IMPACT OF R&D INCENTIVE PROGRAM ON THE PERFORMANCE AND TECHNOLOGICAL EFFORTS OF BRAZILIAN INDUSTRIAL FIRMS

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ABSTRACT

Public policies that promote R&D in firms are evaluated on a regular basis in developed countries. However, this type of study is relatively rare in developing countries. In Brazil no impact evaluation analysis that use information at firms' level has been published. The present study, which assesses the impact of the National Technological Development Support Program (ADTEN)[4] on the technical performance and strength of Brazilian industrial firms, is unprecedented in its content and method. It shows that this R&D incentive program reaches a relatively limited number of firms, considering the magnitude of the Brazilian industrial sector. The program reaches only 0.07% of Brazilian industrial firms with over 10 employees, and the volume of resources that firms borrowed within the program's framework was only 1.6% and 3% of their R&D expenditures in 2000 and 2003, respectively. It was found evidences that ADTEN had a positive influence on companies' private R&D expenditures from 1996 to 2003. One can say that at least the crowding out hypothesis can be rejected. There are also strong evidences that the program has positively influenced the growth of firms, their productivity and patent applications, although results are not conclusive for these two last indicators.

1 INTRODUCTION

The consolidation of the science and technology institutions in Brazil took place when the country's economic growth was led by import substitution industrialization policies characterized by an inward national development strategy. It is important to take into account this national development project to understand the success and effectiveness of the scientific and technological policies of the 1970s, and their decline in the 80s and 90s. In particular, the creation of the Scientific and Technological Development Fund (FNDCT) in 1968 was an essential instrument of the Strategic Plan for Technological Development.

The fund was undoubtedly a powerful mechanism for stimulating scientific and technological development in Brazil, mainly starting in 1971, when the Research and

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Projects Financing Agency (FINEP) became its executive board. There was no radical change in the country's institutional science and technology framework in the 80s, despite the fiscal crisis and the exhaustion of external funding sources.

In the early 70s FNDCT's volume of resources grew rapidly and FINEP moved to establish a different way of operating the fund. The National Technological Development Support Program (ADTEN) was created in this context. Major resources from the FNDCT were allocated to the program between 1976 and 1978. ADTEN has been a reimbursable funding program for companies that are particularly relevant to FINEP. Historically, the program's funding comes from both Treasury Department's earlier loans returns, and multilateral organizations, mainly the Interamerican Development Bank (IDB) and the National Development Fund. In the late 70s, the resources reallocated to ADTEN were about 30% of the FNDCT's [5] total resources. In 1987, at the pinnacle of the program's expenditures, it was lending about US$ 150 million.[6]

The consolidation of FINEP incentives to firms' R&D expenditures was greatly motivated by the creation of ADTEN. From the very beginning, the program prioritized engineering projects, in-house R&D centers, products and processes innovations, marketing, purchases of national or foreign technologies, and the creation of quality control processes. The resources available through the program were especially advantageous for companies because of negative real interest rates. Equalization represented about 40 to 60% of inflation until 1980[7]. However, inflation scaling up in the 80s forced gradual increases in the equalization ratio and from 1987 onwards the financial adjustment of loans to inflation was complete. It is worth noting that ADTEN has provided different ways of risk capital financing. The most widely used methods were loans that could be reimbursed using royalties and sales revenue. In 1991 there were about 60 risk capital operations.

Nowadays, ADTEN is still one of the instruments through which FINEP finances invests in development projects, in technology improvement projects for products and processes that have been executed by a company's own technical team, engineering firms, national consulting firms, universities and research institutions. Projects that are eligible for financing are: basic engineering projects with a technological development element, establishment of research and development centers, the purchase and incorporation of technology from Brazil or abroad, quality control and management, and innovative marketing. The program has a grace period of up to three years, and an amortization period of up to seven years, with FINEP participating in up to 80% of the project. Guarantees are established for each operation. Currently there are no loan subsidies and the financial charges are the same as the long-term loans of the National Development Bank (BNDES). The charges include the long-term interest rate (TJLP), which is currently 9.00% per annum (Jan/2006), with an average annual spread of 5% and an opening credit line tax of 1%.

The authors of this study are not aware of any published work that seeks to evaluate the impact of ADTEN or any other similar program on the performance and expenditures of companies in research and development (R&D). That is exactly what this paper will attempt to achieve. More specifically, it seeks to contribute to the process

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[5] Guimarães 1993.
[6] Naidin *et al*.
[7] CGEE (2001) – Apoio direto à inovação - Programação do fundo verde e amarelo 2002-2003. (Direct support for innovations – Green and Yellow Fund Program 2002-2003).

of evaluating public policies that focus on stimulating technologically innovative activities by answering the following questions. Is there complementarities or substitution between ADTEN's public funds and private funds used for R&D? In other words, is there crowding in or crowding out effects of the public funds to financing firms' R&D activity?[8] Is the economic/financial performance of beneficiaries of the ADTEN program superior to that of non-beneficiaries?

This report is divided into four sections besides the Introduction. In Section 2, we present the methodological procedures and database that will be used in the evaluation. The extent of ADTEN's reach is analyzed, considering the magnitude of Brazilian industry, in section 3. In Section 4, we attempt to verify the program's impact on company expenditures for R&D in order to seek whether there is substitution or complementarity between public funds from ADTEN and the companies' own private funds, or funds of other companies on the market. In the same section 4, the program's impact on a company's growth and productivity is also evaluated. The final remarks are in Section 5.

2 MATERIAL AND METHODS

2.1 Building up an integrated database

One of the reasons for the lack of evaluation work on ADTEN is possibly the dearth of information that could be used to compare firms that receive support from the program to those that don't. To conduct this study, however, we worked with an original database from the Institute for Applied Economic Research (IPEA). IPEA's[9] database combines information from: i) Annual Industrial Survey (PIA), Technological Innovation Survey (PINTEC), both from the National Census Bureau (IBGE); ii) Annual Social Information Report (RAIS) of the Ministry of Labor (MTE); iii) data of Foreign Trade from Foreign Trade Secretary (SECEX) of the Ministry of Industrial Development and Foreign Trade (MDIC); iv) the Census of Foreign Capitals in Brazil, from Central Bank (BACEN); v) Data about patents register and applications, from National Institute of Industrial Property (INPI).[10]

The main databases are the Annual Industrial Survey (PIA) and the Technological Innovation Survey (PINTEC). PIA provides data by sector of activity on output and expenditure of Brazilian industrial firms and it is available since 1996 until 2003. PINTEC is survey that collect information on technological innovations of the Brazilian industrial firms. It follows the Community Innovation Survey model (CIS) and contains information such as: a) characterization of the firms' innovative efforts (expenditures for internal and external R&D, acquisition of R&D, if these expenditures are occasional or recurrent, whether the firm has an R&D department, the number and qualification of the individuals working in R&D, etc); b) if the firm has introduced technological innovations on the market; c) what are the sources of information used for introducing the innovations; d) what are the funding sources for the innovations, etc.

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[8] David, P. A.;, B. and Tole, A. A. (2000) provide a comprehensive review of the econometric evidence about crowding in and crowding out effects.

[9] For details on the database see De Negri (2003). IPEA does not have legal title to the information used in this study. However this and other work has been made possible through the partnerships established between IPEA, IBGE, MTE, BACEN, MPO, SECEX/MDIC and FINEP.

[10] Access to the necessary information rigorously followed the procedures that guarantee the secrecy of restricted information.

Information available from PINTEC and PIA will be merged with the other databases having the firm as the common information link.

Other database that deserves description is the Annual Social Information Report (RAIS). This database contains information related to the profile of the labor force that works in the firms: age, gender, level of education, how long employed by the firm, when recruited and when left, remuneration, position within the firm. The information covers the period from 1996 to 2003, also on an annual basis.

The set of information that integrates all these databases should provide a rather complete profile of the Brazilian industrial firms. With the possibility of integrating these databases using a code that identifies each firm, it is possible to know whether a specific firm is innovative; the amount of its expenditures for R&D; its expenditures, and output structure and profitability; whether it is foreign or national; if it has registered a patent; how it finances its innovation-related activities; if it cooperates with other institutions to introduce an innovation; the profile of its workers, etc.

The database is a sample of approximately 80,000 industrial firms with over 10 employees and five million workers. These firms are responsible for approximately 95 % of the value added in the Brazilian industry. The analysis covers an eight-year period, from 1996 to 2003. With FINEP's collaboration, it was possible to identify the firms that were beneficiaries of ADTEN from 1997 until 2005, and to perform the evaluation of the program.

2.2 Methodological procedures

The empirical analysis of this structure of data requires micro-econometric tools capable of eliminating some problems related to the evaluation of public policies. These methods seek to evaluate if the performance of the beneficiaries or policy participants is better than it would be without public incentives.

This question brings to the forefront one of the principal methodological problems in the evaluation of public policies, of which technological development incentive programs are a part. In order to measure the impact of these programs, the evaluator should know what would have happened to the beneficiaries if they had not had access to the program. The evaluator can only observe the performance of non-beneficiaries compared to that of beneficiaries. However, the performance of the beneficiaries, in the case that they had not had access to the program is a non-observed variable for the evaluator, just as the performance of the non-beneficiaries is not observed in the case they had had access to the program.

The treatment to which a group of companies is subjected is the actual participation in the technological program. We can formally call Y_{i1} the outcome variable (economic or technological performance for example) with the treatment, and Y_{i0} the outcome without the treatment. It is not possible that the individuals evaluated belong to the two groups simultaneously, therefore it is not possible to observe both results Y_{i0} and Y_{i1} for the same individual *i*. Hence, the problem that we encounter in the evaluation is related to missing data (Wooldridge, 2002).

The principal methodological question consists of constructing an adequate counterfactual for evaluating the program's impact (Klette *et al*, 2000; Arvanitis, 2002). Arvanitis (2002) lists a series of problems that could make the construction of this counterfactual difficult.

First of all, given the policy's explicit objectives, the evaluator needs to know whether it will influence the companies' results directly or indirectly, through another economic variable (for example, if public research complements private investments in R&D, therefore improving the companies' performance by stimulating private investment). In addition, the evaluator must be able to identify other determining factors, besides public policy, for the performance variable being evaluated. In other words, it is necessary to construct a vector (X_i) of explanatory variables that are theoretically relevant to explain the firm's performance, as well as a policy variable (P_i) that will distinguish beneficiaries from non-beneficiaries.

Formally, we have:

$$Y_i = \alpha_i + \beta_{0i}(X_i) + \beta_{1i}P_i + \mu_i \qquad (1)$$

where: Y_i is an outcome variable that should be positively affected by the public policy; X_i is a vector of explanatory variables that are theoretically relevant in determining the outcome; P_i is a variable of the policy that discriminates between participants and non-participants and μ_i is the error term.

Second of all, Arvanitis (2002) refers to the existence of positive externalities, which are not taken into account by the evaluator. This problem indicates that it is possible that the program's non-participating firms are being benefited by the spillover effects resulting from the program's participants, which could cause the estimated effects of the program to be underestimated.

Finally, the third and most serious problem has to do with selection bias: "since neither the firms receiving support, nor those not applying for government-sponsored projects can be considered random draws, the construction of a valid control group is a challenging task to be performed by the evaluator". The relevant issue is that, to analyze the impact of the program by a simple comparison between beneficiaries and non-beneficiaries, both groups must be chosen randomly from the universe of the companies. In the absence of randomness, it becomes more difficult to construct a valid control group.

This randomness of access to technological programs is not feasible, neither for the companies that require public support nor for the agencies responsible for granting the funding[11]. With regard to the firms, it is possible that only the most technologically suitable, or those more inclined to make greater technological efforts, seek government support for realizing technological projects. For the funding agencies, there are possibly a series of prerequisites for the companies before they can take part in the program.

According to Blundell and Costa Dias (2000), "an individual's participation decision is probably based on personal characteristics that may well affect the outcome Y as well". If this is true, there should be some correlation between the participation in the policy variable (P) and the error term. To summarize, the variable P_i, which identifies the participants and non-participants in the policy, is not a random variable, contradicting one of the prerequisites of the ordinary least squares (OLS) models. That is the reason why these models generate biased estimates in the parameters of the equation (Hussinger, 2003).

[11] Busom (2000) discusses the determining factors for firms that seek public support as well as the decision of financing agencies to grant funding.

Busom (2000) adds another problem that is in a way closely related to selection bias: the problem of the endogeneity of public funding. This problem stems from the fact that for most of the financing agencies, the decision to grant funding may be based on certain performance indicators for firms that are also, possibly, the firms' own performance indicators, which will be evaluated later to determine the effectiveness of the programs. Funding would therefore be granted on a priority basis, for example, to more productive firms, which would make the evaluation of the impact of the funding on the productivity of these firms later on much more difficult. In this way, once again, there will be a correlation between the P_i variable and the error term, due to the non-randomness of the participation in the policy. The firm's participation in a given policy would actually be a function of a vector of variables related to the determinants of those seeking to participate in the program, on the part of the firms, and the determinants of the funding grant, on the part of the funding agencies.

There are different methods available for correcting problems related to the evaluation of the impact of public funding programs, especially selection problems. According to Blundell and Costa Dias (2000) "the appropriate methodology for non-experimental data depends on three factors: the type of information available to the researcher, the underlying model and the parameter of interest". In this sense, the range and quality of available information play an essential role in the selection of adequate models. Longitudinal data allow less restrictive models to be applied, due to the existence of information from the same company at distinct moments in time, in other words, before and after participating in the program.

As we have these two kinds of databases, we will use various different methods in order to perform the evaluation. Related to the impact of ADTEN in technological efforts of beneficiary firms, the database used will be the Technological Innovation Survey (PINTEC) of 2000, which is a cross section database. Thus, the methods applied will be the Propensity Score Matching and a Selection Model. Regarding to the impact of the program over productivity and growth of beneficiary firms, the difference-in-difference method will be applied to longitudinal data of the Annual Industrial Survey (PIA). The methods will be detailed as follow.

2.2.1 Propensity Score Matching

One of the methods commonly used to analyze the impact of public policies is propensity score matching (PSM). The quasi-natural experiments generally use this technique, which is also largely used to evaluate social programs[12].

The main objective of PSM is to perform counterfactual evaluations to respond what would have happened if those that did not receive a given treatment had received it. In other words, 'what is the mean treatment effect'? In case the distribution of the treatment was random within a given sample (for example if the experiment were natural), this question would have a simple answer: it would suffice to test the difference in the means of the variable that is supposedly impacted by the treatment for case groups (consisting of those receiving the treatment) and control groups (composed of those who are not receiving the treatment)".

[12] Meyer (1995) provides a good description of the procedures for natural and quasi-experiments in economics and Wooldridge (2002) describes the mean treatment effect.

The PSM technique is actually a probabilistic model that seeks to correct the fact that the distribution of the treatment group is not random, as it constructs control groups based on the probability that the firm has received the treatment. In this case, the probability that the firm has received the treatment is estimated using a probabilistic model with independent variables selected in accordance with theoretical assumptions.

According to the procedures in the literature, PSM does a matching of the estimated probabilities of each individual. This matching considers two types of individuals: one that receives the treatment and one that does not. Consider *i* the individual that received the treatment and $\hat{p}_i(X)$ its probability of receiving the treatment. Consider *j* the individual that does not receive the treatment and $\hat{p}_j(X)$ its probability of receiving the treatment. If within a small radius based on $\hat{p}_i(X)$ there is at least one $\hat{p}_j(X)$, i and j, they will form a pair of treatment-control individuals.

So, one of the econometric procedures that will be used in this study consists to find a control group using propensity score matching, following the same procedures described in Aerts and Czernitski (2004). After that, a test of difference between two means will be implemented, comparing the two groups of firms: beneficiaries and control group. The steps are the followings:

- Linking information from FINEP about firms that received support of ADTEN, with information from the other available databases.
- Establishing and estimating a probabilistic model to obtain the estimated probability of whether or not the firm might be a beneficiary of the program from 1997 to 1999.
- Based on estimated probabilities, calculating the Mahalanobis distance between each of the beneficiary firms and all the non-beneficiary firms.
- Choosing the non-beneficiary that is closest to each beneficiary firm, in order to get the best control group possible.
- The previous steps were carried out using the whole sample of industrial firms and two sub-samples, of innovative industrial firms and of industrial firms with positive R&D spending.
- This set of beneficiary firms would thus have three control groups, one consisting of a complete sample, another would be a sample of innovating firms and a third would be a sample of firms with R&D spending. These would be the three contrafactuals used in the next step. In each sub-sample, the restrictions of either being innovative or having positive R&D spending will be applied also to the beneficiaries firms in order to avoid that control group be more innovative that the treatment one.
- Establishing a t-test between the averages of these groups for variables such as R&D expenditures, productivity and size of the firms in 2000.

2.2.2 Difference-in-differences model

The difference-in-differences method is also widely used in the evaluation of the impact of public policies, specifically incentive policies (subsidies) to R&D. Contrary to “two step selection model”, which is more useful in cross-section data but could also be used satisfactorily with longitudinal data, this method can only be used for the latter (longitudinal data).

Also known as a natural experiment, this method, according to Blundell and Costa Dias (2000) "typically considers the policy reform itself as an experiment and tries to find a naturally occurring comparison group that can mimic the properties of the control group in the properly designed experimental context".

The method consists of evaluating changes in the average behavior or performance of the individuals "treated" before and after the policy being evaluated, and comparing these changes with those on the control group. So, the first step of this procedure is to apply the PSM in order to get a control group for the participants firms.

According to Arvanitis (2002), for empirical procedures that use panel data, this estimator, constructed based on temporal change of the differences between beneficiary and non-beneficiary firms, is one of the most widely adopted procedures. "Under certain conditions, this approach can be used to recover the average effect of the programme on those individuals who entered into the programme (…) thus measuring the *average effect of the treatment on the treated*[13]" (our italics). This way, the method manages to remove the individual non-observable effects.

Formally, the coefficient that it will measure, in this case, the impact of the policy, is δ_1 and could be defined as:

$$\delta_1 = (\overline{Y}_{1t} - \overline{Y}_{1t-1}) - (\overline{Y}_{0t} - \overline{Y}_{0t-1}) \qquad (2)$$

where $\overline{Y}_{0t-1}$ is the sample mean of the outcome variable resulting from the first year for non-beneficiaries, and $\overline{Y}_{0t}$ is the same mean for the non-beneficiaries (control group) the second year. $\overline{Y}_{1t-1}$ and $\overline{Y}_{1t}$ are defined in a similar way for the treatment group. This method does nothing more than expurgate the temporal effects caused by non-observable variables.

This method would get around the problem of the lack of information on the beneficiaries in case they would not have received the treatment. To estimate this effect, the method starts out with the supposition that once a set of the firms' characteristics that can influence its outcome variable (like productivity or size) is controlled, the value of this variable for the firms of the comparison group are the same as that the treated firms would have had if they had not been treated.

One of the method's disadvantages is that it adopts two important and rather restrictive hypotheses: i) that the temporal effects are the same for the two groups (treated and non treated); and ii) that there are no changes in the composition of the two groups.

2.2.3 Two-step selection models

This type of model, inspired in Heckman (1979) is more adequate for cross-section data and consists of estimating, in the first stage, the likelihood that the firm is participating in a given program. In the second stage, an outcome equation will be estimated with the selection bias correction.

[13] Also see Wooldridge (2002).

Formally, the first step would estimate, using a Probit model, the following equation:

$$P_i = \gamma Z_i + \varepsilon_i \ , \tag{3}$$

This is the ***selection equation***, where P_i is the observed variable that says whether a firm is participating in the funding program or not and Z_i is a vector of relevant explanatory variables.

Busom (2000) lists some determining factors for access to R&D funding programs, such as the size of the firm, origin of capital, external and technological performance, among others. With regard to the determining factors for the funding agency as to whether to grant the funding or not, this depends greatly upon each program's specific characteristics. To illustrate this point, Busom mentions some possible determining factors, such as the sector in which the firm operates, the existence of major or minor positive externalities resulting from the investment in a specific project, the size of the company, etc.

Based on equation (3), estimates of the inverse Mill's ratio will be obtained for each individual from the sample as shown by:

$$\lambda_{i1}(Z_i\gamma) = \frac{\phi(Z_i\gamma)}{\Phi(Z_i\gamma)} \text{ for the firms participating in the program and} \tag{4}$$

$$\lambda_{i0}(Z_i\gamma) = -\frac{\phi(Z_i\gamma)}{1-\Phi(Z_i\gamma)} \text{ for non-participating firms;} \tag{5}$$

where $\phi(.)$ is the density function and $\Phi(.)$ is the cumulative distribution function of the standard normal distribution N(0, 1) .

The inverse Mill's ratio is an instrument that will be used to correct the selection bias in the second stage, which consists of estimating the objective equations (6) and (7) through the ordinary least squares (OLS) model for all the sample and for the group of participants and non-participants separately (Jarmin, 1999 and Busom, 2000). The equations are:

$$Y_{ik} = \alpha_k + \beta_k X_{ik} + \lambda_{ik}(Z_i\gamma) + \mu_{ik} \tag{6}$$

$$Y_{ik} = \alpha_k + \delta_{ik} P_{ik} + \beta_k X_{ik} + \lambda_{ik}(Z_i\gamma) + \mu_{ik} \tag{7}$$

Equation (6) is the ***treatment equation*** that will be estimated for each group (beneficiaries and non-beneficiaries) separately and equation (7) will be the ***treatment equation*** estimated for whole sample. In both equations, k = 0 for non-participants and k = 1 for the firms that participate in the program; X_{ik} is a vector of explanatory variables; $\lambda_{ik}(Z_i\gamma)$ is the Mill´s inverse ratio and P_{ik} is the dummy variable for firms that participate in the program.

The existence of selection bias can, therefore, be corrected and tested based on the statistical significance of the term λ in equations (6) and (7). After estimating the treatment equations, it is necessary to estimate the Average Treatment Effects (ATE).

There are at least two ways of estimating ATE. One of them can be found in Busom (2000). The author seeks to evaluate the effect of the R&D subsidy on the actual R&D effort of beneficiary firms, in order to estimate the effects of crowding in and crowding out. What this paper seeks to do is very similar. The procedure consists of estimating equation 6 for the two groups of firms (participants and non-participants in the subsidy policy) separately, using the firms' R&D expenditures (or productivity) as a dependent variable. After that, we compare the predict value of dependent variable (R&D expenditure or productivity) for participating firms ($Y_1^{predict} = E\{Y_1 \mid P = 1\}$) with their potential outcome, which are those predict using the coefficients estimated for the non-participants ($Y_1^{potential} = E\{Y_1 \mid P = 0\}$). The $Y_1^{potential}$ constitutes the policy's necessary counterfactual, and the comparison with the predict expenditures would measure the impact of the policy on the firms' R&D efforts. Formally, the ATE based on equation (6) will be:

$$ATE1 = Y_1^{predict} - Y_1^{potential} = E\{Y_1 \mid P = 1\} - E\{Y_1 \mid P = 0\} \text{ or} \quad (8)$$

$$ATE1 = X_1\beta_1 - X_1\beta_0 \quad (9)$$

where β_1 is the vector of estimated coefficients for participating firms; β_0 are the estimated coefficients for non-participating firms and X_1 are the regressors of participating firms[14]. The treatment effects will be estimated only to participating firms, that is, it is the "average treatment effects on treated".

Another way to calculate the average treatment effects is based on equation (7), that is, the treatment equation estimated for the complete sample. In this equation, there will be a dummy variable to identify the participants of the program. The average treatment effect is very similar to the first one. According to Greene (2000, p. 933), it can be estimate as follows:

$$ATE2 = E\{Y_1 \mid P = 1\} - E\{Y_1 \mid P = 0\} \text{ or, in this case} \quad (10)$$

$$ATE2 = \left[\beta_i X_i + \delta + \varphi\left(\frac{\phi(Z_i\gamma)}{\Phi(Z_i\gamma)}\right)\right] - \left[\beta_i X_i + \varphi\left(-\frac{\phi(Z_i\gamma)}{1-\Phi(Z_i\gamma)}\right)\right] \quad (11)$$

$$ATE2 = \delta + \varphi\left[\frac{\phi_i}{\Phi_i(1-\Phi_i)}\right] \quad (12)$$

where δ is the estimated parameter for the dummy variable of program participation (P_i), like in equation (7); φ is the estimated parameter for Mill's inverse ratio (lambda) and the terms $\left(\frac{\phi(Z_i\gamma)}{\Phi(Z_i\gamma)}\right)$ and $\left(-\frac{\phi(Z_i\gamma)}{1-\Phi(Z_i\gamma)}\right)$ are the Mill's inverse ratio for participants and non-participants, respectively. Again, we will calculate the ATE2 only for participating firms, that is, the average treatment effect on treated.

One of the principal advantages of the two step selection models, to correct the selection bias, is the fact that it can be applied in cross-section data. Moreover, it can demonstrate that the procedure produces asymptotically consistent and non-biased estimates of the regression parameters. Anyway, we always will estimate a simple OLS model in order to provide a benchmark for the results of the selection models.

[14] The Mill's inverse ratio is one of the regressors. However, in the second term of right side of equation (9), the Lambda that will be used will be that calculated for non-participating firms in equation (5), like in Greene (2000), p. 933.

In general, there can be some overlap between the Probit and regression variables and the model will continue to be identified, once the residuals are normal and the model is correct. However, if vector X (equation 6 and 7) was equal to vector Z (equation 3), there could be a high correlation between inverse Mill's ratio ($\lambda_{ik}(Z_i\gamma)$) and $\beta_k X_{ik}$, which could result in very high standard errors for the estimates of the parameters (Hussinger, 2003).

3 SCOPE OF THE ADTEN PROGRAM IN THE BRAZILIAN INDUSTRY

Table 1 presents the volume of resources disbursed within the framework of ADTEN and the number of firms that benefited from the program from January 1997 to May 2005. During this period, 457 different firms were benefited from the program, in 506 credit operations. The number of firms is different from the number of operations because 49 of the firms had more than one project approved during this period. There has been a decreasing number of firms that benefited annually from the program. Over 90 firms were benefited in 1997, increasing to 128 firms in 1998, and afterwards a decreasing trend to reach 18 firms in 2004. In 2005 there was an increase to 52 firms. The amount disbursed by FINEP also decreased slightly, but not as much as the reduction observed in the number of firms. This significantly increased the average amount lent to each beneficiary firm, especially during the past four or five years of the period under consideration.

TABLE 1. NUMBER OF FUNDING OPERATIONS, FIRMS BENEFITED AND AMOUNT OF FUNDING DISBURSED BY ADTEN FROM 1997 TO 2005.

Year	Number of firms	Number of operations	Amount disbursed (in constant R$)	Amount disbursed (in US$)
1997	93	95	678,802,183	629,686,626
1998	128	132	722,699,975	622,748,794
1999	55	56	234,922,505	129,455,285
2000	36	36	116,967,498	63,909,681
2001	41	41	221,107,544	94,072,304
2002	52	52	328,916,005	112,596,195
2003	27	27	208,449,234	67,715,698
2004	18	18	135,932,395	46,458,319
2005	48	49	573,603,177	235,546,640
1997 to 2005	457*	506	3,221,400,517	2,002,189,543

*Source: FINEP. * The total number of firms is not equal to the sum of firms in each year, because some firms had received ADTEN funds in more than one year. That also is the reason because the number of operations is greater than the number of firms benefited from the program in each year.*

ADTEN's small direct impact on stimulating innovative activities becomes clear when one compares its disbursements with just one type of expenditure for innovative activities: R&D. In 2000, Brazilian industrial firms invested US$ 2.02 billion[15] in R&D internally. In 2003, they spent US$ 1.66[16] billion on the same activity. In 2000, ADTEN spent 1.6% of the total expenditure for R&D of companies in Brazil. In 2003, the program spent around 3% of the investments of Brazilian firms in R&D. Inasmuch as FINEP is the main funding agencies for technological innovations in Brazil, apart from

[15] Spot market exchange rate of US$ 1 = R$ 1.83 (2000).
[16] Spot market exchange rate of US$ 1 = R$ 3.07 (2003).

capital-goods purchases, the figures would seem to indicate that the availability of public credit may be limited in Brazil for innovative activities in general, and especially for R&D. Even private sources of credit seem to be very low in Brazilian industry, as one can see in the figures of sources of credit to innovation activities: about 90% of expenditure in R&D in Brazilian industry is financed by innovating firm's own resources[17].

The second relevant indicator regarding the effect of the ADTEN program is the number of companies funded. In Brazilian industry, there are approximately 80 thousand industrial firms with more than 10 employees. From 1998 until 2003, an average of about 23 thousand firms produced technological innovations. Out of all the firms that generate product or process innovations, only 7000 had annual in-house R&D. Between 1998 and 2003, ADTEN financed an average of 57 firms per year, amounting to 0.2% of the innovating firms and 0.8% of the firms that invested in R&D. Considering the total number of industrial firms with over 10 employees, ADTEN funded only 0.07% of Brazilian firms.

With current expenditures around US$ 2 billion between 1997 and 2005, and with a small number of firms actually having benefits, it seems that the impact of the program and its potential to significantly improve national technological innovation is rather limited. Therefore, it would not be realistic to expect significant spillover effects of this program on non-beneficiary firms. This implies that the evaluation of the program will be limited to only the program's direct impact on actual beneficiary firms.

What are the characteristics of firms that are the beneficiaries of ADTEN? In this respect, this paper will analyze just firms in the industrial sector, because information about R&D spending and innovation is provided only to industrial firms. This is one of the reasons why the number of firms has decreased from 457 to 95. Another reason is that the industrial innovation survey (PINTEC) is a representative sample of industrial firms with more than 10 employees. In this sense, not all participants firms are in this survey. Finally, we are only evaluating the performance of the firms that were benefited from the program until 2000.

Table 2 shows a few indicators for industrial firms that are beneficiaries of ADTEN compared to those that are not. Statistics are also presented only for innovating firms and only for firms that had invested in R&D in 2000[18].

Firms that are beneficiaries of the program clearly perform much better economically and technologically than those that do not. They are much larger than the others in terms of the number of workers as in terms of turnover.

The same may be observed for variables such as productivity, workers' average level of education, number of patent applications, value of exports, and R&D spending. The total amount of expenditures for R&D of firms that benefited from the program is substantially higher than the expenditures for R&D of those that did not. When measured as a proportion of the net income from sales the expenditure for R&D of the beneficiaries equals 1.2% of the revenue, compared to a national average of 0.7%. However, when compared only with innovating firms or with firms that have R&D

[17] According to the Brazilian Innovation Survey (PINTEC) in 2003.

[18] It is worth noting that the number of beneficiary firms that are part of the sample decreases after comparing information about firms that benefit from ADTEN with the PINTEC sample. This was to be expected due to the sample procedures used by PINTEC, and also because among the beneficiaries there are firms from the service sector that are not part of the industrial survey of PIA and PINTEC.

spending, the share of R&D in revenue of the beneficiary firms is lower than the other two groups.

With regard to external performance, in 2000, beneficiary firms exported an average of R$87.6 million compared to an average of R$8 million for other Brazilian industrial firms. Once again, firms with R&D spending are the group that comes closest to the ADTEN beneficiaries, with average exports of approximately R$ 17 million in 2000.

TABLE 2. SELECTED INDICATORS OF BRAZILIAN INDUSTRIAL FIRMS THAT WERE OR WERE NOT BENEFICIARIES OF ADTEN - 2000.

Indicators	Beneficiaries of ADTEN	Non-beneficiaries of ADTEN		
		Total	Innovating Firms [1]	Firms with R&D spending
	Average	Average	Average	Average
Number of employees	743	68	116	207
Turnover (R$ 1000)	157,030	8,488	18,934	41,738
Labour productivity [2] (R$)	57,847	18,335	23,740	31,722
Employees' schooling years	8.37	7.14	7.56	7.81
Stock of patent applications	1.48	0.09	0.21	0.48
Stock of patent applications (per 100 employees)	0.76	0.12	0.21	0.42
Foreign established firms (%)	10%	3%	6%	9%
Exports (R$ 1000) [3]	87,579	8,004	11,676	17,132
Export coefficient[3]	0.16	0.15	0.14	0.12
R&D spending [4] (R$)	2,940,360	55,810	157,050	441,719
R&D on turnover (%)	1.2%	0.7%	1.9%	5.4%
Private R&D spending [4] (R$)	2,586,011	54,163	152,412	428,673
Private R&D on turnover (%)	1.1%	0.7%	1.9%	5.2%
Private resources on total R&D	88%	97%	97%	97%
Number of firms (sample)	95	10,231	5,333	2,600
Number of firms (population)	138	71,859	24,581	9,079

Source: IBGE, Directorate of Research, Industrial Coordination, Industrial Research – Technological Innovation Survey - 2000. Developed by authors based on the processing of data received from the source and with the incorporation of data from Annual Industrial Survey (IBGE), External Trade Database (SECEX/MDIC), Census of foreign capitals in Brazil (BACEN), Annual Social Information Register (MTE) and FINEP. (1) Innovating firms are those that had some type of innovation between 1998 and 2000 or had incomplete or unfinished innovation projects during this period. (2) Value added by employee. (3) Only for exporter firms. (4) The total R&D spending includes internal R&D and acquisition of external R&D and is divided in private and public resources.

Despite these differences, it is still not possible to confirm that the beneficiaries performed better because of the program. The fundamental question is whether the program truly improved the economic performance and technological outputs of beneficiary firms, or if these firms were already more competitive and would have invested more in R&D even without access to the program. This is a crucial problem of public policies that stimulate innovative activities, mainly those focused on promoting in-house R&D. To broaden this evaluation of ADTEN in order to shed light on this point, the next sections use statistical tools described in the methodological section to evaluate the program's effective impact on variables such as R&D spending, productivity and growth of the firms.

4 RESULTS

Although the ADTEN program reaches only a limited number of firms, it is important to know if its disbursements stimulate or simply shift R&D investments from private to public ones, the well-known "crowding out" effect of public policy incentives. Although ADTEN's incentive scheme does not involve direct subsidies and it does not only finance R&D, this question is applicable because the program provides technology funding whose supply in Brazil is in general not available, specially with long-term interest rates below that of the short-term for firms' running expenses. Thus, it can also have a positive impact on R&D private expenditures. To determine whether ADTEN has or not has a "crowding out" effect, we use propensity score matching and selection models, as described before. In addition, we use these methods to evaluate whether the productivity is higher in participating firms comparing to the non-participating ones.

Another set of questions regards the evolution of some economic indicators of the beneficiary firms, like productivity and growth. That is, the dynamic aspects of firm's performance. The question is whether the participant firms grew more than those who did not participate in the program and whether they show a higher productivity growth rate. This evaluation is performed by the difference-in-difference method based on 1996-2003 data of the Industrial Survey (PIA).

Therefore we use two different datasets, a cross sectional database (the 2000 Technological Innovation Survey) and a longitudinal one (the 1996-2000 Industrial Survey). Two selection equations will be estimated in order do construct the control group to participant firms, for the years 1996 and 2000.

4.1 Propensity Score Matching

The first step of the propensity score matching is to specify a model for estimating the probability of participating in the ADTEN program. That is, the ***selection equation*** that will be used in the selection models as well. The PROBIT uses several variables that are relevant for explaining the firm's access to ADTEN:

i) Size, measured by the logarithm of number of employees in the firm;

ii) Solvency indicator, expressed in dummies CR1 to CR4, which measure the relationship between firm's running expenses funded by borrowing and the firm's turnover[19].

iii) Age of the firm;

iv) Market share of the firm.

v) Capital origin, by a dummy variable to identify the foreign firms;

vi) Exporting firm, measured by a dummy exports variable two years lagged to avoid simultaneity between participating in the program and being an exporter,

vii) Technological effort, measured by a dummy variable to identify firms that execute continuous R&D activities;

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[19] Solvency is one of FINEP's criteria for granting funding.

viii) Sector and region origin, by dummies relative to the sector – high technology sectors versus low ones – and region where the firm is located.

TABLE 3. PROBABILITY ESTIMATE WHETHER OR NOT A FIRM RECEIVED FUNDING FROM ADTEN – 2000 (PROBIT MODEL).

Explanatory variables	Total sample		Innovating firms		Firms with positive R&D spending	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Intercept	-4,19 ***	0,22	-3,72 ***	0,25	-3,85 ***	0,33
Employees (LOG)	0,23 ***	0,03	0,20 ***	0,04	0,19 ***	0,05
Dummy variable CR1 (first quintile of expenditures with interest/turnover)	-0,44 ***	0,11	-0,39 ***	0,13	-0,46 ***	0,17
Dummy variable CR2 (second quintile of expenditures with interest/ turnover)	-0,49 ***	0,15	-0,60 ***	0,18	-0,95 ***	0,31
Dummy variable CR4 (fourth quintile of expenditures with interest/ turnover)	0,13	0,09	0,07	0,11	0,05	0,13
Dummy variable CR5 (fifth quintile of expenditures with interest/ turnover)	0,10	0,10	-0,02	0,12	-0,05	0,14
Age of firm (LOG)	0,09 **	0,04	0,01	0,05	0,13 **	0,06
Market Share	0,29	0,69	0,56	0,71	0,60	0,74
Foreign firm (dummy variable)	-0,51 ***	0,12	-0,60 ***	0,14	-0,66 ***	0,17
Exporter firm in 1998 (dummy variable)	0,39 ***	0,08	0,50 ***	0,09	0,28 **	0,12
Continuous R&D (dummy variable)	0,29 ***	0,08	0,20 ***	0,09	0,24 **	0,11
Intensive technology sector (dummy variable)	0,20 ***	0,07	0,22 ***	0,08	0,19 *	0,10
South or Southeast Region (dummy variable)	0,09	0,08	0,11	0,10	0,06	0,12
Beneficiaries (n / N)	94 /	135	77 /	110	58 /	76
Non-beneficiaries (n / N)	9.884 /	69.463	5.214 /	25.006	2.600 /	8.138
Log likelihood	-703,5		-544,9		-340,6	
R^2	0,3		0,25		0,24	

Source: FINEP (Research and Projects Financing Agency); IBGE (National Statistics Bureau): PINTEC (Technological Innovation Survey) and PIA (Annual Industrial Survey); SECEX/MDIC (External Trade Office/Ministry of Industry and Trade); Censo de Capital Estrangeiro/BACEN (Census of foreign capitals/Braziliain Central Bank); RAIS/MTE (Annual Social Information Register/Ministry of Labor).
Obs. (*), (**), (***): significance at 10%, 5% and 1%, respectively. (ns) Non-significant variable. The number of firms (n) refers to the observations in the sample of Innovation Survey and (N) regards the number of observations in the population.

Table 3 shows the results of probabilistic models – that is, the selection equations – used in propensity score matching to create control groups. The signs from the parameters generally corresponded to those expected. The statistical significance of the parameters was good and the statistics of the models showed consistency in the selection of explanatory variables. Table 3 presents the results of estimates for three different samples: 1) the entire sample, ii) the sub sample of innovating firms, and iii) only for R&D spending firms.

The models indicate that size is generally a relevant variable in the probability that the firm is a beneficiary of ADTEN. The firms' performance characteristics – such as insertion in foreign markets and carrying out continuous R&D activities – also have a major influence on access to the program, possibly showing the existence of self-selection in the sample. The firm's age, a variable used in different studies as an important factor for accessing technological activity funding programs, was also relevant, as was the firm's sector of activity. Firm's geographical region, therefore, wasn't statistically significant. Lastly, foreign firms are less likely to obtain loans from ADTEN.

TABLE 4. TEST OF DIFFERENCES IN AVERAGES ACCORDING TO SELECTED VARIABLES FOR FIRMS THAT RECEIVE SUPPORT FROM ADTEN AND THE CONTROL GROUP – 2000.

Variables	Total sample			Innovating firms			Firms with positive R&D spending		
	Control Group	Bene-ficiaries	t value	Control Group	Bene-ficiaries	t value	Control Group	Bene-ficiaries	t value
Turnover (R$ 1000)	152,633	147,983	0.06	84,988	161,675	-1.39	118,188	200,984	-1.04
Employees	773	816	-0.20	800	697	0.51	686	876	-0.91
Labour productivity[1] (R$)	49,639	59,400	-0.96	38,124	64,421**	-2.44	57,782	67,307	-0.63
R&D spending [2] - Total (R$ 1000)	1,689	1,504	0.13	468	1,849*	-1.93	796	2,329	-1.58
R&D share on turnover (%)	0.53	1.36**	-2.01	1.50	1.68	-0.31	1.65	2.23	-0.85
Private R&D spending [2] (R$ 1000)	1,663	1,454	0.15	407	1,785*	-1.94	747	2,240	-1.52
Private R&D share on turnover (%)	0.52	1.18**	-2.17	1.44	1.46	-0.05	1.57	1.92	-0.71
Number of firms	92	92		73	73		52	52	

Source: FINEP (Research and Projects Financing Agency); IBGE (National Statistics Bureau): PINTEC (Technological Innovation Survey) and PIA (Annual Industrial Survey); SECEX/MDIC (External Trade Office/Ministry of Industry and Trade); Censo de Capital Estrangeiro/BACEN (Census of foreign capitals/Braziliain Central Bank); RAIS/MTE (Annual Social Information Register/Ministry of Labor). (1) Value added by employee. (2) The total R&D spending include internal R&D and acquisition of external R&D and is divided in private and public resources.Obs. (*), (**),(***): significance at 10%, 5% and 1%, respectively.

The purpose of estimating the model only for innovating firms or simply firms that spend in R&D activities was to select more homogenous groups of firms. It is reasonable to believe that innovating firms and firms that spend in R&D are different than the average industrial firm. The selection procedure for the control group therefore becomes more rigorous in a more homogenous group of firms.

After estimating the selection equation, a matching procedure that follows what was suggested in section 2.2.1 was applied to the data. After that, the difference between firms that benefit from ADTEN and the control group for each category were compared (table 4). The number of beneficiary firms analyzed was reduced to 92 in the complete sample, to 73 in the sub-sample of innovating firms, and to 52 in the sub-sample of firms with R&D spending. The reason for this is, first of all, the lack of proximity between some of the beneficiaries and most of the non-beneficiaries, which precludes the creation of a consistent contra factual for the formers. Another reason is that the two sub-samples (innovating firms and R&D firms) are smaller than the complete sample, including in the group of beneficiaries[20].

The relevant variable in the analysis of the policy's impact on the R&D expenditures of beneficiary firms of ADTEN is the R&D expenditure as a proportion of net sales turnover (RLV). In the model with a complete sample, there is a positive and statistically significant difference in the relationship R&D/RLV between the group of beneficiary firms and the control group. In this case, the beneficiary ones invested 2.3 times more than the firms which were not beneficiaries of the program. In this case, we are considering only private resources. In the case of R&D expenditures of public and private resources, the difference is even greater. When we analyze the sub-sample of innovating firms and firms with R&D spending, this difference is no longer significant. However, in this group of firms there is a statistical significant difference in labour productivity and in the amount of R&D expenditure. In the sub-sample of firms with R&D spending, no variable was significant.

These results indicate that in 2000, investments made in R&D by firms were greater among those that received support from ADTEN. This is evidence of crowding in, because access to ADTEN influenced R&D private expenditures beneficiary firms. However, this evidence has not been statistically proven in the model for innovating firms and R&D firms, most likely because the difference among those firms in these more homogenous samples would only appear if the sample size was larger. Despite this technical difficulty, it is important to note that R&D expenditures of firms that receive support from ADTEN continue to be positive in these two models, and do not show any evidence that would support the existence of crowding out effects.

4.2 Two step selection model

The second methodological procedure utilized to test the impacts of ADTEN on the firms' R&D expenditures is a two-stage selection model, inspired on Heckman (1979), as described previously, and further used by Busom (2000) and Jarmin (1999).

The first phase consists of assessing the probability of a firm being a participant of ADTEN. Thus, we will use the same PROBIT'S ***selection equation*** of the propensity score matching using the sub-sample of R&D firms, i.e., the estimate equation of table 3. In this case the control group is constructed only for R&D firms. Subsequently, the Mill's inverse ratio is calculated for each firm, following the procedures described in section 2.4 (equations 4 and 5). The second phase estimates an OLS model, with Mill's inverse ratio acting as one of the explanatory variables. This procedure would correct the selection bias observed. The significance of this variable in the model would prove whether or not there is indeed selection bias.

Table 5 shows the results of the OLS estimates with and without correction for selection bias. The dependent variable is the logarithm of companies' R&D private expenditures. The first regression is a simple OLS model that will be used to compare the results of the selection models. The other tree equations are the models with selection bias correction, according to section 2.4. There are two equations, one of them

[20] The criteria of being innovative or having positive R&D spending were applied also to participant firms.

estimated for participants and non-participants separately, and another one for the complete sample.

The explanatory variables used in the model are very similar to that used in the selection equation. However, in order to avoid identification problems in the equation, some variables must be different between the selection equation (table 3) and the treatment equation (table 5). Thus, in the treatment equation the dummies which seek to assess the solvency of the firm are not used. Furthermore, there is no economic sense in using these variables in the treatment equation. And a new variable is used as proxy for both the firm's labor qualification and its technological capacity, the employees' schooling years.

The results show that the explanatory variables are significant for the most part and show the expected signs. The statistical significance of Mill's inverse ratio indicates the existence of selection bias.

TABLE 5. REGRESSION MODELS FOR TOTAL R&D EXPENDITURES (ONLY FOR FIRMS WITH POSITIVE R&D EXPENDITURES) - 2000

Explanatory variables	OLS		Selection models					
			Beneficiaries		Non-beneficiaries		All firms	
	β	t value	β	t value	β	t value	β	t value
Intercepto	5.11***	24.70	18.16***	3.36	5.55***	19.93	5.29***	19.67
Dummy for Beneficiaries	0.36	1.22	-	-	-	-	5.43***	5.08
Employees (LOG)	0.67***	25.47	0.06	0.17	0.62***	18.74	0.67***	22.40
Employees' schooling	0.14***	8.65	0.29**	2.01	0.23***	12.61	0.23***	12.94
Firm's age (LOG)	0.19***	4.91	-0.11	-0.20	0.05	1.01	0.05	1.18
Firm's patents (1998)	0.36***	3.45	0.32	0.65	0.19**	2.32	0.23***	2.82
Export firm (1999)	0.32***	4.40	-0.48	-0.69	0.07	0.93	0.13*	1.79
Foreign firm	0.46***	4.36	1.91*	1.88	0.59***	6.22	0.45***	5.09
South-Southeast Region	0.19***	2.88	-0.76	-1.27	0.04	0.57	0.03	0.49
Technology-intensive sector	0.56***	9.11	-0.25	-0.41	0.53***	7.84	0.56***	8.50
Lambda (Mills inverse ratio)	-	-	-3.12***	-2.51	-4.89***	-6.07	-2.23***	-4.82
F value	283.4		4.0		248.6		227.0	
Adjusted R^2	0.51		0.33		0.48		0.48	
Number of firms	2485		57		2428		2485	

Source: FINEP (Research and Projects Financing Agency); IBGE (National Statistics Bureau): PINTEC (Technological Innovation Survey) and PIA (Annual Industrial Survey); SECEX/MDIC (External Trade Office/Ministry of Industry and Trade); Censo de Capital Estrangeiro/BACEN (Census of foreign capitals/Braziliain Central Bank); RAIS/MTE (Annual Social Information Register/Ministry of Labor). Obs. (*), (**),(***): significance at 10%, 5% and 1%, respectively.

To estimate the average treatment effect (ATE) we follow the calculation described in section 2.4. The first way to calculate the treatment effect uses the two equations of selection models estimated to participant and non participant firms separately. Therefore, the average treatment effect in this case – ATE1 – is based on equations 8 and 9 (section 2.4). The second approach is to calculate the average treatment effect (ATE2) based on equation estimated to all firms. This calculation follows the procedures described in equations 10 to 12.

Table 6 synthesizes the results of the ADTEN program's effects on R&D expenditures according to the OLS model and to the selection models.

TABLE 6. EFFECT OF TREATMENT ON R&D EXPENDITURES OF FIRMS

Model	Impact of ADTEN program		
	ATE		t value
OLS	0.36	(ns)	1.22
ATE1 - Selection model (beneficiaries X non-beneficiaries)	0.33	***	3.70
ATE2 - Selection model (all firms)	0.25	***	3.08

Source: FINEP (Research and Projects Financing Agency); IBGE (National Statistics Bureau): PINTEC (Technological Innovation Survey) and PIA (Annual Industrial Survey); SECEX/MDIC (External Trade Office/Ministry of Industry and Trade); Censo de Capital Estrangeiro/BACEN (Census of foreign capitals/Braziliain Central Bank); RAIS/MTE (Annual Social Information Register/Ministry of Labor) Obs. (*), (**),(***): significant variables at 10%, 5% and 1%, respectively. (ns) Non-significant variable. ATE1 is based on equations 8 and 9; ATE2 is that on equations 10 to 12.

Results show that there is evidence that the program has both positive and significant impacts on the R&D expenditures of beneficiary firms. According to selection models, firms that receive funding from ADTEN have, in average, R&D expenditures between 28% and 39%[21] more than firms that do not benefit from this program. This result shows a positive impact of ADTEN in R&D spending of participant firms, like in propensity score matching, even for a sub-sample of more homogenous firms, that is, those with positive R&D expenditures. Although there is a bias, the difference between the estimates of the treatment effect on selection models and on OLS is small, since in simple OLS model the ATE is around 43%. In both estimates the program has positive impacts on R&D expenditures. In conclusion, there is concrete evidence that the ADTEN program stimulates private investments in R&D.

How about the impact of ADTEN on participant firms' productivity? To answer this question the study has applied the same procedure (selection models) to another dependent variable defined as the logarithm of firm's productivity. For this we used, in order to calculate the Mill's inverse ration, the same selection equation presented in table 3. The difference is that we estimate the treatment equation with the complete sample instead of the sub-sample of firms with positive R&D spending. The results for the OLS and selection models for productivity are shown in Table 7.

The specification of the treatment equation is the same as that used for the R&D firms' spendings. However, in the treatment equation for productivity, the Mill's inverse ration was not statistically significant which evidences that there is no selection bias in the sample when we analyze the impact on productivity. In this way, the impact of ADTEN on firm's productivity may be calculated by the simple OLS model.

Therefore, the results of this procedure are consistent with those found when propensity score matching with different averages was used. In other words, although the evidence was positive in both procedures, the results are not conclusive because the parameters are not statistically significant.

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[21] Once that the dependent variable is expressed in terms of logarithm, the percentual impact results from the following equation: $[\exp(\beta)-1]*100$.

TABLE 7. REGRESSION MODELS FOR ESTIMATING DETERMINANTS OF FIRMS' PRODUCTIVITY (IN LOGARITHM) - 2000.

Explanatory variables	OLS		Selection models					
			Beneficiaries		Non-beneficiaries		All firms	
	β	t value	β	t value	β	t value	β	t value
Intercepto	6.54 ***	51.50	10.19	5.5	5.83 ***	41.33	5.79 ***	42.90
Dummy for Beneficiaries	0.50	1.28	-	-	-	-	-0.51	-0.57
Employees (LOG)	0.11 ***	5.99	-0.13	-1.18	0.13 ***	7.25	0.14 ***	8.44
Employees' Schooling	0.11 ***	11.81	0.22 ***	4.96	0.16 ***	15.60	0.16 ***	15.90
Firm's age (LOG)	0.19 ***	8.30	0.08	0.46	0.31 ***	12.49	0.31 ***	12.60
Firms with patents (1998)	0.33 ***	2.61	-0.19	-1.12	0.11	1.48	0.11	1.55
Export firm (1998)	0.59 ***	9.43	-0.02	-0.1	0.48 ***	10.07	0.49 ***	10.90
Foreign firm	0.66 ***	5.83	0.29	0.12	0.56 ***	8.33	0.53 ***	8.27
Technology-intensive sector	0.45 ***	9.49	0.02	0.12	0.34 ***	7.73	0.35 ***	8.02
South-Southeast Region	0.18 ***	4.94	-0.01	-0.05	0.14 ***	3.56	0.14 ***	3.63
Lambda (Mills inverse ratio)	-	-	-0.45	-1.28	-0.35	-0.71	0.30	0.85
F value	134		5.01		252.5		232.3	
Adjusted R^2	0.11		0.28		0.19		0.19	
Number of firms	9831		94		9737		9831	

Source: FINEP (Research and Projects Financing Agency); IBGE (National Statistics Bureau): PINTEC (Technological Innovation Survey) and PIA (Annual Industrial Survey); SECEX/MDIC (External Trade Office/Ministry of Industry and Trade); Censo de Capital Estrangeiro/BACEN (Census of foreign capitals/Braziliain Central Bank); RAIS/MTE (Annual Social Information Register/Ministry of Labor).Obs. (*), (**),(***): significance at 10%, 5% and 1%, respectively. (ns) Non-significant variable.

4.3 *Difference in difference method*

Another major goal is to measure the impact of ADTEN on the performance of firms, grasping a dynamic view of the policy evaluation. In other words, we wish to know whether participant firms have a major rate of growth both of productivity and of size than non participants ones. Despite the program's limited reach, this is a particularly relevant issue for public policies. In order to do this evaluation, the best procedure is the difference in difference method, described in section 2.3.

The selection of control groups was made in 1996, in other words, the PROBIT for estimating the firm's likelihood of benefiting from ADTEN was estimated using data from 1996. The treatment period was from 1997 to 2002. The year of comparison for verifying the difference between groups was 2003. Thus, the variation rates were from 1996 to 2003.

Table 8 presents the results of the PROBIT model, with the dependent variable being whether the firm is a beneficiary or not of the ADTEN program. This is the same model used in table 3. The difference is that the year used for the estimate is 1996 and the database used is the Annual Industrial Survey. Therefore, we do not have, in this case, variables of technological efforts of firms and we have a larger sample than in the Technological Survey. The signs and meaning of the parameters are consistent with the expected.

TABLE 8. ESTIMATE OF PROBABILITY THAT THE FIRM IS A BENEFICIARY OF THE ADTEN PROGRAM - 1996 (PROBIT MODEL ONLY FOR FIRMS WITH MORE THAN 30 EMPLOYEES)

Variáveis	All firms	
	Coefficient	Standard error
Intercept	-3.97 ***	0.35
Employees (LOG)	0.22 ***	0.04
Dummy variable CR1 (first quintile of expenditures with interest/turnover)	-0.23 *	0.13
Dummy variable CR2 (second quintile of expenditures with interest/ turnover)	-0.13	0.13
Dummy variable CR4 (fourth quintile of expenditures with interest/ turnover)	0.07	0.11
Dummy variable CR5 (fifth quintile of expenditures with interest/ turnover)	-0.02	0.11
Age of firm (LOG)	0.03	0.07
Market Share	0.49	0.61
Foreign firm (dummy variable)	-0.47 ***	0.15
Exporter firm in 1995 (dummy variable)	0.39 ***	0.09
Firm with patents register in 1995 (dummy variable)	0.27 **	0.13
Intensive technology sector (dummy variable)	0.23 ***	0.08
South or Southeast Region (dummy variable)	0.16 *	0.09
Beneficiaries (n)	126	
Non-beneficiaries (n)	11519	
Log likelihood	-596.65	
R^2	0.15	

Source: FINEP (Research and Projects Financing Agency); IBGE (National Statistics Bureau): PINTEC (Technological Innovation Survey) and PIA (Annual Industrial Survey); SECEX/MDIC (External Trade Office/Ministry of Industry and Trade); Censo de Capital Estrangeiro/BACEN (Census of foreign capitals/Braziliain Central Bank); RAIS/MTE (Annual Social Information Register/Ministry of Labor). Obs. (*), (**),(***): significance at 10%, 5% and 1%, respectively. (ns) Non-significant variable.

The next step is to create a control group using again the propensity score matching procedure, as described in section 2.2. After that, we have estimated a difference in averages test on the rate of increase of turnover, productivity, number of employees and average wage of the firms[22]. Table 9 shows the statistics for the average difference between 1996 and 2002 for the group of companies that received support from ADTEN and the control group.

[22] The rate of growth of this variables is calculated as [(value in 2003 - value in 1996) / value in 1996] for all the variables in table 9.

TABLE 9. RATE OF GROWTH OF REPRESENTATIVE VARIABLES FOR THE PERFORMANCE OF FIRMS THAT RECEIVED SUPPORT FROM ADTEN AND THE CONTROL GROUP FROM 1996- 2003

Variables	Rate of growth		
	Control group	Beneficiaries	t value
Turnover	0.12	0.76	2.58***
Employees	-0.04	0.75	- 3.32***
Average Wage	1.67	1.61	0.98
Labour productivity	0.15	0.14	0.11
Number of firms	118	118	

Source: FINEP (Research and Projects Financing Agency); IBGE (National Statistics Bureau): PINTEC (Technological Innovation Survey) and PIA (Annual Industrial Survey); SECEX/MDIC (External Trade Office/Ministry of Industry and Trade); Censo de Capital Estrangeiro/BACEN (Census of foreign capitals/Braziliain Central Bank); RAIS/MTE (Annual Social Information Register/Ministry of Labor). Obs. (*), (**),(***): significance at 10%, 5% and 1%, respectively. (ns) Non-significant variable. Turnover, wage and productivity were deflated by the wholesale price index (IPA).

Results show higher growth rates for firms that were beneficiaries of ADTEN. This can be inferred from the variables net turnover and number of employees. The null hypothesis that the growth rates in the control and treatment groups were equal between 1996 and 2003 was rejected for these two variables.

In the case of productivity and average wage the non significant results indicate that it was not possible to reject the null hypothesis regarding the groups' equality in the period 1996-2003. This period of analysis is still too short to verify significant changes in these indicators of the firm's performance. Moreover, the theoretical literature about technological innovation and technological efforts shows that innovating firms can loose productivity immediately after the innovation. Productivity gains would require, therefore, a longer time lag to occur.

To sum up, the ADTEN program had a positive impact on the firms' growth regarding turnover and number of employees. However, the results are not conclusive with regard to other two performance criteria, productivity and average wage, which seem to require a longer maturation process to show up the positive effects.

5 FINAL REMARKS

Evaluation of public policies that focus on stimulating innovative technological activities, especially R&D in firms, are relatively common in literature for developed countries. However, these studies are comparatively rare in developing countries such as Brazil. Moreover, no econometric study has been published in this country using information on firms. This study seeks to make a contribution in this area. It evaluates the impact of the Technological Development Support Program (ADTEN) on the performance and technological efforts of Brazilian industrial firms. This work is unprecedented in its content and procedures, providing for the first time a comprehensive analyzes of the impact of technological innovation support programs in Brazil at the firm's level.

The study has shown that ADTEN reaches a relatively limited number of firms, considering the magnitude of Brazilian industry. It reaches only 0.07% of Brazilian industrial firms with over 10 employees. The volume of resources borrowed by firms within the framework of the program amounts to only 1.6% and 3% of the companies' expenditures used for R&D in 2000 and 2003, respectively.

Table 10 shows a synthesis of the evidences found regarding the impact of ADTEN in the performance of Brazilian industrial firms, considering the methods and outcome variables that were analyzed.

TABLE 10. IMPACT OF ADTEN PROGRAMA ON THE PERFORMANCE AND TECHNOLOGICAL EFFORTS OF BRAZILIAN FIRMS ACCORDING TO DIFFERENT METHODS: 1996 TO 2003.

Method	Impacts of ADTEN on		
	Growth	Productivity	Technological efforts
Propensity Score Matching		Ns*	+
Selection models		Ns	+
Difference in Difference	+	Ns	

*Obs. (**Ns***) means that, despite the significance of the difference of averages in one sample, in other two samples this difference was non significant. (**Ns**) means a non significant difference and **(+)** means a positive and statistically significant difference between participants and non participants of ADTEN.*

The program was evaluated between 1996 and 2003 from two points of view. The first was to see if there was complementarity or substitution between public and private resources in the firms' R&D expenditures. Compelling evidence was found that ADTEN positively influences a firm's private R&D expenditures. The second was to assess the impact of ADTEN on a firm's overall performance. Three indicators were analyzed: growth, productivity and technological effort. The results indicate that there is clear evidence that the program positively influences the economic growth of firms, which was measured by the rate of increase of net turnover on sales and the number of employees. There is also evidence that ADTEN has a positive impact on productivity and patent applications, although the results are not conclusive as the parameters are not statistically significant.

6. BIBLIOGRAPHY

ABADIE, A. et all (2001) "Implementing Matching Estimators for Average Treatment Effects in Stata". *The Stata Journal*, n. 1, pp 1-18.

AERTS, K.; CZARNITZKI, D. "Using Innovation Survey Data to Evaluate R&D Policy: the case of Belgium". Discussion Paper n. 05-55. ZEW: Centre for European Economic Research, 2004. http://opus.zbw-kiel.de/volltexte/2004/2193/pdf/dp0455.pdf

ARAÚJO, R. D. "Esforços tecnológicos das firmas transnacionais e domésticas". In DE NEGRI, J. A. E SALERNO, M. *Inovações, padrões tecnológicos e desempenho das firmas industriais brasileiras*. Brasília: IPEA, 2005.

BALTAGI, B. H. *Econometric analysis of panel data*. England: John Wiley & Sons Ltd, 1995.

BARCELLOS, Silvia Helena e ASSUNÇÃO, Juliano Junqueira "Guerra Fiscal Municipal: uma Estratégia de Desenvolvimento? O Caso de Barueri e Santana de Parnaíba" . In Anais do XXVI Encontro Brasileiro de Econometria: João Pessoa, 2004.

BLUNDELL, R; COSTA DIAS, M (2000) “Evaluation Methods for non-experimental data”. *Fiscal Studies* 21(4), pp 427-468.

BUSOM, I. (2000), “An empirical evaluation of the effects of R&D subsidies”, *Economics of Innovation and New Technology* 9(2), 111–148.

CZARNITZKI, D. and FIER, A. (2004) “Do Innovation Subsidies Crowd Out Private Investment? Evidence from the German Service Sector”. Discussion Paper n. 02-04, *Centre for European Economic Research (ZEW).* ftp://ftp.zew.de/pub/zew-docs/dp. (published 2002 in: *Applied Economics Quarterly* 48(1), 1-25)

DAVID, P., HALL, B. and TOOLE, A. (2000). “Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence”, *Research Policy*, 29, pp.497-529.

GONZÁLEZ, X. and PAZÓ, C. (2005) “Do public subsidies stimulate private R&D spending?”. (http://www.fep.up.pt/investigacao/seminarios/05.10.21_GonzalezPazo.pdf)

GREENE, W. H. *Econometric Analysis*. 4th ed. New York: Prentice Hall, 2000.

HECKMAN, J. (1979) “Sample selection bias as a specification error”. *Econometrica*, v. 47, pp. 153-61.

HECKMAN, J., ICHIMURA, H.; TODD, P. Matching as an econometric evaluation estimator, Review of Economic Studies, v. 64, p. 605-654, 1997.

HSIAO, C. *Analysis of panel data*. Cambridge: Cambridge University Press, 1986.

HUSSINGER, K. (2003), “R&D and Subsidies at the Firm Level: An Application of Parametric and Semi-Parametric Two-Step Selection Models”, ZEW Discussion Paper No. 03-63, Centre for European Economic Research, Mannheim.

JARMIN, R.S. (1998), ‘Manufacturing Extension and Productivity Dynamics’, *CES Working Paper* No. 98-8, Washington DC: U.S. Bureau of the Census.

KAISER, U. (2004) “Private R&D and Public R&D Subsidies: microeconometric evidence from Denmark”. Discussion Paper 2004-19. Centre for Economic and Business Research (CEBR). (www.cebr.dk/upload/dp2004-19.pdf)

LÖÖF, H. and HESMATI, A. (2005) “The Impact of Public Funding on Private R&D Investment. New evidence from a firm level innovation study”. Paper n. 06, *CESIS – Eletronic Working Paper Series*, The Royal Institute of Technology. (http://www.infra.kth.se/cesis/research/publications/working papers).

MEYER, B., (1995), “Natural and Quasi-Experiments in Economics,” *Journal of Business and Economic Statistics*, 13, 151-161.

WOOLDRIDGE, J. M. (2002) *Econometric Analysis of Cross Section and Panel Data*. The Mit Press, Cambridge, Massachusetts.