Published in *Research Policy*, 2008, vol 37, pp. 258-275.

R&D support programs in developing countries: The Turkish experience

Emre Özçelik[a], Erol Taymaz[b,*]

[a] Department of Economics, Ondokuz Mayis University, Samsun 55139 Turkey
[b] Department of Economics, Middle East Technical University, Ankara 06531 Turkey

Abstract
In this study, the determinants of private R&D investment are examined at the level of firms in the Turkish manufacturing industry. We focus our attention on the effect of public R&D support programs. Our findings indicate that public R&D support significantly and positively affects private R&D investment. There seems to be even an "acceleration effect" on firm-financed R&D expenditures. Smaller R&D performers benefit more from R&D support and perform more R&D. In addition, technology transfer from abroad and domestic R&D activity show up as complementary processes. Given the scarcity of studies on R&D support in technologically weaker economies, our hope is that the less-developed countries can exploit these findings in constructing socially beneficial technology policies.

JEL classification: O38, O32, L24

Keywords: Public R&D support; R&D investment; Evaluation; Turkish manufacturing

[*] Corresponding author. Tel.: +90 312 210 3034; fax: +90 312 210 7964.

E-mail addresses: eozcelik@omu.edu.tr (E. Özçelik), etaymaz@metu.edu.tr (E. Taymaz).

Knowledge . . . might be a cultivated crop, responsive to fertilizers.
H. G. Wells

1. Introduction

Market failures may arise due to "incomplete private appropriability" of the returns on investment in scientific and technological knowledge (Nelson, 1959; Arrow, 1962). The market alone tends to fail in creating the necessary incentives in the private domain to the extent that social return exceeds private return on R&D investment. Public R&D support can raise the private rate of return (towards the social rate) so that investment gets closer to its socially optimum level. Thus, the need for public support to R&D is theoretically justifiable. There are two conventional ways for governments to improve R&D: i) performing R&D directly in public institutions and national laboratories, and ii) providing firms in the private sector with (publicly-funded) incentives for performing their own R&D. This second type of R&D improvement comes generally in two forms: i) tax incentives, and ii) direct subsidies.[1] The focus of attention in our study is the effect of direct subsidies on private R&D activity at the level of firms in the Turkish manufacturing industry.

Emanating from the now-classic work by Blank and Stigler (1957), various studies have tried to test the hypothesis that public efforts are conducive to private R&D. Whereas it is generally agreed that tax incentives contribute to private R&D (Bloom et al., 2000; Hall and van Reenen, 2000), opposing results have been obtained as to whether publicly-funded R&D subsidies complement (and "add to") or substitute (and "crowd out") private R&D investment (David et al., 2000; Hall, 2002; Jaffe, 2002). Such studies dealing with

[1] Beside tax incentives and direct subsidies, governments can also encourage private R&D by providing (financial as well as political) support for the formation of private "RD consortia", which are generally the outcome of private initiatives for enhancing R&D-collaboration among firms.

the effects of public R&D policy have focused mostly on the developed countries, while it is formidable to find similar studies for the developing countries.[2] It goes without saying that lack of relevant data on R&D support is the main reason for the scarcity of studies on developing countries. Fortunately, we do not suffer from such a drawback in the case of Turkish manufacturing industry.

The motivation behind this study is to contribute to the empirical literature by providing firm-level evidence from Turkey as a developing country. R&D support policies are worth considering not only for the technologically advanced economies, but also for less-developed countries. Even though Turkey has an "infant" national system of innovation, its manufacturing industry is relatively productive and technologically dynamic (see Özçelik and Taymaz, 2004). It is in this light that we inquire into the determinants of R&D investment in the Turkish manufacturing industry by focusing on the effect of R&D support programs.

In section 2, we provide a concise theoretical/empirical review of regression and matching (treatment effect) analyses, both of which have been used to evaluate the effect of R&D subsidies. In Section 3, we present the two major R&D support programs in Turkey and summarize the developments in R&D activities since the early 1990s. In Section 4, we introduce our data-sets and analyze the R&D behavior of Turkish firms descriptively in terms of all firms, R&D performers and subsidy recipients. In section 5, we present and discuss our estimation results. Collating our findings from regression and matching analyses, we end the paper with concluding remarks in Section 6.

---

[2] The abundance of studies on the developed countries (at various levels of aggregation) is exemplified by the following eclectic list: Klette and Moen (1999) for Norway; Diamond (1998), Lerner (1999) and Wallsten (2000) for the US; Duguet (2004) for France; Busom (2000) and Gonzalez et al. (2005) for Spain; Czarnitzki and Fier (2002), Almus and Czarnitzki (2003) and Licht and Stadler (2003) for Germany; Toivanen and Niininen (2000), Hyytinen and Toivanen (2005), Ebersberger (2005) and Ali-Yrkkö (2005) for Finland;

2. Theoretical background and empirical literature

The principal question to be answered in the evaluation of R&D support is "what the firm would have spent on R&D had it not received the subsidy" (Lach, 2002, p. 372). In order to determine whether the recipients of support (in comparison to non-recipients) increased their R&D activity thanks to R&D subsidy, (parametric) regression analyses and (non-parametric) matching methods are extensively used. We provide below a concise theoretical and empirical review of regression and matching analyses, respectively, since we will incorporate both types of analysis in this study.

2.1. Regression analysis with controls

The determinants of R&D activity are usually examined in the context of R&D investment demand models that have been studied for at least a couple of decades (Nadiri and Schankerman, 1981; Mohnen et al., 1986; Bernstein and Nadiri, 1988). In this context, the effect of R&D support can be examined by estimating a standard R&D investment demand function as follows:

(1) $g_{it} = \alpha + \beta D_{it} + \delta x_{it} + \varepsilon_{it}$

where g is the (log) level of the R&D stock of firm i at time t, x is a vector of explanatory variables (output level and input prices including the cost of R&D), and ε is the stochastic error term (Hall and van Reenen, 2000, pp. 459-460).[3] D_{it} is a dummy variable, which is equal to one if firm i benefits from the R&D support, and zero otherwise. The magnitude of the estimated coefficient of the dummy (β) is equal to the amount of R&D induced by the presence of the support program.

Branstetter and Sakakibara (2002) for Japan; Hanel (2003) for Canada; and Guellec and van Pottelsberghe (2003) for OECD countries.

[3] For recent discussions on and applications of R&D investment models, see Irwin and Klenow, 1996; Bond et al., 1999; David et al., 2000; Klette et al., 2000; Bloom et al., 2002; Chiao, 2002; Lach, 2002; Heijst, 2003; Hyytinen and Toivanen, 2005; Ali-Yrkkö, 2005.

One main problem in estimating this R&D investment demand function is that the dependent R&D variable is defined as a *stock* variable. R&D stock can be estimated by the perpetual investment method, but the time span of available data is usually too short to estimate a stock variable. However, Hall and van Reenen (2000) show that if one assumes constant growth rate of R&D stock at the firm level, then:

(2) $r_{it} = \eta_i + g_{it}$

where r_{it} is the log level of R&D investment of firm *i* at time *t*, and η_i is a firm-specific constant. Substituting this term into Eq. (1), we obtain:

(3) $r_{it} = \alpha + \eta_i + \beta D_{it} + \delta x_{it} + \varepsilon_{it}$

This equation implies that if firm-specific fixed effects are accounted for, annual R&D investment can be used as the dependent variable in the R&D demand function.

Endogeneity in program participation is another important problem encountered in regression analysis. Conventional regression analysis assumes that allocation of R&D subsidies is a random process. However, in reality, governments may allocate subsidies non-randomly by considering the potential success of the firms and of the projects. For instance, larger firms can be allowed to benefit more from R&D support programs, which may also be true for the firms operating in the more technology-oriented sectors (Klette et al., 2000; Wallsten, 2000; Hanel, 2003). To avoid criticisms that blame for wasting public funds, governments may tend to favor those firms and projects, which seem more promising in advance (Lach, 2002). The problem of “crowding out” of private R&D by public R&D funding emerges as an unintended consequence at this point. The projects selected in a “premeditated” (rather than random) manner could have been funded by own-private resources, or the supported firms could have maintained their R&D activities on their own. Such governmental premeditation violates the assumption of randomness, which, in turn, brings about the problem of “selection bias” in the allocation of R&D

subsidies (David et al., 2000; Klette et al., 2000). Hence, receiving public R&D support may turn out to be the result (rather than the cause) of higher private R&D investment. This is the problem of "endogeneity" (of R&D subsidies), which should be considered seriously as a potential problem within the context of evaluation studies. If it is ignored, the impact of R&D support on private R&D can be overestimated.[4]

Many empirical studies with various model specifications have been carried out in order to explain the effect of public support on private R&D. For broader reviews of the literature, one should especially see: i) David et al. (2000) for pre-2000 studies with regression analyses at various levels of aggregation, and ii) Hall (2005, p. 47, Table 6) for post-2000 studies mostly with non-parametric matching methods. Klette et al. (2000) includes a review of five microeconometric studies with a focus on the effect of public R&D efforts on the R&D- and manufacturing-performance of private firms, whereas Hall and van Reenen (2000) survey the effect of tax incentives. For our own purposes, it seems a good idea to proceed with a concise review of empirical studies, which rely on a model specification analogous to the one adopted in this study. Since our disaggregate data allow us to perform analysis at firm-level, we will not concern ourselves with aggregate studies at sectoral or country level.

Two earlier studies found some evidence that the effect of public R&D grants on private R&D activity is positive to some extent. For a panel of Canadian firms grouped into three industries, Howe and McFetridge (1976) found that grants raise private R&D intensity in general, even if the effect is statistically significant in only the electrical industry. Holemans and Sleuwaegen (1988) found that elasticity of private R&D with respect to public R&D grants is positive (between 0.25 and 0.48) for a cross-section of Belgian firms. These two studies used such control variables as size, royalties,

[4] Blanes and Busom (2004) specifically analyze the decision to participate in R&D support programs.

depreciation, profits, product diversification, etc. However, they did not consider the possibility of the endogeneity of R&D grants. The possibility of firms' self-selection for participating in R&D support programs may entail simultaneity between the existing R&D performance and acquiring the support. Some studies (such as Klette and Moen, 1998; Busom, 2000; Wallsten, 2000; Hussinger, 2006) took into account the possibility of such endogeneity in their analyses.

Using data on "lines of business" in high-tech firms in Norway, Klette and Moen (1998) employ fixed effects regression analysis by controlling for sales (output) and cash flows in addition to time dummies. They find no negative (crowding-out) effect of public R&D subsidies on private R&D performance. However, subsidies do not stimulate private R&D considerably since the elasticity (of the latter with respect to the former) is very close to zero (0.06). All the same, thanks to their analysis of the dynamic effects of the subsidy programs, the authors are able to conclude that support leads to a "permanent increase" in private R&D. Busom (2000) examines a cross-section of Spanish firms by means of selection controls. Controlling for size, patents, share of exports along with industry dummies, she regresses R&D intensity (in terms of R&D per employee) on a dummy variable for participating in the R&D loan program. The results indicate that private R&D increases by 20 percent of the subsidy. However, this finding is valid for two-thirds of the firms. For the remaining one-third, she reports complete crowding-out. Hussinger (2006) estimates a parametric two-step selection model to test the effect of R&D grants in Germany, and finds that R&D subsidies have a positive effect on firms' R&D expenditure.

Among the studies that find crowding-out effects, Wallsten (2000) has become one of the most frequently-cited, probably due to its striking conclusion that there is one-for-one crowding-out of private R&D as a result of the R&D awards of the Small Business Innovation Research Program (SBIR) in the US. Using three-stage least squares with controls for age, size, patents, past R&D expenditure, and a dummy variable for firms that never applied to the program (along with other industrial and regional dummies), Wallsten concludes that governmental decision-makers tend to allocate R&D support to those projects with already most promising outcomes. In an analogous framework of instrumental variables approach (using such control variables as investment, cash flows, interest rate, etc.), Toivanen and Niininen (2000) also find a negative elasticity (–0.10) of private R&D expenditure with respect to the public support given to the large firms in Finland, whereas the same effect is insignificant in the case of small firms.

2.2. Matching (treatment effect) analysis

Non-parametric methods have been used to cope with the problem of endogeneity in assessing the impact of various public policies and programs (Blundell and Costa Dias, 2000). For instance, matching (treatment effect) methods have been extensively applied in the evaluation of labor market policies (Heckman et al. 1999). Such non-parametric methods have been recently used also in assessing the effects of R&D support programs (for example, Czarnitzki and Fier, 2002; Almus and Czarnitzki, 2003; Czarnitzki and Hussinger, 2004; Duguet, 2004). Interestingly, an overwhelming majority (11 out of 12) of post-2000 micro-level studies, most of which use matching methods, reports ***no*** complete crowding-out effect (Hall, 2005, p. 47, Table 6). Since we will also employ matching analysis (in addition to regression analysis) in Section 5, an explanation of the matching methods is needed.

As we have already emphasized, evaluation studies on R&D support should reveal "what the firm would have spent on R&D had it not received the subsidy" (Lach, 2002, p. 372). Matching methods are based on a comparison between the realized outcomes and the outcomes that would have been observed for supported ("treated") firms had they not benefited from the program. In this framework, let RD^1 be the outcome conditional on R&D support ("treatment") and RD^0 the outcome that would have been observed if the same firm received no support ("no treatment"). The impact of the program is:

(4) $\Delta = RD^1 - RD^0$

Since only RD^1 or RD^0 is observed for each firm, Δ is not observable. Although it is not possible to identify the ***individual*** effect of the support program, the ***average*** effect can be estimated under certain assumptions. The main parameter estimated in empirical studies is the mean "impact of treatment on the treated", which is defined as:

(5) $TT = E(\Delta | D = 1) = E(RD^1 | D = 1) - E(RD^0 | D = 1)$

where E (.) is the expectation operator. "D = 1" denotes the group of support-receiving firms, while "D = 0" denotes the group of firms that do not participate in the program.

The counterfactual $E(RD^0 | D = 1)$ must be estimated because it is not observed. There are three estimators available: ***before-after*** (using data on support-recipients prior to program participation), ***cross-section*** (using data on non-participants), and ***difference-in-differences*** (DID, using both types of data). The DID estimator is defined as:

(6) $DID = E(RD^1_{it} - RD^1_{it-1} | D_{it} = 1, D_{it-1} = 0) - E(RD^0_{it} - RD^0_{it-1} | D_{it} = 0, D_{it-1} = 0)$

It compares the ***average change*** in R&D intensity of supported (participant) and non-supported (non-participants) firms conditional on not having received a subsidy at time ***t-1*** ($D_{it-1} = 0$). Thanks to its panel data feature, DID is superior to the other (before-after and cross-section) estimators. It allows for firm-specific and time-specific unobserved effects to be eliminated by "same-firm" and "same-period" differences, respectively (Lach, 2002; Smith and Todd, 2005).

In this paper a control group is to be constructed to estimate the second part of Eq. (6). We will use "nearest neighbor matching", whereby each firm receiving support at time ***t*** but not at time ***t-1*** ($D_{it} = 1$ and $D_{it-1} = 0$) is matched with its closest non-supported neighbor ($D_{it} = 0$ and $D_{it-1} = 0$). Firms are matched on the propensity score (the probability to receive R&D support), which is estimated by a logit model.[5] This method ensures that the groups of support receiving and non-supported firms are statistically not different in terms of the variables used in the estimation of propensity scores (see Table A3).

We end this section with an interesting empirical remark: In general, the studies using propensity score matching methods have found evidence of *no* crowding-out effect of public R&D subsidies on private R&D investment. Recent examples are: Almus and Czarnitzki (2003) for East Germany, Aerts and Czarnitzki (2004) for Belgium, and Czarnitzki and Hussinger (2004) for Germany. These studies, respectively, find that R&D investment increases by 100 percent (in East Germany), 150 percent (in Belgium), and 30 percent (in Germany) as the result of receiving public subsidies. Our main objective in this study is to reveal whether public R&D support has similar "additionality" effects on Turkish manufacturing firms.

3. R&D support programs in Turkey

The initiation of R&D support programs in Turkey in the early 1990s has been one of the most important institutional novelties leading to the establishment and development of a national system of innovation. The Technology Development Foundation of Turkey (TTGV, in the Turkish acronym) was established in 1991 to provide R&D support in the form of interest-free "R&D loans" since 1992.[6] Besides TTGV, the Technology Monitoring and Evaluation Board of the Scientific and Technical Research Council of Turkey (TIDEB of TUBITAK, in Turkish acronyms) is the other major R&D supporter in

[5] For this purpose, we used the "psmatch2" program written by Leuven and Sianesi (2003).

[6] Projects supported by TTGV last for a maximum of two years, whereas the loan cannot exceed 50 percent of the project budget. Financial support on equipment is paid back upon the completion of the project, and the rest is paid within a maximum of four years' time. A fee is also due for "project supervision and service outlays" at a rate of 3-4 percent of the project budget. Since the loan is denominated in USD, supported firms undertake the exchange rate risk.

Turkey. TIDEB started to give "R&D grants" on September 15, 1995 in accordance with the "Decision on R&D Support" taken by the Board of Money, Credit and Coordination on June 1, 1995. TIDEB serves as the referee institution, while the Undersecretariat of the Prime Ministry for Foreign Trade pays for the grants, which go to the firms at a rate of up to 50 percent of the R&D expenditures in Turkish liras. The average grant rate is about 40 percent, but the real rate is generally lower due to inflation. R&D support rate depends on such factors as the share of the products (produced through R&D) in total sales, employment of PhD researchers, R&D services obtained from universities, R&D performed within techno-parks, and projects undertaken in priority areas. 10 percent of the original support is additionally granted in case that the R&D activity results in a patent.[7]

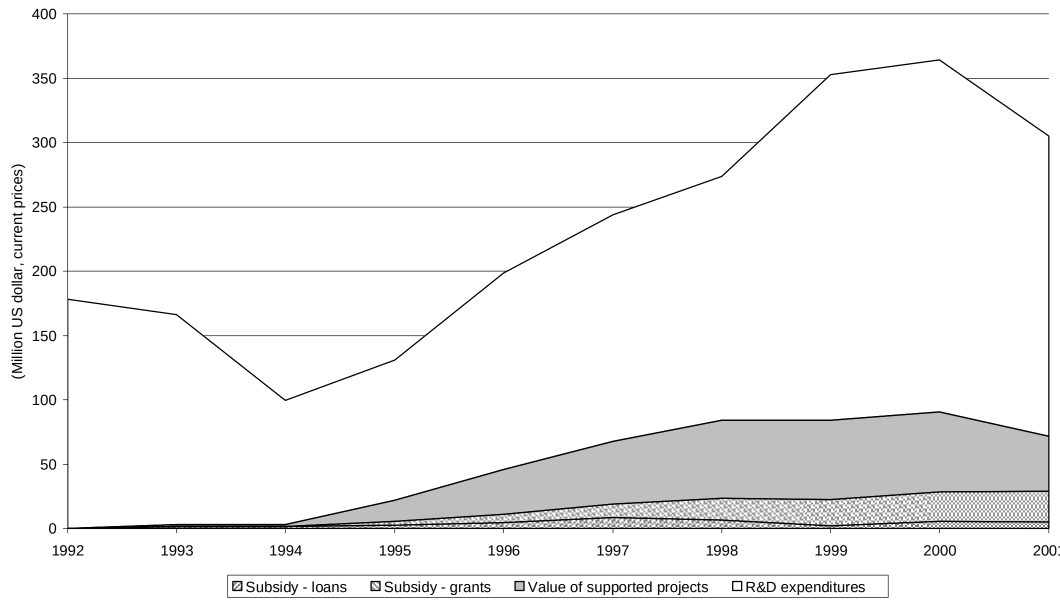
R&D data in Turkey have been collected since 1990 by the Turkish Statistical Institute[8] (Turkstat). R&D expenditures and R&D support in Turkish manufacturing industry are illustrated in Fig. 1 from 1992 to 2001. Decreasing R&D expenditures reached a trough of USD 100 million in 1994.[9] After the economic crisis of 1994, R&D expenditures increased steadily and reached USD 364 million in 2000 (USD 830 million according to the purchasing power parity). Another crisis in 2001 led to another slump in R&D expenditures.

[7] In addition to the R&D loans of TTGV and R&D grants of TIDEB-TUBITAK, "tax incentives" are another policy instrument in supporting R&D activities in Turkey. Tax credits are provided by the Ministry of Finance. 20 percent of the corporate taxes within the period of R&D activity can be delayed for three years without interest, provided that the delayed amount does not exceed the R&D expenditure. The significance of this policy for firms relies on the amount to be paid as corporate tax. There are no incentives for those firms that are not obliged to pay corporate taxes. The incentive element in tax credits is computed by the so-called B-index that is estimated as 1 for Turkey (OECD, 1996). In other words, the incentive impact of tax credits is not so significant. There are only a few firms that applied for tax credits in Turkey. Hence, the impact of tax credits is not examined in this study.

[8] We should note that Turkstat renamed itself in 2005. The "State Institute of Statistics" was the official name of the institution before 2005. We prefer to use the new name along this study, even though our data-sets come from the pre-2005 period.

[9] All the data are converted to USD by the current exchange rate. Purchasing power parity (PPP) is a better indicator for international comparisons. PPP is about 2 times higher than the current exchange rate in Turkey in the 1990s. The sharp devaluation of the Turkish lira in 2001 raised the "PPP/current exchange rate" ratio to 2.9. It dropped to 2.4 in 2002.

Figure 1. R&D expenditures and R&D subsidies in Turkish manufacturing, 1992-2001
(Million US dollar, current prices)



The number of firms supported by loans and grants increased rapidly following the inauguration of the programs. Thus, the value of projects supported by the programs accounted for almost half of the increase in R&D expenditures. Although there was no project supported in 1992, the value of supported R&D projects reached almost USD 100 million in 2000. The increase in the number of firms using TIDEB-grants, which are financially more attractive, turned out to be higher. Subsidies covered about 30 percent of the value of supported projects, and they remained less than 10 percent of all R&D expenditures throughout the 1990s (as depicted by the two shaded areas in Fig. 1).

4. Data and descriptive analysis

This study is based on three panel databases: *Annual Survey of Manufacturing Industries* (ASMI), *R&D Survey*, and a database on the clients of R&D support programs. These databases were carefully matched by the establishment codes used by Turkstat to keep track of the establishments in annual surveys. Conducted by Turkstat, ASMI covers all public and private establishments with 10 or more employees.[10] There are about 11,000 establishments in the database each year. *R&D Survey* is also conducted by the Turkstat. It covers all manufacturing firms known to perform R&D activities as defined by the *Frascati Manual* (OECD, 2002). There were more than 300 firms covered by the survey in the late 1990s. The third database was prepared for all the clients of TTGV and TIDEB. It covers basic information on all projects (the project budget, the amount of support, etc.) supported by these institutions.

A summary of descriptive information about Turkish manufacturing industry is provided in Table 1. Generic aspects of R&D performers are presented in the "R&D performers" column, whereas "loan recipients" and "grant recipients" denote those firms which have been supported by TTGV and TIDEB, respectively.

Partly as a result of the support programs, the number of R&D performers increased more than two-fold in only four years (from 1994 to 1998). Nonetheless, the proportion of R&D performers in manufacturing industry is still low (less than 3 percent in 2000). R&D intensity (the ratio of R&D expenditure to output) of R&D performers increased from 1.45 percent in 1993 to 3.62 percent in 2001. Loan-receiving firms, starting with 5.95 percent in 1993, achieved a very high ratio of 10.58 percent in 2001. Average R&D intensity of the grant recipients was 3.13 percent in 1995 (the first year of the program), and reached 4.88 percent in 2001. In all years, support-receiving firms, on average, exhibit much higher R&D intensities than the non-supported ones. The average firm size (in terms of the number of employees) in the Turkish manufacturing industry as a whole increased slightly in the early 1990s, and remained rather stable around 44 in the more recent years. The

[10] There was a change in the questionnaire for small establishments employing 10-to-24 people in 1992. TTGV started its R&D support program in the same year. By the time this study was conducted, 2001 was the last year of available data. Hence, we use data for the period 1993-2001 in this study. "Establishment" is the statistical unit. An establishment is defined in the Turkstat Database as a functional and decision-making unit that operates at a single location. All data, including the accounting data, are collected at the

average firm size for R&D performers was around 500 during the first half of the 1990s, but it declined to almost 200 in the early 2000s. It seems that the new R&D performers tend to be smaller than the "incumbent" performers. Support recipients are smaller than the non-supported R&D performers. In other words, among the R&D performers, relatively smaller firms have a somewhat higher tendency to receive R&D support.

Table 1. Number of establishments, R&D intensity and size in Turkish manufacturing by R&D status, 1992-2001

	Total	R&D performer	Loan-recipient	Grant-recipient
Number of establishments				
1993	10,565	145	9	0
1994	10,125	143	12	0
1995	10,190	160	17	43
1996	10,581	204	31	90
1997	11,370	304	39	129
1998	12,320	342	35	151
1999	11,260	346	32	136
2000	11,112	327	37	127
2001	11,303	294	35	130
Average R&D intensity (%)				
1993	0.02	1.45	5.95	
1994	0.01	1.05	5.78	
1995	0.02	1.34	5.35	3.13
1996	0.04	2.04	6.45	3.44
1997	0.08	3.18	7.13	4.47
1998	0.08	2.90	7.84	4.34
1999	0.08	2.61	6.70	4.09
2000	0.08	2.84	8.34	4.20
2001	0.09	3.62	10.58	4.88
Average establishment size (number of employees per establishment) [a]				
1993	37	479	421	
1994	38	523	289	
1995	40	487	503	447
1996	43	368	263	289
1997	44	272	199	256
1998	43	256	196	218
1999	44	239	148	201
2000	46	252	144	222
2001	44	235	148	217

a Geometric average

Source: Turkstat, *Annual Surveys of Manufacturing Industries* and *Annual R&D Surveys*, and the database on loan- and grant-recipient firms.

Descriptive statistics on some variables are presented in Table 2 (For variable definitions, see Table A1 in the Appendix). "R&D intensity" and "own R&D intensity" are higher for support recipients. An average R&D performer spent 2.27 percent of its output (sales) on R&D in the period 1993-2001. The same ratio is 5.98 percent for loan recipients

establishment level. Since a large part of firms operating in Turkish manufacturing have only one establishment, we use the terms "establishment" and "firm" interchangeably.

and 3.41 percent for grant recipients. "Subsidized R&D intensity" is 1.55 percent for loan recipients, and 0.82 percent for grant recipients. However, the average share of subsidy in total R&D expenditure reaches 20 percent for both loan and grant recipients (1.55/7.53 and 0.82/4.24, respectively).[11]

It is a well-known fact that firms can achieve technological improvement not only through R&D activity but also by (disembodied) technology transfer.[12] The proportion of technology transferring firms in R&D performers is 17 times higher than that in non-performers. The proportion of technology transferring firms in the support recipients is also quite high (16 and 17 percent for loan and grant recipients, respectively). This relatively higher propensity to transfer technology (on the part of R&D performers and support-recipients) suggests that R&D activity and technology transfer can be complementary processes in the Turkish manufacturing industry.

Table 2. Descriptive statistics, 1993-2001 average values

		All firms	Non-R&D performers	R & D performers			
				All[a]	Nonsupported[a]	Loan-recipient[b]	Grant-recipient[b]
R&D intensity	Percentage	0.06		2.58 **	1.46 **	7.53 ++	4.24 ++
Own R&D intensity	Percentage	0.05		2.27 **	1.46 **	5.98 ++	3.41 ++
Subsidized R&D intensity	Percentage	0.01		0.31 **	0.00	1.55 ++	0.82 ++
Loan-recipient	Binary (0/1)	0.00		0.11 **		1.00 ++	0.22 ++
Grant-recipient	Binary (0/1)	0.01		0.35 **		0.72 ++	1.00 ++
Technology transfer	Binary (0/1)	0.02	0.01	0.17 **	0.17 **	0.16	0.17
Sectoral R&D intensity	Percentage	0.18	0.17	0.46 **	0.36 **	0.70 ++	0.66 ++
Sectoral share of supported firms	Percentage	0.94	0.64	2.83 **	1.57 **	3.87 ++	4.19 ++
Regional share of supported firms	Percentage	0.90	0.65	1.33 **	1.09 **	1.54 ++	1.52 ++
Capital intensity	(log K/L ratio)	2.99	2.96	4.38 **	4.39	4.25	4.38
Wage rate	(log)	4.36	4.33	5.45 **	5.49 **	5.30 ++	5.39 ++
Real output	(log)	10.64	10.57	13.54 **	13.76 **	12.94 ++	13.21 ++
Size	(log employees)	3.74	3.70	5.69 **	5.84 **	5.31 ++	5.47
Relative labor productivity		0.00	-0.02	0.97 **	1.06 **	0.77 ++	0.82 ++
Share of skilled employees	Percentage	17.60	17.51	21.56 **	20.98 **	23.90 ++	22.59 ++
Sectoral growth rate	Percentage	5.07	5.03	6.49 *	7.67 **	4.82	4.55
Number of observations		96984	94778	2206	1347	245	790

a: ** (*) means the average of all R&D performers/unsupported R&D performers is different from the average of non-performers at the 5% (10%) level.
b: ++ (+) means the average of loan recepients/grant recipients is different from the average of other R&D performers at the 5% (10%) level.
Source: See Table 1.

[11] Although "subsidized R&D intensity" of loan recipients (1.55 percent) is higher than that of grant recipients (0.82 percent), the share of subsidy in total R&D intensity is almost the same for these two categories of firms. This can be explained by the fact that some firms were supported by TTGV and TIDEB simultaneously. Indeed, 72 percent of the loan-recipients also received R&D grants, whereas only 22 percent of the grant-recipients benefited also from R&D loans (see the corresponding average values for the dummy variables "Loan-recipient" and "Grant-recipient" in Table 2).

[12] "Technology transfer" here refers to any transfer of technology from abroad through license or know-how agreements, i.e., it includes only the transfer of intellectual property rights. The data are collected through ASMI.

Aggregate R&D intensity in the sectors of supported firms ("Sectoral R&D intensity") is higher than in the sectors of other R&D performers. In other words, firms operating in R&D-intensive sectors seem to participate more in R&D support programs. Similarly, support recipients constitute a larger proportion (4 percent) of the total number of firms in their sectors (the "sectoral share of supported firms") compared to non-supported R&D performers (2 percent) and non-performers (1 percent). Also, there seems to be some regional clustering of the supported firms. Compared with non-supported firms, supported R&D performers account for a proportion of all firms in their provinces (the "Regional share of supported firms") that is twice as high.

Compared to the average non-R&D performers, both supported and non-supported R&D performers pay much higher wages and are larger in terms of output and employment (see the log variables "wage rate", "real output" and "size" in Table 2). However, support recipients pay lower wages and are smaller than the non-supported performers. "Capital intensity" and "relative labor productivity" are somewhat lower, whereas "share of the skilled employees" is somewhat higher in supported firms as compared to the non-supported R&D performers.

5. Estimation results

5.1. Regression analysis with controls

In accordance with Eq. (3), which we introduced in Section 2.1, we set up our basic model of R&D investment demand as follows:

(7) $r_{it} = \beta x_{it} + \varepsilon_{it}$

where r_{it} is the R&D intensity (R&D expenditures/output) of firm i at time t; β is a vector of coefficients; x is a vector of explanatory variables including the firm-specific effects (η_i), and ε_{it} is the error term. The dependent variable (R&D intensity) is zero for most firms in the Turkish manufacturing industry since they do not invest in R&D. However, R&D support programs may have an impact on non-performers as well. Therefore, we will use random effects Tobit model (in addition to fixed effects and dynamic panel models) to estimate the R&D investment demand function, because it allows us to use the data for R&D performers and non-performers together.[13]

In Eq. (7), $x_{it} = (\eta_i, LOAN_{it}, GRANT_{it}, pr_t, pm_{it}, w_{it}, q_{it})$, where LOAN is a dummy variable that is equal to 1 if the firm *i* received an R&D loan from TTGV at time *t*; GRANT is a dummy variable that is equal to 1 if the firm *i* received an R&D grant from TIDEB at time *t*; *pr* is the (log) R&D cost index; *pm* is the (log) input price index; *w* is the log real wage rate; and *q* is log real output level of the firm.[14] In addition, we use two more variables to control for technology transfer and sectoral R&D intensity. We explain briefly below the reason why we include these explanatory variables.

Loan-recipient and grant-recipient: R&D support may encourage firms to increase their R&D expenditures by rendering R&D more profitable.[15] However, the support may crowd out private investment if the government finances those projects that could have been financed by the firm. Crowding out could also be observed when R&D subsidies make non-subsidized projects unprofitable because of inelastic supply of R&D inputs like scientists and engineers (David and Hall, 2000; Lach 2002). Thus, the coefficients of support variables will test if the net effect is positive or not. A positive (negative)

---

[13] For a recent application of Tobit models, see Hyytinen and Toivanen (2005). The Tobit model imposes the restriction that the effects of explanatory variables on "R&D intensity" and on "R&D decision" (to do or not to do R&D) are equal up to a constant of proportionality. Hence, we will also estimate a separate R&D decision function by panel data logit models.

[14] All price variables are divided by the product price index. Input and product prices are calculated at the ISIC 4-digit industry level (Rev. 2), and the wage rate at the firm level.

[15] The financial and *technical* support provided by TTGV and TIDEB may also induce changes in firms' attitude towards R&D ("change in decision rules" *à la* Nelson and Winter, 1982; or "behavioral additionality" as defined by Buisseret et al., 1995), and consequently, affect the level of R&D expenditures. It is noteworthy that R&D support programs in Turkey have provided the firms with indirect benefits. About half of the supported firms stated that they benefited from the support program so as to develop an institutional setup for team-work in performing R&D (for details, see Taymaz, 2001, Tables 8.30 and 8.31).

coefficient will imply a crowding-in (crowding-out) effect of public R&D support on private R&D.

Cost of R&D, cost of inputs, real output, and wage rate: These variables come directly from the theoretical specification of an R&D investment demand function, as in Eq. (1) (Hall and van Reenen, 2000, p. 460, Eq. 3.3). Cost of R&D[16] can be considered as the own-price variable (with a negative expected sign) in a conventional R&D demand function, whereas cost of inputs represent the price of related inputs (with a positive or negative expected coefficient depending on whether the inputs are complements or substitutes for R&D investment).[17] Real output is included as a firm-specific measure of size. Larger firms – in terms of output or number of employees – may tend to benefit more from R&D support (Wallsten, 2000; Hanel, 2003).[18] A positive (negative) estimated coefficient for real output will indicate that larger firms have a higher (lower) R&D intensity. Finally, there can be a complementary relationship between the qualification of employees and technological activities. The wage rate (as the cost of labor input) may be considered as an indicator of the qualification employees, which, in turn, may affect firm-specific technological capabilities, such as R&D activities. A positive estimated coefficient is expected.

[16] "Cost of R&D" variable can be calculated by including the effect of the subsidy. But as Hall and van Reenen (2000) suggest, even if it does not contain a measure of the subsidy, it is possible to use the measured elasticity of R&D with respect to price to infer the response induced by an R&D support of a given size. Since Turkstat does not calculate the R&D cost index, we calculated it as a Tornqvist price index in terms of a weighted average of "current costs" and "investment costs" (about 60% and 40% of the total R&D costs, respectively). Personnel costs amount to half of the current costs, whereas machinery and equipment constitute the bulk of investment costs. The R&D survey collects detailed information about the number and wages of research personnel. We used these data to calculate a cost index for the research personnel for the period 1993-2001. The R&D personnel wage index was used for current R&D expenditures and the cost index for machinery and equipment for R&D investments.

[17] Unfortunately, our data-sets do not allow us to calculate cost of inputs and cost of R&D as firm-specific variables. The input cost index is at sectoral level. R&D cost index is the same for all firms. Hence, its estimated coefficients are likely to fail in capturing its effects on firm-specific R&D intensity.

[18] However, our descriptive analysis suggested that relatively smaller firms (among the R&D performers) exhibit somewhat a higher tendency to receive R&D support. The well-known Schumpeterian legacy led some researchers to postulate a positive relationship between firm size and R&D and some empirical studies confirmed this (for instance, Kumar and Saqib, 1996). Some others found U-shaped as well as cubic (horizontal S-shaped) relationships (for instance, Acs and Audretsch, 1988; Audretsch and Acs, 1991).

Technology transfer: The relationship between technology transfer from abroad and domestic R&D activity has been an important subject of debate (Blumenthal, 1979; Kumar and Siddhartan, 1997). They can complement each other or substitute for one another. Most studies suggested complementarity (such as Siddharthan, 1992; Aggarwal, 2000), some indicated substitution (such as Fikkert, 1993), and some found them to be unrelated (such as Kumar and Saqib, 1996). The technology transfer variable is defined as a dummy variable that takes value one if the firm transferred technology from abroad through license or know-how agreements, zero otherwise. A positive (negative) coefficient will imply a complementary (substitution) effect on R&D.

Sectoral R&D intensity: Non-supported firms may spend more on R&D if they feel that increased R&D in supported firms threatens them, or if they benefit from knowledge spillovers. There is evidence of significant spillovers in R&D activities and innovative processes (Jones, 1998; Klette et al., 2000; OECD, 2004).[19] Moreover, sectoral differences in technological opportunities are also an important source of differences in R&D intensity (Klevorick et al. 1995; Nelson and Wolff, 1997). This variable, defined as the ratio between sectoral R&D expenditures and output (calculated at the ISIC (Rev. 2) 4-digit level), will control for firms' additional R&D activity thanks to operating in an R&D-intensive sector.

Given this regression framework, we present the estimation results for the R&D investment model in Table 3 (Models 1-5). Model 1 is estimated for all firms (R&D performers and non-performers) by random effects Tobit. All the other models (2-5) are estimated for R&D performers only. Model 2 is a fixed effects model. The rest (3-5) are dynamic panel models estimated by generalized method of moments (GMM).

---

[19] Knowledge spillovers are likely to yield more productive outcomes in performing R&D (Trajtenberg, 2001). Subsidies may have dynamic effects in further stimulating R&D activities by encouraging alternative channels of funding. According to a recent study, recipients of R&D subsidies increase their R&D funding from other sources in comparison to non-recipients (Feldman and Kelley, 2006).

In Model 1, all variables have statistically significant coefficients (except the cost of R&D).[20] R&D support variables stimulate R&D intensity. If the wage rate is an indicator of the qualification of employees, skilled labor contributes to R&D activities. Larger firms have higher R&D intensity. The positive coefficient of the technology transfer variable suggests that technology transfer and in-house R&D complement each other. Sectoral R&D intensity also positively affects firm-level R&D intensity. R&D-intensive sectors seem to benefit more from R&D support.[21]

Table 3. Determinants of R&D intensity
(Dependent variable: R&D intensity)

	Model 1 Tobit			Model 2 Robust Fixed Effects		Model 3 Dynamic		Model 4 Dynamic/Own R&D		Model 5 Dynamic/DID	
	Coeff.	Marg. eff.	std.dev.	Coeff.	std.dev.	Coeff.	std.dev.	Coeff.	std.dev.	Coeff.	std.dev.
Loan-recipient	8.12	3.00	0.43 **	2.82	0.58 **	2.06	0.86 **	0.05	0.69		
Grant-recipient	8.59	3.17	0.29 **	0.57	0.31 *	1.92	0.49 **	0.13	0.41 **		
Support-recipient										1.89	0.50 **
Subsidized R&D intensity								0.94	0.37 **		
Lagged R&D intensity						0.39	0.06 **	0.29	0.06 **	0.09	0.06
Cost of R&D	-0.40	-0.15	0.49	1.83	0.71 **	0.60	0.61	0.22	0.53	0.08	0.76
Cost of inputs	1.12	0.41	0.52 **	0.41	0.61	0.38	0.63	-0.09	0.52	0.44	0.68
Wage rate	2.00	0.74	0.19 **	0.15	0.32	0.52	0.44	0.68	0.34 **	0.40	0.46
Real output	1.50	0.55	0.09 **	-1.53	0.34 **	-0.14	0.21 **	-0.98	0.18 **	-0.90	0.20 **
Technology transfer	1.44	0.53	0.39 **	0.05	0.23	0.75	0.42 *	0.96	0.32 **	0.55	0.32 *
Sectoral R&D intensity	1.12	0.41	0.15 **	0.54	0.23 **	0.27	0.21	0.12	0.18	0.31	0.20
Wald test, Chi^2(df)/F-test (df/df)	2200.7 (9) **			11.09 (9/1567) **		23.6 (10/450) **		10.47 (11/450) **		5.87 (9/506) **	
Hausman test, Chi^2(d.f.)				20.5 (9) **							
Heteroskedasticity test, Chi^2(d.f.)				74.9 (8) **							
Hansen overiden test, Chi^2(d.f.)						158.7 (156)		202.01 (180)		117.8 (126)	
AR (1) test						-3.89 **		-2.89 **		-2.16 **	
AR (2) test						-1.47		-1.6		-0.24	
Number of observations	98366			2226		1461		1461		858	
Number of estab.	20036			650		451		451		307	
Observations per estab.	4.9			3.4		3.2		3.2		2.8	

Notes: All models include a time variable and/or a constant term. ** (*) means statistically significant at the 5% (10%) level, two-tailed test.
Marginal effects for the Tobit model (Model 1) are calculated at the mean values of continuous variables and unit values for dummy variables.
In dynamic models (models 3-5), sector-specific variables (cost of R&D, cost of inputs and sectoral R&D intensity) are assumed to be exogenous. The following variables are included as instruments: Sectoral share of supported firms, Regional share of supported firms, Capital intensity, Relative labor productivity and Share of skilled employees.

Model 2 (for R&D performers) exhibits some significant differences with respect to Model 1 (for all firms). First, the coefficient of R&D cost is now significant with an

[20] The marginal effects are also calculated to compare the results of the Tobit model with the results of other models. For the calculation of marginal effects, see Wooldridge (2002: 523, Eq. 16.16).

[21] As we have already stated (fn. 13), the Tobit model imposes the restriction that the effects of variables on R&D decision (to do or not to do R&D) are equal to their effects on R&D intensity up to a constant of proportionality. Therefore, we also estimated a separate R&D decision model by random effects (RE) and fixed effects (FE) logit (Models 1a and 1b, Table A2 in the Appendix). The number of observations in the FE logit model is only 4540 (whereas it is 96671 for random effects model) because FE model is estimated for those firms that change their R&D status. Almost all coefficients in the RE model are statistically significant at the 5 percent level. In the FE logit model, real wages, firm size (in terms of real output and employment) and the sectoral share of supported firms tend to increase the probability to perform R&D. The impact of the last variable is meaningful because it shows that if there are many firms supported by TTGV and TIDEB, other firms in the same sector tend to initiate R&D activities.

unexpected positive sign.[22] Secondly, the coefficient of real output switches from positive to negative. This indicates that the proportionality assumption is not valid for the Tobit model, because large firms are more likely to perform R&D (see the R&D decision models in Table A2), but R&D performing large firms tend to have lower R&D intensity. Thirdly, cost of inputs, wage rate and technology transfer lose their significance. Despite these differences, R&D support variables are still positively significant.[23]

In the dynamic models (3, 4 and 5), "lagged R&D intensity" is used as regressor to capture the effect of the adjustment of R&D investment over time. In these models, sectoral variables (cost of R&D, cost of inputs and sectoral R&D intensity) are assumed to be exogenous. "Sectoral share of supported firms", "regional share of supported firms", "capital intensity", "relative labor productivity" and "share of skilled employees" are used as instruments (in addition to standard GMM instruments) to control for the possible endogeneity of program-participation and other firm-specific variables. The results are not sensitive to the choice of these instruments, and the Hansen test shows that the instruments are valid. There is first order but no second order autocorrelation as required in these models.

Model 3 is estimated in difference form to account for fixed effects. The significant positive coefficient of the lagged R&D dependent variable indicates that there can be a

[22] The coefficients of the R&D cost variable are insignificant in most of the models (1, 3, 4, and 5). There is no cross-sectional variation in the R&D cost index due to lack of data (see fn. 17). This can partly explain the poor performance of this variable in our regressions.

[23] Before estimating this fixed effects (FE) model for R&D performers (Model 2), we also estimated a standard random effects (RE) model. Since the Hausman test strongly rejects the null hypothesis of consistency of the RE model and the results of both the FE and RE models are qualitatively the same in terms of the significance and signs of the estimated coefficients, we report here only the results for the FE model. Since both models are estimated for only R&D performers (i.e., for a sub-sample of all firms), they may suffer from selection bias. To determine whether there is evidence of selection bias in the primary (R&D) equation, we computed three test statistics suggested by Semykina and Wooldridge (2005) by adding, one at a time, the lagged and lead values of the selection indicator (i.e., the R&D status), and the vector of inverse Mills ratio terms estimated by regressing the R&D status each year on a set of explanatory variables and their mean values. The t-tests on the lagged and lead values of the selection indicator and the Wald test on the inverse Mills ratio terms provide evidence on the significance of selection bias. It is found by all three statistics that the hypothesis of no selection bias cannot be rejected at the 10 percent level.

partial adjustment process in R&D activities. The coefficients of support variables are positive, significant, and almost the same size. Price variables (cost of R&D, cost of inputs and wage rate) have all insignificant coefficients. Real output has a negative impact on R&D intensity, whereas technology transfer contributes to R&D.

In Model 4, the dependent variable is "own R&D intensity" (firm-financed R&D), and "subsidized R&D intensity" is added as a regressor. The coefficient of R&D loans is positive yet insignificant. The coefficient of R&D grants, although smaller than the one in Model 3, is positive and significant. Moreover, subsidized R&D intensity has also a significant and positive effect on firm-financed R&D. These results suggest that firms benefiting from R&D subsidies tend to increase their *own* R&D expenditures thanks to lower R&D costs and matching requirements. Public R&D support does not crowd out private R&D. On the contrary, it has a crowding-in effect. In addition to their effect of cost reduction, R&D grants seem to induce firms to spend more on R&D, possibly because of indirect effects and/or lowering the costs of other R&D projects. The wage rate has now a significant coefficient supporting the hypothesis that high-wage firms (possibly the ones that employ high-skilled employees) spend more on R&D. As in Model 3, real output (with a negative sign) and technology transfer (with a positive sign) have significant coefficients. Once again our findings verify that larger firms have lower R&D intensity, and that technology transfer and R&D are complementary.

Model 5 includes a sub-sample of firms, which did not receive R&D support in the previous period. This is a difference-in-differences (DID) estimation, the theoretical foundation of which has already been explained in Section 2.2. In this model, the two types of R&D support are combined. Once again, the support variable has a positive and significant coefficient as in the case of other models.

Finally, we should note for the “sectoral R&D intensity” variable that the results vary between static models (1 and 2) and dynamic models (3, 4 and 5). Measuring the average R&D intensity of all other firms in the same sector (i.e., of all “competitors”), this variable has invariably positive coefficients in all models. However, they are significant only in the static models. We should cautiously conclude that spillovers may have some positive effects on R&D activities.

Consequently, our estimation results can be summarized as follows:

i) Public R&D support *by no means* crowds out private R&D activity of the firms in Turkish manufacturing industry. On the contrary, R&D grants even stimulate the firm-financed component of R&D.

ii) For R&D performers, price variables such as R&D cost, input cost, and wage rate are not significant determinants of R&D intensity. This result confirms that R&D is not generally subject to the usual rate of return calculations that drive other investments.[24]

iii) Firm size (in terms of real output) has shown up as an invariably significant determinant of R&D intensity in all our models. Turkish manufacturing industry as a whole seems to confirm the well-known Schumpeterian hypothesis that larger firms are more advantageous in performing R&D activities. However, smaller R&D performers benefit more from R&D support and perform more R&D.

iv) In general, technology transfer from abroad has positive (complementary) effects on domestic R&D activity.

v) Even though sectoral R&D intensity has invariably positive effects on firm-level R&D intensity in all the models, its coefficient is insignificant in the

[24] We thank one of our referees for this comment.

dynamic models (which include firm-specific "lagged R&D intensity"). In other words, operating in an R&D-intensive sector leads the firms to benefit more from R&D support (and encourages them to engage more in R&D activities). However, "lagged R&D intensity" as a firm-specific measure of past R&D performance has a dominating explanatory power. Once it is included as a regressor in the dynamic models, the significance of intra-sectoral spillover effects vanishes.

5.2. Matching (treatment effect) analysis

As explained in Section 2.2, propensity scores are used to construct the matched control group in the context of "matching analysis". The variables we use in the matching function are shown in Table A3. The t-tests show that the supported firms and the matched non-supported firms are *not* significantly different from each other in the set of variables used for matching. However, the supported firms are significantly different from the unmatched group of non-supported firms in almost all respects (except the cost of R&D and sectoral growth rate). In other words, the supported (the treated) and the matched control groups have quite similar characteristics on average.

Table 4 shows DID estimation results. The DID parameter in Eq. (6) was estimated for two cases: Case 1 includes all observations, whereas Case 2 includes only the R&D performers in both years (***t-1*** and ***t***). The DID in R&D intensity as well as in own R&D intensity is estimated for three categories of support: loan-recipients, grant-recipients, and support-recipients (i.e., firms that received either type of support).

Case 1 shows the effect of R&D support programs on non-performers. For all support categories, the DID estimates for R&D and own R&D are quite substantial and significantly different from zero. From ***t-1*** to ***t***, supported firms increased their R&D

intensity by 2.56 percentage points and own R&D intensity by 1.95 percentage points (and the difference is the subsidized amount). There is almost no change in the R&D intensity of non-supported firms that have similar characteristics. We observe a similar change in Case 2 that includes only R&D performers. Support-recipients experienced an increase of 1.14 percentage points in R&D intensity and an increase of 0.78 percentage points in own R&D intensity. However, R&D remained almost constant for the matched control (the difference is only 0.03 percentage points). The DID estimator for R&D intensity is significant at 10 percent level, whereas the estimator for own R&D is not.

Table 4. Average effects of R&D support programs, treated (supported) and control groups

	Case 1: All observations RD_t=0/+, RD_{t-1}=0/+				Case 2: All-time R&D performers RD_t=+, RD_{t-1}=+			
	Treated	Control	DID	n	Treated	Control	DID	n
Change in R&D intensity from time t-1 to t								
Support-recipient	2.56	0.06	2.49 *	259	1.14	0.03	1.11 *	89
Loan-recipient	5.22	-0.11	5.33 *	77	3.67	0.06	3.61 *	40
Grant-recipient	2.48	0.00	2.49 *	253	1.27	-0.11	1.39 *	97
Change in own R&D intensity from time t-1 to t								
Support-recipient	1.95	0.06	1.89 *	259	0.78	0.03	0.76	89
Loan-recipient	3.79	-0.14	3.93 *	77	2.35	-0.01	2.36 *	40
Grant-recipient	1.85	0.00	1.85 *	253	0.85	-0.12	0.96 *	97

Groups: Treated, D_t=1, D_{t-1}=0; Control, D_t=0, D_{t-1}=0

* means DID (difference-in-differences) is different from zero, 10 % significance level, bias-corrected bootstrap estimate based on 250 replications.

n is the number of establishments in the treated and matched control groups.

These results, along with the results of regressions, suggest that there is no crowding-out effect of public R&D subsidies on private R&D investment in Turkish manufacturing industry. Firms' own R&D does not decline with R&D support. Even an "acceleration effect" can be said to exist because an average firm increases its *own* R&D intensity if it receives any type of R&D support. In this respect, our findings are similar to those of Almus and Czarnitzki (2003) for East Germany, Aerts and Czarnitzki (2004) for Belgium, and Czarnitzki and Hussinger (2004) for Germany.

6. Concluding remarks

In an effort to understand the effects of public R&D support on industrial R&D activity, we analyzed the determinants of R&D intensity in Turkish manufacturing firms. Controlling for the potential problem of the endogeneity of R&D support by appropriate regression analyses and matching methods (treatment effect models), we found crowding-in effects of public R&D support on private R&D. Even though overall R&D spending remains quite low in Turkey as compared to developed countries and subsidies account for less than 10 percent of all R&D expenditures, public R&D loans and grants are still conducive to private R&D investment.

Our findings provide additional support for those studies that report crowding in effects in "late industrializing" countries (see Busom, 2000, Gonzales et al., 2005, and Callejón and García-Quevedo, 2005, who find crowding-in in Spain; Lach, 2002, who reports substantial stimulation of the own R&D spending of small Israeli firms; and Görg and Strobl, 2007, who suggest that small R&D grants create additionality effects for domestic plants in Ireland), although the evidence for crowding in/out for "advanced countries" is not unambiguous (for recent surveys, see David et al., 2000; Hall, 2002; Jaffe, 2002). These findings may suggest that public R&D support is likely to play a more important role in stimulating private R&D in "late industrializing" countries and/or small firms. The impact could diminish as the firms learn more about R&D activities.

We get analogous results on the effect of firm size on R&D. Although larger firms are more likely to conduct R&D activities, within the group of R&D performers, smaller firms participate more in R&D support programs and have higher R&D investment per output. The hypothesis that larger firms tend to benefit more from R&D support (Wallsten, 2000; Lach, 2002; Hanel, 2003) seems to be invalid in the case of R&D performing firms in Turkey.

Our panel data-sets allowed us to control for the effects of disembodied technology transfer from abroad through license and know-how agreements. Our findings indicate that technology imports complement and augment in-house R&D activities (like in Aggarwal, 2000).

Finally, our findings provide some support for the hypothesis that R&D grants and loans could be more effective than R&D tax incentives in developing/late industrializing countries. Although R&D grants/loans in Turkey stimulate private R&D, the number of firms benefiting from R&D tax incentives has been negligible. Further studies on this issue, which is very important for constructing socially beneficial technology policies, are necessary.

We hope we have provided some contemporary and partial evidence for the historical axiom that, as H.G. Wells noted in an incommensurably broader context, knowledge can be "a cultivated crop, responsive to fertilizers". [H. G. Wells, *A Short History of the World*; 1960: 267].

Acknowledgements

We would like to thank Martin Bell and three anonymous referees for their extremely helpful comments and suggestions. This paper is partly based on an evaluation study on the effects of R&D support programs financed by the Technology Development Foundation of Turkey.

References

Acs, Z. J, Audretsch, D.B., 1988. Innovation in large and small firms: an empirical analysis. American Economic Review 78 (4), 678–690.

Aerts, K., Czarnitzki, D., 2004. Using innovation survey data to evaluate R&D policy: The case of Belgium. ZEW Discussion Paper No. 04-55, Mannheim, Germany.

Aggarwal, A., 2000. Deregulation, technology imports and in-house R&D efforts: An analysis of the Indian experience. Research Policy 29 (9)**,** 1081–1093.

Ali-Yrkkö, J. 2005. Impact of public R&D financing on private R&D: Does financial constraint matter? European Network of Economic Policy Research Institutes Working Paper No.30, Brussels.

Almus M., Czarnitzki, D. 2003. The effects of public R&D subsidies on firms' innovation activities: The case of Eastern Germany. Journal of Business and Economic Statistics 21 (2), 226–236

Arrow, K.J., 1962. Economic welfare and the allocation of re sources to invention, in: Nelson, R. (Ed.), The Rate and Direction of Inventive Activity. Princeton Univ. Press, pp. 609–625.

Audretsch, D. B., Acs, Z. J., 1991. Innovation and size at the firm level. Southern Economic Journal 57 (3), 739–744.

Bernstein, J. I., Nadiri, M. I., 1988. Interindustry spillovers, rates of return and production in high-tech industries. American Economic Review Papers and Proceedings 78, 429–434.

Blanes, J.V., Busom, I., 2004. Who participates in R&D subsidy programs? The Case of Spanish manufacturing firms. Research Policy 33, 1459–1476.

Blank, D.M., Stigler, G.J., 1957. The demand and supply of scientific personnel. National Bureau of Economic Research, New York.

Bloom, N., Griffith, R., van Reenen, J., 2002. Do R&D tax credits work? Evidence from a panel of countries, 1979-1997. Journal of Public Economics 85 (1), 1–31.

Blumenthal, T., 1979. A note on the relationship between domestic research and development and imports of technology. Economic Development and Cultural Change 27 (2), 303–306.

Blundell, R., Costa Dias, M., 2000. Evaluation methods for non-experimental data. Fiscal Studies 66, 427–468.

Bond, S., Harhoff, D., van Reenen, J., 1999. Investment, R&D and financial constraints in Britain and Germany. IFS Working Paper No. 99/5. The Institute for Fiscal Studies, London.

Branstetter, L.G., Sakakibara, M., 2002. When do research consortia work well and why? Evidence from Japanese panel data. American Economic Review 92, 143–159.

Buisseret, T.J., Cameron, H.M., Georghiou, L., 1995. What difference does it make? Additionality in the public support of R&D in large firms. International Journal of Technology Management 10, 587–600.

Busom, I., 2000. An empirical evaluation of the effects of R&D subsidies. Economics of Innovation and New Technology 9, 111–148.

Callejón, M., García-Quevedo, J. 2005. Public subsidies to business R&D: Do they stimulate private expenditures? Environment and Planning C: Government and Policy 23 (2), 279–293.

Chiao, C., 2002. Relationship between debt, R&D and physical investment: Evidence from US firm-level data. Applied Financial Economics 12 (2), 105–121.

Czarnitzki, D., Fier, A., 2002. Do innovation subsidies crowd out private investment? Evidence from the German service sector. Konjunkturpolitik - Applied Economics Quarterly 48 (1), 1–25.

Czarnitzki, D., Hussinger, K. 2004. The link between R&D subsidies, R&D spending and technological performance. Center for European Economic Research (ZEW) Discussion Paper No. 04-56, Mannheim.

David, P. A., Hall, B. H., 2000. Heart of darkness: Modeling public-private funding interactions inside the R&D black box. Research Policy 29 (9), 1165–1183.

David, P. A., Hall, B. H., Toole, A. A., 2000. Is public R&D a complement or substitute for private R&D? A review of econometric evidence. Research Policy 29 (4–5), 497–529.

Diamond, A. M., 1998. Does federal funding “crowd in” private funding of science. Contemporary Economic Policy, 16, 423–431.

Duguet, E. (2004). Are R&D subsidies a substitute or a complement to privately funded R&D? An econometric analysis at the firm level. Revue d'Economie Politique 112 (4), 245–274.
Ebersberger, B., 2005. The impact of public R&D funding. VTT technical research centre of Finland. VTT Publications 588, Finland.
Feldman, M. P., Kelley, M. R., 2006. The *ex ante* assessment of knowledge spillovers: Government R&D policy, economic incentives and private firm behavior. Research Policy 35, 1509–1521.
Fikkert, B., 1993. An open or closed technology policy? The effects of technology licensing, foreign direct investment, and technology spillovers on R&D in Indian industrial sector firms. Unpublished Ph.D. Dissertation, Yale University, New Haven, CT.
Gonzalez, X., Jaumandreu, J., Pazo, C., 2005. Barriers to innovation and subsidy effectiveness. Rand Journal of Economics 36 (4), 930–950.
Görg, H., Strobl, E. 2007. The effect of R&D subsidies on private R&D. Economica 74, 215–234.
Guellec, D., van Pottelsberghe, B., 2003. The impact of public R&D expenditures on business R&D. Economics of Innovation and New Technologies 12 (3), 225–244.
Hall, B.H., 2002. The financing of research and development. Oxford Review of Economic Policy 18 (1), 35–51.
Hall, B. H., 2005. Government policy for innovation in Latin America. UC Berkeley, mimeo. http://emlab.berkeley.edu/users/bhhall/papers/HallJun05_LAC.pdf (Date of access: 14 March 2007).
Hall, B., van Reenen, J., 2000. How effective are fiscal incentives for R&D? A review of the evidence. Research Policy 29, 449–469.
Hanel, P., 2003. Impact of government support programs on innovation by Canadian manufacturing firms. Paper presented at the International Conference: Evaluation of government funded R&D activities (May 2003), Vienna.
Heckman, J.J., LaLonde, R.J., Smith, J.A. 1999. The economics and econometrics of active labor market programs, in: Ashenfelter, A., Card, D. (Eds.), Handbook of Labor Economics. Vol 3A, North-Holland, Amsterdam, pp.1865–2097.
Heijst, J., 2003. Freerider behaviour and the public finance of R&D activities in enterprises: The case of the Spanish low interest credits for R&D. Research Policy 32 (3), 445–461.
Holemans, B., Sleuwaegen, L., 1988. Innovation expenditures and the role of government in Belgium. Research Policy 17, 375–379.
Howe, J.D., McFetridge, D.G., 1976. The determinants of R&D expenditures. Canadian Journal of Economics 9, 57–71.
Hussinger, K. 2006. R&D and subsidies at the firm level: An application of parametric and semi-parametric two-step selection models. Center for European Economic Research (ZEW). 2006-version of the 2003-Discussion Paper No. 03-63, Mannheim.
Hyytinen, A., Toivanen, O., 2005. Do financial constraints hold back innovation and growth? Evidence on the role of public policy. Research Policy 34 (9), 1385–1403.
Irwin, D. A., Klenow, P. J., 1996. High-tech R&D subsidies: Estimating the effects of Sematech. Journal of International Economics 40 (3–4), 323–344.
Jaffe, A. B., 2002. Building programme evaluation into design of public research-support programmes. Oxford Review of Economic Policy 18 (1), 22–34.
Jones, C. I., 1998. Introduction to Economic Growth. W. W. Norton, New York, N. Y. & London.

Klette, T. J., Moen, J., 1998. R&D Investment responses to R&D subsidies: a theoretical analysis and econometric evidence. Paper presented at the NBER Summer Institute, July.
Klette, T. J., Moen J., 1999. From growth theory to technology policy – coordination problems in theory and practice. Nordic Journal of Political Economy 25, 53-74.
Klette, T. J., Moen, J., Griliches, Z., 2000. Do subsidies to commercial R&D reduce market failures? Microeconometric evaluation studies. Research Policy 29 (4–5), 471–495.
Klevorick, A., Levin, R., Nelson, R., Winter, S., 1995. On the sources and inter industry differences in technological opportunities. Research Policy 24 (2), 185–205.
Kumar, N., Saqib, M., 1996. Firm size, opportunities for adaptation, and in-house R&D activity in developing countries: the case of Indian manufacturing. Research Policy 25 (5), 712–722.
Kumar, N., Siddharthan, N. S., 1997. Technology, Market Structure and Internationalization: Issues and Policies for Developing Countries. Routledge & UNU Press, London and New York.
Lach, S. 2002. Do R&D subsidies stimulate or displace private R&D? Evidence from Israel. Journal of Industrial Economics 50 (4), 369–390.
Lerner, J. 1999. The Government as venture capitalist: The long-run impact of the SBIR Program. Journal of Business 72 (3), 285–318.
Leuven, E., Sianesi, B. 2003. PSMATCH2: Stata module to perform full Mahalanobis and propensity score matching, common support graphing, and covariate imbalance testing. http://ideas.repec.org/c/boc/bocode/s432001.html. Version 1.2.3.
Licht, G., Stadler, M., 2003. Auswirkungen öffentlicher Forschungsförderung auf die private F&E-Tätigkeit: Eine mikroökonometrische Evaluation. Discussion Paper No. 256, University of Tübingen.
Mohnen, P., Nadiri, M. I., Prucha, I., 1986. R&D, production structure and productivity growth in the U.S., Japanese and German manufacturing sectors. European Economic Review 30, 749–772.
Nadiri, M. I., Schankerman, M., 1981. The structure of production, technological change and the rate of growth of total factor productivity in the Bell System, in: Cowing, T. G., Stevenson, R. E. (Eds.), Productivity Measurement in Regulated Industries. Academic Press, New York, pp. 219–247.
Nelson, R.R., 1959. The simple economics of basic scientific research. Journal of Political Economy 67, 297–306.
Nelson, R., Winter, S., 1982. An Evolutionary Theory of Economic Change. The Belknap Press, Cambridge, MA.
Nelson, R., Wolff, E., 1997. Factors behind cross-industry differences in technical progress. Structural Change and Economic Dynamics 8, 205–220.
OECD, 1996. Fiscal Measures to Promote R&D and Innovation. OECD, Paris.
OECD, 2002. Frascati Manual: Proposed Standard Practice for Surveys of Research and Experimental Development. OECD, Paris.
OECD, 2004. Understanding Economic Growth. OECD, Paris.
Özçelik, E., Taymaz, E. 2004. Does innovativeness matter for competitiveness in developing countries? The case of Turkish manufacturing industries. Research Policy 33, 409–424.
Semykina, A., Wooldridge, J. 2005. Estimating panel data models in the presence of endogeneity and selection: Theory and application. Unpublished paper, Department of Economics, Michigan State University, East Lansing.
Siddharthan, N. S., 1992. Transaction costs, technology transfer, and in-house R&D: a

study of the Indian private corporate sector. Journal of Economic Behaviour and Organization 18, 265–271.
Smith, J.A., Todd, P.E. 2005. Does matching overcome LaLonde's critique of nonexperimental estimators? Journal of Econometrics 125, 305–353.
Taymaz, E., 2001. National System of Innovation (in Turkish). TÜBİTAK/TTGV/DİE, Ankara.
Toivanen, O., Niininen, P., 2000. Investment, R&D, subsidies, and credit constraints. Department of Economics MIT and Helsinki School of Economics, Working Papers no 244.
Trajtenberg, M., 2001. R&D policy in Israel: an overview and reassessment, in: Feldman, M. P., Link, A. N. (Eds.), Innovation Policy in the Knowledge-Based Economy. Kluwer Academic Publishers, Boston, MA, pp. 409–454.
Wallsten, S.J. 2000. The Effects of government-industry R&D programs on private R&D: The case of the Small Business Innovation Research Program. Rand Journal of Economics 31 (1), 82–100.
Wells, H. G., 1960. A Short History of the World. Harmondsworth, Penguin Books, Middlesex.
Wooldridge, J.M. 2002. Econometric Analysis of Cross Section and Panel Data, MIT Press, Cambridge, MA.

Appendix

Table A1. Variable definitions

Variable	Unit	Definition
R&D intensity	Percentage	Total R&D expenditures to output ratio
Own R&D intensity	Percentage	R&D expenditures financied by the firm to output ratio
Subsidized R&D intensity	Percentage	R&D subsidies to output ratio
Loan-recipient	Binary (0/1)	1 if the firm received an R&D loan, 0 otherwise
Grant-recipient	Binary (0/1)	1 if the firm received an R&D grant, 0 otherwise
Technology transfer	Binary (0/1)	1 if the firm transferred technology from abroad through license or know-how agreements, 0 otherwise
Sectoral R&D intensity[a]	Percentage	Sectoral R&D expenditures to sectoral output ratio
Sectoral share of supported firms[a]	Percentage	Proportion of all firms in a sector that are supported
Regional share of supported firms[a]	Percentage	Proportion of all firms in a province that are supported
Cost of R&D[b]		log (R&D cost index / output price index)
Cost of inputs[b]		log (input price index / output price index)
Wage rate		log (annual wage rate, million TL / output price index)
Real output		log (real output, million TL, 1997 prices)
Size		log (number of employees)
Capital intensity		log (real depreciation allowances, million TL, 1997 prices / number of employees)
Relative labor productivity		log (value added per employee / sectoral value added per employee)
Share of skilled employees	Percentage	Number of skilled employees to number of employees ratio
Sectoral growth rate	Percentage	Annual growth rate of real output at the sectoral level

Notes: 1997 is the base year for all price indices. "Sector" is defined at the ISIC (Revision 2) 4-digit level.

a These variables are calculated by using the data for the rest of firms operating in the same sector or province.

b These variables are defined at the ISIC (Revision 2) 4-digit level.

Table A2. Determinants of R&D decision
(Dependent variable: R&D decision, 1 for R&D performers, 0 for non-performers)

	Model 1a RE logit			Model 1b FE logit		
	coeff.	std.dev.		coeff.	std.dev.	
Cost of R&D	-0.729	0.333	**	0.043	0.433	
Cost of inputs	0.755	0.295	**	-0.252	0.371	
Wage rate	1.049	0.097	**	0.509	0.143	**
Real output	0.290	0.084	**	0.335	0.142	**
Technology transfer	0.366	0.181	**	-0.172	0.206	
Sectoral R&D intensity	0.458	8.665	**	0.120	9.464	
Sectoral share of supported firms	20.757	2.064	**	8.111	2.412	**
Regional share of supported firms	9.169	4.580	**	-3.662	5.020	
Capital intensity	0.154	0.036	**	0.043	0.044	
Relative productivity	0.180	0.068	**	-0.022	0.080	
Size	1.332	0.098	**	0.838	0.182	**
Share of skilled employees	1.896	0.330	**	0.536	0.396	
Sectoral growth rate	0.069	0.067		0.069	0.061	
Wald/LR test, Chi^2 (d.f.)	1435.4	(21) **		534.2	(21) **	
Log likelihood	-4582.2			-1565.1		
Number of observations	96671			4540		
Number of establishments	19910			583		
Observations per establishment	4.9			7.8		

Notes: All models include time dummies. ** (*) means statistically significant at the 5% (10%) level, two-tailed test.

Table A3. Characteristics of supported firms, and matched and unmatched control groups
All support-recipients, Case 1

Average values at time t-1	Supported firms	Matched group	Unmatched group	
Cost of R&D	0.217	0.222	0.202	
Cost of inputs	0.020	0.019	-0.012	**
Wage rate	5.158	5.133	4.375	**
Real output	12.874	12.925	10.740	**
Technology transfer	0.166	0.170	0.016	**
Sectoral R&D intensity	0.515	0.526	0.168	**
Sectoral share of supported firms	2.722	2.499	0.889	**
Regional share of supported firms	1.182	1.276	0.851	**
Capital intensity	4.151	4.201	3.049	**
Relative labor productivity	0.724	0.831	0.037	**
Size	5.280	5.257	3.809	**
Share of skilled employees	20.604	19.300	17.322	**
Sectoral growth rate	8.446	11.816	6.264	
Number of observations	259	259	74154	

** means statistically significantly different from the mean of the group of supported (treated) firms.