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EVALUATING EFFECTIVENESS OF PUBLIC SUPPORT TO BUSINESS R&D IN TURKEY THROUGH CONCEPTS OF INPUT AND OUTPUT ADDITIONALITY

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Abstract

It is the purpose of this paper to examine the impact of direct public support granted to business R&D not only on the R&D expenditures of enterprises (would the recipients of incentives have carried out the same amount of R&D expenditures even in the absence of subsidies?) but also on the output of R&D expenditures of these enterprises (would the recipients of R&D subsidies have recorded growth rates -or exported or hired people- to the same extent if they had not received these subsidies?) We will use enterprise-level data for the Turkish economy over the period 2003-2006 –a time span where a substantial increase occurred in funds aimed at supporting business R&D– and a semi-parametric matching technique to examine the effectiveness of R&D incentives given to private R&D as far as their effects on R&D expenditures (input additionality) and output of R&D activity (output additionality) is concerned.

ملخص

الغرض من هذه الورقة هو دراسة أثر الدعم الحكومي المباشر الممنوح لقطاع الأعمال R & D، ليس فقط على نفقات البحث والتطوير للمؤسسات (وهل صرف المستفيدين من هذه الحوافز نفس الكمية من نفقات البحث والتطوير حتى في غياب الدعم؟) ولكن أيضا على الناتج من نفقات البحث والتطوير لهذه المشاريع (وهل سجل المستفيدين من إعانات R & D معدلات نمو أو تم استأجار الناس بنفس القدر إن لم تكن قد تلقت هذه المساعدات؟) سوف نستخدم بيانات على مستوى مؤسسة الاقتصاد التركي خلال الفترة 2003-2006، وهي الفترة الزمنية التي شهدت زيادة كبيرة في الصناديق التي تهدف إلى دعم أعمال البحث والتطوير وايضا التقنية الشبه بارامترية المطابقة لدراسة فعالية الحوافز الممنوحة R & D والتطوير بقدر آثارها على نفقات البحث والتطوير (المدخلات المضافة) والناتج من نشاط البحث والتطوير (المخرجات المضافة).

1. Introduction

In the aftermath of their switch from an import-substitution industrialization strategy to a more outward-oriented one, and together with the acceleration of the globalization process, many developing countries began to restructure their science and technology (S&T) policies. The crucial change was the transition from a supply-based S&T policy approach to a demand-based one. The main objective in the former approach was to create knowledge through basic and applied research in public research centers (and universities) and transfer it to the business sector in order to increase the innovative performance and competitiveness of enterprises. Following the renunciation to this approach together with the demise of ISI strategy, a new approach aimed at funding R&D activities of enterprises by means of direct support (and fiscal incentives) through technology development funds (TDFs) has come into the policy agenda. Over time, the volume of public resources granted to business R&D activities through TDFs came to represent important amounts in absolute terms as well as in terms of R&D expenditures. This situation justifies efforts aimed at the evaluation of the effectiveness of R&D incentives provided by governments to business through TDFs in developing countries.

Similarly, public support to business R&D has gained momentum in Turkey in the mid-nineties: on the one hand, resources aimed at supporting private R&D have increased steadily and reached an annual amount of 150-200 million dollars by the year 2005 and on the other hand, the share of direct support in total private R&D expenditures increased from less than 1% in 1996 to around 10% in 2008. The only quantitative ex post evaluation exercise of two R&D support programs is carried out in Ozcelik and Taymaz (2008) for the period 1993-2001. Another tour of evaluation is needed for the post-2001 period given that a rapid increase in public support for private R&D has been observed since 2003.

It is the purpose of this paper to examine the impact of direct public support granted to business R&D not only on the R&D expenditures of enterprises (would the recipients of incentives have carried out the same amount of R&D expenditures even in the absence of subsidies?) but also on the output of R&D expenditures of these enterprises (would the recipients of R&D subsidies have recorded growth rates -or exported or hired people- to the same extent if they had not received these subsidies?) We will use enterprise-level data for the Turkish economy over the period 2003-2006 –a time span where a substantial increase occurred in funds aimed at supporting business R&D– and a semi-parametric matching technique to examine the effectiveness of R&D incentives given to private R&D as far as their effects on R&D expenditures (input additionality) and output of R&D activity (output additionality) is concerned.

We will use data mainly from the *Structural Business Statistics Survey* (SBS) collected by the Turkish Statistical Institute (Turkstat) by means of annual surveys conducted among enterprises. This database spans a period of five years from 2003 to 2006. *SBS* will be merged carefully with other databases and after rigorous data cleaning an econometric analysis will be implemented to assess additionality issues.

Our research question – whether direct R&D incentives granted in Turkey to enterprises over 2003-2006 led to any input and output additionality effect – will be addressed through the use of a semi-parametric matching method. Because a selection bias may occur for a number of reasons inherent to the process of subsidy application and granting[1], comparing the R&D expenditures of recipient firms with those of non-recipients does not inform us about the true impact of the support programs. Unless we know what a subsidized firm would have spent for its R&D activities in the absence of any subsidy –which we do not know since an

[1] Such as preferences of the public agency in allocating grants, characteristics of applying firms and peculiarities of the grant process itself.

enterprise cannot be observed in both states simultaneously– we must construct an appropriate counterfactual to assess the additionality effect.

In order to construct a valid control group for recipient firms, conditioning on observables we match each recipient firm with a non-recipient firm that is 'very' similar to it except for its subsidy status. To remove the so-called "curse of multidimensionality", we use a scalar, the propensity score –i.e. the probability that a firm receives a R&D grant– together with the Mahalanobis distance to carry out the matching procedure. Once we have a selected control group for subsidy recipient firms, we calculate the average impact of treatment on the treated by subtracting the average R&D expenditure (intensity) of support recipients from those recorded for the firms in the control group. Since the number of support recipients is low compared to the whole population of firms, we also use bootstrapping to estimate the subsidy impact (the aforementioned method is also used for testing output additionality of R&D support). One shortcoming of the matching method is that it controls only for observables but not for time-invariant non-observable factors as well as common macroeconomic shocks which might cause the selection bias. The difference-in-differences (DiD) estimator will be used to deal with this issue.

Next, we will first examine the evolution of R&D activities in the Turkish economy and the evolution of direct R&D support of the Scientific and Technological Research Council of Turkey (TUBITAK). Second, we will discuss the semi-parametric method – propensity score matching (PSM) – to be used in our paper. Third, after presenting the datasets used in our analysis, we will examine the results of the PSM analysis and test successively for input and output additionality of direct R&D subsidies. A final section will be devoted to the discussion of policy implications of our findings and a number of research avenues to be explored in future research will be proposed as well.

2. Public support programs for business R&D in Turkey

Public support to business R&D began to be implemented in Turkey in the early 1990s. However, until recently, the volume of funds allocated by government to this end was rather limited and the instruments used very few. In this section, public support programs and other incentives which have been in force for promoting industrial R&D activities in Turkey since the year 2000 will be examined[2]. The key organizations implementing these programs over the period 2003-2006 were the Undersecretariat of Foreign Trade (DTM) through its financial support provided to the Scientific and Technological Research Council of Turkey (TUBITAK), Technology Development Foundation of Turkey (TTGV) and Small and Medium-size Industry Development Organization (KOSGEB) affiliated with the Ministry of Industry and Trade. In addition to these direct supports, the Ministry of Finance introduced a scheme in 2005 involving a fiscal incentive of 40% tax allowance for business R&D expenditures which led to the adoption of a new tax law. This law itself was extended in 2008 in such a manner to increase the number of fiscal incentives and the extent of tax breaks associated with each incentive. It is too early, however, to conduct an impact assessment exercise for this scheme which has been implemented only since 2008.

In the sequel, only data on the direct support provided by TUBITAK to business R&D will be examined. This is due to the fact that subsidies provided by TUBITAK represent the major part of total business R&D support in Turkey. It is precisely additionality effects associated with TUBITAK's support programme that will be dealt in the econometric part of our paper.

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[2] For a recent overview of policy measures and support programmes for industrial R&D in Turkey, see World Bank (2009).

2.1. TUBITAK industrial R&D projects support programme

The most important public R&D support programme in Turkey has been the Industrial R&D projects support programme, which was launched by DTM and Technology and Innovation Support Programmes Directorate of TUBITAK (TUBITAK-TEYDEB in the sequel) in 1995[3]. In the context of the programme, while DTM provides funding, TUBITAK serves as the referee institution. TUBITAK's grant committees distribute funds in a wide range of technological fields. The evaluation of applicants' R&D projects for grant and the assessment of the legitimacy of firms' R&D expenditures -if they are granted- are done by external evaluators selected by related grant committee members.

The applicants, which are either large firms or SMEs, select one of the following technology groups according to their projects' focus of interest: (i) machinery and manufacturing technologies, (ii) electrical and electronics, (iii) information technologies, (iv) materials, metallurgical and chemical technologies, (v) biotechnology, agriculture, environmental and food technologies. The distribution of submitted projects between 1995 and 2009 by technology fields is shown in Figure 1. The qualified projects are supported by means of non-reimbursable grants covering 50-60% of their eligible expenses in a matching fund scheme[4].

The objective of TUBITAK-TEYDEB support programme is to enhance international competitiveness of industrial companies in Turkey by means of higher R&D and innovation expenditures. This concerns especially the R&D phases of product and process innovations until the prototype formation but excludes investments in the manufacturing stage or any marketing and organizational innovations. Over the period 1995-2009, 4,752 firms applied to the programme and submitted 10,161 R&D projects –of which 6,122 were supported. The volume of support received by beneficiary firms was 1.07 billion USD and 80% of this amount was spent after 2005. The total amount of R&D expenditures carried out by enterprises during this period was 2.13 billion USD. As illustrated in Figure 2 an upward trend has been observed since the year 2004 in the evolution of the total number of industrial R&D grants provided by TUBITAK-TEYDEB, which is why the year 2004 was selected as the reference year for the evaluation exercise conducted in this paper. The amount of average subsidy per supported project also increased more than three times, from 80,000 USD in 2002 to 270,000 USD in 2007 (see Figure 3).

Both large firms and SMEs can apply to the industrial R&D support programme. In order to promote R&D activities of SMEs, TUBITAK-TEYDEB has launched a new R&D funding scheme in 2007 targeting only SMEs. In this way, it provides grants up to 75% of the expenditures of eligible SMEs' first two R&D projects. As depicted in Figure 4, the SME programme helped significantly to boost the share of SMEs in the total number of applicants. The decrease in the number of proposals in 2009 is believed to be caused by the global economic crisis in 2008.

The rate of acceptance was comprised between 80-90% -a very high rate by international standards- from 2000 to 2006. However, as the number of applications increased over the years, the acceptance rate of project proposals - evaluated by external evaluators- decreased from 80% in 2006 to 72% in 2007, 52% in 2008 and to 50% in 2009 (Figure 5). This evolution might indicate either an increase in the quality of evaluations of projects submitted

[3] According to the Turkish Statistical Institute (Turkstat), 86% of total public funding for business R&D in Turkey over the period 2003-2006 was provided by TUBITAK through its industrial R&D projects support programme.

[4] Beneficiary firms report project expenditures including personnel costs, consultancy and outsourcing fees, cost of equipments and material used in the project during each six months period. TUBITAK-TEYDEB conducts an evaluation and transfers 50-60% of eligible costs already incurred by firms.

or diminishing returns in the scope or quality of proposals submitted, or both as suggested in Teubal (1996).

Figure 6 shows that the evolution of TUBITAK-TEYDEB grants provided via industrial R&D projects support programme soared more than ten times in ten years, thanks to a generous budget allocation of the government aimed at increasing the volume and scope of public R&D incentives since 2005.

3. Key Science-Technology-Innovation (STI) indicators for Turkey

In this section, recent key indicators related to R&D and innovation performance of the Turkish economy will be examined in order to illustrate progress made on the R&D and innovation fronts, as well as to identify challenges it must face in the coming years.

One of the most frequently used STI indicator, GERD (gross expenditures on R&D) as a percentage of GDP is presented in Table 1 for Turkey and EU-27 as well as for a number of countries. Although EU-27 has not shown any sensible progress towards the target of 3 % (Lisbon objective) the improvement in GERD/GDP ratio observed in Turkey during 2000-2008 needs further impetus to enable catching up with the EU-27 average of 1.77 %. The key STI indicators that show steady progress in the last five years are presented in Table 2. While GERD per person rose from $51.4 in 2004 to $121 in 2009, FTE (full time equivalent) researchers per 10,000 total employment increased from 18.1 to 34.6 during the same period.

Recently, patent applications originating from Turkey has shown a significant upward trend compared to previous periods. Table 3 indicates that domestic patent applications rose from 170 in 1995 to 2588 in 2009. On the other hand, foreign applications were shifted from Turkish Patent Institute to the European Patent Convention. However, the number of patent granted to domestic agents is still much less than those granted to foreigners over the period 1995-2009 (Figure 7).

Another key STI indicator is related to human resources mobilized in scientific and technological activities. As illustrated in Figure 8, the rapid growth in full time equivalent (FTE) R&D personnel and researchers in Turkey after 2002 was in line with the modification of the national objective related to the number of FTE R&D personnel from 80,000 to 150,000 persons in 2013. However, comparing Turkey's number of FTE researchers per 10,000 total employments with EU-27 and other countries shows that the abovementioned progress should further be accelerated (see Table 4).

Yet another set of indicators which is particularly relevant for this study is related to public incentives provided to private R&D and innovation activities. These incentives can be grouped in two categories and include policy instruments for direct support and fiscal incentives. Table 5 provides a summary of the allocation of main funds within Turkey's national innovation system over the period 2005-2008 and shows that annual public expenditures for R&D and support programmes in Turkey increased more than 34% in four years. In addition, Figure 9 indicates that not only the volume of direct public support has increased over the period 1996-2008 but that the share of this direct support in business R&D expenditures increased as well.

4. Impact analysis of direct public support to business R&D in Turkey

4.1. Construction of data and descriptive analysis

In this study, a number of different datasets were merged and subsequently used to estimate the determinants of industrial R&D and assess the impact of public subsidies on business R&D expenditures in Turkey over the period 2003-2006.

The dataset used in our paper was constructed on the basis of six data sources pertaining to the years 2003-2006:

- *Structural Business Statistics survey* (SBS): around 80,000 enterprises per year (source: Turkstat)
- *Foreign Trade Statistics*: data on imports and exports at the sector level (source: Turkstat)
- *General Census of Industry and Establishments*: around 3,500,000 entries (source: Turkstat)
- *Producers' Price Index* in three digits sector codes (source: Turkstat)
- *Administrative Data* maintained by *TUBITAK-TEYDEB*: around 2,500 business enterprises which applied to industrial support programs of TUBITAK-TEYDEB.

The SBS, which is the major element of the dataset used here, covers annual performance figures as well as basic firm-level data for public and private establishments with twenty and more employments. The questionnaire used for this survey was modified by Turkstat in 2002 for reasons of compliance with the European Council decision No 58/97 accepted in 1996[5]. The number of respondent firms[6] varies from 70,000 to 85,000 depending on the year. The total number of firms participating in the SBS over the period 2003-2006 is 18,278.

The sectoral coverage of the SBS extends divisions from C to K and M to O in NACE Rev. 1.1. According to economic activity branches:

(C) Mining and Quarrying

(D) Manufacturing Industry

(E) Electricity, Gas and Water

(F) Construction and Public Works

(G) Wholesale and Retail Trade; Motor Vehicle, Motorcycle, Personal and Household Goods Repair

(H) Hotel, Restaurant and café

(I) Railway Transportation, Pipeline Transportation, Airway Transportation

(K) Renting Real Estates and Business Activities

(M) Education

(N) Sanitary Affairs and Social Services

(O) Other Social and Personal Service Activities

Data on R&D expenditures of firms as well as for general characteristics of enterprises (number of employees, annual sales, sector of activity) is taken from Turkstat's SBS survey.

The import and export activities at the four-digit NACE Rev. 1.1 are from the Foreign Trade Statistics which are based on customs declarations made by firms.

Firm age is extracted from the General Census of Industry and Establishments database using the establishment year of business units.

All variables expressed in monetary values are expressed in 2003 constant prices and deflated with a 3-digit sector-level price index published by Turkstat. For R&D expenditures, a fixed composite deflator has been constructed as the weighted average of labor and capital costs. Since, impacting on the capital intensity of firms is one of the objectives of the TUBITAK TEYDEB technology support program, instead of constructing a single composite R&D cost index separate cost deflators for labor and capital could have been utilized in our study.

[5] The statistical unit of SBS also changed in 2002 from *firm (legal unit)* to *enterprise*. The enterprise is defined by Turkstat (2010) as "an organizational form that produces goods and services using decision autonomy at first degree. An enterprise carries out one or more activities at one or more locations. The relation between enterprise and legal unit is directly stated by this definition: An enterprise corresponds to a legal unit or combination of legal units." This major modification in the survey organization results in an important obstacle for the researchers in Turkey for merging data collected before and after 2002.

[6] We will use the terms, firm and enterprise interchangeably in this paper.

Although this can be done in future studies, note that the R&D cost deflator – whether composite or separately constructed for labor and capital – is available for the manufacturing sector level.

TUBITAK-TEYDEB administrative database is based on industrial R&D projects grant program and provides project-level data for industrial R&D performers. The original records which consist of information on each R&D project submitted to the program were reconsolidated to obtain firm-level data on direct support for industrial R&D provided by TUBITAK.

Two annual variables are created from the previous database: the first one is related to the support status of the firm7 and a second variable is about the amount of support received by the firm. Computer-related research activities such as software development have special characteristics in applied research area8. TUBITAK-TEYDEB's administrative database shows as well that subsidy beneficiaries in software development industry have in general higher R&D intensity and R&D employee intensity than firms funded in the manufacturing industries (see Table 6). We hence add data for this industry to the data of the manufacturing industry and use it in our study.

Table 7 shows the distribution of beneficiary firms with respect to the year of reception of subsidy[9]. During 2003-2006, only 5 % of the 237 beneficiary firms received TUBITAK grants in four consecutive years. In Table 7, the group of funded firms used in the matching analysis is marked with a rectangular box (plain line) presenting the firms that received TUBITAK grants in 2004 which is selected as the reference year. These firms are used as the treatment group in propensity scores matching analysis with the non beneficiary firms being used as the control

4.2 Impact of R&D subsidies on business R&D: propensity score matching method

In this section, Propensity Score Matching (PSM), the method adopted in our paper for assessing the impact of R&D subsidies on business R&D and on two indicators of output of the R&D process will be presented and discussed.

Over the last 15 years, a steady evolution was observed for both structural and non-structural evaluation methodologies in the econometric literature aiming to measure the impact of government R&D intervention. Recent theoretical studies based on earlier work have now achieved a level of maturity that makes them an essential instrument in many areas of empirical research in economics for the assessment of causal effects[10]. The main problem in studies related to the evaluation of government intervention is that of measuring the effect on a certain outcome of the exposure of a collection of individuals (e.g. people, firms or countries) to a treatment (e.g. subsidy program or tax incentive regulation). Unlike the earlier studies, taking care of the selection bias problem, and considering subsidy as an endogenous variable are the common characteristics of recent literature on subsidy evaluation.

Scholars in a range of countries utilize a number of statistical and econometric methodologies to address the issues of program selection and missing data in counterfactual situations. Depending on available data and the choice of dependent variable(s), the following parametric and semi-parametric methods have been employed extensively during the last

[7] (at least one project is; (i) accepted for funding, (ii) rejected by TUBITAK or retrieved by the firm itself or (iii) funded)

[8]OECD (2002).

[9] The number of firms that received grants from TUBITAK-TEYDEB is actually 3-4 times higher than the figures reported in Table 7. Indeed, only those beneficiary firms present both in Turkstat's SBS surveys and in TUBITAK-TEYDEB's administrative database are used in our analysis: see Table 9.

[10] Imbens and Wooldridge (2009).

decade: (i) *matching methods*[11], (ii) *two or three stages selection models*[12] (iii) *difference in difference methods*[13] and (iv) *instrumental variables methods*[14]. Matching methods using comparison techniques between treated and untreated groups provides a rather reliable way to measure the effects of a public intervention by taking care of the counterfactual effect and by mitigating the selection bias problem. In addition, its utilization does not require availability of appropriate instruments to be used in the econometric estimation.

In the search for a causal relationship between treatment[15] and the impact on the treated, the principle question is: *What would the treated individual act or be like, if it had not been treated, i.e. what is the additionality caused –if any– by the treatment?* The difficulty in answering such a question emerges from the hypothetical or *counterfactual* characteristic of the outcome observation[16]. As it is impossible to observe both the treated and the untreated cases using the same unit of analysis at the same time interval, a suitable control group should be selected for comparison. Heckman et al. (1998) argue that the counterfactual problem should be handled at the population level since it is impossible to solve it at the individual level.

The other important limitation when it comes to evaluate R&D subsidies is the existence of a selection bias, since neither program application by the firm nor the acceptance program by the funding agency is a randomized event. Firms may opt to engage in R&D activities according to their pre-defined policies. In fact, the characteristics of R&D performers and non-R&D performers often show significant differences. Regarding such restrictions, instead of adopting simple OLS models (which requires randomly sampled variables for unbiasedness of estimators) the use of propensity score matching (PSM) *which involves pairing treatment and comparison units that are similar in terms of their observable characteristics* seems to bring certain advantages for correcting the sample selection bias problem[17]. Since the influential studies on propensity score matching (PSM) by Rubin (1974 and 1977) and Rosenbaum and Rubin (1983), numerous scholars have further developed and exploited this model[18].

Many studies used PSM method to measure the impact of government interventions on private R&D in a range of countries, including one study for Turkey relating to the period 1993-2001[19]. In this paper, we aim to assess the impact of direct R&D subsidies on business R&D –i.e. assess the existence and extent of input and output additionality effects associated with these subsidies– in Turkey during a period which witnessed a significant increase in these funds.

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[11] See Czarnitzki (2001), Aerts and Czarnitzki (2004), Duguet (2004), Ebersbergier and Lehtorante (2005), Chudnovsky et al. (2006), Lööf and Hesmati (2005), Görg and Strobl (2007), Ozçelik and Taymaz (2008), Cerulli and Poti (2008), Aerts and Schmidt (2008); Gonzales and Pazo (2008).

[12] See Busom (2000), Wallsten (2000), Janz (2003), Hussinger (2008), Negri et al. (2006), Takalo et al. (2008).

[13] Lach (2002), Chudnovsky et al. (2006), Negri et al. (2006), Aerts and Schmidt (2008).

[14] Bloom et al. (2002), Ali-Yrrkö (2004), Clausen (2009).

[15] For the analysis conducted in this paper, treatment can be defined as the techniques or actions customarily applied to a specific individual or a group of individuals in a specified situation. Therefore, *any government intervention in business R&D can be regarded as treatment*.

[16] Winship and Morgan (1999).

[17] Dehejia and Wahba (2002).

[18] , Heckman, Ichimura and Todd (1998); Dehejia and Wahba (2002), Blundel and Costa Dias, (2002), Sianesi (2004), Caliendo and Kopeinig (2008), Imbens and Wooldridge, (2009).

[19] Czarnitzki, (2001), Aerts and Czarnitzki (2004) Duguet (2004), Ebersberger and Lehtorante (2005), Chudnovsky et al. (2006), Lööf and Hesmati (2005), Görg and Strobl (2007), Cerulli and Poti (2008), Aerts and Schmidt (2008), Gonzales and Pazo (2008). The study on Turkey is Ozçelik and Taymaz (2008).

The main advantage in using PSM would be the problem of dimensionality of the covariates. Indeed, in most of the cases, the number of pre-treatment characteristics of the individuals (firms) which is used to determine comparison groups is too high for PSM to be implemented empirically. As a practical solution to this problem, Rosenbaum and Rubin (1983) suggest to use a function of all relevant covariates, X_i, and a so-called balancing score, $b(X_i)$ such that the conditional distribution of X_i given $b(X_i)$ does not depend on treatment assignment[20]. The balancing score that provides the probability of being exposed to a treatment given observed covariates is called *propensity score* and the matching method making use of such a balancing score is therefore called PSM. We present below assumptions under which the practical usage of PSM is possible.

The key assumption is presented by Rosenbaum and Rubin (1983) as the *unconfoundedness* characteristic of treatment assignment. Presenting the independence of potential outcomes $Y_i(0,1)$ and treatment W_i given set of covariates X_i, it can be defined as

Assumption 1 (Unconfoundedness):

$$(Y_i(0), Y_i(1)) \perp W_i \mid X_i \quad (1)$$

This strong assumption implies that besides the potential outcomes, available data should include all the variables that influence the probability of exposure to treatment (i.e. selection of observables). If the available data cannot provide this condition, an alternative method such as difference-in-differences or instrumental variable should be used to include selection on unobservables.

The second assumption on joint distribution of covariates and treatment is

Assumption 2 (Overlap):

$$0 < P(W_i = 1 \mid X_i = x) < 1, \text{ for all} \quad (2)$$

It indicates that individuals with the same set of covariates X have a positive probability of both being participant and nonparticipant. That is, for all possible values of covariates, there are both treated and control units which is called the *common support* condition.

By assuming independence only for control group a weak unconfoundedness can be defined as

Assumption 3 (Unconfoundedness for control):

$$Y(0) \perp W \mid X \quad (3)$$

Similarly, a weak overlap assumption is

Assumption 4 (Weak overlap):

$$P(W = 1 \mid X) < 1 \quad (4)$$

To put this into words, probability of receiving treatment is less than 1, given the same set of covariates indicating a weaker overlap condition than Assumption (2). Assumptions (3) and (4) are sufficient to estimate average treatment effect for the treated (ATT) which is one of the most commonly studied estimates in PSM. If τ denotes the treatment effect,

$$\tau^{ATE} = E(\tau) = E[Y(1) - Y(0)] \quad (5)$$

[20] Therefore, such a function of related covariates creates a natural weighting scheme which provides an unbiased estimate of treatment effects.

Equation (5) gives the difference of the expected outcomes in case of participation and non-participation. Alternatively, parameter of interest can be ATT and formulated as

$$\tau^{ATT} = E(\tau) = E[Y(1) - Y(0) \mid W = 1] \quad (6)$$

Equation (6) indicates that ATT is the difference between expected outcomes with and without treatment for those individuals (firms) who actually received treatment. In this case, a counterfactual condition as explained earlier should be considered in the model.

The outcome pertaining to treated individuals is directly observable, whereas direct observation for potential outcome of treated individuals is not possible, hence estimation is required. In case of matching, the potential outcome for treated individuals is generated from a group of untreated individuals. Obviously, this counterfactual effect cannot be estimated as the average outcome of non-participants due to a possible selection bias. In order to overcome the selection bias, the following equation is proposed:

$$E(Y(0)|W = 1, X) = E(Y(0)|W = 0, X) \quad (7)$$

Equation (7) indicates that the outcome of non-treated individuals can be used to estimate the counterfactual outcome of the treated individuals (in case of non-treatment), provided that no systemic difference exists between these two groups21. From Equations (6) and (7), the population average treatment effect can be written as:

$$\tau^{ATT} = E(Y(1)|W = 1, X = x) - E(Y(0)|W = 0, X = x) \text{ for all} \quad (8)$$

For non-experimental studies, holding the weaker assumptions (3) and (4) are sufficient to estimate τ^{ATT} as indicated by Caliendo and Kopeinig (2008). One problem with Equation (8) is that it may require dealing with many variables in the covariate vector X. As discussed in the previous section, Rosenbaum and Rubin (1983) suggest using propensity score $P(X_i)$ for dimensionality reduction where $P(X_i)$ is the probability of individual i having been exposed to treatment, defined as

$$P(X_i) \equiv \Pr(W_i = 1| X_i) = E(W_i|X_i)$$

Hence, replacing the covariate vector in Equation (8) by the propensity score, $P(X)$, ATT for PSM denoted as τ_{PS}^{ATT} (i.e. PSM estimator) will be

$$\tau_{PS}^{ATT} = E(Y(1)|W = 1, P(X)) - E(Y(0)|W = 0, P(X)) \quad (9)$$

Equation (9) simply indicates that, in the boundaries of common support (assumption (4) holds); the PSM estimator is the mean difference in outcomes, weighted by propensity score distribution of the treated individuals. At the point of arrival in equation (9), selection bias seems to be minimized; the dimensionality problem of a possible large covariate vector and counter-factuality dilemma is taken care of by introducing a propensity score distribution into the picture. Yet, as the PSM approach completely depends on the selection of observable factors, the effects of unobservables cannot be integrated into the PSM estimands which is accepted to be the main weakness of the method. Fortunately, using hybrid methods such as adopting PSM in the framework of difference-in-differences (DiD) method[22], a non-parametric matching approach may become a powerful instrument in evaluating the effects of

[21] In evaluation of R&D subsidies using PSM method, Equation (7), based on conditional independence assumption suggested by Rubin (1974 and 1977), implies that for each subsidized firm, a firm having the same X characteristics as the treated one must be searched in the group of non-subsidized firms.

[22] Heckman (1998); Aerts and Schmidt (2008).

both observables and unobservables. The differences-in-difference (DiD) estimation technique controls for (i) macroeconomic trends which are common for all individuals and (ii) unobserved heterogeneity that may be observed between the treated and untreated groups.

Therefore, for empirical evaluation of the effects of TUBITAK's industrial R&D grants on the beneficiary firms, propensity score matching which is frequently employed in recent evaluation studies is adopted in this study.

4.3 A matching protocol and DiD

Equation (9) is reproduced below:

$$\tau_{PS}^{ATT} = E(Y_i^T | S_i = 1, P(X_i)) - E(Y_i^C | S_i = 0, P(X_i))$$

where τ_{PS}^{ATT} is the estimated average treatment effect on treated, S_i is the treatment status for firm *i*, Y_i^T and Y_i^C are the output of the treated and non-treated firm *i* respectively. Box 1 presents the details of the matching protocol developed by Aerts and Schmidt (2008).

If a two-period time domain is introduced into the model by adopting differences-in-difference methodology as it is depicted with links B and C in Figure 10.

The equation given at Step 7 in Box 1 can be rewritten as:

$$\hat{\boldsymbol{\tau}}_{\boldsymbol{PS}}^{\boldsymbol{DiD}} = \frac{\mathbf{1}}{\boldsymbol{n}^{\boldsymbol{T}}} \sum_{\boldsymbol{i}} \left[(\boldsymbol{Y}_{\boldsymbol{it_1}}^{\boldsymbol{T}} - \boldsymbol{Y}_{\boldsymbol{it_0}}^{\boldsymbol{C}}) - \sum_{\boldsymbol{h}} (\boldsymbol{Y}_{\boldsymbol{ht_1}}^{\boldsymbol{C}} - \boldsymbol{Y}_{\boldsymbol{ht_0}}^{\boldsymbol{C}}) \right]$$

In Figure 10 where the indices $\boldsymbol{i}$ and $\boldsymbol{h}$ are used for treated and non-treated firms respectively, $\boldsymbol{T}$ and $\boldsymbol{C}$ denote treatment status, $\boldsymbol{t_0}$ and $t_1$are pre-treatment and post-treatment periods respectively.

Three essential criteria, argued by Blundell and Costa Dias (2002) for creating adequate control groups are satisfied in this study. First, the comparisons are drawn from the same compilation of firms. Second, the data used for selecting units for treated and control groups is extracted from the same set of surveys. Third, the constructed dataset with 10,243 observations per year is rich enough to clearly make a distinction between individuals. The dependent and control variables used in this part of the study are presented in Table 8.

The objective in this paper is to examine the existence and extent of input and output additionalities generated by TUBITAK-TEYDEB's industrial R&D support programme for private R&D projects.

For *input additionality*, R&D intensity, annual R&D expenditures per employee and the share of R&D personnel in the total number of employees are selected as the dependent variables. The question of whether subsidies have crowding out effects on R&D investment will be tested with the first two variables.

On the other hand, export intensity and import intensity at the firm-level are selected as the dependent variables for examining *output additionality*[23]. Import intensity is measured as the share of intermediate imports in total imports at the firm-level. Substitution of imports of any kind by local production is one of the goals of the industrial support programme, hence its use in this study.

The variable IFTUBITAK represents the grant status of the firm and it is a dummy variable that takes value of 1 for a specific year if the firm's R&D project is funded by TUBITAK in that year. Table 9 depicts the number of programme beneficiaries extracted from

[23] Matching analysis was applied for other variables such as sales, labor productivity, wage rate and total number of employees of the firm but no significant additionality was found. The impact of subsidies on these variables should be tested with longer time series data when it will become available in the future.

TUBITAK's administrative data and Turkstat's SBS data. Unfortunately, only around 30 percent of the total number of firms funded by TUBITAK could be found (i.e. matched) in Turkstat's SBS data. Turkstat data shows that the share of programme beneficiaries among R&D performers increased from 5.3% in 2003 to 17.2% in 2006.

In Table 10, descriptive statistics for average values of variables before and after matching are presented for both the treated and untreated groups. The probability value reported in the last column tests the null hypothesis of equality of means for each variable. Not surprisingly, the null hypothesis is rejected for all variables in the case of the unmatched sample while the matched dataset fails to reject it at any usual level of significance. This last result points to the fact that by using PSM we were able to match treated firms with their controls.

4.4 Estimation results

The results from the probit estimation made to calculate the probability of receiving a TUBITAK-TEYDEB R&D project grant are presented in Table 11.

R&D intensity, wage rate, total sales and industry share in total public support in 2003 affect positively the probability of receiving public R&D subsidies at 1% significance level. Capital intensity and technology transfer influence positively firm's propensity to receive R&D grants at 5% significance level. Coefficients associated with firm age, export intensity and operating in a medium-high industry are insignificant at conventional significance levels. However, foreign ownership, and belonging to any industry other than medium-high technology industries cause a significant negative effect. Preferences of the funding agency for giving higher priority to high-tech domestic companies might explain this negative impact, although no formal criteria against foreign firms exist. On the other hand, the positive and significant effect of R&D intensity in 2003 on the probability of reception of an R&D subsidy in 2004 might point to the risk averse attitude of grant committees.

Next, nearest neighbor matching method with Mahalanobis distance calculation (see Box 1) was used to find counterpart firms to treated firms from the control group[24]. Propensity score estimates together with firm size were used in the matching process. Kernel density estimates for propensity scores and logarithm of the number of employees before and after the matching procedure are shown in Figure 11, indicating that initially different distributions reach sufficient overlap after matching.

The estimations of average treatment effect on treated are performed employing both simple (propensity score) matching protocol and matching with DiD for the post-treatment years of 2005 and 2006. Three R&D input variables (R&D intensity, R&D expenditures per person and share of R&D personnel in total number of employees) and two R&D output variables (export and import intensities) are the selected estimands to examine the average treatment effects of the TUBITAK's industrial R&D subsidy programme on beneficiary firms.

Table 12 shows the results of the first set of matching estimations for R&D intensity: receiving public R&D subsidies in 2004 significantly increased firm's post-treatment R&D intensity. Indeed, after the matching procedure is implemented, funded firms are observed to have average R&D intensities of 4.13 and 4.43% in 2005 and 2006 respectively, whereas the average R&D intensities of non–treated counterparts for the same years are 1.39 and 1.05%. Differences of 2.74 and 3.38 % in 2005 and 2006 respectively can be interpreted as the average treatment effect -i.e. evidence of input additionality- and it is statistically significant below 1%. When DiD methodology is used in the matching process to eliminate unobservable constant firm-specific effects and common macroeconomic trends, a 3.39% contribution of the programme to R&D intensity of beneficiaries can be observed between

[24] *psmatch2* command which is written by Leuven and Sinaesi (2003) is employed in STATA 10 for the calculation of propensity score matching.

the years 2003 (i.e. pre-treatment year) and 2005 at 1 % level. However, the DiD estimation between 2003 and 2006 reveals no significant treatment effect even if the bootstrap estimator is used.

At this stage, our findings pertaining to the magnitude of the additionality effect will be compared with those obtained in Ozcelik and Taymaz (2008). We believe that such an exercise is necessary since these two studies are the only ones to this date attempting to assess econometrically the impact of R&D support programs in Turkey.

The time period covered by their data is 1993-2001, which is much longer than the time span examined in our paper. While applying the matching procedure, they use two alternative samples: for a year *t,* the first one comprises all firms whether they are R&D performers or not, and the second one includes only R&D performers in two successive years (*t* and *t-1*). The input additionality effect of R&D support provided by TUBITAK TEYDEB is estimated separately for each of these two samples[25]. In Ozcelik and Taymaz (2008) study, the total number of firms in the first sample is 98,366 over 1993-2001[26]. As for the second sample comprising only R&D performers, the number of firms amounts to 2,226. In both cases, the number of observations available to them is much larger than in our case. In addition, due in part to the fact that they had access to a large database over a long time span, they were able to define a treated group at time *t* as including all those firms which did not receive any support at time *t-1*. Firms in the control group are defined in the usual manner, as those firms which have not benefited from R&D support earlier.

For the first sample, authors were able to match 253 treated firms (support beneficiaries) with the control group. The input additionality reported is an average over the whole period 1993-2001 and equals 2.49%. The corresponding finding for the second sample amounts to 1.39%. These figures are lower than what we obtain in our paper for 2006 (3.38%) and 2005 (2.74%).

It is difficult to compare our findings with theirs because of the differences involved in the nature of data used (number of firms, time period and its length), definition of the treatment group (in their study firms receiving support at year *t* have not been support beneficiaries earlier)[27] and in the presentation of findings (only an average additionality effect for 1993-2001 is reported). However, it can be said tentatively that our study points to a positive impact of R&D support on R&D expenditures of firms in Turkey which is larger than the one reported in Ozcelik and Taymaz (2008). This outcome may be explained by one or more of the following factors: (i) exhaustion over time of the initial positive support effect on R&D (ii) necessity for firms to go through a learning period before they really know how to conduct R&D, and (iii) existence of a threshold level since the magnitude of the impact of R&D support might depend on the volume of support provided –as mentioned earlier, the amount of direct R&D support has increased significantly during the period under investigation in our study.

The results of the second set of matching estimations for R&D expenditures per employee are presented in Table 13. After the matching procedure, beneficiary firms have average R&D expenditures per employees of TL 5,210 and TL 5,558 in 2005 and 2006 respectively, whereas the average R&D intensities of non–treated counterparts for the same years are TL 1,862 and TL 1,768. The difference of TL 3,348 and TL 3,790 in 2005 and 2006 respectively

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[25] See Table 4 in Ozcelik and Taymaz (2008).

[26] See Table 3 in Ozcelik and Taymaz (2008).

[27] Imposing this requirement in the matching exercise in our study for 2004 would have left us with only 25 firms in the treatment group. Therefore, distinguishing between firms receiving subsidy in one year only and those receiving it in more than one year is not feasible with the present dataset.

is found to be statistically significant at the 1% level and can be interpreted as the average treatment effect. When the DiD methodology is adopted in the matching process, a contribution of TL 2,733 of the programme can be observed between the years 2003 (i.e. pre-treatment year) and 2005 at 1% significance level. As in the previous case with the R&D intensity, DiD estimation between 2003 and 2006 reveals no significant treatment effect which indicates that the longer term effect cannot be observed with the available sample data.

One important issue in ex post impact assessment of R&D subsidies is whether a full or partial crowding out effect is observed on the beneficiary firm's R&D investment behavior[28]. Evidence presented in Tables 12 and 13 confirm a statistically significant treatment effect on firm's R&D expenditures and therefore the full crowding out effect can be rejected. In order to test for partial crowding out, firm's net R&D investment without the subsidy should be used in the model. This information, however, is not available in our dataset. However, a rough calculation from TUBITAK's administrative data for the years under investigation shows that the average annual subsidy per employee varied between TL 1,500 and TL 2,800. Since these values are less than the ATT differences given in Table 13 for the years 2005 and 2006, the hypothesis of partial crowding out effect of the programme can be confidently rejected.

The last estimand examined for input additionality is the share of R&D personnel in the total number of employees. Table 14 presents strong evidence in favor of the contribution of grants to the R&D personnel both in 2005 and 2006. The ATT differences between the firms belonging to funded and control groups after the matching is found to be 4.9 and 4.4 percent during 2003-2005 and 2003-2006 respectively at the 1% significance level. This significant positive effect may be related to the nature of R&D investment in which the largest portion is generally used for financing the relatively high wages of R&D personnel. Subsidized R&D performers may employ a larger number of highly qualified R&D personnel and keep them longer than their counterparts which conduct R&D without any subsidy, offsetting in this way the high of cost of R&D staff.

The estimations for output additionality are presented in Tables 15 and 16, respectively for export and import intensity. Contrarily to variables used to test for input additionality none of the results point to a significant contribution of the subsidies on these two performance variables. This outcome might be expected since the dataset used in the analysis most likely does not cover a period long enough to reveal any real output additionality effect of the programme. Although the exact number may change from one industry to another, the funding agency's experience with the long term beneficiaries, as well as previous evaluation studies show that 2-3 years are not generally sufficient to observe the effect of R&D subsidies on firm's business performance. Therefore, our findings indicating the absence of output additionality over 2003-2005/2006 should be taken with caution.

5. Conclusion

Developed as well as developing nations have used R&D support programmes to promote R&D expenditures of their enterprises with the expectation that additionality effects thus generated might lead *inter alia* to new products and processes and create new employment. Turkey has not been an exception and implemented different types of R&D support schemes since the early nineties. The amount of support provided and the range of instruments used to this end has increased since the early 2000. As a result, not only the amount of subsidies provided increased but the proportion between these subsidies and business R&D expenditures went up as well. On the other hand, indirect support mechanisms involving

[28]See Czarnitzki & Hussinger (2004) for an excellent definition of partial and full crowding out.

fiscal incentives for business R&D and innovation were recently strengthened in Turkey. The new fiscal incentives provided to the business sector through the Law 5746 enacted in 2008, has provided a range of R&D-related incentives including up to 150% tax allowance for R&D expenditure, income tax and social security contributions exemptions for researchers.

In this paper, using a dataset carefully constructed through merging several databases we used the propensity matching score and difference-in-differences (DiD) methods to test for input and output additionality of R&D subsidies provided by TUBITAK-TEYDEB over the period 2003-2006.

As far as *input additionality* is concerned, three indicators used in this study point to the existence of such an effect over the period 2003-2005, a finding similar to the one obtained for the Turkish manufacturing industry for 1993-2001 by Ozcelik and Taymaz (2008). This additionality effect is not observed, however, over the longer period 2003-2006. It should be noted that in 2006, the number of R&D performers recorded a decrease of 28% compared to the previous year (see Table 9). Such a sharp change may indicate a sample selection problem in Turkstat's SBS survey for 2006 since there is no other causal macro indication observed in the dataset in 2006. This remark might explain the absence of input additionality effect over the period 2003-2006.

Two indicators were used in our study to test for the *output additionality* of R&D subsidies. This is after all a crucial aspect of industrial R&D subsidy programmes since it is the additional output generated by the program that really counts. Due most likely to the short time span covered in this study, our analysis does not reveal any statistically significant output additionality effect.

Based on the findings of our study, a number of policy recommendations for Turkey as well as issues for further research are formulated below.

Firstly, data covering a longer time span should be accessed and used to reproduce the quantitative analysis implemented in this paper in order to check whether input additionality effect identified here for the period 2003-2005 is confirmed. Such a finding would show that TUBITAK-TEYDEB's industrial R&D support programme is fulfilling its mission. Use of longer time series is crucial for detecting a possible output additionality effect. Cooperation between Turkstat and TUBITAK is needed in order to access and merge more easily data used in this kind of exercise. International institutions such as the World Bank and the OECD recommended such an impact analysis to be conducted for accountability reasons[29].

Second, evaluation analyses should not be limited to TUBITAK-TEYDEB's support programme but should be carried out for other major R&D support schemes implemented in Turkey (see World Bank, 2009). The considerable amount of funds involved is characterized with huge social opportunity costs.

Third, the matching methodology used in our study aims principally at achieving similarity between treated and untreated firms. However from a policy making point of view, it would be justified to estimate the additionality effect separately for small and large firms, or in different industries. Our opinion is that applying the matching procedure to answer these questions is not feasible without a significant reduction in the number of firms which makes it extremely difficult to find appropriate controls for support beneficiaries. It would be more judicious to use a regression analysis framework –for instance, estimation of a R&D demand equation- to investigate at least the impact of R&D support on firms of different sizes. In addition, adding sector-level dummy variables in the R&D equation and interacting them

[29] For instance, see World Bank (2009).

with the support dummy variable would take into account to a certain extent the sector-specific impact of R&D support.

Fourth, qualitative as well as quantitative methods should be exploited to investigate other dimensions of the additionality issue such as *behavioral additionality*[30], which is difficult to analyze through quantitative methods but might be particularly important in a developing country like Turkey[31]. Such an effort would require most probably designing and conducting surveys for R&D performers as well as face-to-face interviews with company directors. Moreover, employing a similar matching method used in this study with the data that will be collected through surveys and interviews for measuring behavioral additionality could be suggested.

Finally, it should be emphasized that careful selection of appropriate evaluation and data collection methodologies - ex ante as well as ex post assessment- have to be an integral part of the design stage of every new policy tool before it is implemented.

[30] Buisseret et al. (1995).

[31] Teubal (1996).

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Box 1: Matching protocol algorithm

1. Specify and estimate a probit model to obtain propensity scores $\boldsymbol{P(X)}$.
2. Restrict the sample to common support: Delete all observations on treated firms with probabilities larger than the maximum and smaller than the minimum in the potential control group (This step is also performed for other covariates that are possibly used in addition to the propensity score as matching arguments).
3. Choose one observation among the treated firms and delete it from the sample
4. Calculate the Mahalanobis distance (MD) between this firm and all non treated firms to find the most similar observation:

$$\boldsymbol{MD_{ih} = (Z_h - Z_i)'\Omega^{-1}(Z_h - Z_i)}$$

Where for the current analysis, $\boldsymbol{Z}$ contains the estimated propensity score $P(\boldsymbol{X})$ and the firm size (logarithm of production sales, LREVPROD) as additional arguments in the matching function. $\boldsymbol{\Omega}$ is the empirical covariance matrix of these arguments, based on the sample of potential controls.

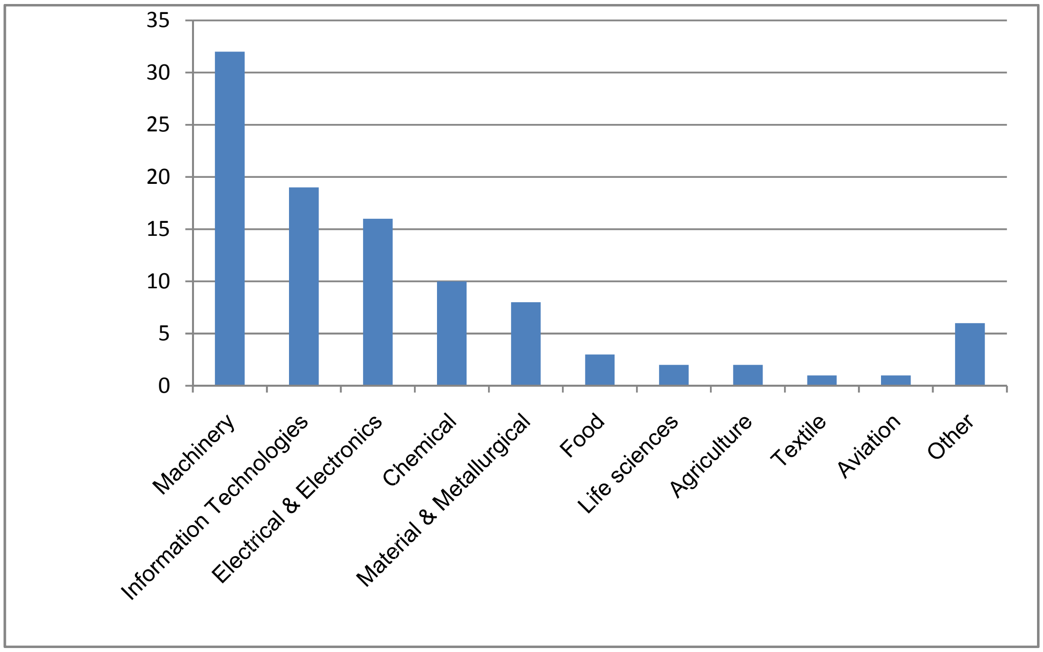
5. Select the observation with the minimum distance from the remaining sample. (Do not remove the selected control from the pool of potential controls, so that it can be used again.)
6. Replace the selected control into the sample and repeat steps 2 to 5 for all treated firms
7. Using the matched control group, the average treatment effect on the treated ($\boldsymbol{\hat{\tau}_{PS}^{ATT}}$) thus can be calculated as the mean difference of the matched samples:

$$\boldsymbol{\hat{\tau}_{PS}^{ATT} = \frac{1}{n^T}\left(\sum_i Y_i^T - \sum_i \hat{Y}_i^C\right)}$$

Where $\boldsymbol{\hat{Y}_i^C}$ being the counterfactual output for firm *i* and $\boldsymbol{n^T}$ is the sample size (of treated firms). Note that the same observation may appear more than once in that group (matching with replication).

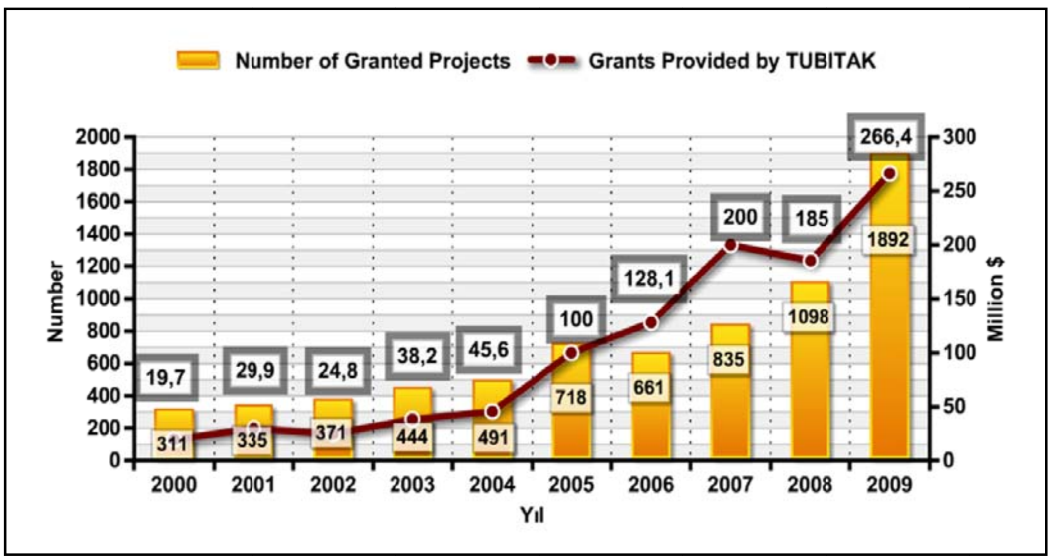
Source: Aerts and Schmidt (2008)

Figure 1: Distribution of TUBITAK-TEYDEB project proposals by technology field: 1995-2009 (%)



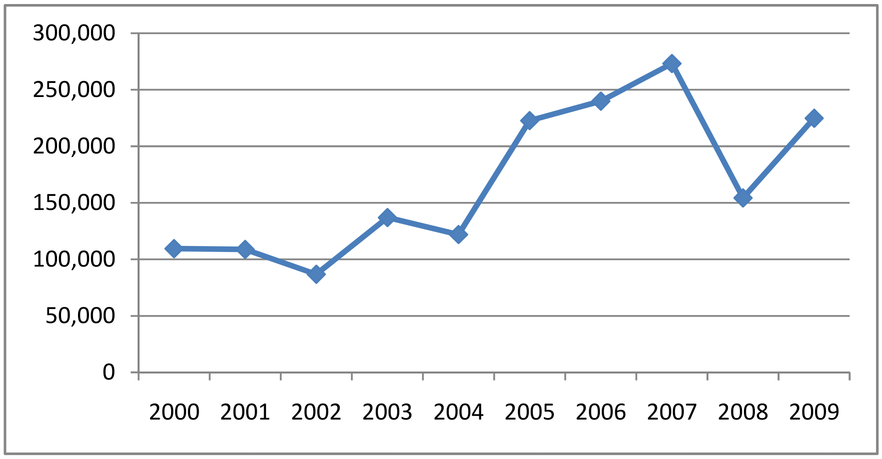
Source: TUBITAK

Figure 2: Evolution of total industrial R&D grants by TUBITAK-TEYDEB: 2000 – 2009



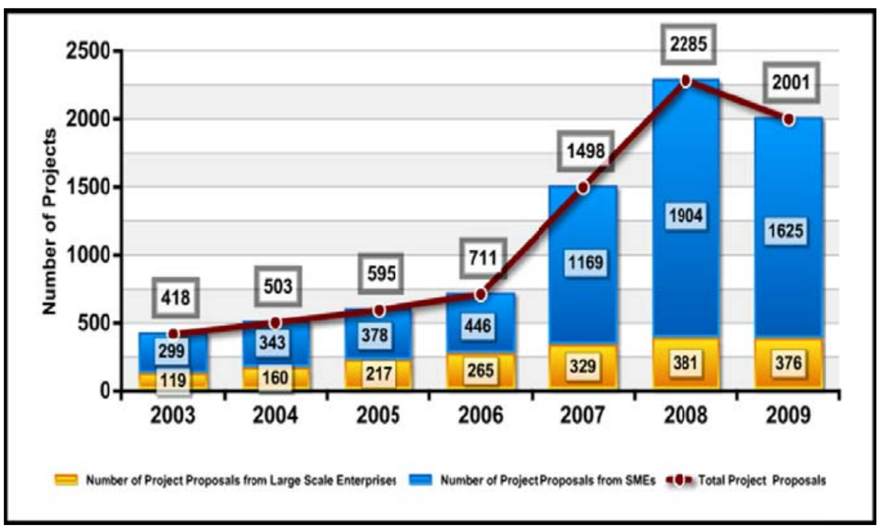
Source: TUBITAK

Figure 3: Average subsidy (in USD) per project supported by TUBITAK-TEYDEB: 2000 – 2009



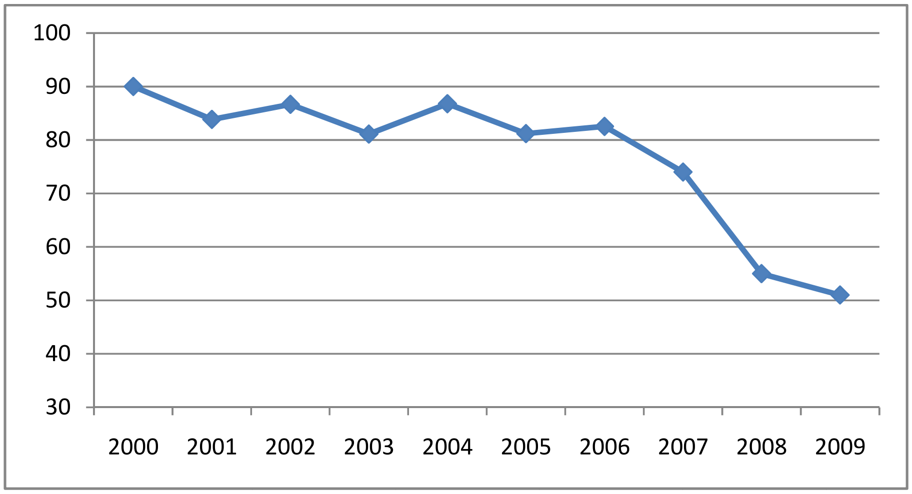
Source: TUBITAK

Figure 4: Distribution of project proposals for TUBITAK-TEYDEB based on firm size: 2000 – 2009



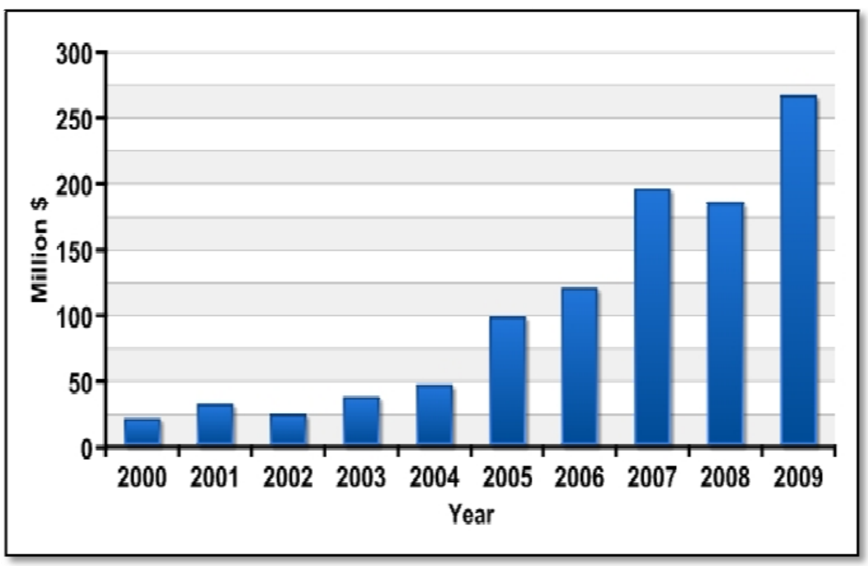
Source: TUBITAK

Figure 5: Acceptance rate of project proposals by TUBITAK-TEYDEB: 2000-2009 (%)



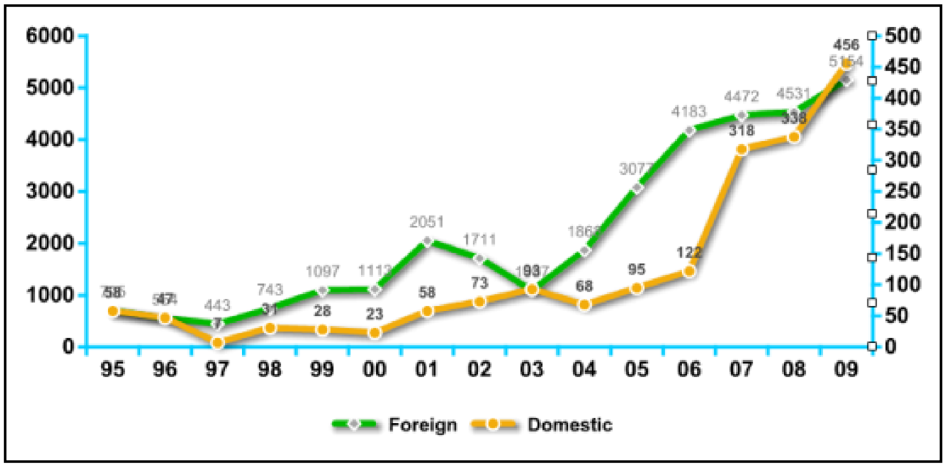
Source: TUBITAK

Figure 6: Evolution of grants provided by TUBITAK-TEYDEB: 2000-2009 (million USD)



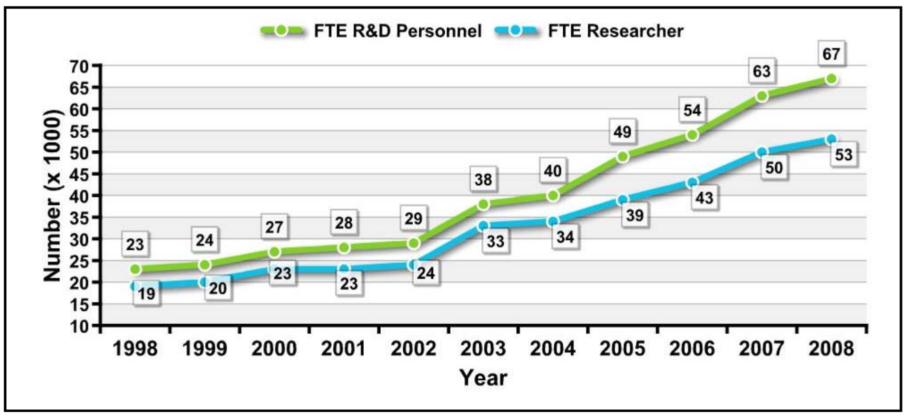
Source: TUBITAK

Figure7: Distribution of total patents granted in Turkey: 1995-2009



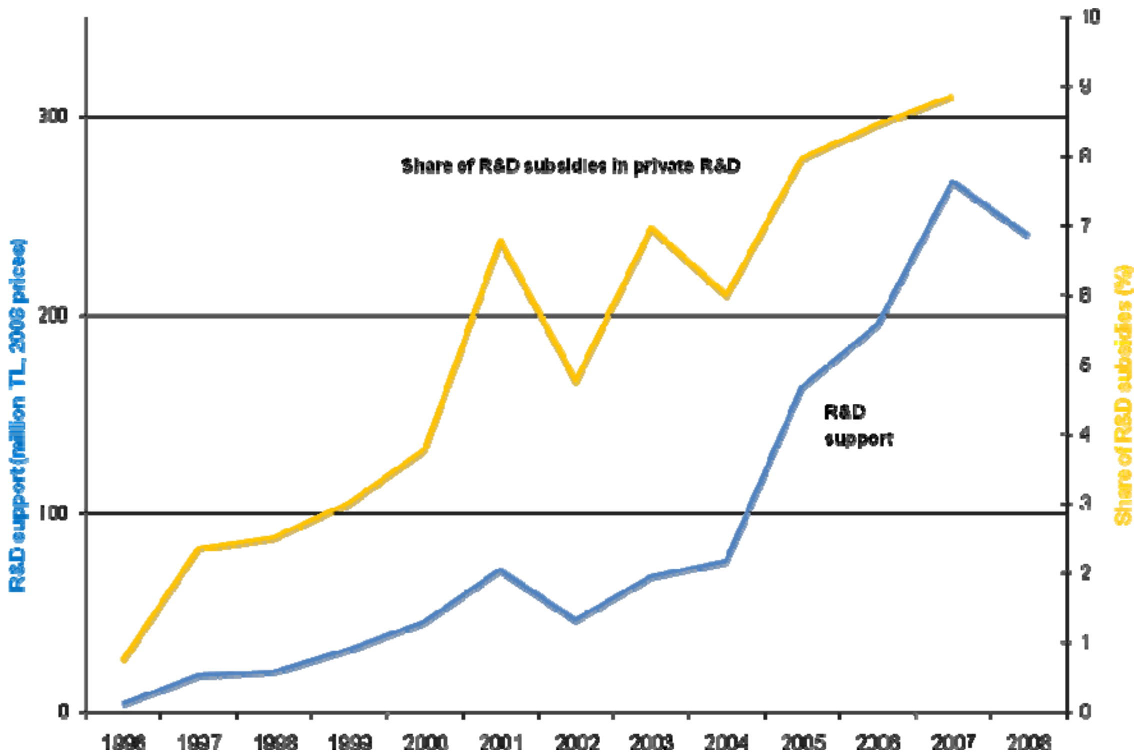
Source: Own calculation on the basis of TPE data

Figure 8: Number of FTE R&D personnel and researchers in Turkey: 1998-2008



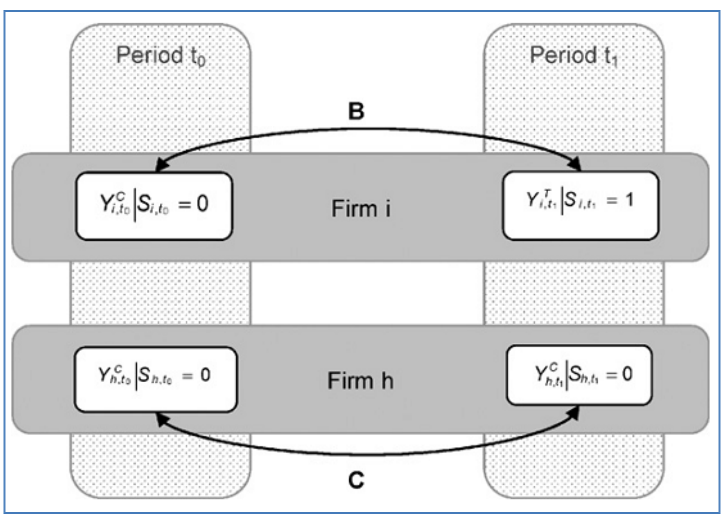
Source: TUIK

Figure 9: Evolution of the share of direct R&D subsidies in business R&D (%) and the amount of total direct R&D support (constant million TL)



Source: Own calculations from World Bank (2009)

Figure 10: Illustration of differences-in-difference methodology (DiD)



Source: Aerts and Schmidt (2008)

Figure 11: Kernel density estimates of firm size and propensity score distributions

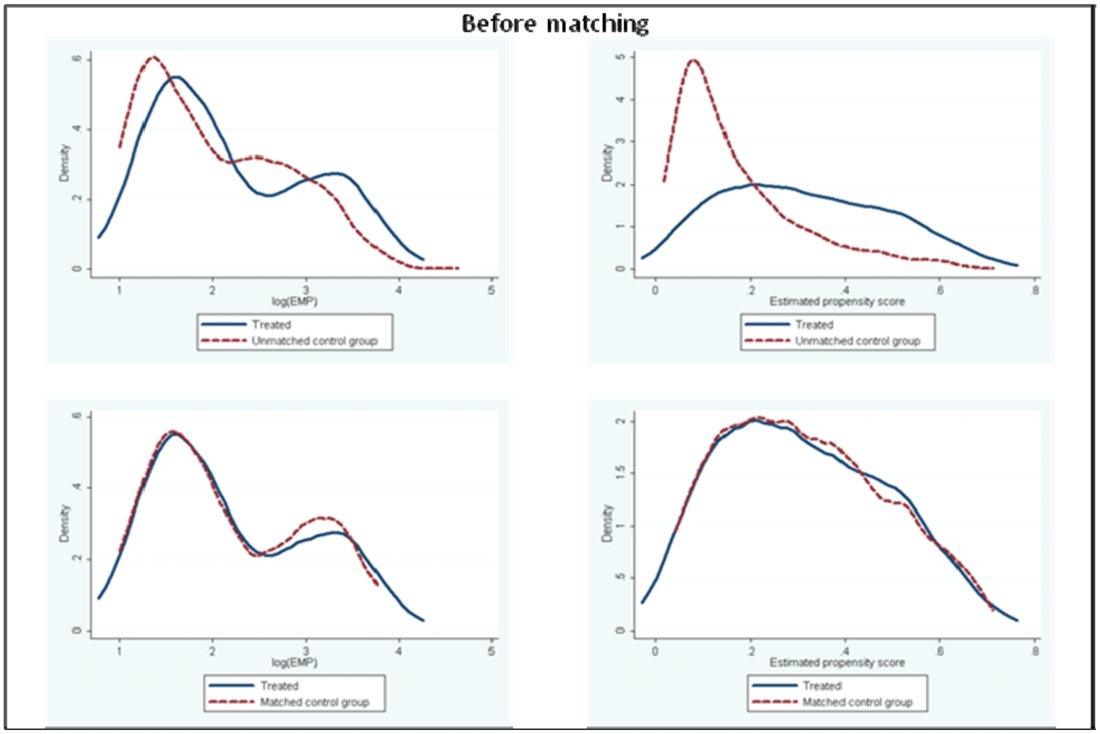


Table 1: Evolution of GERD/GDP ratio Turkey in over 2000-2008 (%)

	2000	2001	2002	2003	2004	2005	2006	2007	2008
EU-27	1.74	1.75	1.76	1.75	1.73	1.74	1.76	1.77	…
Turkey	**0.48**	**0.54**	**0.53**	**0.48**	**0.52**	**0.59**	**0.58**	**0.72**	**0.73**
Hungary	0.79	0.92	1.00	0.93	0.87	0.94	1.00	0.97	…
Poland	0.56	0.54	0.56	0.57	0.56	0.57	0.56	0.57	0.60
Romania	0.37	0.39	0.38	0.39	0.39	0.41	0.45	0.52	0.59
Spain	0.91	0.92	0.99	1.05	1.06	1.12	1.20	1.27	1.35
Korea	2.30	2.47	2.40	2.49	2.68	2.79	3.01	3.21	…
Mexico	0.34	0.36	0.40	0.40	0.40	0.41	0.39	0.38	…

Source: OECD Main Science and technology indicators database, 2009/1

Table 2: Evolution of basic STI indicators in Turkey over 2004-2009

	2004	2005	2006	2007	2008	2009
GERD / GDP in percentage	0.67	0.79	0.76	0.71	0.73	0.85
GERD (Million TL)	2 898	3 835	4 400	6 091	6 893	8 087
GERD (PPP* – Million USD)	3 653	4 373	4 883	6 578	7 034	8 819
GERD per person (PPP* – USD)	51.4	60.7	69.2	93.2	98.4	121.5
Sectoral share of GERD in percentage						
Higher Education	67.9	54.6	51.3	48.2	43.8	47.4
Private	24.2	33.8	37	41.3	44.2	40.0
Government	8.0	11.6	11.7	10.6	12.0	12.6
Total R&D personnel (FTE)	39 960	49 252	54 444	63 777	67 244	73.571
Total R&D personnel (FTE), sectoral share in percentage						
Higher Education	61.9	51.6	49.1	46.6	44.5	42.2
Private	22.1	30.4	33.1	38.3	40.8	42.8
Government	16	17.9	17.8	15.1	14.7	15.0
FTE researchers per 10,000 total employment	18.1	20.4	24.5	30.6	31.7	34.6
Number of scientific publications	15 443	16 718	18 928	21 961	22 995	
Turkey's position in the world list of scientific publications	21	19	19	18	18	

Source: High Council of Science and Technology, 2010 and Turkstat.

Table 3: Distribution of patent applications made by residents in Turkey: 1995-2009

	Domestic					Foreign					General	
	TPE	PCT	EPC	Total	Rate of Growth (%)	TPE	PCT	EPC	Total	Rate of Growth (%)	Total	Rate of Growth (%)
1995	170	0	0	**170**	**-**	1520	0	0	**1520**	-	**1690**	-
1996	189	0	0	**189**	**11.18**	687	26	0	**713**	**-53.09**	**902**	**-46.63**
1997	202	1	0	**203**	**7.41**	598	730	0	**1328**	**86.26**	**1531**	**69.73**
1998	201	6	0	**207**	**1.97**	596	1680	0	**2276**	**71.39**	**2483**	**62.18**
1999	265	11	0	**276**	**33.33**	524	2220	0	**2744**	**20.56**	**3020**	**21.63**
2000	258	19	0	**277**	**0.36**	442	2714	0	**3156**	**15.01**	**3433**	**13.68**
2001	298	39	0	**337**	**21.66**	119	2756	2	**2877**	**-8.84**	**3214**	**-6.38**
2002	387	27	0	**414**	**22.85**	88	1335	37	**1460**	**-49.25**	**1874**	**-41.69**
2003	454	35	1	**490**	**18.36**	43	305	314	**662**	**-54.66**	**1152**	**-38.53**
2004	633	49	3	**685**	**39.80**	68	167	1342	**1577**	**138.22**	**2262**	**96.35**
2005	895	33	7	**935**	**36.50**	75	143	2308	**2526**	**60.18**	**3461**	**53.01**
2006	979	93	18	**1090**	**16.58**	71	89	3915	**4075**	**61.32**	**5165**	**49.23**
2007	1747	60	31	**1838**	**68.62**	71	139	4141	**4351**	**6.77**	**6189**	**19.83**
2008	2159	69	40	**2268**	**23.39**	68	107	4694	**4869**	**11.91**	**7137**	**15.32**
2009	2473	74	41	**2588**	**14.11**	69	105	4479	**4653**	**-4.44**	**7241**	**1.46**

Note: TPE: Turkish Patent institute, PCT: Patent cooperation treaty, EPC: European patent convention.
Source: TPE

Table 4: FTE researchers per 10,000 total employment in selected countries (2000-2008)

YEAR	Turkey	EU-27	Hungary	Poland	Romania	Spain	Korea	Mexico
2000	13	94	61	50	32	73	65	…
2001	13	95	60	54	31	74	77	11
2002	14	96	61	55	34	77	78	…
2003	18	97	60	57	36	85	84	15
2004	18	98	55	57	37	87	86	19
2005	22	100	56	55	36	91	94	21
2006	24	103	61	51	33	94	103	16
2007	25	104	62	50	31	98	115	16
2008	…	…	…	47	…	105	…	…

Source: OECD Main Science and technology indicators database, 2009/1

Table 5: Public Expenditures on Innovation and Technology Programmes (2005-2008) (million TL)

Implementing Agency	2005	2006	2007	2008
Universities	274,2	278,7	256,3	253,5
TUBITAK **(TUBITAK Research Centers)**	108,8	155,0	141,8	183,3
TUBITAK **(Turkey Research Area Programs) ***	346,0	415,0	425,0	450,0
Academic Research Projects	90,0	80,0	85,0	105,0
Industrial Research Projects (of companies)	116,0	215,0	215,0	175,0
Research Projects of Public Institutions	50,0	50,0	50,0	65,0
Defense and Space Research Projects	50,0	60,0	65,0	80,0
Researcher Development	25,0	5,0	5,0	15,0
Science and Technology Awareness	15,0	5,0	5,0	10,0
Public Institutions (Outside TUBITAK)	36,2	49,3	80,2	78,2
Nuclear Energy Council (TAEK)	6,3	13,1	20,0	18,9
Ministry of Industry and Trade **	-	11,0	16,9	17,6
Ministry of Agriculture and Rural Affairs	2,2	2,5	4,0	3,6
Ministry of Health	0,1	6,2	5,2	4,9
National Boron Research Institute ***	0,1	3,0	6,0	6,3
Ministry of Energy ***	-	-	-	1,0
KOSGEB	12,5	5,4	4,6	6,5
TTGV	8,9	35,6	35,4	35,5
State Planning Organization (DPT),	1,1	10,0	18,0	18,0
Undersecretary of Foreign Trade (DTM)	40,0	42,0	63,5	n/a
TOTAL (TL)	**1182,4**	**1441,8**	**1501,9**	**1527,3**
TOTAL (USD)	**877,6**	**1002,6**	**1148,4**	**1175,5**

Notes: * TUBITAK funds projects of other institutions' R&D projects. **Includes SAN-TEZ program that supports PhD students' theses that aim to solve. company specific problems and the support for the physical infrastructure of Techno-parks. *** Includes programmes in which projects of other institutions are supported.
Source: World Bank (2009) and State Planning Organization.

Table 6: Sectoral distribution of R&D expenditures and direct R&D subsidies in 2004

Industry (NACE Rev1.1)	Number of firms (share %)	Mean R&D exp. per employee (TL)	Mean subsidy per employee (TL)	Subsidy / Expenditure (%)
Food (15)	1038 (15.56)	1,745	741	42.46
Textile (17)	1411 (21.15)	1,809	127	7.02
Paper (21)	192 (2.88)	213	148	69.48
Chemicals (24)	346 (5.19)	5,270	1,479	28.06
Metal (27-28)	928 (13.91)	828	107	12.92
Machinery (29)	750 (11.24)	2,367	1,406	59.40
Elect-Opt (30-33)	391 (5.86)	9,269	1,789	19.30
Transport (34-35)	388 (5.82)	8,592	437	5.07
Manuf. n.e.c. (36)	469 (7.03)	2,389	442	18.50
Sale (51)	77 (1.15)	8,162	2,546	31.19
Computer (72)	60 (0.90)	7,961	3,500	43.96
Business (74)	622 (9.32)	13,091	3,223	24.62
TOTAL	**6672 (100.00)**	**5,141**	**1,329**	**25.46**

Source: Turkstat and TUBITAK-TEYDEB administrative database

Table 7: Number of subsidy beneficiary firms: 2003-2006

2003	2004	2005	2006	# firms	percentage
0	0	0	1	42	18
0	0	1	0	18	8
0	0	1	1	40	17
0	1	0	0	**25**	11
0	1	0	1	**3**	1
0	1	1	0	**19**	8
0	1	1	1	**44**	19
1	0	0	0	12	5
1	0	0	1	3	1
1	0	1	0	2	1
1	0	1	1	3	1
1	1	0	0	**9**	4
1	1	0	1	**1**	0
1	1	1	0	**3**	1
1	1	1	1	**13**	5
Total subsidized firms				**237**	100

Notes: 1 (0): Firm did (not) receive subsidy from TUBITAK
Source: Turkstat SBS surveys and TUBITAK-TEYDEB administrative database

Table 8: Description of variables (SBS data) used in the PSM analysis

LRDINT	Natural logarithm of firm's R&D intensity calculated by firm's annual R&D expenditures divided by total sales
SRDEMP	Share of R&D personnel in total number of employees in percentage
LRDEXP_PP	Firm's annual R&D expenditures per person in TL
EXPOINT	Export intensity in percentage (exports divided by sales)
IMPOINT	Import intensity in percentage (imports divided by sales)
PSMODEL0 <primary variable used in mahalanobis dist.>	Propensity scores calculated through the Probit model in percentage
LREVPROD <second variable used in mahalanobis dist.>	Natural logarithm of total production sales
IFTUBITAK	A dummy variable taking the value of 1 if the firm funded by TUBITAK , 0 otherwise
FIRMAGE	Firm age in 2004 in years
IFTECHXFER	A dummy variable taking the value of 1 if the firm purchases any technology license or knowhow agreement from abroad, 0 otherwise
LCAPINT	Natural logarithm of firm's capital intensity (capital depreciation divided by total number of employees)
LWAGE_PP	Natural logarithm of firm's average wage per person
SUBPUBINT_SEC	Total public subsidy received by firms in the same industry (identified by 2 digits NACE codes) divided by total amount of subsidies received by all industries
LOWTECH	A dummy variable to indicate if the firm belongs to a low technology industry (NACE 1.1 codes 15-22 or 36-37) in 2004
MEDLOTECH	A dummy variable to indicate if the firm belongs to a low-medium technology industry (NACE 1.1 codes 23, 25-28 or 351) in 2004
MEDHITECH	A dummy variable to indicate if the firm belongs to a medium-high technology industry (NACE 1.1 codes 241-246, 29, 31, 34, 352, 354 or 355) in 2004

Table 9: Number of funded firms in TUBITAK and Turkstat data bases (2003-2006)

	2003	2004	2005	2006
Actual number of firms funded by TUBITAK	297	326	452	458
Firms funded by TUBITAK and matched in Turkstat's database	46	117	142	149
Total R&D performer firms in Turkstat's database	864	1151	1171	840
Share of funded firms in R&D performers (%)	5.33	10.2	12.1	17.7
Share of funded firms in all firms (%)	0.45	1.14	1.39	1.46

Source: TUBITAK and Turkstat

Table 10: Descriptive statistics for unmatched and matched (n=96) samples in 2004 (mean values)

Variable	State	Treated Group	Control Group	p>|t|
Foreign ownership	Unmatched	0.224	0.054	0.000
	Matched	0.227	0.213	0.845
RD intensity	Unmatched	5.418	0.149	0.000
	Matched	3.350	2.375	0.458
Ln (wage rate)	Unmatched	9.481	8.578	0.000
	Matched	9.465	9.482	0.894
Ln (capital intensity)	Unmatched	8.558	7.395	0.000
	Matched	8.548	8.490	0.835
Ln (sales)	Unmatched	17.215	15.238	0.000
	Matched	17.244	17.241	0.992
Export intensity	Unmatched	24.184	17.106	0.028
	Matched	23.354	25.626	0.610
Age (years)	Unmatched	21	14.389	0.000
	Matched	21.2	22.52	0.572
Technology transfer	Unmatched	0.224	0.062	0.000
	Matched	0.227	0.293	0.355
Sector share in total support	Unmatched	0.068	0.047	0.002
	Matched	0.068	0.069	0.778
Propensity score	Unmatched	0.145	0.098	0.000
	Matched	0.133	0.131	0.929

Table 11: Probit estimation for receiving R&D subsidy in 2004

Variables (in 2003)	Coefficients	Std Err.	Marginal effects	Std Err.
RD intensity	0.081***	0.0247	0.001***	0.0003
Foreign ownership	-0.259*	0.1599	-0.001**	0.0007
Ln (wage rate)	0.240***	0.0862	0.002**	0.0008
Ln (capital intensity)	0.061**	0.0304	0.0005*	0.0003
Ln (sales)	0.221***	0.0366	0.002***	0.0004
Export intensity	0.0006	0.0019	$4.48x10^{-6}$	0.00001
Age (2004)	-0.001	0.0036	$-7.02x10^{-6}$	0.00003
Technology transfer	0.322**	0.1330	0.004	0.0024
MedHiTech (2004)	0.051	0.2050	0.0004	0.0018
MedLowTech (2004)	-0.523**	0.2050	-0.003**	0.0012
LowTech (2004)	-1.047***	0.2468	-0.011***	0.0038
Other (2004)	-0.296	0.2598	-0.002	0.0012
Sector share in total support	2.915***	1.0488	0.023***	0.0081
Number of observations	6,608			
Log Likelihood	-339.7			
Pseudo R2	0.3284			

Notes: *** p<0.01, ** p<0.05, * p<0.1

Table 12: Average Treatment Effect on the Treated Companies and DiD: R&D intensity in percentage

Variable	Status	Subsidized Firms	Control Group (all firms)	ATT	ATT (bootstrap)
R&D intensity (2006)	unmatched	5.07 (97 firms)	0.22 (6.511 firms)		
	matched	4.43 (96 firms)	1,05 (96 firms)	3.38***	3.38***
R&D intensity (2005)	unmatched	5.11 (97 firms)	0.21 (6.511 firms)		
	matched	4.13 (96 firms)	1.39 (96 firms)	2.74***	2.74***
Change in R&D intensity (2003-2006) : *DiD*	unmatched	-0.14 (97 firms)	0.01 (6.511 firms)		
	matched	0.91 (96 firms)	-1.02 (96 firms)	1.93	1.93
Change in R&D intensity (2003-2005) : *DiD*	unmatched	1.67 (97 firms)	0.14 (6.511 firms)		
	matched	2.24 (96 firms)	-1.15 (96 firms)	3.39**	3.39**

Notes: *** p<0.01, ** p<0.05, * p<0.1

Table 13: Average Treatment Effect on the Treated Companies and DiD: R&D expenditures per employee (in Turkish liras - TL)

Variable	Status	Subsidized Firms	Control Group (all firms)	ATT	ATT (bootstrap)
R&D expenditures per employee (2006)	unmatched	6,159 (97 firms)	225 (6.504 firms)		
	matched	5,558 (96 firms)	1,768 (96 firms)	3,790***	3,790***
R&D expenditures per employee (2005)	unmatched	5,830 (97 firms)	337 (6.504 firms)		
	matched	5,210 (96 firms)	1,862 (96 firms)	3,348***	3,348***
Change in R&D expenditures per employee (2003-2006) : *DiD*	unmatched	1,062 (97 firms)	-139 (6.504 firms)		
	matched	1,123 (96 firms)	-262 (96 firms)	1,385	1,385
Change in R&D expenditures per employee (2003-2005) : *DiD*	unmatched	2,422 (97 firms)	-76 (6.504 firms)		
	matched	2,209 (96 firms)	-524 (96 firms)	2,733***	2,733***

Table 14: Average Treatment Effect on the Treated Companies and DiD: Share of R&D personnel in total employment (in percentage)

Variable	Status	Subsidized Firms	Control Group (all firms)	ATT	ATT (bootstrap)
Share of R&D personnel (2006)	unmatched	9.8 (97 firms)	0.6 (6.504 firms)		
	matched	9.3 (96 firms)	2.3 (96 firms)	7.0***	7.0***
Share of R&D personnel (2005)	unmatched	8.3 (97 firms)	0.6 (6.504 firms)		
	matched	8.0 (96 firms)	2.5 (96 firms)	5.5***	5.5***
Change in the share of R&D personnel (2003-2006) : *DiD*	unmatched	4.5 (97 firms)	-0.8 (6.504 firms)		
	matched	3.8 (96 firms)	-0.6 (96 firms)	4.4***	4.4***
Change in the share of R&D personnel (2003-2005) : *DiD*	unmatched	5.1 (97 firms)	-1.4 (6.504 firms)		
	matched	4.4 (96 firms)	-0.5 (96 firms)	4.9***	4.9***

Notes: *** p<0.01, ** p<0.05, * p<0.1

Table 15: Average Treatment Effect on Treated Companies and DiD: export intensity (in percentage)

Variable	Status	Subsidized Firms	Control Group (all firms)	ATT	ATT (bootstrap)
Export intensity (2006)	unmatched	23.07 (97 firms)	16.15 (6.511 firms)		
	matched	22.90 (96 firms)	19.72 (96 firms)	3.18	3.18
Export intensity (2005)	unmatched	22.66 (97 firms)	16.79 (6.511 firms)		
	matched	22.18 (96 firms)	20.46 (96 firms)	1.72	1.72
Change in export intensity (2003-2006) : *DiD*	unmatched	1.24 (97 firms)	-1.93 (6.511 firms)		
	matched	2.16 (96 firms)	-2.22 (96 firms)	4.38	4.38

Notes: *** p<0.01, ** p<0.05, * p<0.1

Table 16: Average Treatment Effect on the Treated Companies and DiD: Import intensity (in percentage)

Variable	Status	Subsidized Firms	Control Group (all firms)	ATT	ATT (bootstrap)
Import intensity (2006)	unmatched	20.13 (97 firms)	7.27 (6.511 firms)		
	matched	20.34 (96 firms)	18.74 (96 firms)	1.60	1.60
Import intensity (2005)	unmatched	20.79 (97 firms)	7.92 (6.511 firms)		
	matched	21.00 (96 firms)	20.59 (96 firms)	0.41	0.41
Change in import intensity (2003-2006) : *DiD*	unmatched	-1.97 (97 firms)	-1.96 (6.511 firms)		
	matched	-1.99 (96 firms)	-5.56 (96 firms)	3.57	3.57

Notes: *** p<0.01, ** p<0.05, * p<0.1