* | 0.02459 | 0.04918 | -14.2 | -70.2 | -1.02 | 0.31 | . |
| *cnae_32* | 0.03279 | 0.01639 | 10 | -101 | 0.82 | 0.41 | . |
| *cnae_33* | 0.0082 | 0.0082 | 0 | 100 | 0 | 1 | . |
| *cnae_35* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_38* | 0 | 0 | . | . | . | . | .* |
| *cnae_50* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_58* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_59* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_60* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_61* | 0.0082 | 0.0082 | 0 | 100 | 0 | 1 | . |
| *cnae_62* | 0.01639 | 0.03279 | -9.5 | 44.2 | -0.82 | 0.41 | . |
| *cnae_63* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_71* | 0.0082 | 0 | 12.1 | -23 | 1 | 0.318 | . |
| *cnae_72* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_81* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_89* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_91* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_99* | 0 | 0 | . | . | . | . | . |
| Sample | Ps R2 | LR chi2 | p>chi2 | MeanBias | MedBias | | |
| Unmatched | 0.397 | 466.04 | 0 | 26.9 | 15.4 | | |
| Matched | 0.092 | 30.59 | 0.538 | 7.3 | 4.6 | | |

Variables' results for matched sample only.

Table A2.13

*Results of the Means Test for the estimated propensity score. Outcome Variable: personnel*

| Variable | Mean | | %bias | %reduct | t-test | | V(T)/ |
|---|---|---|---|---|---|---|---|
| | Treated | Control | | \|bias\| | t | p>\|t\| | V(C) |
| *personnel* | 6.5096 | 6.4735 | 3.4 | 97.5 | 0.28 | 0.783 | 1.03 |
| *age* | 26.814 | 27.403 | -4.5 | 83.2 | -0.37 | 0.711 | 1.18 |
| *nac_control* | 0.62791 | 0.63566 | -1.9 | 97.5 | -0.13 | 0.898 | . |
| *for_control* | 0.44186 | 0.4031 | 9.2 | 89 | 0.63 | 0.53 | . |
| *rd_cont* | 0.72093 | 0.75194 | -7.9 | 94.9 | -0.56 | 0.574 | . |
| *group* | 0.51163 | 0.49612 | 3.3 | 94.6 | 0.25 | 0.804 | . |
| *revenue* | 12.398 | 12.423 | -1.6 | 99 | -0.14 | 0.892 | 0.85 |
| *imp* | 0.73643 | 0.74419 | -1.7 | 97.4 | -0.14 | 0.888 | . |
| *exp* | 0.90698 | 0.93023 | -5.7 | 94.9 | -0.68 | 0.496 | . |
| *personnel* | 0.06202 | 0.03101 | 12.7 | -527.4 | 1.18 | 0.239 | . |
| *dummyN* | 0.04651 | 0.0155 | 15.7 | -353.2 | 1.44 | 0.152 | . |
| *dummyNE* | 0.03876 | 0.06977 | -12.5 | 47.9 | -1.1 | 0.273 | . |
| *dummySE* | 0.08527 | 0.05426 | 9.4 | 57.3 | 0.98 | 0.33 | . |
| *dummyS* | 0.4186 | 0.47287 | -11.6 | 59.7 | -0.87 | 0.383 | . |
| *dummyCO* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_10* | 0.12403 | 0.12403 | 0 | 100 | 0 | 1 | . |
| *cnae_11* | 0.00775 | 0 | 7.5 | -17 | 1 | 0.318 | . |
| *cnae_12* | 0.00775 | 0 | 10.8 | -73.8 | 1 | 0.318 | . |
| *cnae_13* | 0.0155 | 0.00775 | 4.4 | 77.9 | 0.58 | 0.563 | . |
| *cnae_14* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_15* | 0.00775 | 0 | 5.2 | 75.3 | 1 | 0.318 | . |
| *cnae_16* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_17* | 0.0155 | 0.00775 | 5.1 | 55.5 | 0.58 | 0.563 | . |
| *cnae_18* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_19* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_20* | 0.07752 | 0.1938 | -48.4 | -374.1 | -2.76 | 0.006 | . |
| *cnae_21* | 0.04651 | 0.05426 | -4.6 | 74.4 | -0.28 | 0.777 | . |
| *cnae_22* | 0.04651 | 0.07752 | -13.4 | -23.4 | -1.03 | 0.304 | . |
| *cnae_23* | 0.0155 | 0.0155 | 0 | 100 | 0 | 1 | . |
| *cnae_24* | 0.03876 | 0.03876 | 0 | 100 | 0 | 1 | . |
| *cnae_25* | 0.03101 | 0.02326 | 3.5 | 75.2 | 0.38 | 0.703 | . |
| *cnae_26* | 0.13178 | 0.11628 | 5.7 | 83.9 | 0.38 | 0.707 | . |
| *cnae_27* | 0.06202 | 0.04651 | 7.5 | 42.9 | 0.55 | 0.584 | . |
| *cnae_28* | 0.14729 | 0.13178 | 5 | 80.2 | 0.36 | 0.721 | . |
| *cnae_29* | 0.13178 | 0.07752 | 18.9 | 49.5 | 1.42 | 0.156 | . |
| *cnae_30* | 0.00775 | 0 | 8.4 | -238.9 | 1 | 0.318 | . |
| *cnae_31* | 0.02326 | 0.03876 | -9.1 | 3.2 | -0.72 | 0.474 | . |
| *cnae_32* | 0.03101 | 0.0155 | 9.6 | -175.2 | 0.82 | 0.411 | . |
| *cnae_33* | 0.00775 | 0 | 7.3 | 4 | 1 | 0.318 | . |
| *cnae_35* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_38* | 0 | 0 | . | . | . | . | .* |
| *cnae_50* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_58* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_59* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_60* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_61* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_62* | 0.0155 | 0.03101 | -9.1 | 48.8 | -0.82 | 0.411 | . |
| *cnae_63* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_71* | 0.00775 | 0 | 11.8 | -27.8 | 1 | 0.318 | . |
| *cnae_72* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_81* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_89* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_91* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_99* | 0 | 0 | . | . | . | . | . |
| Sample | Ps R2 | LR chi2 | p>chi2 | MeanBias | MedBias | | |
| Unmatched | 0.412 | 509.69 | 0 | 28.1 | 14.9 | | |
| Matched | 0.06 | 20.9 | 0.863 | 5.7 | 4.5 | | |

Variables' results for matched sample only.

Table A2.14

*Results of the Means Test for the estimated propensity score. Outcome Variable: rev_person*

| Variable | Mean | | %bias | %reduct | t-test | | V(T)/ |
|---|---|---|---|---|---|---|---|
| | Treated | Control | | \|bias\| | t | p>\|t\| | V(C) |
| *personnel* | 6.7093 | 6.73 | -1.7 | 98.7 | -0.14 | 0.889 | 0.77 |
| *age* | 26.729 | 27.993 | -9.4 | 59.7 | -0.79 | 0.431 | 1.04 |
| *nac_control* | 0.61111 | 0.60417 | 1.7 | 97.9 | 0.12 | 0.904 | . |
| *for_control* | 0.46528 | 0.46528 | 0 | 100 | 0 | 1 | . |
| *rd_cont* | 0.73611 | 0.75 | -3.6 | 97.8 | -0.27 | 0.788 | . |
| *group* | 0.53472 | 0.56944 | -7.5 | 88.8 | -0.59 | 0.555 | . |
| *revenue* | 12.599 | 12.565 | 2 | 98.7 | 0.17 | 0.861 | 0.74 |
| *imp* | 0.75694 | 0.81944 | -13.7 | 85 | -1.3 | 0.196 | . |
| *exp* | 0.90278 | 0.96528 | -15 | 88.4 | -2.15 | 0.033 | . |
| *personnel* | 0.09028 | 0.07639 | 5.1 | 55.8 | 0.43 | 0.671 | . |
| *dummyN* | 0.04167 | 0.00694 | 17.8 | -49522.1 | 1.92 | 0.056 | . |
| *dummyNE* | 0.03472 | 0.04861 | -5.2 | 69.6 | -0.59 | 0.557 | . |
| *dummySE* | 0.09028 | 0.03472 | 16 | 18.8 | 1.95 | 0.052 | . |
| *dummyS* | 0.39583 | 0.43056 | -7.4 | 64.4 | -0.6 | 0.551 | . |
| *dummyCO* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_10* | 0.125 | 0.15278 | -8.9 | -240.1 | -0.68 | 0.497 | . |
| *cnae_11* | 0.00694 | 0.03472 | -22.7 | -672.9 | -1.65 | 0.1 | . |
| *cnae_12* | 0.00694 | 0.00694 | 0 | 100 | 0 | 1 | . |
| *cnae_13* | 0.01389 | 0.02083 | -4.4 | 75.9 | -0.45 | 0.653 | . |
| *cnae_14* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_15* | 0.01389 | 0.01389 | 0 | 100 | 0 | 1 | . |
| *cnae_16* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_17* | 0.01389 | 0.00694 | 5.2 | 47 | 0.58 | 0.563 | . |
| *cnae_18* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_19* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_20* | 0.07639 | 0.08333 | -2.9 | 80.7 | -0.22 | 0.829 | . |
| *cnae_21* | 0.04861 | 0.0625 | -8.8 | 50.5 | -0.51 | 0.608 | . |
| *cnae_22* | 0.04167 | 0.05556 | -6.6 | 46.6 | -0.55 | 0.585 | . |
| *cnae_23* | 0.02083 | 0.01389 | 3.6 | 78 | 0.45 | 0.653 | . |
| *cnae_24* | 0.04167 | 0.04167 | 0 | 100 | 0 | 1 | . |
| *cnae_25* | 0.02778 | 0.03472 | -3.1 | 85.3 | -0.34 | 0.736 | . |
| *cnae_26* | 0.11806 | 0.09722 | 8.5 | 71 | 0.57 | 0.57 | . |
| *cnae_27* | 0.05556 | 0.06944 | -7 | 26 | -0.49 | 0.628 | . |
| *cnae_28* | 0.13889 | 0.15972 | -6.8 | 71.7 | -0.49 | 0.621 | . |
| *cnae_29* | 0.14583 | 0.08333 | 21.7 | 50.1 | 1.67 | 0.097 | . |
| *cnae_30* | 0.01389 | 0 | 13.8 | -532.2 | 1.42 | 0.157 | . |
| *cnae_31* | 0.02083 | 0.01389 | 4.3 | 63.6 | 0.45 | 0.653 | . |
| *cnae_32* | 0.02778 | 0.04167 | -8.8 | -141.4 | -0.64 | 0.521 | . |
| *cnae_33* | 0.00694 | 0 | 6.5 | 43 | 1 | 0.318 | . |
| *cnae_35* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_38* | 0 | 0 | . | . | . | . | .* |
| *cnae_50* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_58* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_59* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_60* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_61* | 0.01389 | 0.00694 | 7 | -148.6 | 0.58 | 0.563 | . |
| *cnae_62* | 0.01389 | 0 | 8.8 | 19.4 | 1.42 | 0.157 | . |
| *cnae_63* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_71* | 0.00694 | 0 | 5.4 | 69.3 | 1 | 0.318 | . |
| *cnae_72* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_81* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_89* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_91* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_99* | 0 | 0 | 0 | 100 | . | . | . |

| Sample | Ps R2 | LR chi2 | p>chi2 | MeanBias | MedBias |
|---|---|---|---|---|---|
| Unmatched | 0.411 | 569 | 0 | 29 | 16.4 |
| Matched | 0.051 | 19.97 | 0.952 | 5.1 | 3.6 |

Variables' results for matched sample only.

# Appendix to Chapter 3

Table A3.1

*Descriptive Statistics for covariates (values for 2011, not including economic sector dummies)*

| | Covariate | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | personnel | age | nac_control | for_control | rd_cont | group | revenue | imp | exp | for_market | dummyN | dummyNE | dummmySE | dummyS | dummyCO |
| Control group (treatment = 0) | | | | | | | | | | | | | | | |
| N | 13403 | 6410 | 13403 | 13403 | 13266 | 13403 | 13401 | 13403 | 13403 | 13403 | 13403 | 13403 | 13403 | 13403 | 13403 |
| mean | 4.55 | 26.15 | 0.94 | 0.08 | 0.11 | 0.13 | 9.14 | 0.38 | 0.31 | 0.04 | 0.04 | 0.10 | 0.18 | 0.28 | 0.05 |
| std. Dev. | 1.41 | 12.87 | 0.24 | 0.27 | 0.31 | 0.34 | 2.27 | 0.49 | 0.46 | 0.20 | 0.20 | 0.30 | 0.38 | 0.45 | 0.22 |
| Treated group (treatment = 1) | | | | | | | | | | | | | | | |
| N | 303 | 260 | 303 | 303 | 298 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 | 303 |
| mean | 6.23 | 28.18 | 0.73 | 0.34 | 0.71 | 0.39 | 12.00 | 0.85 | 0.76 | 0.09 | 0.02 | 0.03 | 0.16 | 0.32 | 0.02 |
| std. dev. | 1.28 | 13.38 | 0.45 | 0.47 | 0.46 | 0.49 | 1.68 | 0.36 | 0.43 | 0.28 | 0.13 | 0.18 | 0.37 | 0.47 | 0.13 |

Source: IBGE (2013, confidential disaggregate data).

Table A3.2

*Descriptive Statistics for covariates: economic sector dummies (values for 2011)*

| | Economic Sector dummy variables (*cnae_ dummies*) | | | | | | | | | | | | | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 11 | 13 | 15 | 17 | 18 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 35 | 50 | 62 | 71 | 72 | 81 | |
| Control group (treatment = 0) | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 1405 | 179 | 538 | 525 | 327 | 269 | 578 | 154 | 803 | 726 | 325 | 1011 | 400 | 430 | 908 | 441 | 122 | 483 | 380 | 239 | 52 | 9 | 458 | 379 | 43 | 176 | 11360 |
| % | 12.37 | 1.58 | 4.74 | 4.62 | 2.88 | 2.37 | 5.09 | 1.36 | 7.07 | 6.39 | 2.86 | 8.90 | 3.52 | 3.79 | 7.99 | 3.88 | 1.07 | 4.25 | 3.35 | 2.10 | 0.46 | 0.08 | 4.03 | 3.34 | 0.38 | 1.55 | 100 |
| Treated group (treatment = 1) | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 23 | 5 | 4 | 4 | 10 | 0 | 36 | 14 | 10 | 10 | 9 | 11 | 14 | 18 | 29 | 32 | 5 | 10 | 4 | 0 | 6 | 0 | 30 | 4 | 0 | 0 | 288 |
| % | 7.99 | 1.74 | 1.39 | 1.39 | 3.47 | 0.00 | 12.50 | 4.86 | 3.47 | 3.47 | 3.13 | 3.82 | 4.86 | 6.25 | 10.07 | 11.11 | 1.74 | 3.47 | 1.39 | 0.00 | 2.08 | 0.00 | 10.42 | 1.39 | 0.00 | 0.00 | 100 |

The following CNAE two-digit sectors are not displayed in the Table because there are four or less firms in the database, and the disclosure of this information would violate confidentiality terms of IBGE: 03, 12, 14, 16, 19, 58, 59, 60, 61, 63, 89 and 99. These observations were not excluded from the estimations. Source: IBGE (2013, confidential disaggregate data).

Table A3.3

*Results of the Means Test for the estimated propensity score. Broad category: different innovative activities*

| Variable | Mean | | %bias | % reduct | t-test | | V(T)/ |
|---|---|---|---|---|---|---|---|
| | Treated | Control | | \|bias\| | t | p>\|t\| | V(C)[b] |
| *revenue* | 3.00E+05 | 4.30E+05 | -9.6 | 71.8 | -1.42 | 0.158 | 0.31 |
| *personnel* | 6.1522 | 6.1492 | 0.3 | 99.7 | 0.03 | 0.978 | 0.86 |
| *age* | 28 | 29.815 | -13.8 | 15.5 | -1.29 | 0.199 | 1.03 |
| *nac_control* | 0.73034 | 0.70787 | 5.9 | 87.7 | 0.47 | 0.638 | . |
| *for_control* | 0.30337 | 0.33708 | -8.4 | 82 | -0.68 | 0.497 | . |
| *rd_cont* | 0.78652 | 0.7809 | 1.3 | 98.7 | 0.13 | 0.898 | . |
| *group* | 0.3427 | 0.32022 | 5.2 | 86.9 | 0.45 | 0.654 | . |
| *imp* | 0.86517 | 0.8764 | -2.7 | 95.4 | -0.32 | 0.753 | . |
| *exp* | 0.77528 | 0.80337 | -6.1 | 89.7 | -0.65 | 0.517 | . |
| *for_market* | 0.05056 | 0.07303 | -10.2 | -410.4 | -0.88 | 0.38 | . |
| *dummyN* | 0.01685 | 0.00562 | 7.9 | -28.2 | 1 | 0.316 | . |
| *dummyNE* | 0.03933 | 0.04494 | -2.3 | 88.5 | -0.26 | 0.793 | . |
| *dummySE* | 0.14607 | 0.17416 | -7.8 | -78 | -0.72 | 0.471 | . |
| *dummyS*[a] | 0.33146 | 0.29213 | 8.4 | -18 | 0.8 | 0.425 | . |
| *dummyCO* | 0.01124 | 0 | 7.5 | 54.8 | 1.42 | 0.157 | . |
| *cnae_10* | 0.10112 | 0.08989 | 3.6 | -22 | 0.36 | 0.719 | . |
| *cnae_11* | 0.01124 | 0.02247 | -10.8 | -2666.7 | -0.82 | 0.412 | . |
| *cnae_12* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_13* | 0.01685 | 0.01124 | 3.2 | 82.2 | 0.45 | 0.654 | . |
| *cnae_14* | 0.00562 | 0 | 3.9 | 82.7 | 1 | 0.318 | . |
| *cnae_15* | 0.01124 | 0 | 8 | 40.4 | 1.42 | 0.157 | . |
| cnae_16 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_17 | 0.04494 | 0.05056 | -2.8 | 64.4 | -0.25 | 0.804 | . |
| cnae_18 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_19 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_20 | 0.1236 | 0.1236 | 0 | 100 | 0 | 1 | . |
| cnae_21 | 0.04494 | 0.0618 | -10.1 | 39.8 | -0.71 | 0.481 | . |
| cnae_22 | 0.02247 | 0.00562 | 8 | 67.8 | 1.35 | 0.178 | . |
| cnae_23 | 0.03371 | 0.05056 | -9.6 | -3281.6 | -0.79 | 0.43 | . |
| cnae_24 | 0.01124 | 0.02809 | -13.2 | -45.7 | -1.14 | 0.253 | . |
| cnae_25 | 0.04494 | 0.0618 | -7.3 | -5.4 | -0.71 | 0.481 | . |
| cnae_26 | 0.03371 | 0.03933 | -2.8 | 71.4 | -0.28 | 0.778 | . |
| cnae_27 | 0.08427 | 0.07865 | 2.3 | 84.9 | 0.19 | 0.847 | . |
| cnae_28 | 0.08989 | 0.06742 | 7.9 | -447.1 | 0.79 | 0.432 | . |
| cnae_29 | 0.10674 | 0.1236 | -6.5 | 72 | -0.5 | 0.62 | . |
| cnae_30 | 0.02247 | 0.01124 | 9.2 | 13 | 0.82 | 0.412 | . |
| cnae_31 | 0.03933 | 0.03933 | 0 | 100 | 0 | 1 | . |
| cnae_32 | 0.02247 | 0.01124 | 7.5 | -279.8 | 0.82 | 0.412 | . |
| cnae_33 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_35 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_38 | 0 | 0 | . | . | . | . | . |
| cnae_50 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_58 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_59 | 0 | 0 | . | . | . | . | . |
| cnae_60 | 0 | 0 | . | . | . | . | . |
| cnae_61 | 0.01124 | 0.00562 | 6.2 | -8.6 | 0.58 | 0.563 | . |
| cnae_62 | 0.10112 | 0.11236 | -4.1 | 66.6 | -0.34 | 0.732 | . |
| cnae_63 | 0.00562 | 0.00562 | 0 | 100 | 0 | 1 | . |
| cnae_71 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_72 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_81 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_89 | 0.00562 | 0 | 8.3 | -271.1 | 1 | 0.318 | . |
| cnae_91 | 0.00562 | 0 | 9.4 | -53.5 | 1 | 0.318 | . |
| cnae_99 | 0 | 0 | . | . | . | . | . |
| Sample | Ps R2 | LR chi2 | p>chi2 | MeanBias | MedBias | | |
| Unmatched | 0.247 | 315.49 | 0 | 17.9 | 11.5 | | |
| Matched | 0.038 | 18.59 | 0.979 | 4.8 | 4.7 | | |

Variables' results for matched sample only.

[a] Not considered firms in the state of São Paulo.

[b] Variance ratio (for continuous covariates) of treated over non-treated.

Table A3.4

*Results of the Means Test for the estimated propensity score. Broad category: R&D outsourcing*

| Variable | Mean | | %bias | % reduct | t-test | | V(T)/ |
|---|---|---|---|---|---|---|---|
| | Treated | Control | | bias | t | p>\|t\| | V(C)[b] |
| *revenue* | 3.60E+05 | 5.60E+05 | -23.6 | 4.7 | -1.17 | 0.244 | 0.21 |
| *personnel* | 6.1754 | 6.1979 | -2 | 97.1 | -0.17 | 0.868 | 0.73 |
| *age* | 28.341 | 28.719 | -2.9 | 82 | -0.25 | 0.804 | 1.36 |
| *nac_control* | 0.73333 | 0.76296 | -7.7 | 82.5 | -0.56 | 0.577 | . |
| *for_control* | 0.28889 | 0.25926 | 7.2 | 80.2 | 0.54 | 0.587 | . |
| *rd_cont* | 0.95556 | 0.91852 | 12.8 | 64.5 | 1.25 | 0.212 | . |
| *group* | 0.37037 | 0.37037 | 0 | 100 | 0 | 1 | . |
| *imp* | 0.86667 | 0.82222 | 11 | 73.2 | 1.01 | 0.315 | . |
| *exp* | 0.79259 | 0.77037 | 4.9 | 87.9 | 0.44 | 0.66 | . |
| *for_market* | 0.05185 | 0.02222 | 13 | -242.7 | 1.29 | 0.199 | . |
| *dummyN* | 0.01481 | 0 | 12.1 | -682.9 | 1.42 | 0.157 | . |
| *dummyNE* | 0.04444 | 0.02222 | 9.4 | 32.6 | 1.02 | 0.311 | . |
| *dummySE* | 0.15556 | 0.14074 | 4.1 | -120.3 | 0.34 | 0.733 | . |
| *dummyS*[a] | 0.2963 | 0.34074 | -9.6 | -66.7 | -0.78 | 0.435 | . |
| *dummyCO* | 0.00741 | 0.01481 | -5 | 75.5 | -0.58 | 0.563 | . |
| *cnae_10* | 0.12593 | 0.08889 | 11.7 | -91.8 | 0.98 | 0.328 | . |
| *cnae_11* | 0.02222 | 0.02963 | -5.8 | 20.3 | -0.38 | 0.703 | . |
| *cnae_12* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_13* | 0.02222 | 0.02222 | 0 | 100 | 0 | 1 | . |
| *cnae_14* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_15* | 0.02222 | 0.02222 | 0 | 100 | 0 | 1 | . |
| cnae_16 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_17 | 0.03704 | 0.04444 | -4 | 55.3 | -0.31 | 0.759 | . |
| cnae_18 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_19 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_20 | 0.14815 | 0.11111 | 11.5 | 27.2 | 0.9 | 0.367 | . |
| cnae_21 | 0.05185 | 0.06667 | -7.8 | 40.1 | -0.51 | 0.608 | . |
| cnae_22 | 0.01481 | 0.01481 | 0 | 100 | 0 | 1 | . |
| cnae_23 | 0.02963 | 0.03704 | -4.4 | -320.3 | -0.34 | 0.736 | . |
| cnae_24 | 0.02222 | 0.03704 | -10.5 | -568.2 | -0.72 | 0.475 | . |
| cnae_25 | 0.05185 | 0.05185 | 0 | 100 | 0 | 1 | . |
| cnae_26 | 0.02222 | 0.00741 | 6.6 | 77.7 | 1.01 | 0.315 | . |
| cnae_27 | 0.08889 | 0.08889 | 0 | 100 | 0 | 1 | . |
| cnae_28 | 0.07407 | 0.07407 | 0 | 100 | 0 | 1 | . |
| cnae_29 | 0.07407 | 0.08148 | -3.2 | 76.8 | -0.23 | 0.821 | . |
| cnae_30 | 0.02222 | 0.00741 | 12.7 | 3.6 | 1.01 | 0.315 | . |
| cnae_31 | 0.03704 | 0.03704 | 0 | 100 | 0 | 1 | . |
| cnae_32 | 0.02222 | 0.01481 | 4.8 | -26.2 | 0.45 | 0.653 | . |
| cnae_33 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_35 | 0 | 0 | . | . | . | . | . |
| cnae_38 | 0 | 0 | . | . | . | . | . |
| cnae_50 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_58 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_59 | 0 | 0 | . | . | . | . | . |
| cnae_60 | 0 | 0 | . | . | . | . | . |
| cnae_61 | 0.00741 | 0.02963 | -21.1 | -258.6 | -1.35 | 0.177 | . |
| cnae_62 | 0.1037 | 0.13333 | -9.9 | -95.8 | -0.75 | 0.453 | . |
| cnae_63 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_71 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_72 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_81 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_89 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_91 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_99 | 0 | 0 | . | . | . | . | . |
| Sample | Ps R2 | LR chi2 | p>chi2 | MeanBias | MedBias | | |
| Unmatched | 0.155 | 123.41 | 0 | 14.5 | 9.6 | | |
| Matched | 0.048 | 17.78 | 0.986 | 4.9 | 3.2 | | |

Variables' results for matched sample only.

[a] Not considered firms in the state of São Paulo.

[b] Variance ratio (for continuous covariates) of treated over non-treated.

Table A3.5

*Results of the Means Test for the estimated propensity score. Broad category: educational level of R&D staff*

| Variable | Mean | | %bias | % reduct | t-test | | V(T)/ |
|---|---|---|---|---|---|---|---|
| | Treated | Control | | bias | t | p>\|t\| | V(C)[b] |
| *revenue* | 6.50E+05 | 1.20E+06 | -38 | -36.2 | -2.01 | 0.045 | 0.30 |
| *personnel* | 6.4075 | 6.4722 | -5.4 | 92.7 | -0.48 | 0.635 | 0.55 |
| *age* | 28.638 | 29.431 | -6 | 65.1 | -0.53 | 0.594 | 0.9 |
| *nac_control* | 0.6954 | 0.74138 | -11.4 | 74.4 | -0.95 | 0.342 | . |
| *for_control* | 0.34483 | 0.3046 | 9.3 | 77.1 | 0.8 | 0.424 | . |
| *rd_cont* | 0.94828 | 0.97701 | -9.8 | 68.1 | -1.41 | 0.158 | . |
| *group* | 0.41379 | 0.4023 | 2.5 | 93.7 | 0.22 | 0.828 | . |
| *imp* | 0.89655 | 0.91379 | -4.5 | 90.3 | -0.55 | 0.584 | . |
| *exp* | 0.8046 | 0.84483 | -9 | 78.3 | -0.99 | 0.325 | . |
| *for_market* | 0.07471 | 0.06322 | 4.5 | -39.3 | 0.42 | 0.673 | . |
| *dummyN* | 0.01724 | 0.01724 | 0 | 100 | 0 | 1 | . |
| *dummyNE* | 0.04023 | 0.02874 | 5 | 67.6 | 0.59 | 0.558 | . |
| *dummySE* | 0.17241 | 0.12644 | 12.5 | -220.6 | 1.2 | 0.23 | . |
| *dummyS*[a] | 0.26437 | 0.32184 | -12.7 | -51.4 | -1.18 | 0.24 | . |
| *dummyCO* | 0.01724 | 0.01724 | 0 | 100 | 0 | 1 | . |
| *cnae_10* | 0.10345 | 0.10345 | 0 | 100 | 0 | 1 | . |
| *cnae_11* | 0.01724 | 0 | 14.2 | -322.6 | 1.74 | 0.082 | . |
| *cnae_12* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_13* | 0.01724 | 0.01724 | 0 | 100 | 0 | 1 | . |
| *cnae_14* | 0.00575 | 0 | 5.9 | 28.8 | 1 | 0.318 | . |
| *cnae_15* | 0.01724 | 0.03448 | -11.5 | -39.7 | -1.01 | 0.312 | . |
| cnae_16 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_17 | 0.03448 | 0.08046 | -25.2 | -353.9 | -1.85 | 0.066 | . |
| cnae_18 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_19 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_20 | 0.13218 | 0.10345 | 9.1 | 18.4 | 0.83 | 0.407 | . |
| cnae_21 | 0.06897 | 0.04023 | 13.4 | 24.8 | 1.18 | 0.239 | . |
| cnae_22 | 0.01724 | 0.02299 | -3 | 86.5 | -0.38 | 0.704 | . |
| cnae_23 | 0.02874 | 0.04598 | -10.2 | -488 | -0.85 | 0.398 | . |
| cnae_24 | 0.02874 | 0.02299 | 3.7 | 7.2 | 0.34 | 0.736 | . |
| cnae_25 | 0.04598 | 0.04023 | 2.6 | -297.6 | 0.26 | 0.793 | . |
| cnae_26 | 0.04598 | 0.05172 | -2.3 | 85.6 | -0.25 | 0.804 | . |
| cnae_27 | 0.08621 | 0.1092 | -8.8 | 0.6 | -0.72 | 0.472 | . |
| cnae_28 | 0.06897 | 0.04598 | 8.7 | -47.2 | 0.92 | 0.358 | . |
| cnae_29 | 0.0977 | 0.12069 | -9 | 62.3 | -0.69 | 0.493 | . |
| cnae_30 | 0.02299 | 0.01149 | 9.5 | 24.2 | 0.82 | 0.412 | . |
| cnae_31 | 0.02874 | 0.03448 | -3.6 | -31.6 | -0.31 | 0.76 | . |
| cnae_32 | 0.01724 | 0.02874 | -7.9 | -19.7 | -0.71 | 0.476 | . |
| cnae_33 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_35 | 0 | 0 | . | . | . | . | . |
| cnae_38 | 0 | 0 | . | . | . | . | . |
| cnae_50 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_58 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_59 | 0 | 0 | . | . | . | . | . |
| cnae_60 | 0 | 0 | . | . | . | . | . |
| cnae_61 | 0.01149 | 0.02299 | -11.2 | -858.3 | -0.82 | 0.412 | . |
| cnae_62 | 0.08621 | 0.05747 | 10.2 | -578.7 | 1.04 | 0.301 | . |
| cnae_63 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_71 | 0.00575 | 0 | 9.4 | -51.5 | 1 | 0.318 | . |
| cnae_72 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_81 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_89 | 0.00575 | 0.00575 | 0 | 100 | 0 | 1 | . |
| cnae_91 | 0.00575 | 0 | 10.1 | -22.1 | 1 | 0.318 | . |
| cnae_99 | 0 | 0 | . | . | . | . | . |
| Sample | Ps R2 | LR chi2 | p>chi2 | MeanBias | MedBias | | |
| Unmatched | 0.158 | 155.1 | 0 | 14.4 | 8.9 | | |
| Matched | 0.05 | 23.79 | 0.904 | 6.5 | 5.4 | | |

Variables' results for matched sample only.

[a] Not considered firms in the state of São Paulo.

[b] Variance ratio (for continuous covariates) of treated over non-treated.

Table A3.6

*Results of the Means Test for the estimated propensity score. Broad category: type of innovation*

| Variable | Mean | | %bias | % reduct bias | t-test | | V(T)/ |
|---|---|---|---|---|---|---|---|
| | Treated | Control | | | t | p>\|t\| | V(C)[b] |
| *revenue* | 9.90E+05 | 1.10E+06 | -3.7 | 93.6 | -0.3 | 0.763 | 0.56 |
| *personnel* | 6.8242 | 6.8727 | -3.3 | 97.8 | -0.27 | 0.787 | 0.82 |
| *age* | 29.456 | 28.669 | 5.9 | 74.9 | 0.46 | 0.649 | 1.15 |
| *nac_control* | 0.632 | 0.70824 | -20.1 | 74.7 | -1.28 | 0.201 | . |
| *for_control* | 0.424 | 0.33931 | 21.2 | 73.9 | 1.38 | 0.169 | . |
| *rd_cont* | 0.808 | 0.81137 | -0.9 | 99.4 | -0.07 | 0.946 | . |
| *group* | 0.424 | 0.4555 | -7.4 | 89.2 | -0.5 | 0.618 | . |
| *imp* | 0.96 | 0.94596 | 3.6 | 97.5 | 0.52 | 0.602 | . |
| *exp* | 0.912 | 0.90369 | 2 | 98.5 | 0.23 | 0.821 | . |
| *for_market* | 0.112 | 0.10407 | 3 | 87.7 | 0.2 | 0.841 | . |
| *dummyN* | 0.04 | 0.0391 | 0.5 | -1190 | 0.04 | 0.971 | . |
| *dummyNE* | 0.032 | 0.02683 | 1.9 | 88.7 | 0.24 | 0.81 | . |
| *dummySE* | 0.104 | 0.08586 | 5.2 | 73.5 | 0.49 | 0.626 | . |
| *dummyS*[a] | 0.4 | 0.45979 | -12.8 | 38.8 | -0.95 | 0.342 | . |
| *dummyCO* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_10* | 0.12 | 0.17326 | -17.1 | -552.1 | -1.19 | 0.236 | . |
| *cnae_11* | 0.008 | 0.0097 | -1.4 | 52.8 | -0.14 | 0.887 | . |
| *cnae_12* | 0.008 | 0.00294 | 7.9 | -62.5 | 0.54 | 0.59 | . |
| *cnae_13* | 0.016 | 0.01823 | -1.4 | 92.3 | -0.14 | 0.892 | . |
| *cnae_14* | 0 | 0 | 0 | 100 | . | . | . |
| *cnae_15* | 0.008 | 0.00645 | 1 | 94.4 | 0.14 | 0.885 | . |
| cnae_16 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_17 | 0.008 | 0.00995 | -1.5 | 85.1 | -0.16 | 0.871 | . |
| cnae_18 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_19 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_20 | 0.064 | 0.06038 | 1.5 | 89.9 | 0.12 | 0.906 | . |
| cnae_21 | 0.048 | 0.03805 | 6.3 | 64.5 | 0.39 | 0.7 | . |
| cnae_22 | 0.04 | 0.04707 | -3.3 | 72.8 | -0.27 | 0.785 | . |
| cnae_23 | 0.024 | 0.0248 | -0.4 | 97.5 | -0.04 | 0.968 | . |
| cnae_24 | 0.04 | 0.03176 | 4.7 | 46.1 | 0.35 | 0.727 | . |
| cnae_25 | 0.04 | 0.048 | -3.6 | 83 | -0.31 | 0.759 | . |
| cnae_26 | 0.128 | 0.1089 | 7.8 | 73.4 | 0.47 | 0.642 | . |
| cnae_27 | 0.048 | 0.04508 | 1.5 | 84.4 | 0.11 | 0.913 | . |
| cnae_28 | 0.144 | 0.15515 | -3.7 | 84.8 | -0.25 | 0.806 | . |
| cnae_29 | 0.168 | 0.14836 | 6.8 | 84.3 | 0.42 | 0.672 | . |
| cnae_30 | 0.016 | 0.00771 | 8.2 | -277.5 | 0.6 | 0.547 | . |
| cnae_31 | 0.016 | 0.01454 | 0.9 | 92.4 | 0.09 | 0.926 | . |
| cnae_32 | 0.024 | 0.01948 | 2.9 | 21.4 | 0.24 | 0.807 | . |
| cnae_33 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_35 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_38 | 0 | 0 | . | . | . | . | . |
| cnae_50 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_58 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_59 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_60 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_61 | 0.008 | 0.00941 | -1.4 | 49.6 | -0.12 | 0.905 | . |
| cnae_62 | 0.016 | 0.0175 | -1 | 91.3 | -0.09 | 0.927 | . |
| cnae_63 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_71 | 0.008 | 0.0033 | 3.7 | 79.2 | 0.49 | 0.621 | . |
| cnae_72 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_81 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_89 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_91 | 0 | 0 | 0 | 100 | . | . | . |
| cnae_99 | 0 | 0 | 0 | 100 | . | . | . |

| Sample | Ps R2 | LR chi2 | p>chi2 | MeanBias | MedBias |
|---|---|---|---|---|---|
| Unmatched | 0.369 | 516.5 | 0 | 28.5 | 16.5 |
| Matched | 0.019 | 6.74 | 1 | 3.4 | 1.5 |

Variables' results for matched sample only.
[a] Not considered firms in the state of São Paulo.
[b] Variance ratio (for continuous covariates) of treated over non-treated.

# Appendix to Chapter 4

Table A4.1

*Robustness Check 1: Alternative specifications. U.S MNEs model (dependent variable: $r\&d_{i,t}^{MNE}$). Least squares dummy variables corrected estimator.*

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| $r\&d_{i,t-1}^{MNE}$ | 0.417*** | 0.507*** | 0.516*** | 0.517*** | 0.522*** | 0.542*** | 0.547*** | 0.735*** | 0.856*** |
| | (0.117) | (0.102) | (0.110) | (0.076) | (0.076) | (0.071) | (0.069) | (0.067) | (0.049) |
| $1\text{-}(b\text{-}index)_{it}$ | -1.084 | -0.691 | -0.705 | -0.506 | -0.491 | -0.391 | -0.393 | -0.332 | -0.200 |
| | (1.222) | (0.736) | (0.627) | (0.414) | (0.407) | (0.444) | (0.424) | (0.479) | (0.414) |
| $sales_{i,t-1}$ | 0.542** | 0.454* | 0.454** | 0.481*** | 0.467*** | 0.486*** | 0.487*** | | |
| | (0.270) | (0.259) | (0.223) | (0.106) | (0.103) | (0.102) | (0.099) | | |
| $pr_{i,t-1}$ | 0.036 | 0.039 | 0.047 | 0.002 | 0.009 | 0.031 | | | |
| | (0.139) | (0.116) | (0.130) | (0.080) | (0.077) | (0.086) | | | |
| $ind_{i,t-1}$ | 0.048 | 0.026 | 0.026 | 0.024 | 0.021 | | | | |
| | (0.062) | (0.054) | (0.041) | (0.028) | (0.028) | | | | |
| $patstock_{i,t-1}$ | -0.004 | -0.016 | 0.013 | 0.104 | | | | | |
| | (0.487) | (0.370) | (0.321) | (0.218) | | | | | |
| $hc_{i,t-1}$ | 0.038 | 0.042 | 0.049 | | | | | | |
| | (0.090) | (0.078) | (0.066) | | | | | | |
| $r\&d^{c}_{i,t-1}$ | 0.194 | 0.110 | | | | | | | |
| | (0.436) | (0.256) | | | | | | | |
| $exp_{i,t-1}$ | -0.003 | | | | | | | | |
| | (0.009) | | | | | | | | |
| Observations | 218 | 238 | 242 | 280 | 280 | 294 | 294 | 294 | 294 |
| Number of id | 31 | 31 | 32 | 34 | 34 | 35 | 35 | 35 | 35 |
| Country FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No |

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Coefficient of the constant variable not presented.

Table A4.2

*Robustness Check 1: Alternative specifications. Fractional Patent Application model (dependent variable: $pat_{it}$). Static fixed effects model.*

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| $pat_{i,t-1}$ | 0.687*** | 0.694*** | 0.692*** | 0.700*** | 0.696*** | 0.695*** | 0.694*** | 0.783*** | 0.712*** |
| | (0.085) | (0.076) | (0.074) | (0.054) | (0.055) | (0.055) | (0.053) | (0.051) | (0.044) |
| $1\text{-}(b\text{-}index)_{i,t-1}$ | 0.195 | 0.173 | 0.173 | 0.119 | 0.144 | 0.143 | 0.143 | 0.025 | 0.059 |
| | (0.215) | (0.169) | (0.169) | (0.145) | (0.162) | (0.159) | (0.158) | (0.152) | (0.152) |
| $gdp_{i,t-2}$ | 0.251** | 0.245** | 0.247** | 0.211*** | 0.233*** | 0.232*** | 0.233*** | | |
| | (0.121) | (0.124) | (0.119) | (0.081) | (0.078) | (0.078) | (0.078) | | |
| $pr_{i,t-2}$ | -0.029 | -0.025 | -0.024 | -0.007 | -0.008 | -0.008 | | | |
| | (0.036) | (0.033) | (0.033) | (0.030) | (0.027) | (0.027) | | | |
| $ht\_exp_{i,t-2}$ | -0.003 | -0.003 | -0.003 | -0.002 | -0.001 | | | | |
| | (0.005) | (0.006) | (0.006) | (0.004) | (0.004) | | | | |
| $ind_{i,t-2}$ | 0.007 | 0.009 | 0.009 | 0.004 | | | | | |
| | (0.010) | (0.014) | (0.013) | (0.008) | | | | | |
| *rd_gdpi,t-2* | 0.033 | 0.045 | 0.046 | | | | | | |
| | (0.116) | (0.075) | (0.068) | | | | | | |
| $patstock_{i,t-2}$ | -0.024 | 0.006 | | | | | | | |
| | (0.093) | (0.091) | | | | | | | |
| $hc_{i,t-2}$ | 0.015 | | | | | | | | |
| | (0.032) | | | | | | | | |
| Observations | 296 | 304 | 304 | 339 | 353 | 353 | 353 | 378 | 378 |
| Number of id | 33 | 33 | 33 | 35 | 36 | 36 | 36 | 36 | 36 |
| Country FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year dummy | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No |

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Coefficient of the constant variable not presented.

Table A4.3

*Robustness Check 2: Investment in Brazil as lower limit. U.S MNEs model (dependent variable: $r\&d_{i,t}^{MNE}$)*

| Variables | Estimator | | | | |
|---|---|---|---|---|---|
| | Random Effects | Fixed Effects | Fixed Effects | Arelano-Bond | LSDVC |
| $r\&d_{i,t-1}^{MNE}$ | | | 0.514*** | 0.575*** | 0.600*** |
| | | | (0.051) | (0.061) | (0.139) |
| $1\text{-}(b\text{-}index)_{it}$ | 0.899** | -0.264 | -0.567 | -0.569 | -0.593 |
| | (0.363) | (0.529) | (0.459) | (0.549) | (1.011) |
| $sales_{i,t-1}$ | 0.964*** | 1.049*** | 0.470*** | 0.398*** | 0.408** |
| | (0.090) | (0.194) | (0.090) | (0.087) | (0.203) |
| $pr_{i,t-1}$ | 0.072 | 0.059 | 0.003 | 0.001 | 0.007 |
| | (0.084) | (0.056) | (0.050) | (0.063) | (0.147) |
| $ind_{i,t-1}$ | -0.015 | 0.022 | 0.038*** | 0.036** | 0.037 |
| | (0.015) | (0.014) | (0.009) | (0.014) | (0.051) |
| $patstock_{i,t-1}$ | 0.148 | 0.824*** | 0.576*** | 0.559*** | 0.509 |
| | (0.104) | (0.237) | (0.148) | (0.192) | (0.420) |
| $hc_{i,t-1}$ | -0.021 | 0.098** | 0.049 | 0.044 | 0.037 |
| | (0.068) | (0.045) | (0.042) | (0.048) | (0.099) |
| $r\&d^{c}_{i,t-1}$ | 0.486*** | 0.036 | 0.013 | -0.015 | 0.031 |
| | (0.168) | (0.153) | (0.100) | (0.138) | (0.399) |
| $exp_{i,t-1}$ | -0.005 | -0.012** | -0.010** | -0.009 | -0.009 |
| | (0.004) | (0.006) | (0.005) | (0.006) | (0.007) |
| Observations | 170 | 170 | 158 | 158 | 158 |
| R-squared | 0.841 | 0.707 | 0.797 | | |
| Number of id | 21 | 21 | 21 | 21 | 21 |
| Country FE | Yes | Yes | Yes | Yes | Yes |
| Year dummy | Yes | Yes | Yes | Yes | Yes |

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Coefficient of the constant variable not presented.

Table A4.4

*Robustness Check 2: Investment in Brazil as lower limit. Fractional Patent Application model (dependent variable: $pat_{it}$)*

| Variables | Estimator | | | | |
|---|---|---|---|---|---|
| | Random Effects | Fixed Effects | Fixed Effects | Arelano-Bond | LSDVC |
| $pat_{i,t-1}$ | | | 0.454*** | 0.514*** | 0.533*** |
| | | | (0.047) | (0.064) | (0.075) |
| $1\text{-}(b\text{-}index)_{i,t-1}$ | 0.053 | 0.028 | 0.042 | -0.114 | 0.053 |
| | (0.146) | (0.132) | (0.078) | (0.097) | (0.186) |
| $gdp_{i,t-2}$ | 0.730*** | 0.662*** | 0.304* | 0.261 | 0.240*** |
| | (0.188) | (0.235) | (0.172) | (0.200) | (0.093) |
| $pr_{i,t-2}$ | 0.104* | 0.077 | 0.007 | -0.008 | -0.002 |
| | (0.054) | (0.046) | (0.037) | (0.042) | (0.035) |
| $ht\_exp_{i,t-2}$ | -0.005 | -0.010 | -0.008** | -0.008*** | -0.008* |
| | (0.006) | (0.007) | (0.003) | (0.003) | (0.004) |
| $ind_{i,t-2}$ | 0.026** | 0.038** | 0.021** | 0.019* | 0.019** |
| | (0.011) | (0.014) | (0.010) | (0.011) | (0.009) |
| $rd\_gdp_{i,t-2}$ | -0.002 | -0.014 | 0.014 | 0.068 | 0.005 |
| | (0.095) | (0.099) | (0.075) | (0.089) | (0.099) |
| $patstock_{i,t-2}$ | 0.112 | -0.061 | -0.024 | -0.030 | 0.002 |
| | (0.118) | (0.159) | (0.088) | (0.103) | (0.097) |
| $hc_{i,t-2}$ | 0.047* | 0.058** | 0.033* | 0.013 | 0.029 |
| | (0.025) | (0.023) | (0.017) | (0.018) | (0.026) |
| Observations | 274 | 274 | 274 | 274 | 274 |
| R-squared | 0.419 | 0.425 | 0.566 | | |
| Number of id | 32 | 32 | 32 | 32 | 32 |
| Country FE | Yes | Yes | Yes | Yes | Yes |
| Year dummy | Yes | Yes | Yes | Yes | Yes |

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Coefficient of the constant variable not presented.