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Tax Incentives and R&D Activity: Firm-Level Evidence from Taiwan

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Abstract

This paper investigates the effect of tax incentives on R&D activities in Taiwanese manufacturing firms. Specifically, we assess the potential R&D-enhancing effect on recipients of R&D tax credits compared with their non-recipient counterparts. Moreover, the potential difference in the R&D-enhancing effect between high-tech and non-high-tech firms is also examined. Utilizing a firm-level panel dataset during 2001 and 2005, empirical results obtained by propensity score matching show that recipients of R&D tax credits appear on average to have 93.53% higher R&D expenditures and a 14.47% higher growth rate for R&D expenditures than non-recipients with similar characteristics. The R&D-enhancing effect of R&D tax credits is not found to be particularly relevant to high-tech or non-high-tech firms. We further employ a generalized method of moment (GMM) of the panel fixed model to control for the endogeneity of R&D tax credits and firm heterogeneity in determining R&D expenditure. Various estimates based on the entire sample and high-tech-firms are quite similar and there is a significantly R&D-enhancing effect of R&D tax credits. This result suggests that the R&D preferential policy has induced more R&D expenditure by firms in Taiwan. While the existence of the R&D-enhancing effect brought on by tax incentives is intuitive, the estimates can provide insightful implications for the R&D tax policy.

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1. Introduction

The importance of innovation on economic growth has been highlighted by endogenous growth theories and evidenced in many existing studies.[1] Therefore, many countries' governments have tried to create a favorable innovation environment and protective regularity, aiming to promote firms' innovative activities and consequently to contribute to sustainable economic growth. However, innovative activity is essentially full of uncertainty as well as time- and money-consuming. Innovation is also recognized to have some characteristics of a public good, preventing the market from providing sufficient quantities of R&D from the perspective of social return. To bridge the gap between the private and social rate of return and foster industrial R&D activity, various policy measures have been launched to stimulate industrial innovation. Specifically, the R&D tax credit has become increasingly popular in some developed countries such as the U.S., Canada, and some OECD countries since the early 1980s.[2]

Taiwan, one of the best performers among latecomers, has been very successful in narrowing the technological gap with its counterparts among leading countries during the past two decades, especially in the electronics industry. In terms of innovation input, Taiwan has devoted a gradually increased ratio of R&D spending to GNP that went from 1.62% in 1990 to 2.62% in 2007, which is similar to those of the U.S. and Germany.[3] Taiwanese firms' patents have also grown extremely fast both domestically and in the U.S. A study of "influential patenting" by the technology consulting firm CHI, Inc. placed Taiwan 4th in the world in terms of the quantity of its U.S. patents in 2000 and it has remained at this ranking. Trajtenberg's (2001) study on an international comparison of patents granted in the U.S. also showed that Taiwan ranks high in terms of patents per capita, compared with the G7 and the other "Asian Tigers". This achievement is quite rare

[1] See Acemoglu *et al.* (2006) for a comprehensive survey on theoretical as well as empirical literature of the innovation-economic growth nexus.
[2] For a survey of tax treatment of R&D around the world, please see Table 1 in Hall and Van Reenen (2000).
[3] The R&D expenditures devoted by the business enterprise sector accounted for 68.8% in 2007.

in the developing world and has almost uniformly failed to happen outside of Asia or within Asia. During the process of technological development, the Statute for Upgrading Industries (SUI) that applies tax incentive, subsidies, and supporting measures to assist innovative activity is considered one of Taiwan's key industrial technology policies (Lien *et al.* 2007).

Since economists have been generally skeptical regarding the efficacy of tax incentives, and the tax implementations of the SUI will expire in the end of 2009, it inspires a legitimate question of concern: Has the R&D-preferential policy induced greater R&D expenditures and a higher growth rate of R&D expenditure from firms in Taiwan? From the perspective of public finance, the tax bases erosion attributed to R&D incentives is possible one cause of fiscal shortage. Whether or not the limited government resources should be used to encourage innovation depends on the efficacy of these measures on inducing much greater innovations and then contributing to sustainable growth.

Given the knowledge economy, knowledge-based industries are thought of as the most important industries to support sustainable economic growth, and therefore many countries are aggressive in developing these knowledge-based industries (usually high-tech). High-tech industries are generally more R&D intensive and are also the primary recipients of R&D tax credits in the U.S. (Wu, 2008) as well as in Taiwan. It inspires another interesting and important issue: Does the R&D-inducement effect, if any, differ between high-tech and other industries in Taiwan? Paff (2005) finds that state-level R&D incentives do not appear to have equal incentive effect across industries, and the industries she examined are high-tech, R&D intensive industries (biopharmaceuticals and prepackaged software industries). In practice, many so-called traditional industries (usually less R&D-intensive) put up criticism, as R&D tax credits work more favorably for high-tech firms in Taiwan. Actually, innovative behavior is strongly related to the technological environment surrounding a firm's location.

In industries with high technological opportunity, the technological environment faced by these firms which are relatively fertile results in a more prevalent and higher R&D expenditure among firms. Alternatively, the appearance of innovation is relatively rare in the environment of low technological opportunity, implying that the patterns of innovative activity within that industry should be less R&D intensive and fewer firms should engage in R&D. To enforce the policy of R&D tax credits more efficiently, one possible improvement is the setting of various tax credits across industries. Therefore, assessing the potential difference of the R&D-inducement effect of R&D tax credits across industries provides insightful implications for policy implementations.

One primary difficulty encountered when using firm-level data to evaluate the effectiveness of an R&D tax credit within a country is the variation between firms in the effectiveness of the credit (Bloom *et al.* 2003). Most existing studies, by using linear regressions, treat tax incentive as an exogenous variable. However, the differences in tax position and expectations regarding future R&D expenditure induce an endogenous problem on choice of tax credit application. To assess the effect of R&D tax credits, it is important to correct for the selection bias, because the recipients of tax credits may differ systematically in some firm characteristics from non-recipients (Czarnitzki *et al.* 2004). In this paper we adopt a non-parametric technique of propensity score matching (PSM) method developed by Heckman et al. (1997, 1998) to correct the possible selection bias. Moreover, firm heterogeneity is potentially a key factor in influencing the assessment of R&D-inducement effect of R&D tax credit.

Hall and Van Reenen (2000) find that the way in which the R&D tax credit creates heterogeneous emerges in many ways and often perverse incentives has been a key feature of the debate on the desirability of R&D tax credits. While the PSM approach can deal with the selection bias problem, it does not take the unobservable firm heterogeneity into account. Fortunately, there is detailed information concerning the amount of deduction of

R&D of business tax as well as firm characteristics, enabling us to adopt the Generalized Method of Moments (GMM) for panel data model in order to evaluate the impact of R&D tax credits on a firms' R&D activity. Using the adequate instrumental variable to deal with the endogenous variable provides asymptotically efficient estimators even under a weak assumption on the disturbance and is robust in the presence of heteroscedasticity across firms, showing a correlation of disturbances within firms over time.

This paper evaluates the impact of tax credits for R&D and its growth in Taiwanese manufacturing firms. Although this question is not new to the literature, this study has distinct novelties that can contribute to the empirical literature. First, the question, of how and to what extent tax credits stimulate industrial R&D, has attracted widespread international attention among economists with limited empirical studies focused on developed countries such as the U.S., Canada, and France. However, tax incentive policies are worthwhile considerations in not only developed economies, but also for newly-industrialized and developing countries. Taiwan has successfully achieved substantial technological development over the last two decades, and its outstanding performance in innovations makes it an excellent case to investigate the tax incentives issue. Our firm-level evidence from Taiwan provides new evidence to the existing literature that concentrates on advanced countries.

Second, we further separate samples into high-tech and non high-tech firms to examine the potential differences in the effectiveness of an R&D tax credit. It is widely criticized that a uniform tax credit system for all industries is not appropriate, because the degree of R&D activity could differ substantially across industries under various types of technological opportunities. Therefore, examining the potential difference in the effectiveness of R&D tax credits across industries provides insightful reference for the further revision of R&D tax credits. Third, this study employs the propensity score matching (PSM) method to correct the selection bias endogeneity of the innovative activities and R&D tax credits. This enables us to compare the R&D activities of R&D tax credit recipients and non-recipients. Owing to the comprehensive nature of the information on the amount of R&D tax credits contained in our dataset we further examine the marginal, rather than the treatment, effect of R&D tax credits on firms' R&D expenditures. In this context, this study employs the technique of GMM of panel fixed effect to deal with the problem of unobservable firm heterogeneity and then assesses the effect of R&D tax credits on the firms' R&D efforts more appropriately.

The remainder of this paper is organized as follows. The next section provides a brief review of the literature on R&D tax credits. Section 3 introduces Taiwanese R&D incentive measures and describes the data used in this study. Section 4 presents the empirical model and then examines the R&D-inducement effect of an R&D tax credit by using the propensity score matching method. The findings from further investigation into the marginal effect of R&D tax credits on R&D across industries are presented in Section 5. The final section concludes with the main results and their policy implications.

2. Literature Review

While the importance of R&D in economic development and sustainable growth is well-recognized, economists generally think that private R&D is under-investment in terms of social optimal level due to imperfect appropriability conditions of new knowledge (Davis *et al.*, 2000) and financing gaps induced by asymmetric information (Hall, 2002). Therefore, governments generally adopt various policy instruments to foster industrial R&D activity directly or indirectly, such as tax incentives, subsidies, government R&D labs, and investing in higher education.

Two primary policy tools applied by governments to stimulate firms' R&D are direct subsidies and tax incentives. While direct subsidies (either R&D contracts or R&D grants) can increase private R&D investment significantly, they may simply substitute for some

R&D investment that the performing firms otherwise would have prepared to undertake (Wu, 2005) – that is, it crowds out firm-financed R&D expenditure and ultimately has no impact whatsoever on such activities (Wallsten, 2000).[4] Moreover, Wu (2005) argues that public R&D subsidies may negatively affect private R&D investment by reducing the upward pressure on the prices of such R&D inputs as the wages of scientists and engineers. Alternatively, the instrument of tax credits reduces the cost of private R&D and seems to be a market-oriented mechanism, because it leaves the choice of how to conduct and pursue R&D programs to enterprises. Although an R&D tax credit is just one of several policy instruments on R&D and is far from the panacea for failure in the market of innovation, it has become a common strategy in many countries compared with government direct subsidies and/or conducting the R&D program directly (Klette *et al.*, 2000).[5]

The wide and increasing prevalence of R&D tax credits has attracted a high degree of concern among economists and policy makers regarding whether and/or how effective are tax incentives for R&D. An emerging amount of studies have utilized various methodologies to evaluate the effect of the tax system on R&D behavior (cost) since the early 1980s. Hall and Van Reenen (2000) provide a comprehensive summary of the literature and indicate that a dollar in tax credit for R&D stimulates about a dollar of additional R&D expenditure. As the tax treatment of R&D becomes more lenient, they also argue that it is likely that countries will increasingly turn to the tax system and away from direct grants.

There are also some studies on tax incentives examining the impact of fiscal incentives on the level of R&D investment, which mainly concentrate on country or state level. Based on nine OECD countries (Australia, Canada, France, Germany, Italy, Japan, the U.S.

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[4] For the studies of direct subsidies on the R&D activities, please see Özçelik, E and E. Taymaz (2008) for a comprehensive survey.

[5] For the advantages and disadvantages of both tax incentives and direct subsidies for R&D, please see Klette *et al*. (2000) for a detailed discussion.

and the U.K.), Bloom *et al*. (2002) find that tax incentives are effective in increasing R&D intensity after controlling for permanent country-specific characteristics, world macro shocks, and other policy influences. A 10% fall in the cost of R&D stimulates a 1% and 10% rise in the level of R&D in the short and long run, respectively. Guellec and Van Pottelsberghe (2003) investigate the impact of R&D tax incentives on business R&D in seventeen OECD countries and reach similar results showing that tax incentives can effectively stimulate business R&D. Wu (2005) employs data from six states (Arizona, California, Colorado, Illinois, Massachusetts, and New Jersey) in the U.S. to examine the effects of state R&D tax credits on private R&D expenditure within each state. The author shows that the presence of an R&D tax credit results in 75 to 118 more R&D dollars per capita. It suggests that the establishment of a state R&D tax is effective in stimulating more company R&D expenditures, but it does not address the cost of implementing such tax credit programs.[6]

Firm-level evidence on the efficacy of tax incentives is quite rare, owing primarily to data limitations. Koga (2003) examines the effectiveness of R&D tax credits on Japanese manufacturing firms over the period 1989-1998 and especially explores the role of firm size. He finds that R&D tax credits mainly stimulate R&D investment in large firms rather than medium firms. The estimated tax price elasticity for large firms and medium firms are -1.036 and -0.118, respectively. R&D tax credits might be less effective in Japan than in western countries. Examining the same issue for Canadian manufacturing firms over the 1997-2003 period, Baghana and Mohnen (2009) reach a contrasting result compared with the findings of Koga (2003).The estimated short-run price elasticity of R&D is -0.142 for small firms and not significantly different from zero for large firms. The authors claim that the reason is partly due to of the deadweight loss associated with level-based

[6] Wu (2008) further examines the effects of state R&D tax credits on growth in the U.S. high-technology sector. The results show that the initiation of a state R&D tax credit has significant and positive effects on the high-technology establishments per 1,000 of population and the high-technology share of business establishments. It highlights the importance of the role of state R&D tax incentives in technology-based economic development.

R&D tax incentives that is particularly acute for large firms. Paff (2005) examines firms' R&D expenditure in response to an R&D tax credit rate increase in the U.S during 1994-1996 and 1997-1999. Empirical estimates obtained from difference-in-difference provide some evidence that firms increase R&D expenditure significantly, while R&D incentives do not appear to have equal incentive effects across industries. It sheds light on the unequal role played by tax credits for R&D investment across industries. Moreover, she finds much higher tax price elasticity than the existing literature's estimates near unity. One possible reason is that the firms she examines are biopharmaceutical and software firms which are highly R&D-intensive.

Different from previous studies focusing on the tax price elasticity, Czarnitzki *et al.* (2005) use a non-parametric matching approach to compare the R&D expenditure of recipients of tax credits with a hypothetical situation in the absence of R&D credits. From evidence in a large sample of Canadian manufacturing firms, they find that R&D tax credits have a positive impact on firms' R&D decisions to conduct R&D as well as firms' improved performance.

3. Taiwan's R&D Incentives and Data Description

3.1 Taiwan's R&D Tax Credits

Over the past three decades, Taiwan's government has undertaken several measures to encourage firms to devote more to innovative activity and to promote their technological capability. The most well-known industrial technology policy in recent years is the *Statute for Upgrading Industries (SUI)*, which was put into practice on January 1, 1991.[7] Contained within the SUI, there are various articles concerning tax incentives, including: accelerated depreciation (Article 5), investment tax credits for R&D, personnel training, automation and pollution control (Article 6), investment tax credits for the newly

[7] Before 1991, Taiwan's main industrial technology policy was law regarding: *The Enactment of Encouragement Investment.*

emerging, important and strategic industry shareholders (Article 8) as well as five-year holiday or shareholder investment tax credits for the newly emerging, important and strategic industries (Article 9). While the first two are functionally encouraging, the last two are industry specific. The SUI also includes tax credits for those investing in scanty areas (Article 7), aiming to improve the overall investment environment.

Article 6 is the most important policy measure that is particularly relevant to R&D tax credits. More specifically, this tax incentive is the long-standing instrument adopted to encourage firms to promote their R&D activities in Taiwan. Figure 1 depicts trends in aggregate R&D spending and the amounts of R&D tax credits in Taiwan from 1992 onward. It is apparent that the amount of R&D expenditure increased steadily from NT$94.828 billion in 1992 to NT$280.980 billion in 2005. Correspondingly, the amount of R&D tax credits has increased more than ten times from NT$1.529 billion in 1992 to NT$16.318 billion in 2005. Compared with the steadily increasing trend of R&D expenditure, the accelerating trend on the usage of R&D tax credits since the late 1990s seems to suggest that R&D tax credit is quite relevant to R&D investment.

[Insert figure 1 approximating here]

While the previously mentioned literature, such as Koga (2003) and Baghana and Mohnen (2009), reached inconsistent findings in the relationship between R&D-inducement effect of tax incentives and firm size, the policy tool of R&D tax credit is widely criticized as only being beneficial for large firms rather than small and medium-sized enterprises (SMEs) in Taiwan.[8] More importantly, the policies of R&D tax credits in favor of specific industries or firms, which are devoted to specific events, cause the problem of tax base erosion and destroy the fairness of the burden of taxation among firms. Specifically, Taiwan has seen serious fiscal difficulties (the government debt reached NT$4 trillion in 2007), including the pressure from tax shortages. On the other hand, Article 6 of SUI accounts for approximately one third of the NT$100 billion of total

[8] In practice, SMEs account for about 97% of Taiwan's manufacturing sector in terms of firm numbers.

tax revenue loss for the Taiwanese government annually (Lien *et al*. 2007). As a result, the question of whether public support encourages firms to engage in R&D activity has recently become an important and hot issue in Taiwan. This debate is particularly topical, as the *Statute for Upgrading Industries* will expire at the end of 2009 and a new policy is required to be put in place. How does the policy contained in the SUI affect firms' innovation behavior? Should the government extend this statute or terminate it as scheduled? These questions are topical and important from the perspective of both public finance and technology policy.

Aggregate evidence shows that the SUI has stimulated firms' R&D activities and economic growth, e.g. Wang and Chen (1995, 2000), Lee *et al*. (2005), and Yang *et al*. (2006), supporting the claim that this statute should be extended. However, as indicated by Yang *et al*. (2006) in that the tax incentives cause the problem of tax distortion, it is therefore important to clarify the R&D-inducement effect of R&D tax incentives.[9]

Although the discussions regarding the SUI and macroeconomic policy have attracted widespread interest in Taiwan, the question of how R&D tax credits affect firms' R&D investment has not been thoroughly addressed, suggesting the need for more empirical evidence at the firm level to fill this gap as well as to provide new evidence to the existing literature.

3.2 Data Source

On examining the potential impact of tax incentives on firms' R&D activities, one primary obstacle encountered is the availability of detailed information on firms' usage of R&D tax credits. Due to this limitation, we therefore utilize a panel dataset of manufacturing firms which are listed on the Taiwan Stock Exchange (TSE) over the 2001-2005 period. One point worth noting is that firms listed on TSE are medium and large enterprises rather than small firms. Information on firm characteristics is obtained by

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[9] Lien *et al*. (2007) use the macroeconomic model to examine tax credits' economic benefits and costs and propose some directions adjustment of the tax credits policy drawn from their analyses.

matching from various data sources. R&D expenditure and other firm-specific variables, including employment, the date of establishment, fixed capital stock, advertising expenditure, and profitability, are acquired from the databank constructed by the Taiwan Economic Journal (TEJ) company.[10] The deduction of R&D of business tax and export data are taken from the annual finance reports of individual enterprise in each year. Finally, the information on outward foreign direct investment (FDI) is drawn from the notification data from the Investment Commission of Ministry of Economic Affairs. By eliminating a few firms with incomplete data for all the relevant variables, we obtain an unbalanced panel data of 621 enterprises, yielding an overall sample of 3,031 observations. In this study we further separate the full sample into two subgroups: one is the electronics industry, representing the high-tech industry, and the other represents other non-tech industries. While this classification seems to be ad hoc, it is acceptable as it coincides with the cutting point using the average industry R&D intensity as the criteria. We therefore have 1,377 and 1,654 observations for high-tech and non-high-tech firms, respectively. Table 1 summarizes the variable definitions and basic statistics.

[Insert Table 1 approximately here]

Before turning to the empirical estimations, the features of the R&D tax credits taken up by the sample firms are briefly introduced. Table 2 shows some basic statistics for recipients and non-recipients of R&D tax credits in terms of the whole sample, high-tech, and non-high-tech firms, respectively. We clearly see that both average R&D expenditure and the growth rate of R&D expenditure of recipients of tax credits are substantially higher than those of non-recipients, suggesting that the recipients have a better innovation performance than non-recipients in terms of R&D activity. It also implies that there is a potential R&D-enhancing effect for firms receiving the R&D tax credit. In addition, the ratio of receiving R&D tax credits, in terms of firm number, within non-high tech firms is

[10] The Taiwan Economic Journal is a commercial company that has a fine reputation for collecting and summarizing the information for companies listed on the Taiwan Stock Exchange. The TEJ databank is reliable and widely adopted by most universities in Taiwan as well as financial sector firms. This data bank contains comprehensive information for balance sheets, financial statements, annual reports, and so on.

only 12.82% which is much lower than that of their high-tech counterparts at 65.65%. Furthermore, the figures in Table 2 reveal that larger and younger firms are apt to receive the R&D tax credits. However, firms with high capital intensity are not inclined to receive the R&D tax credits, as they have mainly applied for tax credits for automation and pollution control, rather than R&D tax credits, and this has especially been the case with non-high-tech firms.

[Insert Table 2 approximately here]

The preliminary descriptive analyses show that the R&D tax credits seem to act as an inducement to Taiwanese manufacturing firms to engage in R&D activities over the 2001-2005 period. However, R&D tax credits are not the main tax credit measure taken up by firms with high capital intensity. It also highlights the importance of firm heterogeneity affecting the impact of tax incentives on R&D investment.

4. Do R&D Tax Credits Induce More R&D?

4.1 Empirical Setting and Estimating Technique

Unlike previous studies which estimate the tax price elasticity of R&D, we first employ the PSM approach to examine the effectiveness of R&D tax credit in Taiwan - that is, we ask the question: What had the firm done in the absence of R&D tax credits? From the point of econometrics, the PSM approach can effectively deal with the endogenous problem when we evaluate the R&D-inducement effect of tax credits. The effect of R&D tax credit on R&D is much like a "treatment effect". It means that we investigate the question of what would a treated firm (recipients of R&D tax credits) with given characteristics have done if it had not been treated. However, the treated firms are usually not selected randomly from a population, but are self-selected based on certain criteria, inducing the comparison of simple averages of a treatment group and a control group to yield biased estimates of the treatment effect. The propensity score matching (PSM) method developed by Heckman *et al*. (1997, 1998) provides as an appropriate approach.

The concept of a PSM approach compares treated firms with a selected non-recipient group with similar characteristics rather than all non-recipients. The estimation steps are as follows. First, let a dummy variable T equal 1 if the treatment is received; 0 otherwise. We assume:

$$Y_i = \begin{cases} Y_{i0} = \beta_0' X_i + \varepsilon_i & \text{if } T_i = 0 \\ Y_{i1} = \beta_1' X_i + \gamma + \varepsilon_i & \text{if } T_i = 1 \end{cases} \tag{1}$$

Here, Y denotes R&D activity, β and X are the respective vectors of parameters (including a constant term) and exogenous variables. Term ε is a random error term with zero expectation. This term picks up the effects of unobserved factors that may affect the outcome, but are uncorrelated with the variables X.

We let g_{1i} indicate the R&D expenditure (or growth rate of R&D expenditure, *G_RD*) of firm *i* if it did not receive R&D tax credits in the initial year, but did so after 1 year - that is, treatment occurs and T equals 1. Alternatively, assume g_{0i} denotes the R&D expenditure (or growth rate of R&D expenditure) for firms which did not receive R&D tax credits during the period (treatment does not occur, T=0). The average treatment effect is therefore:

$$E(g_{1i} - g_{0i} \mid T_i = 1) = E(g_{1i} \mid T_i = 1) - E(g_{0i} \mid T_i = 1) \tag{2}$$

One problem obviously arises: while the outcome of the treated firms (recipients of R&D tax credits) is observable, it is not the case for the non-recipients - that is, g_{0i} is unobservable. What would these firms have realized if they had not received the treatment? The above causal inference relies heavily on construction of counterfactual observations. Therefore, we need rich data on firms that have similar observable characteristics in the initial period, but did not receive R&D tax credit during the period. The average R&D activity $\mathrm{E}(\mathrm{g}_{0i} \mid \mathrm{T}_i = 1)$ is measured by $\mathrm{E}(\mathrm{g}_{0i} \mid \mathrm{X}_i, \mathrm{T}_i = 0)$ instead.

To construct a valid control group, Rosenbaum and Rubin (1983) suggest matching on the propensity score with the probability of receiving a treatment conditional on the covariates. Thus, we assume selection in the program is governed by the latent regression:

$$T_i^* = \delta' Z_i + u_i \qquad T_i = 1 \quad \text{if} \quad T_i^* > 0\ , \ \ 0 \ \ \text{otherwise} \tag{3}$$

Here, δ denotes coefficient and Z denotes a vector of determinants influencing a firm's decision regarding to R&D tax credits. This enables us to compute the probability of a firm's decision to adopt R&D tax credits. With the propensity score of choosing to receive R&D tax credits, we can run the matching algorithm and find the appropriate counterfactual.

Within the matching process, the most important issue is to balance the distribution of the pre-treatment observable characteristics between the treatment and control groups. We therefore adopt Leuven and Sianesi's (2003) approach to proceed with the estimation. To ensure the validity of the results, three different criteria are adopted to determine the optimal matching: kernel matching, nearest-neighbor matching method, and caliper matching.[11]

4.2 Empirical Results

We first estimate the Logit model to get the propensity of a firm's decision on whether or not to apply for the R&D tax credits. The second step is to use the predicted propensity scores to match R&D tax credit recipients with non-recipients which possess similar observable firm characteristics. In the first stage of the Logit regression, seven variables are included: a dummy variable for the firm's previous R&D status (*D_RDSTA*), logarithm of firm size (ln*SIZE*), firm age (*AGE*), logarithm of capital to labor ratio (ln*KL*), one year lag of advertisement intensity (*ADVR1*), one year lag of profitability (*PROFIT1*), and the export ratio (*EXPR*). Table 3 displays the estimation results for all manufacturing firms, high-tech firms, and non-high-tech firms.

[11] For an extensive discussion of matching methods, see Heckman *et al*. (1998).

[Insert Table 3 approximately here]

Estimates obtained by using the entire sample, high-tech firms, and non-high-tech firms are quite similar, but the impacts of determinants are less significant for non-high-tech firms. The propensity of manufacturing firms to apply for R&D tax credits is found to be positively associated with previous R&D status, firm size, profitability, and the export ratio. The results suggest that R&D experience, larger, more profitable, and export-oriented firms have a higher probability of self-selection for becoming R&D tax credit users. This is economically intuitive owing to the fact that firms may possess these characteristics which make them particularly innovation-prone, i.e., more likely to engage in R&D. However, firm age, capital intensity, and advertisement intensity appear to have negative impacts on the propensity to apply for R&D tax credits. This suggests that young firms which engage in R&D tend to rely more heavily on deduction of R&D of business tax. On the other hand, the negative impact of capital intensity on the propensity for R&D tax credits is partly because firms with higher capital intensity tend to apply tax credits for automation and pollution control rather than for R&D tax credits.

We next retrieve the propensity scores from the Logit model to match R&D tax credit recipients with non-recipients under similar observable characteristics. The outcome variables are the growth rate of R&D expenditure and a firm's current R&D expenditure. Table 4 shows the estimation results for all manufacturing firms, reporting the differences in the growth rate of R&D expenditure and R&D expenditures for recipients and non-recipients of R&D tax credits.

[Insert table 4 approximately here]

Column (1) shows the treatment effect of R&D tax credits on the growth rate of firms' R&D investment. After controlling the non-random selection of the treatment groups, the matching results for recipients versus non-recipients of R&D tax credit suggest that the growth rate of R&D expenditure is significantly positive except for the nearest neighbor matching method during the first year following the receipt of tax credits. The results suggest a positive impact of policy incentive on firms' R&D activity, and that recipients of R&D tax credits reach an R&D growth rate ranging from 15.11% to 16.52% higher than their non-recipient counterparts, on average.

From an alternative point of R&D activity in terms of current R&D expenditure, various matching methods show that all the coefficients are positive and statistically significant at the 1% level in column (2). It is surprising to see that recipients of R&D tax credits experience a dramatically higher level of R&D expenditure than their non-recipient counterparts, ranging from 89.79% to 95.98%. This result suggests the existence of a strong R&D-enhancing effect brought on by the R&D tax credits.

Using the technique of PSM approach, Czarnitzki *et al*. (2005) find that about 29% of firms that have used R&D tax credits would not have conducted R&D in the absence of this program in Canada. While the innovation outputs we discuss are different from those in Czarnitzki *et al*. (2005), our findings lend evidence that R&D preferential policy really has induced additional engagement of R&D investment in Taiwan.

Does the R&D-inducement effect differ between high-tech and non-high-tech industries? Turning to the separated estimates for high-tech firms and non-high-tech firms, Table 5 displays the results obtained using various matching methods. While the estimated results overall suggest a significantly positive impact on R&D growth and R&D expenditure for both high-tech and non-high-tech firms, the corresponding R&D-inducement effect seems to vary substantially between them. Various matching methods reach more consistent results for non-high-tech firms, and recipients of R&D tax credits will have a higher (32%) R&D growth and a higher (64%) R&D expenditure than non-recipients.

[Insert table 5 approximately here]

Results obtained from various matching methods differ significantly. The R&D inducement effect obtained by nearest-neighbor matching is dramatically higher than those obtained by the other two matching methods. Within high-tech firms, the corresponding inducement effects on R&D growth and R&D investment are about 20% and 86%, respectively. This suggests that the treatment effect of R&D tax credits on a firm's R&D growth seems to be stronger for non-high-tech firms than for their high-tech counterparts. In contrast, the R&D-inducement impact on R&D expenditure seems to be higher for high-tech firms, probably from the fact that high-tech firms usually devote more outlays on R&D investment and they pay more attention to applying for R&D tax credits.

Drawn from previous analyses, public R&D incentives will not crowd out firms' R&D investment in Taiwan, while private R&D expenditure increases are significantly induced by R&D tax credits. The inducement effect appears to be accelerating, because recipients of R&D tax credits experience a much higher growth rate on R&D expenditure. Moreover, we find that the impact of R&D tax credits differs across industries, which is consistent with findings in Paff (2005).

3.3 Assessing the Matching Quality

As discussed in subsection 3.1, the basic concept of the PSM approach is in constructing the matched control group in the context of the matching analysis. In the matching process, it relies on the idea of balancing the sample of tax credit participants and comparable non-participants. Remaining differences in the outcome variable between two groups are attributed to the treatment (Heckman *et al.* 1997). This reveals that the distribution of the pre-treatment observable characteristics between the treatment and control groups is the key factor to determine whether the matching results are reliable. We therefore assess the balancing of the distribution of covariates used in the propensity scores estimation within each of the matching exercises. The detailed results for the matching statistics are shown in Tables 6 and 7.

[Insert table 6 and table 7 approximately here]

Table 6 reports the standard t-test for the equality of mean sample values along with its p-value. Drawn from the figures of the t-tests, we fail to reject the null hypothesis that the mean is equal between the treatment and control groups for all variables in various matching methods. This result indicates that the recipients of R&D tax credits and the matched non-recipients are not significantly different from each other concerning the set of variables used for matching, implying that the treated and the matched control groups have similar characteristics on average.

Table 7 reports the standardized bias, the joint significance tests, and pseudo-R^2 within the matching process. Figures in Panel A are the reduction in the absolute bias obtained after matching the control and treatment units. Because the bias has been significantly reduced from 88% to 100%, it suggests that the matching procedure is effective.[12] In addition, the mean absolute bias in the matched sample ranges between 1.6 and 1.9, whereas it is nearly 50 in the unmatched sample. Based on the suggested criterion proposed by Sianesi (2004), we check the joint statistical significance of the covariates and the pseudo-R^2 of the propensity score in the estimation procedures for the unmatched and matched samples. As shown in the second bottom row of Panel B, the pseudo-R^2 comes to a value close to zero in the propensity score estimation that uses the recipient firms and the matched control units. Finally, the results of the LR-test also provide evidence that the matching has successfully eliminated any systematic observable differences between the treated and control groups. In sum, the above statistical tests lend strong support to the validity of the previous matching results.

5. Further Investigation into the Marginal Effect of R&D Tax Credits

The main advantage of the PSM approach is that it helps to reduce sampling selection bias arising from observable differences between the treatment and control groups, while it suffers a serious drawback in that it does not control for the unobservable characteristics across firms that may exist between recipients and non-recipients of R&D tax credits.

[12] For the criteria on the effectiveness of matching process, please refer to Heckman *et al*. (1997, 1998)

Fortunately, one advantage of our dataset is that it contains the amount of R&D tax credits, enabling us to examine the marginal rather than the treatment effect of R&D tax credits on firms' R&D activities. Thus, we further include the taxation remit of the R&D tax credits and employ the technique of GMM for panel data model to examine the marginal effect of tax credits on firms' R&D expenditure.

5.1 Empirical Specification and Estimation Techniques

To estimate the impact of tax credits on firms' R&D spending, this study refers to previous studies that discuss the determinants of R&D and then specifies the following simple log-linear equation:

$$\begin{aligned} ln\,RD_{it} &= \beta_0 + \beta_1\, ln\,RDTAX_{it} + \beta_2\, ln\,SIZE_{it} + \beta_3 AGE_{it} + \beta_4\, ln\,KL_{it} \\ &\quad + \beta_5\, ln\,AD1_{it} + \beta_6 PROFIT1_{it} + \beta_7\, ln\,EXP_{it} + \beta_8\, ln\,FDI_{it} + \varepsilon_{it} \end{aligned} \tag{4}$$

The dependent variable $\ln RD_{it}$ denotes the logarithm of R&D spending of firm *i* in year *t*. As for the explanatory variables, theoretical and empirical studies have identified various determinants. Because this study aims to examine the marginal effect of the R&D tax credits on firms' R&D expenditure, the taxation remit of a firm's R&D tax credits *RDTAX* in logarithmic form (ln*RDTAX*) is the primary variable in equation (4).

The explanatory variables include the following three firm characteristics; namely, firm size (*SIZE*), firm age (*AGE*), and capital intensity (*KL*). The size of a firm is measured by the logarithm of employment. Large firms usually have obvious advantages in terms of their ability to support R&D. The famous Schumpeter hypothesis points out that firms wielding monopolistic power (usually larger firms) tend to engage in innovation and this hypothesis has been supported by many empirical studies.[13] Alternatively, Audretsch and Acs (1991) find that small firms tend to outweigh large firms in terms of innovation performance when operating in a more technology-intensive environment. As for the potential impact of the firm's age on R&D, there is a potential learning-by-doing effect on innovation and that incumbent firms have an advantage over their younger counterparts in

[13] For example, please see Lerner (1995) and Hall and Ziedonis (2001).

terms of R&D management. Therefore, a positive relationship between firm age and R&D is expected. The term ln*KL* denotes a firm's capital intensity, measured as the logarithm of physical capital per employee. A firm with higher capital intensity usually engages in more R&D to improve its production process in Taiwan. We therefore observe a positive association between capital intensity and R&D.

Advertising expenditure (*AD*) is an important strategy conducted by firms in order to respond to the competition in markets, and this variable is employed to proxy the toughness in market competition. The financing of innovation has been widely studied in the previous literature.[14] Thus, a firm's profitability (*PROFIT*) is also included to measure the availability of internal financial resources and is expected to have a positive impact on a firm's innovation. To avoid the simultaneous causality between a firm's conduct and performance, both above variables enter the equation in the form of a lag of one year. Under the circumstance towards globalization, firms have more opportunities to acquire technological knowledge through knowledge spillovers in international markets and then spur their additional R&D activity.[15] We therefore include exports (*EXP*) and outward foreign direct investment (*FDI*) as explanatory variables.

5.2 Estimation of the Results

One econometric problem that suffers in the estimation procedure is the endogenous causality between R&D tax credit and R&D investment, which is also the reason why we previously adopted the PSM approach. Therefore, we use the Wu-Hausman test to detect the existence of the endogenous problem. If no endogeneity is found, then we employ the technique of the panel fixed effect model to deal with the unobserved firm heterogeneity. Correspondingly, when endogeneity is detected, the GMM method provides an alternative technique. Using the adequate instrumental variable to deal with the endogenous variable, this approach provides asymptotically efficient estimators even under a weak assumption

[14] For the importance of financing on firms' R&D, please see Hall (2002) for a comprehensive survey.
[15] Please see Yang et al. (2009).

on the disturbance and is robust in the presence of heteroscedasticity across firms, which shows a correlation of disturbances within countries over time.

The testing results indicate that there is an endogenous causality between R&D tax credits and a firm's R&D investment for the entire sample and the category of high-tech firms, but this endogenous problem is not significant among non-high-tech firms.[16] Therefore, we adopt the technique of the GMM to conduct the empirical estimation for the entire sample and high-tech firms.[17] In addition, the technique of the panel fixed effect model is employed to estimate the impact of tax credits on R&D expenditure for non-high-tech firms. Table 8 reports a series of estimates of the R&D equation specified in equation (4). Left and middle columns are estimates obtained from the GMM fixed effect model for all firms and high-tech firms, respectively. The right column of Table 8 displays the results of the fixed effect model for non-high-tech firms.

[Insert Table 8 approximately here]

To what extent does the R&D tax credit stimulate private R&D expenditure? We first look at the variable of concern in this study: ln*RDTAX*. The estimated coefficients for the variable of R&D tax credits are positive and statistically significant at least at the 5% statistical level in all estimates, after controlling for other potential influences. The result is consistent with the previous findings in the PSM estimates that R&D tax credits do foster firms to increase their R&D investment. The estimated elasticity of R&D with respect to R&D tax credits is 0.197 for all firms, 0.149 for high-tech firms, and 0.081 for non-high-tech firms. While the marginal effects of R&D tax credits on R&D expenditure for high-tech and non-high-tech firms are estimated using different econometric techniques, the higher coefficient attached with R&D tax credit variable in column (2)

[16] To save space, the estimating results of Wu-Hausman are not shown in this study, but are available upon request from the authors.

[17] We adopt a one-year lag variable of R&D tax credits as the instrumental variable for R&D tax credits. Before discussing the impacts of determinants, we have carefully assessed the effectiveness of the instrumental variable. Using the F-test developed by Staiger and Stock (1997), the statistic value shows that the null hypothesis is rejected, suggesting that the instrumental variable used in this study is effective.

suggests that the tax policy is more relevant to high-tech firms' R&D expenditures. This finding is consistent with that in previous PSM estimates.

The estimated coefficient on ln*RDTAX* suggests that a one dollar taxation remit of R&D tax credit induces 0.197 dollars more of R&D expenditure in Taiwan. The marginal effect of R&D tax credits on a firm's R&D activities is similar to the finding in Lan and Wang (1992),[18] suggesting that the R&D preferential policy of tax credit has induced additional R&D investment engaged by firms. However, the effect of the R&D tax credits seems to be more relevant to high-tech rather than non-high-tech firms.

With respect to observed characteristics, the estimates show similar results for both of the samples of all firms and high-tech firms. The positive impact of firm size on R&D expenditure supports Schumpeter's hypothesis that large firms (usually having market power) are more inclined to have the wherewithal to exploit innovations. The results also show that capital intensity serves as a crucial factor of innovation propensity. The amount of export (ln*EXP*) is found to have a significantly positive impact on firms' R&D, lending evidence to the importance of international linkage on domestic R&D activity. However, the results of the fixed effects model for non-high-tech firms are quite poor.

To provide a more precise observation on the question of the importance of the tax incentive on fostering a firm's R&D activities, this study further estimates equation (4) using data year-by-year to obtain the elasticity of R&D with respect to R&D tax credits for individual year. Table 9 summarizes the results.

[Insert table 9 approximately here]

The estimated results for various years are quite similar, suggesting that the impacts of determinants did not change substantially during the 2001-2005 period. More importantly, the estimated elasticity are 0.184 in 2001, 0.346 in 2002, 0.304 in 2003, 0.324 in 2004, and 0.361 in 2005. These results suggest that one dollar of taxation remit for investment in

[18] Lan and Wang (1992) investigate the impact of R&D tax incentives on R&D expenditure by using 124 Taiwanese manufacturing industries. Their results suggest that the elasticity of R&D with respect to R&D tax credits is 0.166 on average.

R&D leads the sample firms to increase their spending on R&D by 0.184 dollars 2001 and this gradually increases to 0.361 dollars in 2005. According to the R&D data contained in our sample firms that are listed on TSE, it implies that the induced R&D expenditure brought on by R&D tax credits ranged from NT$9.399 million in 2001 to NT$30.495 million in 2005.

While the induced R&D expenditure has been calculated based on the estimated elasticity, it does not give a clear picture: "To what extent is firms' R&D investment induced by tax credits"? We therefore calculate the average share of R&D spending which was induced by R&D tax credits, in order to lend an insightful implication. From the pie charts in Figure 2 we clearly observe that the corresponding shares to R&D spending range from 5.30% to 13.91%. This result indicates a considerable role played by tax incentive policies on private R&D in Taiwan.

[Insert Figure 2 approximately here]

To summarize, the above analyses give strong evidence for the positive impact of R&D tax credits on private R&D. Because the way of calculating R&D elasticity is different from that in Hall and Van Reenen (2000) and Bloom *et al*. (2003), we cannot compare the impact of a tax incentive on the level of R&D expenditure in Taiwan with that in OECD countries directly. Even though the econometric estimates show a considerable R&D-inducement effect brought on by the tax incentives in Taiwan, it is an encouraging result from the government's point of view having implemented policy tools, mainly the Statute for Upgrading Industries (SUI), to encourage and promote private R&D.

6. Concluding Remarks and Policy Implications

Although the effectiveness of fiscal incentives for private R&D has attracted widespread interest in many developed countries, it has received much less attention in the newly industrialized economies (NIEs) and developing countries. Taiwan is one of the most successful NIEs regarding innovative performance in the world over the past two decades, especially in the technological field of electronics. One possible reason is that the government has long-standing tax incentives adopted to foster private R&D. Economists have traditionally been skeptical over the efficacy of any fiscal provisions. Is the R&D tax credit really an effective mechanism to stimulate firms to invest more R&D? This issue is particularly important and topical to Taiwan, because the tax credit policy attached in SUI will expire at the end of 2009. The government must decide in the near future whether to extend the tax credit policy or make a change in part, if not completely.

This paper aims to evaluate the impact of tax credits for R&D activity in Taiwan. Different from previous studies focusing on estimating the tax price elasticity of R&D based on the information of R&D cost, we first adopt the propensity score matching to simulate the scenario of how the treatment of R&D tax credits affects firms' R&D activity. The PSM approach helps to correct the selection bias that is not well dealt with in previous studies. In the second step, to control for the unobservable firm heterogeneity between treated and control groups which may affect R&D activity, this study employs the technique of the GMM for a panel data model to estimate the elasticity of R&D with respect to tax credits.

Using a panel dataset of 621 enterprises listed on the Taiwan Stock Exchange over the period 2001-2005, the empirical findings are summarized as follows. First, the PSM estimates show that R&D tax credits induce a higher (14.47%) growth rate of R&D expenditure and a higher (93.53%) R&D expenditure on average. It suggests that there is no crowding-out effect of public R&D support on private R&D, whereas there is a strong impact of R&D tax credits on private R&D. Second, the R&D-inducement effect of tax credit is found to differ between high-tech and non-high-tech firms. Specifically, non-high-tech recipients of R&D tax credits seem to have a higher growth rate of R&D expenditure than recipients among high-tech firms. On the other hand, high-tech recipients experienced a high R&D expenditure level compared to non-recipients with similar characteristics. Third, estimates obtained by the technique of the GMM for the panel data model show that the elasticity of R&D with respect to taxation remit is 0.197 on average, and it varies substantially over the years. Specifically, the induced R&D expenditure brought on by tax credits accounts for 5.30% to 13.91% of sample firms' R&D in various years. This suggests the considerable impact of tax credit on private R&D in Taiwan.

Drawn from above analyses, several policy implications are inspired. First, as the R&D-inducement effect of R&D tax credits is found to be significantly positive in all estimates, it suggests that the R&D preferential policy is indeed an effective policy tool to foster private R&D activity, supporting previous aggregate evidence. Second, as the effectiveness of R&D tax credits has been supported in this study, this policy tool can be continuously implemented after SUI expires. Third, since the impact of R&D tax credits is different between high-tech and non-high-tech firms, the government should think of how to adjust the reduction rate of taxation for R&D investment across industries.

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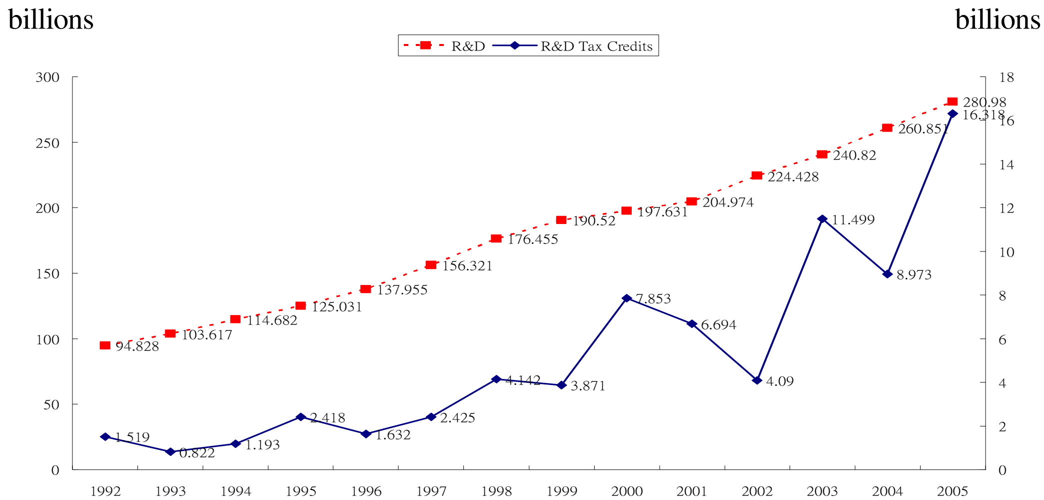
Figure 1   R&D Expenditure and R&D Tax Credits, 1992-2005



Data Source: Indicators of Science and Technology, Taiwan, various issues.
Yearbook of Tax Statistics, Republic of China, various issues.

Figure 2 Share of Induced R&D by Tax Credits to Total R&D, 2001-2005

Notes: a. ■ represents R&D spending which was induced by R&D tax credits.

b. ⬚ represents R&D spending for sample firms.

c. The share of average R&D spending induced by R&D tax credits on the average R&D spending.

Table 1 Variable Definitions and Basic Statistics 2001-2005

Variables	Definition	All Firms	High-Tech Firms	Non-High-Tech Firms
G_RD	Growth rate of R&D expenditure (%)	9.94	24.58	-2.09
		(171.292)	(151.176)	(185.39)
RD	R&D expenditure (NT$ million)	214.537	408.269	53.250
		(781.716)	(1112.215)	(181.950)
RDTAX	R&D tax credits (NT$ million)	73.220	133.182	12.503
		(525.203)	(725.679)	(121.577)
D_RDTAX	Dummy variable	0.368	0.656	0.128
	A firm with R&D tax credits =1	(0.482)	(0.475)	(0.334)
SIZE	Firm Size: number of employees	976.353	1169.513	815.542
		(1972.7)	(2470.633)	(1412.519)
AGE	Firm Age: surveyed year minus the starting year	24.740	17.664	33.081
		(12.567)	(9.052)	(10.906)
KL	Capital intensity: the ratio of fixed capital to employee	5.392	2.736	7.602
	(NT$ million per capital)	(10.861)	(4.920)	(13.613)
AD	Advertising expenditure (NT$ million)	41.430	38.684	43.716
		(232.834)	(278.969)	(185.951)
PROFIT	Ratio of profit to sales (%)	10.735	2.138	17.892
		(352.028)	(521.935)	(16.654)
FDI	Value of outward FDI (NT$ million)	220.010	303.809	150.475
		(1079.022)	(1391.737)	(716.425)
EXP	Export value (NT$ million)	6178.962	10949.64	2211.891
		(24489.65)	(34792.41)	(7590.328)
OBS	Sample size	3031	1377	1654

Note: The means and standard errors are calculated by pooling data for the 2001-2005 period.

Table 2 Firm Details for Recipients and Non-recipients of R&D Tax Credits, 2001-2005

	All firms		High-tech firms		Non-high-tech firms	
	User	Non-user	User	Non-user	User	Non-user
R&D expenditure (NT$ million)	424.359	92.260	493.435	245.500	129.807	41.995
Growth of R&D	21.77%	3.09%	23.63%	26.40%	13.94%	-4.45%
Number of employees	1298.989	788.332	1307.777	905.264	1261.519	749.976
Age of firm	19.904	28.523	16.698	19.512	33.528	32.981
Capital Intensity (NT$ million)	2.826	6.887	2.582	3.030	3.864	8.152
Number of observations	1116 (36.82%)	1915 (63.18%)	904 (65.65%)	473 (34.35%)	212 (12.82%)	1442 (87.18%)

Table 3 Propensity to R&D Tax Credit Recipients－Logit Model

	All Firms	High-Tech Firms	Non-High-Tech Firms
D_RDSTA	3.636***	3.391***	3.401***
	(0.460)	(0.603)	(0.717)
lnSIZE	0.305***	0.146**	0.377***
	(0.0466)	(0.061)	(0.088)
AGE	-0.046***	-0.029***	-0.005
	(0.005)	(0.008)	(0.009)
lnKL	-0.544***	-0.154	-0.342
	(0.115)	(0.160)	(0.217)
ADVR1	-1.344***	-2.244**	-0.642
	(0.391)	(1.024)	(0.466)
PROFIT1	0.021***	0.025***	0.008
	(0.004)	(0.005)	(0.008)
EXPR	0.007***	0.010***	-0.006*
	(0.002)	(0.002)	(0.003)
CON	-3.482***	-3.599***	-5.587***
	(0.618)	(0.802)	(1.132)
Pseudo R^2	0.211	0.117	0.111
Log likelihood	-1277.043	-706.299	-468.960

Notes: (1) Figures in parentheses are standard deviations. (2) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (3) The dummy variable D_RDSTA, which equals unity for firms, exhibits positive R&D expenditures during the past four years.

Table 4 Treatment Effect of R&D Tax Credits for All Firms

	R&D Growth	RD
	(1)	(2)
Kernel	0.165*	0.948***
bwidth=0.06	(1.88)	(4.46)
Nearest	0.118	0.960***
neighbor	(1.05)	(4.49)
Caliper	0.151*	0.898***
caliper=0.01	(1.67)	(4.10)

Notes: (1) Figures in parentheses are t-values. (2) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (3) The propensity score function includes D_RDSTA, lnSIZE, AGE, lnKL, ADVR1, PROFIT1, and EXPR

Table 5 Treatment Effect of R&D Tax Credits for High-tech and Non-high-tech Firms

	High-Tech Firms		Non-High-Tech Firms	
	R&D Growth	RD	RD Growth	RD
Kernel	0.126	0.769***	0.305***	0.687***
bwidth=0.06	(1.31)	(2.95)	(2.18)	(2.41)
Nearest	0.341***	1.042***	0.346	0.575
neighbor	(3.72)	(4.51)	(1.55)	(1.50)
Caliper	0.145*	0.775***	0.310***	0.660***
caliper=0.01	(1.74)	(3.35)	(2.14)	(2.24)

Notes: (1) Figures in parentheses are t-values. (2) ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (3) The propensity score function includes D_RDSTA, lnSIZE, AGE, lnKL, ADVR1, PROFIT1, and EXPR

Table 6 Matching Covariates Balancing Property: Summary Statistics and Test Statistics for All Firms

		Kernel				Nearest Neighbor				Caliper			
		Mean		t-test		Mean		t-test		Mean		t-test	
Variables	Sample	Treated	Control	t	p>|t|	Treated	Control	t	p>|t|	Treated	Control	t	p>|t|
D_RDTAX	Unmatched	0.995	0.721	19.56	0.000	0.995	0.721	19.56	0.000	0.995	0.721	19.56	0.000
	Matched	0.995	0.992	0.83	0.406	0.995	0.995	0.00	1.000	0.995	0.994	0.24	0.812
lnSIZE	Unmatched	6.325	5.943	8.35	0.000	6.325	5.943	8.35	0.000	6.325	5.943	8.35	0.000
	Matched	6.344	6.327	0.36	0.718	6.344	6.318	0.55	0.584	6.346	6.3359	0.20	0.838
AGE	Unmatched	19.904	28.523	-18.2	0.000	19.904	28.523	-18.22	0.000	19.904	28.523	-18.22	0.000
	Matched	20.829	21.067	-0.51	0.611	20.829	20.792	0.08	0.938	20.844	20.994	-0.32	0.750
lnKL	Unmatched	3.120	3.351	-11.6	0.000	3.120	3.351	-11.60	0.000	3.120	3.3513	-11.60	0.000
	Matched	3.127	3.112	0.80	0.424	3.127	3.098	1.53	0.126	3.127	3.108	1.01	0.314
ADVR1	Unmatched	0.039	0.077	-5.8	0.000	0.039	0.077	-5.86	0.000	0.039	0.077	-5.86	0.000
	Matched	0.041	0.045	-0.88	0.379	0.041	0.043	-0.53	0.599	0.041	0.045	-0.86	0.392
PROFIT1	Unmatched	21.998	8.210	1.09	0.275	21.998	8.210	1.09	0.275	21.998	8.210	1.09	0.275
	Matched	22.038	21.992	0.07	0.944	22.038	21.984	0.08	0.932	21.966	21.985	-0.03	0.976
EXPR	Unmatched	62.631	34.788	21.42	0.000	62.631	34.788	21.42	0.000	62.631	34.788	21.42	0.000
	Matched	62.594	63.598	-0.72	0.469	62.594	61.895	0.50	0.617	62.584	63.353	-0.55	0.581

Notes: The p-value of the t-test represents the equality of means in the treated and control groups.

Table 7 Matching Covariates Balancing Property: The Standardized Bias and the Joint Significance Tests for All Firms

Panel A

		Kernel		Nearest Neighbor		Caliper	
Variables	Sample	% bias	|bias|	% bias	|bias|	% bias	|bias|
D_RDTAX	Unmatched	85.5		85.5		85.5	
	Matched	0.9	98.9	0.0	100.0	0.2	99.7
lnSIZE	Unmatched	31.		31.7		31.7	
	Matched	1.5	95.4	2.2	93.1	0.8	97.4
AGE	Unmatched	-73.4		-73.4		-73.4	
	Matched	-2.0	97.2	0.3	99.6	-1.3	98.3
lnKL	Unmatched	-45.1		-45.1		-45.1	
	Matched	3.0	93.3	5.8	87.2	3.8	91.5
ADVR1	Unmatched	-23.4		-23.4		-23.4	
	Matched	-2.9	87.6	-1.7	92.7	-2.8	88.0
PROFIT1	Unmatched	4.7		4.7		4.7	
	Matched	0.0	99.7	0.0	99.6	-0.0	99.9
EXPR	Unmatched	83.5		83.5		83.5	
	Matched	-3.0	96.4	2.1	97.5	-2.3	97.2

Panel B

	Kernel		Nearest Neighbor		Caliper	
|bias| summary statistics:	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
Mean	49.609	1.908	49.609	1.726	49.609	1.616
Std. Dev.	31.738	1.172	31.738	2.026	31.738	1.419
Maximum	85.464	3.034	85.464	5.775	85.464	3.841
Minimum	4.659	0015	4.659	0	4.659	0006
Pseudo R^2	0.210	0.001	0.210	0.001	0.210	0.001
LR test p-value	0.000	0.857	0.000	0.866	0.000	0.940

Notes: % bias is the standardized bias as suggested by Rosenbaum and Rubin (1985) reported together with the achieved percentage reduction in |bias|.

Table 8 R&D Effects of R&D Tax Credits

	(1) All Firms	(2) High-Tech Firms	(3) Non-High-Tech Firms
	Panel Fixed GMM	Panel Fixed GMM	Fixed Effects
lnRDTAX	0.197**	0.151**	0.081***
	(0.085)	(0.068)	(0.024)
lnSIZE	0.397*	0.426*	0.485*
	(0.214)	(0.244)	(0.275)
AGE	0.035	0.054*	0.023
	(0.031)	(0.031)	(0.041)
lnKL	0.441*	0.646***	0.270
	(0.241)	(0.247)	(0.416)
lnAD1	-0.009	0.011	-0.044**
	(0.011)	(0.011)	(0.023)
PROFIT1	-0.005	-0.002	-0.007
	(0.005)	(0.005)	(0.010)
lnEXP	0.054**	0.122***	0.040
	(0.024)	(0.031)	(0.036)
lnFDI	-0.001	-0.005	0.006
	(0.007)	(0.007)	(0.013)
Constant	2.983	2.546*	2.426
	(1.912)	(1.480)	(3.191)
# of obs.	3031	1377	1654

Notes: Figures in parentheses are standard deviations. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 9 R&D-Inducement Effects of R&D Tax Credits in Various Years

	2001	2002	2003	2004	2005
lnRDTAX	0.184***	0.346***	0.304***	0.324***	0.361***
	(0.051)	(0.060)	(0.052)	(0.048)	(0.046)
lnSIZE	0.783***	0.732***	0.557***	0.671***	0.560***
	(0.183)	(0.179)	(0.162)	(0.153)	(0.162)
AGE	-0.067***	-0.026	-0.028	-0.027	-0.031**
	(0.016)	(0.017)	(0.016)	(0.015)	(0.015)
lnKL	-0.565	-0.731**	-0.707**	-0.677**	-0.383
	(0.370)	(0.359)	(0.342)	(0.318)	(0.334)
lnAD1	0.036	0.034	0.080***	0.048**	0.073***
	(0.035)	(0.031)	(0.030)	(0.027)	(0.028)
PROFIT1	0.058***	0.030***	0.031***	0.033***	0.35E-03*
	(0.012)	(0.011)	(0.012)	(0.011)	(0.196E-03)
lnEXP	0.339***	0.257***	0.326***	0.303***	0.281***
	(0.050)	(0.048)	(0.046)	(0.042)	(0.045)
lnFDI	0.012	0.009	0.035	0.031	0.017
	(0.030)	(0.027)	(0.028)	(0.028)	(0.032)
Constant	1.136	1.943	1.758	1.250	1.873
	(1.512)	(1.512)	(1.443)	(1.319)	(1.312)
R^2	0.379	0.373	0.392	0.428	0.405
# of obs.	603	606	608	606	608

Notes: Figures in parentheses are standard deviations. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.