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IMPACTS OF THE ECONOMIC SUBSIDIES PROGRAM TO INNOVATION: EVALUATION OF LONG-TERM EFFECTS ON THE BRAZILIAN ECONOMY

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ABSTRACT

The practice of fiscal and financial incentives for innovation is commonly adopted by a number of countries with the aim of stimulating the private sector to expand its innovative efforts to increase competitiveness and contribute more forcefully to local economic growth. This works proposes to investigate the effectiveness of one of the public policy instruments to foster research, development and innovation (P,D&I) in Brazil, the economic subsidy to innovation. Empirical studies have tested the existence of the effectiveness of Brazilian policies in several ways and point to positive effects in terms of expanding the innovative effort of companies benefiting from some kind of legal program in relation to non-beneficiary companies. However, the objective of this work is to propose an alternative evaluation, testing by means of a dynamic computable general equilibrium model, how much the productive sectors of the Brazilian economy have benefited by the concession of the economic subsidies to the activities of technological innovation in the companies. In addition, in order to adequately characterize this group of beneficiary companies, multivariate analysis techniques will be used to capture the specific configurations that can generate a common profile of the target companies of the public policies related in this work.

Keywords: Innovation policies, multivariate analysis, dynamic computable general equilibrium

JEL Classification: O38, R15, R59, C38

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1. Introduction

Public policies to foster innovation in Brazil have gained space in the incentive agenda for the private productive sector in the last thirty years. There were improvements in the legal framework aiming to stimulate more intensive processes of technological progress in the private sector, aiming at creating an institutional environment favorable to the greater interaction between public agents of the scientific and technological institutions and the productive sector.

There is an understanding that technological progress is central to any development process, a fact favored by its progressive incorporation into conventional economic theory, which originally regarded it as a variable external to the core of its formulation. The innovations generated by research and development (R&D) processes, knowledge spillovers and the accumulation of human capital were identified in the literature as the main driving forces of economic growth. Lucas (1988) emphasizes the role of the externalities of human capital, while Romer (1990), Grossman and Helpman (1991) and Aghion and Howitt (1990) focus on emphasizing the capacity of industrial innovation via R&D to be a determinant of growth through mechanisms of accumulation of knowledge. In common, these authors point out that there is the capacity of public policies to impact the rate of growth in the long term. Thus, government policies can affect economic growth, encouraging companies to devote more resources to R&D activities, such as through market incentives (GARAU; LECCA, 2008).

The legal framework for innovation in Brazil is determined, mainly, by the Innovation Law (Law 10.973/04), the Law of Good (Law 11.196/05), the Informatics Law (Law 8.248/91) and by the establishment of Sectoral Funds (Law 11.540/07), as well as for its subsequent amendments sanctioned by the federal government. This set of laws and regulations gives legal support to innovation incentives in companies such as economic subsidy, financing, state shareholding, technological ordering, tax incentives, granting of scholarships, and use of state purchasing power, among other legislated instruments (BRAZIL, 2004).

The economic subsidy to innovation is one of the main instruments of the recent innovation policy among the mechanisms available to encourage innovation in companies established in the aforementioned legal framework. One of the characteristics of this instrument is that it does not require a return of resources to the grantor, in this case the *Financiadora de Estudos e Projetos* (Finep), which is the executive secretary of the program. It should also be pointed out that one of the characteristics of is the sharing of project risks between the State and the applicant companies, since they must provide a counterpart to the subsidized resource.

From the year 2006, Finep began to operationalize the instrument through the Program for the Economic Subsidy for Innovation, using public call invitations. The program provides for the coverage of costs of research projects and development of innovative products and processes of Brazilian companies, regardless of the origin of their capital, with the mission of dividing the risks inherent in the innovation process. The resources made available through the Economic Subsidy Program are destined to companies of all

sizes and there may be some reserve of the total resources for concession to micro and small companies and in certain regions of the country, depending on the edict in force.

Although there is some evidence of positive effects on the productivity and competitiveness of the economy, the effectiveness of the introduction of this mechanism has been questioned as to its ability to promote the stimulus necessary for companies to increase their own investments in technological activities and thereby accelerate the pace of innovation in the country. This is because it is one of its main characteristics, the contribution of public resources in companies with no need for repayment. Thus, its proper use and results are questioned, being pertinent the analysis of its operation.

There are in the empirical literature, using mostly econometric estimation methods, studies that investigate the effectiveness of several public innovation policy instruments for Brazil. These surveys seek to know the effects of fiscal and financial incentives policies on the level of investment in companies' internal research and development, as well as seek to establish the most effective type of policy, since the institutional environment can change the effectiveness of the implemented instruments.

Although the phenomenon of public policy-induced innovation has long been recognized in the field of economic sciences, incorporating this phenomenon into policy models has been hampered by conceptual and computational issues. The methodological contribution proposed by this work is the development of a consistent general equilibrium model that allows such analysis in conjunction with the application of multivariate analysis methods. Thus, in order to answer the raised issues, this work will be supported methodologically in the approach of dynamic computable general equilibrium (CGE) models and also in the statistical techniques of cluster analysis and discriminant analysis.

The techniques of multivariate analysis make up a section of characterization of the target companies of innovation policies. This analysis will extract information from the broad set of variables that make up the database for companies that received economic subsidy resources between the years 2007 to 2013. The adoption of cluster analysis aims to create groups of similar units from the latent factors defined in the factorial analysis. Given the formation of the groups between 2007 and 2013, the discriminant analysis will be used to classify new companies in subsequent periods, classifying them among the groups previously formed.

With the results of the discriminant analysis, it will be possible to observe the transition of companies between groups formed from specific characteristics between the years 2007 and 2013. This transition between groups, revealed from the perspective of the companies analyzed, indicates that there was a behavior change over time. However, due to the methodological characteristics of the discriminant analysis, it is not possible to analyze the economic effects that may have contributed to such changes during the period. To overcome this limitation, we adopt the computable general equilibrium analysis, which were the peculiar objectives of the methodology, to allow the visualization of the trajectory of change of the macroeconomic variables, accusing the deviation that may exist in relation to the reference scenario stipulated over the course of the period analyzed.

The adoption of CGE models allows to explore how public policies focused on specific sectors, as in the case of innovation policies, can affect the level of production and the

rate of technological progress. Thus, by incorporating the R&D element into the model, it is possible to increase understanding about the role of R&D generation in the economy. Thus, this work seeks to address issues related to the capacity to effectively expand private investment in Research, Development and Innovation (R,D&I) activities, since public policies to foster innovation aim to act directly in the productive sector. In addition, it is possible to systematically disaggregate the effects of promoting innovation across sectors of the economy by identifying which sectors benefit from such incentives.

Another issue considered is the adoption of a dynamic recursive model, which will allow the analysis of the temporal trajectory of the effects of the policy of granting economic subsidies to the beneficiary firms. There are many reasons to adopt a model that considers the transition dynamics. First, it is possible to know whether, from a given stock of arbitrary initial capital, the economy will converge to a certain steady state, revealing what are the economic forces that drive the economy to that state. Another point is the possibility of a comparative analysis of the behavior of some variables along the transition path (DIAO et al., 1996).

While the empirical literature of evaluations of public policies of incentive to innovation has generated relevant results on the effectiveness of the mechanisms used, the question remains about the systemic impacts in the economy of this type of public investment. Such a gap may be due to frequently adopted econometric methods that fail to capture the analytical dimension that is achieved with the CGE approach. With the adoption of this method of analysis, it is possible to evaluate impact in a systemic approach, since the results of CGE models occur from the analysis of the interdependencies of the sectors of the economy.

Besides this introduction, this paper is divided into five more sections and the final considerations. In the next section, the foundations of the legal mechanism for fostering innovation through economic subsidies are discussed. In Section 3, the main empirical studies that use the CGE methodology to deal with the effects of innovation policies in some countries are mentioned. Subsequently, in Section 4, static methods of describing data are applied to the companies benefiting from the innovation subsidy program in Brazil in the period 2007-2013. Section 4 also presents the database, the description of the variables and the results obtained. In this section, the CGE methodology is presented along with the calibration of the model adopted, the closing of the scenario and the discussion of the results achieved. Finally, we present the final considerations on the impacts of innovation promotion policy on economic indicators.

2. Economic subsidies for technological innovation

The possibility of financing technological development in companies, combining both reimbursable and non-reimbursable resources, provides a great inducement power for innovation activities. Public support for R&D and innovation in companies is a common practice for developed countries, as recognized by the World Trade Organization (MCTI, 2007).

This is justified by the strong positive correlation between expenditure on R & D activities and the increase in total factor productivity (OECD, 2005). This situation makes the discussion about the role of the State and its need for intervention in the economy less

relevant than the debate about how the State should intervene in the promotion of technological development (DOSI et al., 1990).

According to the Ministry of Science, Technology and Innovation, the operationalization of support for innovation activities in Brazil is based on the following institutional and financial mechanisms available to companies: low interest financing, entrepreneurial capital funds, fiscal incentives, economic subsidies and direct purchases by the public sector (MCTI, 2007).

Formally, economic subsidy is a kind of government grant in which public resources are earmarked for public or private enterprises. It is envisaged and defined in Law 4,320 of Public Accounting, which classifies it as a current transfer, that is, does not demand direct consideration in goods or services, which unlike government purchases and is exclusively used for costing expenses, not being confused, therefore, with investment. Financial support for innovation projects through an economic grant, modality instituted by the Innovation Law and the Law of Good, consists of the direct granting of non-reimbursable financial resources to companies, to cover expenses for the costing of P,D&I projects innovative products and processes (MORAIS, 2008).

Created in Brazil in August 2006, this mechanism is based on the improvement and consolidation of the use of economic subsidies to the activities of P,D&I and the employment of researchers in companies. The purpose of this type of mechanism is to promote a significant increase in innovation activities and increase the competitiveness of companies and the country's economy.

One of the justifications for the analysis of the impacts caused by this mechanism is the fact that the grant of economic subsidy for innovation in companies is a government policy instrument widely used in developed countries and is operated in accordance with the norms of the Organization World Trade Organization (WTO). In addition, the economic subsidy can be understood as the sharing, between company and state, of R&D costs and risks. Thus, it is a mechanism that intends to promote, through the agencies of science and technology development, the increase of innovation activities, the implementation of researches and the incentive to competitiveness of companies and the economy of the country.

The decree that regulates the Law of Innovation determines that the grant of economic subsidy necessarily entails the presentation of a counterpart by the beneficiary company. In the budget of the projects, the minimum percentages required as a counterpart are defined according to the size of the candidate companies and their respective gross invoices.

The portion of the project budget to be subsidized should only include costs directly related to P,D&I, such as: payment of own personnel allocated to P,D&I activities and respective employer obligations; hiring of specialized consultants of natural or legal persons; consumables; lease of movable or immovable property, as long as they are effectively applied in the project and expenses for the pioneering introduction of the product, process or service in the market.

The capital expenditures necessary for the project must be borne by the proponent and must form part of the consideration of the proponent. In this case, expenses such as preliminary prospecting and market studies for the product, process or service to be developed are also included; participation in events that are not of a technical nature; acquisition of consumer materials for the purpose of manufacturing permanent equipment and installations; works and reforms of any nature; costing of accounts related to research, development and innovation activities, as well as the payment of employees that are not directly related to the development of the proposed activities.

The rules of application of this mechanism encourage the hypothesis that there is an intention to induce private investment in the generation of innovation and, therefore, makes it a mechanism that can be analyzed from two points of view: the granting of these resources and that of private investment, which is being stimulated to increase. For these reasons, it is highlighted that the instrument of economic subsidies will be the main object of empirical study of this work.

3. Evidence of empirical research

For the analysis of the effects of the generation of innovation and technological changes, the sectorial, regional and chronological dimensions are relevant. Innovations do not remain restricted in certain industries or some areas of the economy, but include the entire economy. For this reason, the instrument for the analysis must consider the entire economic context. More specifically, with respect to the chronological dimension, a medium- or long-term perspective is appropriate because adjustment reactions due to technological change need time to be perceived (ZÜRN et al., 2007).

A CGE model is adequate to meet the required specification on the analytical instrument in relation to the necessary dimensions. Due to the total analytical approach, such models are enabled for the quantitative analysis of the implications of technological change, especially for development analysis, the description of technological changes in CGE models is of particular interest. On the one hand, the results obtained are significantly affected by the theoretical assumptions made about the implementation of technological changes in these models. This means that, through a more precise implementation of technological changes, the results can be better classified and explained.

The first works using EGC models that inserted data referring to technological innovation and R&D date back to the 1990s and have as main objective to study the effects on productivity against technological progress.

Firstly, Diao et al. (1996) proposed an EGC model based on the theory of endogenous economic growth incorporating R&D data. For this, the capital values were divided into physical capital and knowledge capital so that the latter could be the production input of the R&D sector. The authors carried out three simulations using the calibrated model aiming to obtain results for both static and dynamic effects. The first simulation eliminated taxes on production and eliminated tariffs on agricultural goods. Another simulation replicated the situation for the non-agricultural sector, while the third liberalized both sectors. For each of these simulations, the transition trajectories converging to the steady state are also obtained.

In order to examine the impact of alternative policies to promote R&D on productivity and economic growth in Canada, Ghosh (2007) developed a theoretical specification of a CGE model whose production function is enabled so that differentiated capital (called R&D sector) affect productivity by reducing the relative importance of other intermediate inputs and primary factors. The results show that direct incentives, such as subsidies for R&D activities, have the greatest impact on productivity in the Canadian economy, while an increase in subsidies to R&D capital users has a positive but small impact. Trade liberalization has minimal effects on productivity growth through its impacts on international R&D spillovers.

Zürn et al. (2007) used the NEWAGE-W model for the quantitative analysis of the implications of technological change induced by R&D. In the CGE model improved by the authors, the endowment of knowledge is endogenously determined by R&D investments. To analyze the economic and environmental impacts of investments in R&D and knowledge inputs, two scenarios were analyzed in this work. First, a scenario was simulated with direct subsidies to knowledge inputs and, later, another scenario with subsidies to R&D investments. The results showed that the accumulation of knowledge generates a much stronger impact on economic development than changes in knowledge allocation.

In order to evaluate the capacity of the incentives policies for R&D to affect the long-term growth rate, Garau and Lecca (2008) developed the SGEM model for the Italian region of Sardinia. The calibration of the authors' model incorporates induced technical changes and allows the analysis of international knowledge spillovers. The incorporations of this model extend the availability of all possible technologies, which can be understood as basically including an intangible factor in the production function. The intangible factors given by the regional level of knowledge endowment are divided into excluding and non-excluding knowledge. The former is treated as a primary factor of production that accumulates according to the traditional perpetual inventory change. In turn, non-exclusive knowledge derives from the potential spillover effect of knowledge arising from interregional and international trade. In methodological terms, to make changes in the Social Accounting Matrix (SAM) that could capture the effects of investments in R & D and technological spillovers, a weighting was used by the Yale Technology Matrix (YTM) matrix. The results indicate that the cost of R&D policies can vary according to the prevailing wage setting in the region. In addition, the ability of such a policy to generate knowledge spillovers through international and interregional trade presents itself rather modest.

In the work of Bye, Fæhn and Heggedal (2009) for Norway, it is explored how innovation incentives in a small open economy can be designed to achieve better standards of well-being and development. The model treated by the authors allows the technological change conducted by R&D to be incorporated into the available capital varieties. External knowledge spillovers are calibrated in the model to cause about 95% of Norwegian technological change and are absorbed through the use of all resources, in which investment goods that incorporate technological improvements caused by R&D, being a type of driver. This feature of the model contributes to a significant reduction in the role of R&D stimulus policies. The results show that subsidizing domestic investments,

excluding stimulus to the international market, generates less R&D, capital formation, economic growth and welfare than other alternative policies.

Bor et al. (2010) investigated the impact of public investment in R&D on economic growth and productivity levels in Taiwan by developing a dynamic CGE model called SciBud-CGE. The authors used econometric methods to estimate the percentage of the input of knowledge capital incorporated in the total physical capital, according to the GTAP database. The authors' results show that public investment in R&D as well as producing different impacts on the short and long term real GDP of the Taiwanese economy also boosted the production of high technology industries through increased exports.

Bye, Fæhn and Grünfeld (2011) have developed a dynamic CGE model to analyze the interrelationships between R&D, trade and productivity and to compare public assistance for R&D and its promotion via exports in terms of long-term growth and impact on the well-being of a small open economy, in this case Norway. The authors extended previous models of endogenous growth by introducing the bidirectional relationship between export and productivity and played a relevant role for export promotion policy instruments. An CGE model was applied to capture how the final goods industries vary in relation to the absorption of international knowledge spillovers, depending on their respective trade and R&D intensities. The model presented in this paper is a refinement compared to Diao et al. (1999), in which all spillovers are channeled through the (single) R&D industry. The results show that the promotion of exports is inferior to support for R&D in the generation of innovation via R&D. The authors argue that the impact of this kind of incentives and export promotion on growth and efficiency is not obvious. In a real economy there are several market imperfections and government interventions. Thus, distortions due to favorable policies directed at traditional industries, which tend to hamper productivity growth and economic efficiency, become particularly relevant.

Křístková (2012) investigates how the results obtained with standard EGC models can be improved with the incorporation of the effects of R&D activity. This analysis is driven by a recursive dynamic CGE model built for the Czech Republic economy. Thus, the author seeks to quantify the impact of R&D activities on long-term economic growth. The effect of R&D investment is shaped by the accumulation of knowledge that is treated as a specific production factor. Thus, investments in R&D were considered as a knowledge capital offering sector and included in the added value in the SAM database. The main result shows that the accumulation of knowledge can contribute to high economic growth, but the impact of the dynamics in the CGE model is small. In the long run, the CGE model showed that R&D investment is less efficient at producing added value compared to capital goods investment. This inefficiency is partly determined by the flexibility of the substitution between physical and R&D investments in the CGE model, which in fact may represent a dispute. However, in terms of structural change in the economy, the omission of knowledge capitalization may underestimate the long-term results for the tertiary sector.

As shown, the empirical literature on the analysis of the effects of R&D on the economy using CGE models emphasizes that, like the results of domestic R&D, the absorption of R&D knowledge from other sources is also decisive for productivity and firms'

competitiveness and for the efficiency of economies (BYE; FAEHN; GRÜNFELD, 2011).

For the Brazilian economy, Pio (2016) worked with the main objective of analyzing the impacts of accumulation of knowledge capital, formed from investments in R&D, on the productive structure and on the macroeconomic aggregates in the long term. This analysis was carried out by means of the construction of a static EGC model with detailed specification of investments in R&D and formation of knowledge capital. It was proposed that, when implementing changes in the stock of knowledge capital, there would be changes in the use of primary factors, implying changes in productivity. The main results indicate that positive changes in the sectorial productivity, causes an increase in the level of competitiveness of the sectors of the Brazilian economy. At the aggregate level, there was an increase in the volume of exports, an increase in aggregate real consumption, a positive impact on real GDP and an improvement in well-being.

This application to the Brazilian economy, however, did not evaluate the effectiveness of the political mechanisms to foster innovation. With this purpose, there are in the empirical literature works that evaluate the impacts of public policies of innovation using other methodologies. However, it is emphasized that part of the empirical results is obtained from short-term relationships based on partial equilibrium structures. This emphasizes the suggestion that a general equilibrium model incorporating R&D would be useful for analyzing long-term effects on welfare in policy implementation scenarios (GHOSH, 2007).

For the purpose of analyzing the results and conclusions about the object of study, some econometric evaluation works were applied to Brazil (e.g., AVELLAR, ALVES, 2008; AVELLAR, 2009; COELHO; DE NEGRI, 2010; KANNEBLEY; PORTO, 2012; ARAÚJO ET AL., 2012). These works exemplify the existing economic evaluation of public innovation policies in Brazil and show that there are considerable effects of applying the various incentives on innovation generation and economic indicators, pointing to the effectiveness of such policies. However, the gap of an analysis that addresses the interrelationship of the productive sectors in relation to the stimuli to innovation remains.

4. Statistical Methods of Data Description

In order to describe the main characteristics about the beneficiaries of the economic subsidy, managed by Finep, statistical techniques of multivariate analysis will be used, which are useful exploratory procedures to understand the nature of the relationship between the many variables that compose the sample.

In the case of this study, the purpose of the multivariate analysis is to know what are the common characteristics of the target companies of innovation policies and to try to recognize patterns of groupings between them, regarding the characteristics of the workers and the project contemplated. Based on the results of these analyzes, it is intended to understand if, over the years, the companies that benefited from the economic subsidy resources changed their structural characteristics regarding the profile of their employees, that is, if they passed between the groups initially formed after receipt of the economic grant.

By adopting the clusters analysis technique, the use of arbitrary group classification metrics is alternated by techniques that adopt information from the set of variables as a classification basis. In this way, this technique intends to create groups of similar units based on the latent characteristics of the selected variables, finding and characterizing groups of companies with vectors of random variables that show associations between the elements, denoting correlated characteristics.

The discriminant analysis technique will also be used to verify the classification error rate of the groups formed. The methodological choice is justified by the fact that this technique is a probabilistic classification technique. In addition, it is worth investigating whether this same suggestion for the formation of groups of companies benefiting from the economic subsidy programs for innovation has remained appropriate over the years, allowing the analysis of transition between groups. Therefore, the two techniques are articulated to group and also to discriminate and to reclassify the groups, if appropriate, from their individual characteristics.

The transition analysis, made possible by the discriminant analysis, contributes methodologically to the evaluation of the mechanism of granting economic subsidies to innovation. This is because it indicates that when there is a transition between groups due to changes in their characteristics, companies may be responding to the stimuli generated by the support of R,D&I activities.

4.1 Database and variables description

The database used to characterize the beneficiary companies of the economic subsidy program is made up of public data accessed in the Aquarius Platform linked to the MCTI, and identified data from the *Relação Anual de Informações Sociais*[4] (RAIS) provided by the Ministry of Labor.

The analysis sample is made up of 324 companies, known as proponent institutions in the form of legal entities, benefiting from the economic subsidies of the Sectoral Innovation Funds. The grants were in fact granted to the sample companies after 2007, the year following the entry into force of the legal framework of the program. For this reason, the analysis begins for the year 2007.

The choice of variables is due to the objective of characterizing the beneficiary companies of the grant programs, analyzing characteristics that are linked to an innovative behavior and other characteristics that reflect the properties of the labor market. As the analysis is performed between two time periods, it was necessary to work only with the companies that presented regularity of data availability in the years 2007 and 2013. For this reason, the total of companies analyzed refers to firms that delivered the data from the RAIS in the two periods, excluding those that were created as of 2007.

Once these considerations have been made, the variables constructed for the application of multivariate analysis techniques are presented in Table 1. In addition to these related

[4] This database comes from a socio-economic information report requested by the Brazilian Ministry of Labor and Employment to legal entities and other employers annually.

variables, the analysis will have the variables on the values contracted by the companies with Finep and also on the number of technical researchers involved in submitted project.

TABLE 1 - Summary of the variables used for the multivariate analysis application

Variable	Description	Aplication	Data Source
Age	Average age of the employees of the company	CA and DA	RAIS
Female percentage	Percentage of women employed in the company	CA and DA	RAIS
Average remuneration	Nominal average remuneration of employees	CA and DA	RAIS
Time	Average time of employment of company employees	CA and DA	RAIS
Contracted hours	Average number of employees' contracted hours	CA and DA	RAIS
CBO2	Proportion of workers under the occupation code "professionals of the sciences and arts" of the company	CA and DA	RAIS
CBO3	Proportion of workers under the occupation code "high school technicians" of the company	CA and DA	RAIS
CBO7	Proportion of workers under the occupational code "workers of the production of industrial goods and services" of the company	CA and DA	RAIS
Higher education	Proportion of workers with higher education	CA and DA	RAIS
Postgraduate studies	Proportion of postgraduate workers	CA and DA	RAIS
Amount contracted	Amount of the concession contract for the economic subsidy	Characterization	Plataforma Aquarius
Researchers hired	Number of technical researchers hired to develop the project	Characterization	Plataforma Aquarius
City	City where the contracting company is located	Characterization	RAIS
Companies´s size	Size of the companies according to the number of registered employees	Characterization	RAIS
CNAE Sector	Productive sector of the contracting companies according to the code CNAE 2.0	Characterization	RAIS

Note: CA = Cluster Analysis, DA = Discriminant Analysis

4.2 Aplicação e resultados da análise multivariada

The clusters analysis technique adopted in this work is a combination called two-stage clusters analysis, which basically consists of performing a hierarchical clustering procedure, in this case by means of middle links and the Ward method, and later executing the non-hierarchical procedure, using the k-means method. The first stage is to indicate, based on the statistical and graphical criteria[5], what would be the ideal final partition of groups of companies, while the second stage, when using the partition indicated in the first stage, effectively performs the separation of the groups.

Thus, the four groups were defined by hierarchical methods and the non-hierarchical k-means method was applied. This method is a partitioning technique that gives more

[5] Calinski-Harabaz and Duda-Hart test and dendogram, respectively.

precise indications about the number of clusters that must be formed. In this way, the final partition and the distribution of the elements in each group ends in the second stage of the procedure.

The Lachenbruch method was used to analyze the discrimination of the groups. This procedure has the purpose of removing the possible bias of overvaluation of the probabilities by the classification method. This function is used to classify the observation withdrawn, that is, if in fact the observation was classified correctly in a given group. The classifications generated by this procedure, for the year 2007, can be observed in Table 2. After the classification of the companies in their respective groups, the discriminant analysis was performed to examine the apparent error rate of the final partition generated by the clusters analysis for both the year 2007 and the year 2013.

TABLE 2 – Lachenbruch classification method for the year 2007

Groups	1	2	3	4	Total
1	111	2	0	10	123
	(90,24%)	(1,63%)	(0,00%)	(8,13%)	(100%)
2	1	37	0	0	38
	(2,63%)	(97,37%)	(0,00%)	(0,00%)	(100%)
3	0	0	4	0	4
	(0,00%)	(0,00%)	(100%)	(0,00%)	(100%)
4	9	0	0	150	159
	(5,66%)	(0,00%)	(0,00%)	(94,34%)	(100%)
Total	121	39	4	160	324
	(37,35%)	(12,04%)	(1,23%)	(49,38%)	(100%)

Note: The values in parentheses are the probabilities of correct classifications. The results were achieved considering equal prior probabilities (priors).

Observing the results of the classifications, it is noticed that the classifications are not well distributed between the groups, concentrating in groups 1, 2 and 4. Nevertheless, it is recalled that the main reason for the use of the discriminant analysis for the year of 2007 is to verify the classification error rate of the partition generated by cluster analysis.

Taking these considerations about the characteristics of the groupings for the year 2007, the next step is the analysis of the transition of the companies between the clusters in the year 2013. As in 2007, classification rules are used from linear discriminant functions (canonical), evaluating the need to reclassify the companies, observing the incorrect classification rate.

Applying the same clusters partitioning criterion used in the base year of 2007 for the year 2013, one can notice that the configuration between the groups changed significantly, increasing the classification error rate. The results of Table 3 show the classification errors in each group.

TABLE 3- Lachenbruch classification method for the year 2013

Groups	1	2	3	4	Total
1	57	21	0	45	123
	(46,34%)	(17,07%)	(0,00%)	(36,59%)	(100%)
2	14	20	1	3	38
	(36,84%)	(52,63%)	(2,63%)	(7,89%)	(100%)
3	0	0	4	0	4
	(0,00%)	(0,00%)	(100%)	(0,00%)	(100%)
4	38	6	0	115	159
	(23,90%)	(3,77%)	(0%)	(72,33%)	(100%)
Total	109	47	5	163	324
	(33,64%)	(14,51%)	(1,54%)	(50,31%)	(100%)

It should be noted that the classification of companies in the four groups with the information matrix of 2013 indicates a total error rate of 32.17%. For this reason, reclassifications were performed so that the estimated error rate decreased. The final partition for the year 2013 has an estimated error rate of 25.90% and 27 companies are effectively repositioned.

When observing the transition between the clusters, two distinct movements are clearly noticed: the first is the transition of companies with similar characteristics between clusters 1 and 4 and the second is the transition of companies from clusters 1 and 4 to cluster 2.

As the transition to cluster 2 was the largest, the reasons why firms left their source groups were best observed. Of the 15 companies that went to cluster 2, all of them have a percentage of employees with higher education that are well above the averages of their groups of origin in 2007. The average remuneration of the companies that made the transition to cluster 2 presents a value well above the remuneration averages of clusters 1 and 4, in which such companies were originally classified in 2007. Analyzing by productive sector, two-thirds of the companies that made the transition to cluster 2 are classified as being in the information technology services sector.

All the 27 companies that made the transition between groups presented values of the economic subsidy contract smaller than the means of the groups, showing that the transition of the companies between clusters was not due to this variable.

One of the characteristics that separate the companies into distinct groups is the proportion of employees with higher education. The specialized labor force is an important input recognized by the literature as being one of the determinants of the increase of the innovation rates of the companies. The other characteristics of the groups are closely related to the presence of employees with higher education in companies, as in the case of average remuneration, which is a variable that changes significantly from one group to another and is proportionally related to the level of education of employees. The variables on the most frequent occupations in the analyzed companies also reflect the proportion in which the labor with full superior education is demanded by the companies. So does the average age of the employees.

The observation of the variable female participation in the composition of the employees of the companies analyzed brings a result that is the subject of a vast empirical literature. The cluster with the highest proportion of employees is the cluster with the lowest average remuneration and the lowest proportion of employees with higher education. This result indicates that there can be wage differentiation and precariousness of jobs according to gender. The discussion on such an outcome is not part of the scope of this research, but the results point to such a conclusion.

From 2007 to 2013, 27 companies made the transition between groups in a very defined way. Companies with more skilled labor concentrated in sectors other than the manufacturing industry, while companies with the largest share of employment in industrial occupations remained grouped. The results of the cluster analysis were able to distinguish them mainly according to the educational level of their employees and the salaries paid. The sectoral composition of the clusters also revealed a pattern of innovative firms, showing that there is concentration in the manufacturing industry sectors and information technology activities and services.

In turn, the discriminant analysis generated results that led to the observation of the transition of companies among the groups formed. It was noticed by the results that the transition occurred by the change in the level of training of the employees. As a result, firms increased average wages and changed the composition of occupations.

As already mentioned, this result of the transition analysis may constitute a result of the granting of subsidies to these companies. It is recalled, however, that this is an exploratory analysis, and an adequate strategy is needed to establish which are the determinants of the search for innovation by companies.

The results obtained through the multivariate analysis are a part of the search for the evaluation of public policies to foster innovation. The transition presented is observed at company level and does not provide any indication of macroeconomic changes that may be related to these changes in company profiles. To complete this motivation, the next section will present the simulations of the computable general equilibrium model. Thus, it is intended to analyze how the economy reacts to the concession of stimuli to innovation in all its potentiality.

5. Theoretical framework and application of the EGC model

In general equilibrium, economics is seen as an interrelated economic system in which equilibrium must be attained in all sectors simultaneously. The aim of this methodology is to understand and analyze, at the macroeconomic level, the impact of government policies in the economic sectors during the period during which the economic subsidies for innovation promotion were granted.

This advantage is due to the fact that economic details are preserved at the sectoral level, which allows the systemic capture of the effects of political changes on the allocation of resources, once this methodological instrument recognizes the intersectorial channels of the economic system, i.e., considers the complementary and competitive effects generated in the economic interactions of general equilibrium (BETARELLI JUNIOR; PEROBELLI; VALE, 2015).

In this way, the use of EGC models allows the modeling, to a greater or lesser extent, of the complex interdependence between institutions and the agents that compose the economy, covering pertinent policy issues for applications in real economies. The temporal dimension in the solutions of CGE models was incorporated in order to consider the economy's trajectory for long term policy analysis (BETARELLI JUNIOR, 2013). Thus, dynamic models provide, in addition, details of the trajectory of economic effects over time, in the face of exogenous changes in the economy, such as observable facts, scenarios or factual experiments. For this reason, they are used both for the analysis of public policies and for obtaining prospective scenarios.

The model adopted in this work, is a version of the BRIGDE model (DOMINGUES et al., 2016), was developed to analyze the impacts of the application of economic policies to foster innovation. Because it is an intervention that can affect several sectors of the economy, whose effects are likely to spread within the chain of economic interrelations, it is based on the premise that general equilibrium models are adequate alternatives for the treatment of the issue. This is because a development policy adopted can have relevant effects on prices, quantities and also on the structure of the economic system.

The configuration of the adopted model is based on the year 2005, according to the sector and product classification of the input-output matrix of the Brazilian Institute of Geography and Statistics (IBGE). Thus, the model consists of 55 sectors (j = 1, ..., 55), which produce one or more of the 110 products (c = 1, ..., 110). There are five components of final demand (household consumption, government consumption, investment, exports and inventories), two margins (trade and transport), imports per product for each of the 55 sectors and a production. In addition to this specification, the model still presents the labor factor disaggregated in five occupations (engineers, technicians, managers, directors and other occupations) and families are disaggregated by income decile, with ten types of representative families (h = 10).

In order to make feasible the recursive solutions method, the dynamic models start from the adaptive expectations hypothesis (DIXON; RIMMER, 2002), so that the solution of each period depends on the current period and the past periods (BETARELLI JUNIOR, 2013; DOMINGUES et al.,2010; HASEGAWA, 2003). Thus, the calibration of the model is done only for the initial period, being sufficient to verify the economic repercussions of the assumptions raised on the endogenous variables over a period of time.

The specification of the recursive dynamics module is based on the modeling of intertemporal behavior and on backward looking results. Current economic conditions, such as the availability of capital, are endogenously dependent on later periods, but remain unaffected by expectations generated prospectively. Thus, investment and capital stock follow mechanisms of accumulation and intersectoral displacement based on predetermined rules, linked to the rate of depreciation and rates of return (MAGALHÃES, 2013).

In this case, the recursive dynamics is made possible by the insertion of three possible temporal links: the accumulation of physical capital and investment, the accumulation of financial liabilities and the lagged adjustment in the labor market.

As an intertemporal mechanism, the accumulation of physical capital incorporates the dynamic character in CGE models through the rate of capital depreciation and the rate of return on investment. By hypothesis, the rate of capital depreciation does not change over time, but the expectations of the rate of return on investment may change temporarily, causing changes in the volume of investment and, therefore, in the capital stock.

In the model adopted in this paper, capital investment and stock follow mechanisms of intersectoral displacement and accumulation based on pre-established rules, associated with expected rates of return and depreciation of the capital stock. Thus, sectors with an expected return rate, calculated endogenously, attract investment. This investment in period t generates the capital stock in period $t+1$ by means of a standard accumulation rule, from the initial capital stock discounted from the depreciation.

Since this is a policy evaluation considering prospective periods, the responses to the disruptions caused by the policies depend significantly on the projections of the base scenario for the economy. In this way, it is necessary to assume the definition of the growth rates of some determinant variables, such as GDP, consumption and investment for the determined period of time of the analysis.

On the other hand, the policy closure establishes different status for endogenous and exogenous variables related to the basic scenario of the economy, as well as specific shocks for each study market, or the scope of the analysis, and which will indicate deviations from the trend of the economic scenario elaborated, which will be detailed in a timely section. As an example of the policy closure, it is possible to analyze the sectoral effects in relation to the economic trend until 2030 of the economic subsidies granted in the period 2007 to 2013 based on what was stipulated in this closing.

5.1 Calibration

Generally, this phase involves the need to obtain a large amount of information for the purpose of the applied research, either in function of the theoretical specification made in the model or the degree of detail that is intended to obtain.

The database of an CGE model has two types of information: there is information about an input-product matrix and complementary information related to the research problem. Like the ORANI-RD family models, the model adopted in this paper requires exogenous forecasts for the future trajectories of technological change, employment, imported prices and the positions of demand curves for exports. Such forecasts may be simple (uniform growth rates) or can be derived from detailed forecasts made by various government and private agencies.

The specific information that supports the adopted model is data that details the granting of economic subsidies. The purpose of obtaining this data is to meet the theoretical specifications of the model, as well as generate reliable analyzes on the impacts of this mechanism of innovation promotion. For this reason, the economic subsidies granted to private companies between 2007 and 2013, aggregated by each of the 55 sectors of the National System of Accounts (SNA) (TABLE 4), were added. These figures were applied to the model year by year, according to the start date of the agreement between the

companies and Finep and, once the model is dynamic, these values fed the shocks applied annually.

The result shown in Table 3 is consonant with the establishment of some priority sectors in the receipt of economic subsidies. Among them, we highlight the sectors of Information services, Business services, Electronic material and communications equipment and Pharmaceuticals.

TABLE 4 – Amounts awarded from economic subsidy to technological innovation

Sector	Description	Amount received in the period 2007 - 2013 (in millions of R$)
AgricultOut	Agriculture, forestry, logging	2.82
PecuariaPesc	Livestock and fisheries	1.49
AlimentBebid	Food and drinks	13.41
Texteis	Textile	5.69
CouroCalcado	Leather and shoes artifacts	6.49
ProdMadeira	Wood products - exclusive furniture	1.36
CelulosPapel	Pulp and paper products	0.70
JornRevDisc	Newspapers, magazines, records	0.14
ProdQuimicos	Chemicals	4.92
ResinaElasto	Manufacture of resins and elastomers	2.00
ProdFarmac	Pharmaceutical products	83.13
DefAgricolas	Pesticides	0.76
PerfumarOut	Perfumery, hygiene and cleaning	14.59
QuimicosDive	Various chemical products ans preparations	7.94
BorracPlast	Rubber and plastics	28.32
OutPrMNaoMet	Other non-metallic mineral products	4.17
FabAcoDeriv	Manufacture of steel and its derivatives	1.25
ProdMetal	Metal products - exclusive machinery and equipment	19.20
MaqEquipManu	Machinery and equipment, including maintenance and repairs	40.12
EscrInformat	Office machines and computer equipment	19.35
MaqEletriOut	Electrical machinery, apparatus and equipment	38.43
MatEletroOut	Electronic material and communications equipment	145.70
ApMedicoOut	Medical / Hospital Instruments, Measurement & Optics	29.80
PecVeicAutom	Parts and accessories for motor vehicles	2.24
OutEqTransp	Other transportation equipment	18.97
IndDiversas	Furniture; other manufactured goods	49.15
Construcao	Construction	26.72
Comercio	Trade	60.16
TranspArmCor	Transport, storage and mail	7.11
ServInformac	Information services	186.43
FinancSeguro	Financial intermediation and insurance	2.63
ServManutRep	Maintenance and repair services	2.37
ServPrestEmp	Business services	122.35
EducMercant	Merchant education	4.60
SaudeMercant	Mercantile health	6.31
OutrosServic	Other services	5.32

5.2 Closing scenario: baseline for simulations

The evolution of the economy in the analyzed period is based on a scenario of GDP growth, household consumption, government spending, investment and exports. In this way, the base scenario is configured as a trend scenario of the economy in which deviations from it can be measured, estimating the effects of specific policy shocks

(MAGALHÃES, 2013). The projected results and results of these analyzes can be observed in the macroeconomic and sectoral indicators over the time period analyzed. To achieve these results, it is necessary to define the economic environment of the simulation (BETARELLI JUNIOR, 2013). This environment refers to the set of hypotheses described in the model closure, establishing the exogenous variables for the desired simulations.

In the baseline scenario, data on GDP, investment, household consumption, government spending and exports were used in the period from 2005 to 2020. For the years 2005 to 2014, the data were taken from the National Accounts System. On the other hand, prospective figures have been extracted from reports of the World Economic Outlook of the International Monetary Fund (2017) and the Organization for Economic Co-operation and Development (OECD) Economic Outlook of the OECD.Stat (2017), publications of the International Monetary Fund and the Organization for Economic Cooperation and Development, respectively.

It is worth noting that the initial period of this analysis (between 2006 and 2008) was marked by high economic growth, heated domestic demand, expansion of investments and a favorable external scenario. In 2008, the signs of the international crisis show with the increase of the price of imports and reduction of exports, but only in 2009 the country recorded a reduction in the product. With domestic consumption declining, but still positive, there was a reduction of the product accompanied by a reduction in investments and exports. The year 2010 clearly shows the post-crisis recovery, while the rest of the period (2011-2013) shows moderate growth, maintained by domestic demand and the variable external market. The values of the macroeconomic variables show that in the period 2011 to 2014 the Brazilian economy shrank, with exports and investments falling, and domestic demand slowing down. For GDP growth, the series shows a downward trend, including prospectively.

The projected data show that in the long run, from 2018, household consumption and government spending follow the same upward trend in GDP. This is because linear growth trajectories of 2% per year were adopted, starting in 2015, according to the hypothetical scenario of growth of the economy in its steady state.

When implementing a cut in subsidies to the sector proportional to the amount granted as subsidy in that year, it is intended to verify the increase of the production costs of the sectors, generating a direct fall in the production of each of them. As the effect is observed intertemporally, it is assumed that the impacts generated by the application of the shock are dispersed over time, revealing more or less rigidity of the analyzed variables in relation to the increase of the sectoral production costs.

The mechanisms of recursive dynamics allow the explicit use of the EGC model, where the endogenous variables adjust over the analysis period after an initial shock, as a restriction of labor supply for a specific occupation.

It is possible to define the scenario simulation as a simulation that serves as a control path, so that deviations are measured to analyze the effects of a policy shock in future periods. Thus, a policy simulation allows the analysis of the effects of a change in economic policy, being a deviation of the economic variables in relation to the reference scenario.

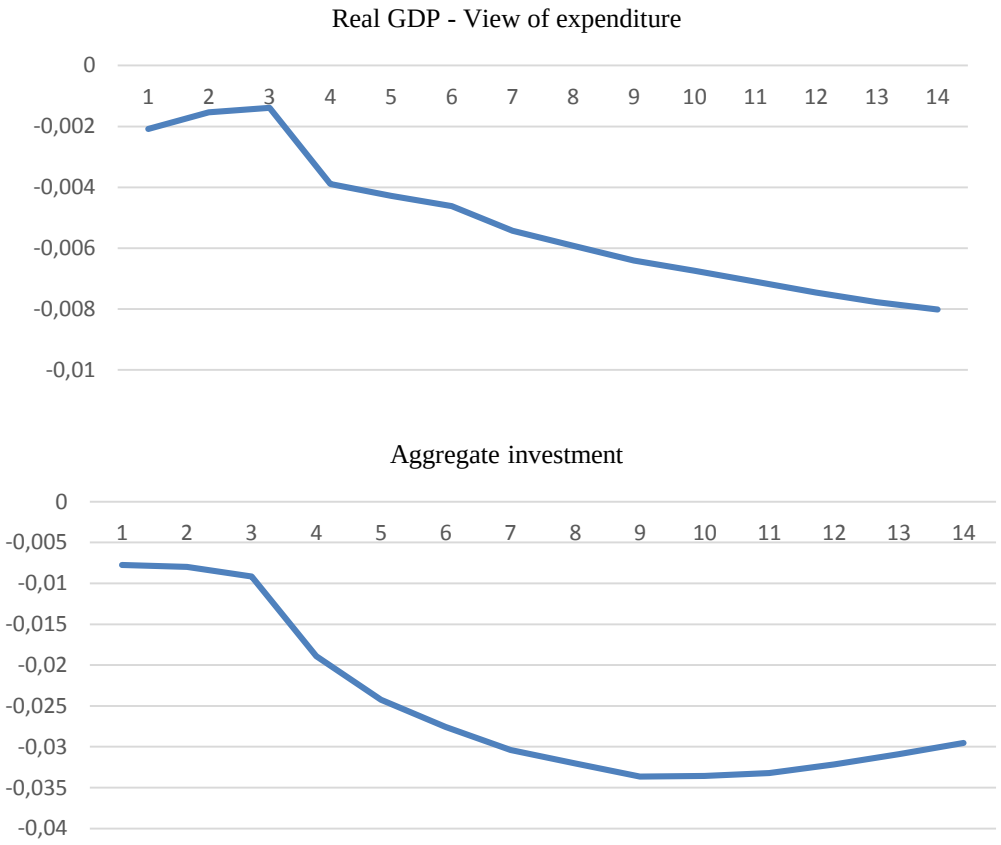
The advantage of calculating policy effects as deviations from the projected scenario is that it brings a growth perspective to the analysis (BETARELLI JUNIOR, 2013).

5.3 Empirical results

In terms of contribution to the economic growth rate (real GDP change), as shown in Figure 1, the impact was an attempt to recover in the first year after the shock, but the trajectory is decreasing. These results indicate that the cut in the amount of subsidies awarded implies an increase in the costs of private companies. This is reflected in the downward trend in economic activity. It is also noted that the aggregate activity takes some periods of time to respond to the cut of the incentives, and the retraction is more prominent after four years given the shock. After that, the dynamics in terms of economic growth continues to decline over time due to the increase in internal costs of companies.

Aggregate investment responds similarly to GDP to the cut in subsidies. In the first few periods there is only a slight fall in the volume of investments, but after the third year given the shock, the series shows a significant decline. However, there is movement of recovery of the growth after ten years of the shock. This trajectory can be explained in two ways. The first is the increase in internal costs, which will cause private companies to reduce their investments. The second concerns the issue of the counterparts required by the grant of economic subsidy, which also occurs in the form of capital goods investments and expansion of productive capacity. With this cutback, there is, therefore, a shortage in private investment (FIGURE 1).

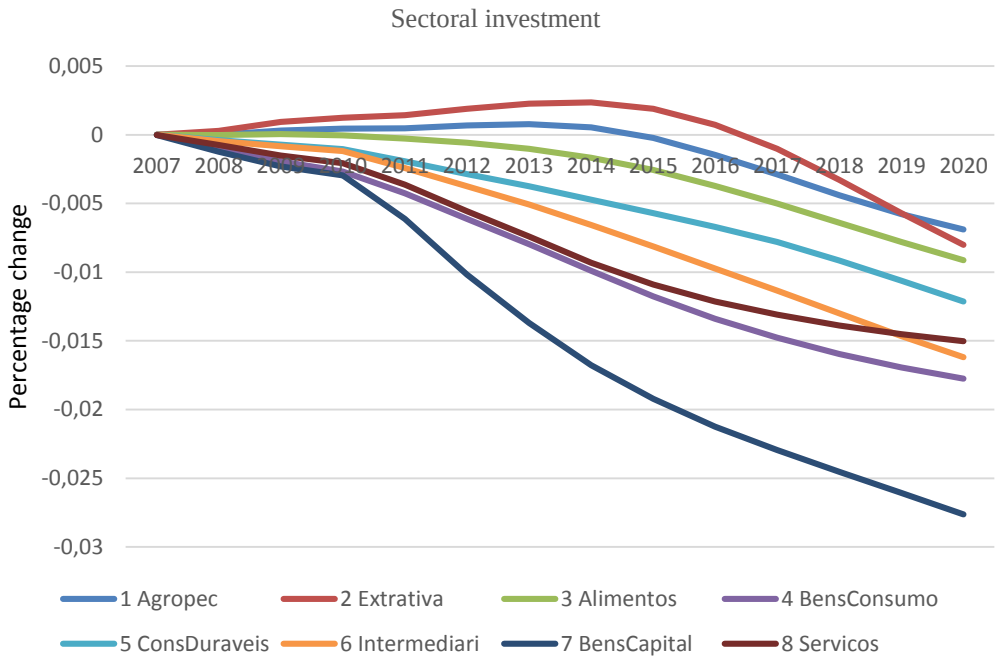
FIGURE 1 – Impact on GDP and aggregate investment (cumulative percentage deviation from baseline)



Regarding the results on the sectors, it can be seen from Figure 2 that there was a drop in investments in the main sectors of the economy. The capital goods industry was the one that presented the biggest drop. This result is consonant with the fact that the capital goods subsector aggregates the sectors of machines, appliances and electrical materials, electronic material and communications equipment, medical / hospital apparatus and instruments, measurements and optics, truck and bus manufacturing, parts and accessories for motor vehicles and other transport equipment.

In the analyzed period, these sectors received R $ 235.14 million. Results of the retraction of the investment in sectors such as agriculture and extractive industry can be explained due to the interrelations with other sectors, whose activity presented a direct deceleration.

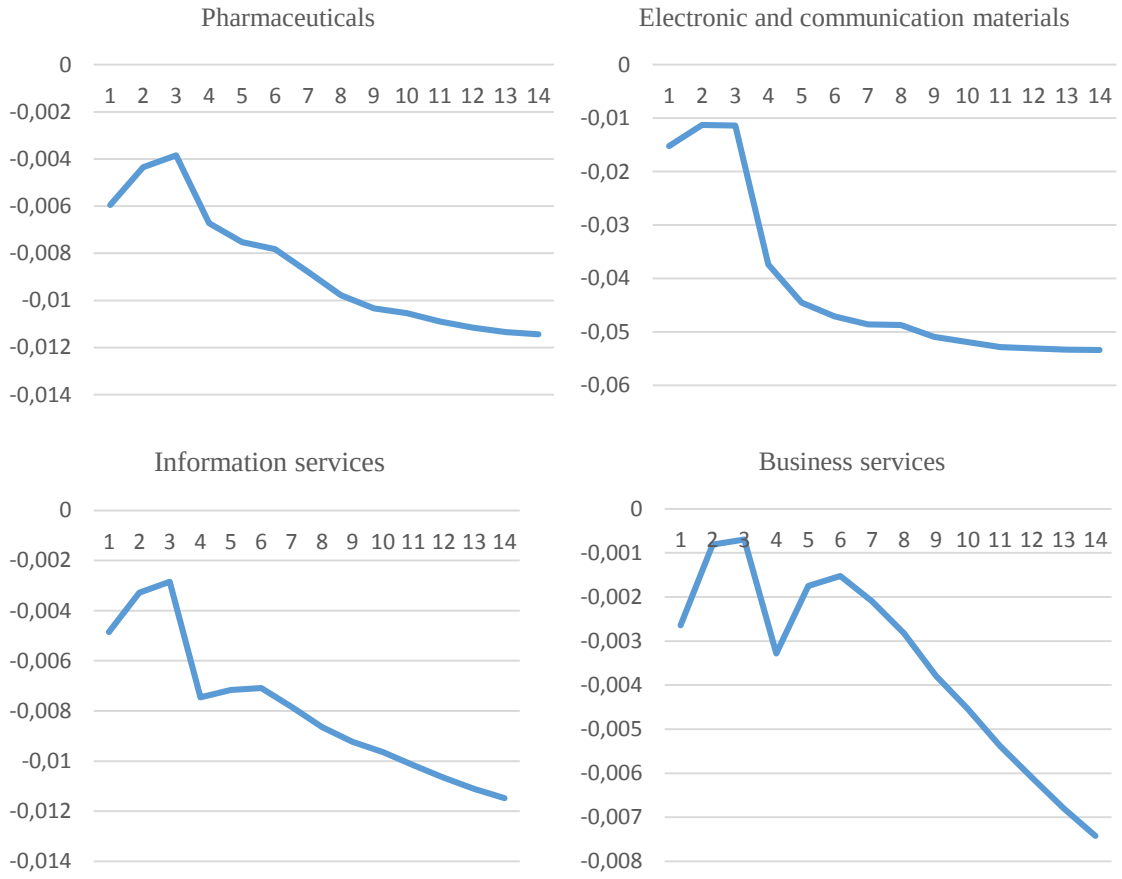
FIGURE 2- Investment trajectory by sector after the shock



Particularly, the results of the level of activity of specific sectors are presented, which were the ones that received the greatest amount of resources through a grant for the generation of innovation. The electronics and communications, information services, business services and pharmaceuticals sectors in the period 2007-2013 together received 55% of the total resources allocated to this type of innovation promotion (TABLE 3).

It can be seen from Figure 3 that there was a sharp drop in activity levels (or value added) in these four specific sectors. This result is due both to the increase in internal costs of the company and to the interrelationships between the sectors of the economy. The pharmaceutical sector is a sector whose costs are high, given the nature of its activity and the need for large contributions in capital goods and productive structure. For this reason, it is understood that a cut in subsidies to innovation, causes a significant decrease in the added value of this sector.

FIGURE 3 – Activity level of selected sectors after the shock



A similar situation occurs in the electronic and communication materials sector, whose deceleration was even more significant. The demand for skilled labor and a productive structure with advanced technologies means that this sector has a high cost structure. This contributes to the decline in the level of investment and activity in this sector.

The sectors of information services and services rendered to companies present more similar results among themselves. The service sector assumes the demand for activity from other sectors and activities within the economy. Since there was a general contraction in the level of economic activity after the shock, there is an expected result of a fall in the value added of these sectors.

As this simple simulation only analyzed the cut of the expenses with the subsidies granted, the results are summarized to the analysis of the level of economic activity. By the mechanisms of transmission of the effects of the shock, one can see that there were expected responses of the macroeconomic and sectoral variables, as a retraction of the sectors that benefited most from the program.

6. Final consideration

This paper aims to analyze, through a dynamic computable general equilibrium model, which are the sectoral and macroeconomic impacts of the policy to foster technological innovation in Brazil. Given that the economic subsidies constitute a tool that grants a recourse to the companies, the adopted model was calibrated with the values passed on

to each productive sector so that the general equilibrium sector analysis could faithfully reflect the amount used for the end of the policy in question.

In addition, statistical techniques for the description of the data concerning the companies benefiting from these subsidies were applied between the years 2007 and 2013. Among the analyzed characteristics, those that the results indicated as important in the classification of groups are the educational level of their employees and of wages paid. As for the transition analysis, it was noticed that the same variable of schooling of the employees was the one that contributed the most to the change in the composition of the clusters. It should be noted that the observation transition during the observed period is related to the peculiar environment of the companies and there is no indication of structural and conjectural changes in the economy that can be correlated to the changes of individual profiles.

On the other hand, the results of the CGE model indicate that the subsidy values reflect an increase in the costs of the companies, since with the simulation of a cut in the granting of economic subsidies, there was a downward trend in the economic growth rate. The aggregate investment also shows a significant reduction after the simulation of the absence of the development policy, but there is a recovery movement in the last years of the projection.

On a sector level, the most significant results were from the capital goods industry, which, due to the aggregation of sectors highly benefited by the economic subsidy policy, showed a marked reduction in the scenario of the simulation of the cut of the incentives.

As mentioned, only a simulation of the absence of the development mechanism analyzed was performed. Nevertheless, this work has been able to indicate that there are inter-related and long-term sectoral effects on the Brazilian economy. As an extension of this research, it is intended to carry out new simulations with the subsidized values and also with the counterpart values by productive sector.

References

AGHION, Philippe; HOWITT, Peter. **A model of growth through creative destruction**. National Bureau of Economic Research, 1990.

ARAÚJO, Bruno César *et al.* Impactos dos fundos setoriais nas empresas. **Revista Brasileira de Inovação**, v. 11, p. 85-112, 2012.

AVELLAR, Ana Paula. Impacto das políticas de fomento à inovação no Brasil sobre o gasto em atividades inovativas e em atividades de P&D das empresas. **Estudos Econômicos** (São Paulo), v. 39, n. 3, p. 629-649, 2009.

AVELLAR, Ana Paula M.; ALVES, Patrick Franco. Avaliação de Impacto de Programas de Incentivos Fiscais a Inovação – Um Estudo sobre os Efeitos do PDTI no Brasil. **Revista EconomiA**, 2008.

BETARELLI JUNIOR, Admir Antonio. **Um modelo de equilíbrio geral com retornos crescentes de escala, mercados imperfeitos e barreiras à entrada: aplicações para setores regulados de transporte no Brasil.** 2013. 366 f. 2013. Doctorate dissertation (Doctorate in Economics) – Centro de Desenvolvimento e Planejamento Regional da Universidade Federal de Minas Gerais (CEDEPLAR/UFMG).

BETARELLI JUNIOR, Admir Antonio; PEROBELLI, Fernando Salgueiro; VALE, Vinicius de Almeida. **Um Modelo Nacional de Equilíbrio Geral Computável Dinâmico Recursivo (EGC-RD) para o Brasil no Ano de 2011 (BIM-RD).** Discussion paper nº 01-2015. Laboratory of Territorial and Sectorial Analysis (LATES), Programa de Pós-Graduação em Economia, Universidade Federal de Juiz de Fora, Juiz de Fora, 2015.

BOR, Yungchang Jeffery et al. A dynamic general equilibrium model for public R&D investment in Taiwan. **Economic Modelling**, v. 27, n. 1, p. 171-183, 2010.

BRASIL. Lei nº 8.248, de 23 de outubro de 1991, aperfeiçoada pela Lei nº 11.077, de 30 de dezembro de 2004.

BYE, Brita; FÆHN, Taran; HEGGEDAL, Tom-Reiel. Welfare and growth impacts of innovation policies in a small, open economy; an applied general equilibrium analysis. **Economic Modelling**, v. 26, n. 5, p. 1075-1088, 2009.

BYE, Brita; FAEHN, Taran; GRÜNFELD, Leo A. Growth and innovation policy in a small, open economy: should you stimulate domestic R&D or exports?. **The BE Journal of Economic Analysis & Policy**, v. 11, n. 1, 2011.

COELHO, Danilo Santa Cruz; DE NEGRI, João Alberto. **Impacto do financiamento do BNDES sobre a produtividade das empresas: Uma aplicação do efeito quantílico de tratamento.** ANPEC-Associação Nacional dos Centros de Pós-graduação em Economia [Brazilian Association of Graduate Programs in Economics], 2011.

DIAO, Xinshen *et al*. **A dynamic CGE model: An application of R&D-based endogenous growth model theory**. University of Minnesota, Economic Development Center, 1996.

DIXON, Peter B.; RIMMER, Maureen T. (Ed.). **Dynamic general equilibrium modelling for forecasting and policy: a practical guide and documentation of MONASH.** Emerald Group Publishing Limited, 2001.

DOMINGUES, E. P. *et al*. **Repercussões setoriais e regionais da crise econômica de 2009 no Brasil: simulações em um modelo de equilíbrio geral computável de dinâmica recursiva.** 38º Encontro Nacional de Economia da ANPEC, 2010.

DOMINGUES, Edson Paulo et al. A dinâmica do emprego na indústria brasileira: comportamento recente (2006-2010) e o efeito de restrições de mão de obra especializada. **Estudos Econômicos** (São Paulo), v. 46, n. 3, p. 539-578, 2016.

DOSI, G.; PAVITT; K; SOETE, L. **The economics of technical change and international trade.** London: Harvester Wheastsheaf, 1990.

FINEP. **Subvenção Econômica.** 2017. Disponível em: http://finep.gov.br/afinep/122-apoio-e-financiamento/tipos-de-apoio/subvencao-economica. Acessado em 05/04/2017.

GARAU, Giorgio; LECCA, Patrizio. **Impact analysis of regional knowledge subsidy: a CGE approach.** 2008.

GHOSH, Madanmohan. R&D policies and endogenous growth: a dynamic general equilibrium analysis of the case for Canada. **Review of development economics**, v. 11, n. 1, p. 187-203, 2007.

GROSSMAN, Gene; HELPMAN, Elhanan. Innovation and Growth in the Global Economy Cambridge. **Mass. and London**, 1991.

HASEGAWA, Marcos Minoru. **Políticas públicas na economia brasileira: uma aplicação do modelo MIBRA, um modelo inter-regional aplicado de equilíbrio geral.** 2003. Tese de doutorado. Universidade de São Paulo.

HORRIDGE, Mark. ORANI-G: **A generic single-country computable general equilibrium model.** Centre of Policy Studies and Impact Project, Monash University, Australia, 2006.

KANNEBLEY JUNIOR, Sergio; PORTO, Geciane. **Incentivos Fiscais à Pesquisa, Desenvolvimento e Inovação no Brasil.** Technical Report 2012.

KŘÍSTKOVÁ, Zuzana et al. Impact of R&D investment on economic growth of the Czech Republic-a recursively dynamic CGE Approach. **Prague economic papers**, v. 21, n. 4, 2012.

LUCAS, Robert E. On the mechanics of economic development. **Journal of monetary economics**, v. 22, n. 1, p. 3-42, 1988.

MAGALHÃES, A. S. **Economia de baixo carbono no Brasil: Alternativas de políticas e custos de redução de emissões de gases de efeito estufa.** 290 f. 2013. Doctorate dissertation (Doctorate in Economics) – Centro de Desenvolvimento e Planejamento Regional da Universidade Federal de Minas Gerais, Belo Horizonte. 2013.

MCTI. **Tecnologia e Inovação para o Desenvolvimento Nacional-Plano de Ação 2007-2010.** Ministério da Ciência e Tecnologia. Brasília, novembro de, 2007.

MORAIS, José Mauro de. Uma avaliação de programas de apoio financeiro à inovação tecnológica com base nos Fundos Setoriais e na Lei de Inovação. **Políticas de incentivo à inovação tecnológica no Brasil. Brasília: Ipea**, p. 68-105, 2008.

ORGANIZAÇÃO PARA A COOPERAÇÃO E O DESENVOLVIMENTO ECONÔMICO (OECD). Oslo Manual. **Guideliness for collecting and interpreting innovation data.** 3rd ed. Paris: OECD, 2005.

PIO, João Gabriel. **Impactos dos Gasto em P&D em Pesquisa e Desenvolvimento sobre a Economia Brasileira: uma abordagem EGC.** 2016. 133 f. Dissertação (Mestrado em Economia Aplicada) – Universidade Federal de São Carlos, Sorocaba, 2016.

ROMER, P. **Human capital and growth: theory and evidence.** In: Carnegie-Rochester Conference Series on Public Policy. North-Holland, 251-286, 1990.

ZÜRN, Marcel et al. R&D investment and knowledge input in a technology oriented CGE model. In: **EcoMod Conference on Energy and Environmental Modelling,** Moscow. 2007.