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. The propensity score matching (PSM) estimates show that recipients of R&D tax credits appear on average to have 53.80 % higher R&D expenditures than that they do without receiving tax credits, while there is no significantly higher growth rate of R&D expenditure. This study further employs the panel instrumental variable (IV) and generalized method of moment (GMM) techniques to control for endogeneity of R&D tax credits and firm heterogeneity in determining R&D expenditure. The R&D tax credit is witnessed to exhibit a significantly positive influence on R&D expenditure and its growth, especially for electronics firms. The marginal effect is moderate, ranging from 0.094 to 0.120. Specifically, the R&D elasticity concerning tax credits tends to increase gradually along with the approaching expiration of R&D tax credits measure, lending a supportive view on its efficacy.

Key words: R&D, Tax, Propensity Score Matching
JEL classification: H25, H32, K34, O32, O38

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1. Introduction

Most empirical studies and endogenous growth theories have highlighted the importance of innovation to economic growth.[1] Many countries have also attempted to create a favorable innovation environment and protective regularity, aiming to promote R&D in firms and consequently to contribute to sustainable economic growth. Essentially, R&D is uncertain and both time- and money-consuming. It is also recognized to possess public good characteristics, thereby preventing the market from providing sufficient quantities of R&D from the perspective of social return. To bridge the gap between private and social rate of return and foster industrial R&D activity, various policy measures have been launched. Specifically, the R&D tax credit has become increasingly popular in 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 during the past two decades with its counterparts among leading countries, especially in the electronics industry. Her R&D/GDP ratio, a simple measure of a knowledge-intensive economy, rose from 1.62 % in 1990 to 2.78 % in 2008 gradually, which was a little higher than corresponding ratios of 2.77 % and 2.64 % in the U.S. and Germany in 2008.[3] As for R&D output, Taiwan has recorded extremely fast growth both domestically and in the U.S. Taiwan not only placed 4th in the world in terms of the quantity of its U.S. patents since 2003, but also ranked high in terms of patents per capita, compared with G7 countries and the other "Asian Tigers" (Trajtenberg, 2001). This achievement is rare in the developing world and is almost nonexistent within or outside of Asia.

[1] See Acemoglu *et al.* (2006) for a comprehensive survey on the theoretical and empirical literature of the innovation-economic growth nexus.

[2] For a survey on the tax treatment of R&D around the world, please refer to Table 1 in Hall and Van Reenen (2000).

[3] The R&D expenditures attrributable to the business enterprise sector accounted for 70.68 % of the total in 2008. Moreover, Taiwan's R&D/GDP ratio increased to 2.94% in 2009.

During the technological development process, the Statute for Upgrading Industries (SUI) that applies tax incentives, subsidies, and supporting measures to assist innovative activity is one of Taiwan's key industrial technology policies (Lien *et al*. 2007). However, economists have been generally skeptical regarding the efficacy of tax incentives. Expiration of the R&D tax credit of the SUI at the end of 2009 raises a legitimate concern: has the R&D-preferential policy induced greater R&D expenditures and a higher R&D growth rate in Taiwanese firms? From the perspective of public finance, the erosion of the tax base attributed to R&D incentives is possibly one cause of the fiscal shortage. Whether or not limited government resources should be used to encourage R&D depends on the efficacy of these measures to induce far greater R&D and contribute to sustainable growth. However, this important issue is not well examined in Taiwan.

High-tech industries are generally more R&D intensive and the primary recipients of R&D tax credits in the U.S. (Wu, 2008). This situation applies to Taiwan, while many so-called traditional industries (typically less R&D-intensive) voice criticism that R&D tax credits work more favorably for high-tech firms. Innovative behavior strongly relates to the technological environment surrounding the location of a firm. A relatively fertile technological environment induces firms to devote more R&D efforts, whereas the appearance of innovation is relatively rare in an infertile technological environment. This implies significant variations in innovative activity patterns between high-tech firms and their non-high-tech counterparts. To enforce a more effective policy of granting R&D tax credits, one possible improvement is to establish various tax credits across industries. This leads to another essential and prominent issue: does R&D-inducement effect differ between high-tech and other industries in Taiwan? Assessing the potential differences in R&D-inducement effects of R&D tax credits across industries can provide useful insights for legislation of new R&D policies.

At least two difficulties arise when using firm-level data to evaluate the effectiveness of an R&D tax credit within a country. Firstly, due to their different tax positions and expectations on future R&D spending, the variation between firms in credit effectiveness is highly endogenous (Bloom *et al*. 2002). Secondly, as indicated in Hall and Van Reenen (2000), there are many ways in which the R&D tax credit gives rise to heterogeneity, and often perverse incentives are a key feature in the debate on the desirability of R&D tax credits. Because the recipients of tax credits may differ in some firm characteristics from non-recipients (Czarnitzki *et al*. 2011), it is important to correct both selection bias and firm heterogeneity across recipients. This study thus adopts the non-parametric propensity score matching (PSM) method developed by Heckman *et al*. (1997, 1998) to correct possible selection bias. While the PSM approach deals with the selection bias problem to differentiate the treatment effect of R&D tax credit, it does not deal well with the second difficulty of unobservable firm heterogeneity. Fortunately, our dataset contains detailed information concerning the amount of R&D business tax deduction and firm characteristics, thus enabling us to adopt the panel instrumental variable (IV) and generalized method of moment (GMM) techniques to deal with both problems of endogeneity and firm heteroskedasticity.

This paper evaluates the effect of tax credits for R&D and its growth in Taiwanese manufacturing firms, to contribute to the empirical literature in the following ways. First, the question of how and to what extent tax credits stimulate industrial R&D has attracted widespread international attention among economists, with only 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 (NIEs). Taiwan has successfully achieved substantial technological development over the past two decades, and its outstanding performance in terms of innovation makes it an excellent case for investigating the tax incentives issue. Our firm-level evidence from Taiwan can complement the existing literature that focuses only on advanced countries. Second, we further separate samples into electronics and non electronics firms to examine whether and to what degree potential differences exist in effectiveness of R&D tax credit. This investigation can provide useful insights into ways to further revise R&D tax credits, because a uniform tax credit system for all industries is widely criticized as inappropriate. Third, this study employs the PSM method to correct the selection bias problem to differentiate the treatment effect of R&D tax credit. This enables us to compare the R&D activities of R&D tax credit recipients and non-recipients. This study further examines the marginal effect of R&D tax credits on R&D expenditures of firms. In this context, this research employs the panel IV and GMM techniques to deal with endogeneity and unobservable firm heterogeneity, appropriately assessing the effect of R&D tax credits on the R&D efforts of firms.

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 examines the R&D-inducement effect of an R&D tax credit using the propensity score matching method. Section 5 presents the findings from a further investigation into the marginal effect of R&D tax credits on R&D across industries. The final section concludes with the main results and their policy implications.

2. Literature Review

Private R&D is widely thought to be under-invested in terms of the socially optimal level, due to the imperfect appropriability 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 both directly or indirectly, such as tax incentives, subsidies, establishing government R&D labs, and investing in higher education.

The two primary policy tools applied by governments to stimulate R&D in firms 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 other R&D investments that performing firms would otherwise have prepared to undertake, that is, it crowds out firm-financed R&D expenditure and ultimately has no effect whatsoever on such activities (Wallsten, 2000).[4] Wu (2005) argued that public R&D subsidies might negatively affect private R&D investment by reducing upward pressure on the prices of such R&D inputs as the wages of scientists and engineers. Alternatively, the tax credit instrument 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 only one of several policy instruments on R&D and is far from a panacea for failure in the R&D market, it has become a common strategy in many countries compared with direct government subsidies or directly conducting the R&D program (Klette *et al.*, 2000).[5]

The increasing prevalence of R&D tax credits has caused wide concern among economists and policy-makers regarding whether or not and how tax incentives affect R&D. Since the early 1980s, a growing number of studies have utilized various methodologies to evaluate the effect of the tax system on R&D behavior (cost). Hall and Van Reenen (2000) provided a comprehensive summary of the literature and indicated that a dollar in the form of a tax credit for R&D stimulates approximately a dollar of additional R&D expenditure. Due to an increasingly lenient tax treatment of R&D, they also argued the likelihood that countries will increasingly turn toward the tax system and away from direct grants. Consequent studies using country or state level data have reached similar

[4] For studies on direct subsidies related to R&D activities, please see Özçelik and 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.

findings. Based on nine OECD countries, Bloom *et al*. (2002) found 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. Using a broader sample of seventeen OECD countries, Guellec and Van Pottelsberghe (2003) arrived at similar results, showing that the stimulating effect of tax incentives is strong in the short-run, reaching an elasticity of 0.5. Wu (2005) employed 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. He showed that the presence of an R&D tax credit results in 75 to 118 more R&D dollars per capita. This 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 relatively rare, owing primarily to data limitations. Utilizing Japanese manufacturing firms over the period 1989-1998, Koga (2003) found that R&D tax credits mainly stimulate R&D investment in large firms rather than medium-sized firms. The estimated tax price elasticities for large firms and medium firms are -1.036 and -0.118, respectively. In contrast, the result of a Canadian case in Baghana and Mohnen (2009) found that the estimated short-run price elasticity of R&D is -0.142 for small firms and is not significantly different from zero for large firms. They reasoned this is partly due to the deadweight loss associated with level-based R&D tax incentives that is particularly acute for large firms. Paff (2005) examined R&D expenditures in firms, in response to an R&D tax credit-rate increase in the U.S during 1994-1996 and 1997-1999. Empirical estimates obtained from the difference-in-difference

[6] Wu (2008) further examined 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 high-technology establishments per 1,000 of population and high-technology shares of business establishments. These findings highlight the importance of the role of state R&D tax incentives in technology-based economic development.

approach provide evidence that firms increase R&D expenditure significantly, while R&D incentives do not appear to have equal incentive effects across industries. Paff (2005) found much higher tax price elasticity than the estimates in the existing literature that are close to unity. One possible reason is that the examined firms are highly R&D-intensive, including biopharmaceutical and software firms.

Differing from previous studies that focus on tax price elasticity, Czarnitzki *et al*. (2011) used a non-parametric matching approach to compare the R&D expenditure of tax credit recipients with a hypothetical situation in the absence of R&D credits. The evidence for a large sample of Canadian manufacturing firms found that R&D tax credits have a positive effect on R&D decisions of firms to engage in R&D and in improved performance of firms.

While the measure of R&D tax credit has been implemented for a long period and thought to effectively stimulate R&D in Taiwan, rare studies examine how tax incentives affect R&D, using simple statistical tests rather than rigorous econometric techniques. Lan and Wang (1992) examined the effectiveness of Enactment of Encouragement Investment rather than Statute for Upgrading Industries (SUI). Based on 124 manufacturing industries and using OLS to estimate, they suggested that R&D elasticity with respect to R&D tax credits is 0.166 on average. Yang *et al*. (2006) reviewed the impacts of the SUI using aggregate data. However, their analyses provided statistics description on tax credits rather than the effect of R&D tax credits on the R&D activity of firms. Wang and Chen (1995, 2000) quantified the encouraging effects of the SUI. Using Linear Structural Relation (LISREL) to analyze the questionnaire sample, they focused on the policy effect on economic growth and the effect of tax credits on international brand image of a firm.

Drawing from the above discussions, limited firm-level studies suggest the need of new evidence, particularly for evidence from non-OECD countries. Because of the excellent innovation performance of Taiwan, and implementation of the SUI that expires in 2009, Taiwan provides an interesting case to revisit the efficacy of R&D tax incentives, which has not been systematically examined. The existing literature does not adequately deal with the problems of selection-bias and unobservable firm heterogeneity. This inspires the main purpose and contribution of this study to use PSM, panel IV, and GMM techniques to systematically examine the effect of tax credits for R&D in Taiwan, a NIE, to obtain both treatment and marginal effects of R&D tax credits.

3. Taiwan R&D Incentives and Data Description

3.1 Taiwan R&D Tax Credits

Over the past three decades, the government of Taiwan has implemented several measures to encourage innovative activity in firms and to promote their technological capability. The most well known industrial technology policy is the *Statute for Upgrading Industries (SUI)*, put into practice on January 1, 1991 for a 20-year tax incentive scheme to encourage industrial R&D, technological upgrading, and development.[7] The policy applies to all manufacturing firms and provides three types of functional incentives, including accelerated depreciation, tax credits, and tax-free. This policy aims to improve firm performance and thus help in industrial development.

The SUI consists of seven chapters and 72 articles. Several articles relate to 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 newly-emerging industries, important and strategic industry shareholders (Article 8), and five-year tax holidays or shareholder investment tax credits for newly-emerging, important, and strategic industries (Article 9).

Article 6 contains the long-standing adopted instrument, R&D tax credit, to encourage firms to undertake R&D. Under Article 6 regulations in the SUI, a firm may credit 35 %

[7] Before 1991, Taiwan's main industrial technology policy was the law entitled the *Statute for the Encouragement of Investment.*

of R&D expenditures and R&D personnel training against the amount of profit-seeking enterprise income tax payable within the coming five years. Specifically, if R&D expenditure of a firm is greater than the average R&D expenditure of the previous two years, 50 % of the excess amount of R&D expenditure can be credited against the amount of profit-seeking enterprise income tax payable. Although R&D tax credits can be used within five years, most Taiwanese firms prefer to use up the tax credits within two to three years, because R&D behavior is generally highly persistent in Taiwan (Huang and Yang, 2010), implying that the accumulated tax credits may increase quickly.

Figure 1 depicts trends in aggregate R&D spending and the amounts of R&D tax credits in Taiwan from 1992 onward. The amount of R&D expenditure apparently increased steadily from NT$112.997 billion in 1992 to NT$251.579 billion in 2005. The amount of R&D tax credits correspondingly increased approximately nine-fold from NT$1.810 billion in 1992 to NT$15.772 billion in 2005. Compared with the steadily increasing trend of R&D expenditure, the usage of R&D tax credits overall appeared an accelerating trend since the late 1990s, suggesting that the R&D tax credit is relatively relevant to R&D investment. However, the total R&D tax credits dropped significantly in years 2002 and 2004. This distinct phenomenon is mainly attributed to the low economic growth in the precious year, leading firms to reduce the application of R&D tax credits. As a firm can credit 35 % of R&D expenditures against the amount of income tax payable within five years, it is naturally that a firm will not apply for R&D tax credit if it encountered operational loss in the previous year. During the 1992-2005 period, Taiwan’s average economic growth rate was 5.19%, while the growth rate of 2001 and 2003 was as low as -1.65% and 3.67%, respectively. It is probably the main reason that causes the sharply decline in the total R&D tax credits in 2002 and 2004.

[Insert Figure 1 approximately here]

While existing literature, such as Koga (2003) and Baghana and Mohnen (2009), reached inconsistent findings in terms of the relationship between the R&D-inducement effect of tax incentives and firm size, the R&D tax credit policy tool is widely criticized as only being beneficial to large firms rather than small and medium-sized enterprises (SMEs) in Taiwan.[8] This is because SMEs generally do not have formal R&D department and financial statements audited by accountants, preventing their qualification for applying for R&D tax credits. The policies of R&D tax credits favor specific industries or firms devoted to specific events, causing the problem of tax base erosion and destroying fairness of the tax burden among firms. Taiwan has experienced serious fiscal difficulties (the government debt reached NT$4 trillion in 2007), including pressure from tax shortages. Article 6 of the SUI accounts for approximately one third of the NT$100 billion shortfall in total tax revenue annually faced by the Taiwan government (Lien *et al.* 2007).[9] Consequently, the question of whether public support encourages firms to engage in R&D activity has recently become a crucial and hot issue in Taiwan. This debate is particularly relevant given that the *Statute for Upgrading Industries* will expire at the end of 2009 and a new policy will need to be put in place. How, then, does the policy contained in the SUI affect innovation behavior of firms? Should the government extend this statute or terminate it as scheduled? These questions are critically important from the perspectives of both public finance and technology policy.

Although the discussions regarding the SUI and macroeconomic policy have attracted widespread interest in Taiwan, no rigorous academic analysis has systematically examined the question of how R&D tax credits affect R&D investment of firms, suggesting the need for further empirical evidence. This firm-level study attempts to fill this gap and to provide new evidence for existing literature focused on developed economies.

3.2 Data Sources

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8 In practice, SMEs account for approximately 97 % of the Taiwan manufacturing sector in terms of firm numbers.

9 Lien *et al.* (2007) used the macroeconomic model to examine the economic benefits and costs of tax credits and proposed some directions for adjusting the tax credit policies drawn from their analyses.

On examining the potential effect of tax incentives on R&D activities of firms, one primary obstacle encountered is the availability of detailed information on firm usage of R&D tax credits. Due to this limitation, this research utilized a panel dataset of manufacturing firms listed on the Taiwan Stock Exchange (TSE) over the 2001-2005 period. Firms listed on the TSE are large and medium enterprises (LMEs) rather than small firms. While the dataset comprises only LMEs, it can serve as a representative sample to examine the influence of R&D tax credits on R&D in Taiwan. This is because LMEs in Taiwan undertake most R&D expenditures and applications of R&D tax credits.[10] Information on firm characteristics was obtained by matching various data sources. R&D expenditure and other firm-specific variables, including employment, date of establishment, fixed capital stock, and profitability, were acquired from the databank constructed by the Taiwan Economic Journal (TEJ).[11] Business tax and export data deducted from R&D were taken from the annual financial reports of individual enterprises in each year. By eliminating a few firms with incomplete data for all the relevant variables and excluding firms without R&D expenditure in each year of the sample period, this work obtained an unbalanced panel data of 576 enterprises, yielding an overall sample of 2,588 observations. This study further separated the full sample into two subgroups: the electronics industry, representing high-tech industry, and non-electronics firms. While this classification seems to be ad hoc, it is acceptable because it coincides with the cutting point using average industry R&D intensity as the criterion and the electronics industry as the key industry in terms of R&D in Taiwan.[12] This research therefore obtained 1,375 and 1,213 observations for electronics and non-electronics firms. Table 1 summarizes the

[10] In 2005, the ratio of R&D expenditure and R&D tax credits of sample firms to those of all Taiwanese firms were 69.83 % and 65.96 %, respectively. The small difference suggests that the sample tends to be a representative sample.

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

[12] In our sample, the mean R&D intensity for all industries is 2.9 % and only the electronics industry experiences a higher R&D intensity of 4.4 %. R&D intensity for the pharmaceutical industry (10 firms in the dataset) reaches only 2.4 %, and is therefore classified into a non-high-tech industry. Due to the small scale compared with international pharmaceutical firms, Taiwanese pharmaceutical firms normally produce generic drugs rather than patent drugs, resulting in low R&D intensity.

variable definitions and basic statistics.

[Insert Table 1 approximately here]

Before turning to empirical estimations, this section briefly introduces the features of R&D tax credits taken up by sample firms. Table 2 shows basic statistics for recipients and non-recipients of R&D tax credits related to the whole sample, electronics, and non-electronics firms. In classifications of all firms and non-electronics firms, both R&D expenditure and its growth rate tax credit recipients are substantially higher than that of non-recipients on average, suggesting that recipients have a better R&D performance than non-recipients do. The finding also implies a potential R&D-enhancing effect for firms receiving R&D tax credit. However, tax credit recipients of electronics firms only experience a higher R&D expenditure rather than average R&D growth rate than their non-recipients electronics counterparts. The ratio of receiving R&D tax credits, in terms of firm number, within non-electronics firms is only 17.48 %, which is much lower than that of their electronics counterparts of 65.75 %. The figures in Table 2 reveal that larger and younger firms are apt to receive R&D tax credits. However, firms with high capital intensity are not inclined to receive R&D tax credits. The degree of capital intensity is mainly attributed to the feature of production and is probably less relevant to R&D activity. For instance, IC design firms are less capital-intensive, but more R&D-intensive, inducing them to have a higher propensity of applying for R&D tax credits.

[Insert Table 2 approximately here]

The preliminary descriptive analyses show that R&D tax credits tend to positively relate to R&D activities for Taiwanese manufacturing firms over the 2001-2005 periods because the recipients of R&D tax credits experienced more R&D expenditures and a higher growth rate of R&D outlet. However, R&D tax credits are not the main tax credit measure taken up by firms with high capital intensity. This also highlights the important effect of firm heterogeneity on the effect of tax incentives on R&D investment.

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

4.1 Empirical Setting and Estimation Technique

Unlike previous studies, which estimate tax price elasticity of R&D, this research employs the PSM approach to examine the effectiveness of R&D tax credits in Taiwan to ask the question: What would the firm have done in the absence of R&D tax credits? From the econometrics viewpoint, the PSM approach can effectively correct for selection bias when evaluating the R&D-inducement effect of tax credits. Receipt of R&D tax credits is probably not an exogenous variable, because tax credit recipients may differ in several characteristics from non-recipients (Czarnitzki *et al*., 2011). The effect of R&D tax credits on R&D is much like a "treatment effect," in that we attempt to answer the question as to what a treated firm (a recipient of R&D tax credits) with given characteristics would have done if it had not been treated. However, treated firms are typically 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 an appropriate approach.

The PSM approach compares treated firms with a selected non-recipient group with similar characteristics rather than all non-recipients. In the case of a binary treatment, the estimation steps are as follows. First, the treatment indicator T_i equals one if individual *i* receives treatment and zero otherwise. The potential outcomes are then defined as $Y_i(T_i)$ for each individual *i*, where *i* = 1, . . , *N* and *N* denotes the total population. Here, *Y* and *T* denote R&D activity and treatment of a tax credit user. The treatment effect for an individual *i* can be written as

$$\tau_i = Y_i(1) - Y_i(0) \tag{1}$$

Because only one of the potential outcomes is observed for each individual i and the counterfactual outcome is unobservable, it is impossible to estimate the individual treatment effect τ_i. We can concentrate only on the average treatment effect of treated (ATT), defined as the difference between expected outcome values with and without treatment for those who actually participated in treatment. In the case of R&D activity, this study examines two alternative outcomes: R&D expenditure and growth of R&D expenditure. The average treatment effect of the treated (ATT, τ_{ATT}) is given by:

$$\tau_{ATT} = E(\tau \mid T = 1) = E[Y(1) \mid T = 1] - E[Y(0) \mid T = 1] \quad (2)$$

One problem obviously arises: while the outcome of treated firms (recipients of R&D tax credits) is observable, the counterfactual mean for those being treated, E[Y (0) |T = 1], is not observed. What would these firms have realized had they not received treatment? The above causal inference relies heavily on the construction of counterfactual observations. Therefore, it needs rich data on firms that have similar observable characteristics in the initial period, but that did not receive R&D tax credits during the period. The average R&D activity E[Y (0) |T = 1] is measured by E[Y (0)|T = 0] instead. Thus, the outcomes of individuals from the treatment and comparison groups would differ even in the absence of treatment leading to a "selection bias."

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

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

Here, δ is a coefficient and Z is a vector of determinants influencing the decision of a firm regarding applying for R&D tax credits (treatment). This enables us to compute the probability of the decision of a firm to adopt R&D tax credits. With the propensity score of choosing to receive R&D tax credits, we can implement 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. To determine optimal matching, this study adopts the popular criterion of kernel matching suggested by Leuven and Sianesi (2003) to proceed with the estimation.[13]

4.2 Empirical Results

This study first estimated the Logit model to derive the propensity of a firm's decision as to whether or not to apply for R&D tax credits. The second step is to use the predicted propensity scores to match R&D tax credit recipients with non-recipients that possess similar observable firm characteristics. To estimate adequate results in the PSM method, the most important issue is choosing covariates. When facing the decision of whether or not to engage in R&D activities, a firm is likely to compare the marginal benefit associated with R&D to marginal cost. The tax credit is one type of public funding that can reduce the costs of R&D. Referring to specification in Czarnitzki *et al*. (2011), this work included several variables of firm characteristics that make them particularly R&D-prone and influence the propensity of applying for R&D tax credits. In practice, most Taiwanese R&D-undertaking firms use up the tax credits within two years. Thus, a firm engaged in R&D in the past two years has a higher propensity to apply for R&D tax credits. Therefore, past R&D expenditure (ln*RD*2) is a critical variable in the decision to apply for R&D tax credits. Other firm characteristics that induce firms to be more R&D-prone include firm size (ln*SIZE*), firm age (*AGE*), and capital intensity (ln*KL*). Generally, larger and more capital-intensive firms tend to be more R&D-intensive, while the influence of firm age on R&D is uncertain. A firm with higher profitability in the current year is more likely to utilize tax credits for tax saving, suggesting that profitability

[13] There are two alternative criteria, including nearest-neighbor matching, and caliper matching. For an extensive discussion of matching methods, see Heckman *et al*. (1998). We employed caliper matching to implement the matching process and reached similar results; while results obtained using nearest-neighbor matching are slightly different.

(PROFIT) is also a critical determinant for the propensity to apply for R&D tax credits. To control heterogeneity among industries and macroeconomic shocks, industry and time dummies were also included in the empirical specification. Table 3 displays the estimation results for all manufacturing firms, electronics firms, and non-electronics firms.

[Insert Table 3 approximately here]

Estimates obtained using all sample firms are overall consistent with the expectation that both past R&D experience and current profitability are positive and significantly related to the propensity of being a R&D tax recipient. Larger and younger firms tend to devote more R&D efforts and increase their propensity of applying for R&D tax credits. However, the determinant effects seem to vary between electronics and non-electronics firms. The influences of past R&D activity and profitability on the decision to be a R&D tax recipient are more relevant to electronics rather than non-electronics firms. The electronics industry is a technologically dynamic industry with a fertile innovation environment, enforcing electronics firms to persistently engage in R&D. Younger and less capital-intensive electronics firms have a higher probability to become R&D tax credit users. This may be because many younger electronics firms are IC design firms, which are more R&D-intensive, but less capital intensive. Alternatively, age and capital intensity reveal a positive and significant effect on the propensity to apply for R&D tax credits for non-electronics firms, as older and more capital-intensive non-electronics firms are more likely to engage in R&D in Taiwan.

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 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 and level of 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 of R&D investment in firms. After controlling non-random selection of the treatment groups, the matching results for the difference between the recipients' outcome with and without the R&D tax credits suggest that the growth of R&D expenditure is positive but not statistically significant during the first year following the receipt of tax credits. While recipients of R&D tax credits achieve a 15.6% higher R&D growth than that they do if there is no R&D tax credit, but it is not statistically significant. The higher R&D growth rate is because recipient firms are essentially more aggressive in undertaking R&D activity and generally experience a high annual growth rate of R&D expenditure. The result casts doubt on the effectiveness of policy incentives on the firms' R&D activity. From an alternative viewpoint of R&D activity regarding current R&D expenditure, the matching result shows that the coefficient is positive and statistically significant at the 1% level in Column (2). Surprising, recipients of R&D tax credits experience a 53.8% higher level of R&D expenditure than that they do without SUI, suggesting the existence of a strong R&D-enhancing effect facilitated by R&D tax credits. A possible reverse causality in R&D expenditure and R&D tax credit suggests that firms expensing higher level R&D may apply R&D tax credit more frequently. The PSM approach does not handle this endogenous problem well.

Using the same technique as the PSM approach, Czarnitzki *et al*. (2011) found that approximately 29% of firms using R&D tax credits would not have conducted R&D in the absence of this program in Canada. While the innovation outputs under discussion differ from those in Czarnitzki *et al*. (2011), the findings of this study lend support to the view that a preferential R&D policy induces additional engagement of R&D investment in Taiwan.

Does R&D-inducement effect differ between electronics and non-electronics industries?

Turning to the separate estimates for electronics firms and non-electronics firms, the corresponding R&D-inducement effect seems to vary substantially between them. Specifically, both treatment effects of R&D tax credits on R&D growth and R&D expenditure are particularly relevant to electronics firms. The tax credit recipients of electronics firms experience a 16.9% higher R&D growth than the situation of lacking R&D tax credit, while the estimated ATT is not significant at the 10% statistical level. Alternatively, tax credit recipients of non-electronics firms exhibit only a 4.9% higher R&D growth on average compared to that they do without this treatment. As RD variables show, the treatment yields positive effects in R&D expenditure for electronics firms, significant at the 1% statistical level, suggesting a strong R&D-enhancing effect from R&D tax credits. The difference between the recipients' R&D expenditure with and without R&D tax credits in electronics firms reaches 71.8%, suggesting that this instrument of R&D tax credit is particularly relevant to electronics firms. This treatment effect remains insignificant on inducing more R&D expenditure for non-electronics firms. Therefore, this work concludes that policy incentives have a positive effect on R&D activity of firms, particularly for electronics firms in Taiwan.

Based on previous analyses, public R&D incentives will not crowd out R&D investment of firms in Taiwan. Recipients of R&D tax credits, particularly the recipients of electronics firms, are witnessed to have a significantly higher R&D expenditure than their non-recipients counterparts. The effect of R&D tax credits was found to differ across industries, consistent with the findings in Paff (2005). One point worth noting is that PSM does not handle endogenous problem in current level estimation, suggesting the growth level estimations is worth more emphasizing. Despite the treatment effect of R&D tax credits are positive, ranging between 4.9% and 16.9%; they are not statistically significant in all estimates. In sum, the inducement effect appears to be growing in importance, because recipients of R&D tax credit overall experience a much higher level of R&D

expenditure than that they do without this policy instrument.

3.3 Assessing the Matching Quality

As discussed in subsection 3.1, the basic concept of the PSM approach is that it constructs the matched control group in the context of matching analysis. The matching process relies heavily on the idea of balancing the sample of tax credit participants and comparable non-participants. Remaining differences in the outcome variables between the two groups are attributed to the treatment (Heckman *et al*. 1997). Thus, distribution of the pre-treatment observable characteristics between the treatment and control groups is the key factor in determining whether the matching results are reliable. This study therefore assessed the distribution balance of covariates used in the propensity scores estimation.

Table 5 reports the standard t-tests for the equality of the mean sample values along with their p-values. Based on these t-test results, we failed to reject the null hypothesis that the mean between the treatment and control groups is equal for all variables for the matching method. This result indicates that the recipients of R&D tax credits and the matched non-recipients do not significantly differ from each other with regard to the set of variables used for matching, implying that the treated and the matched control groups on average have similar characteristics.

[Insert Table 5 approximately here]

The right part of Table 5 reports the standardized bias, the joint significance tests, and the pseudo-R^2 within the matching process. The figures represent reduction in the absolute bias obtained after matching the control and treatment units. The significantly reduced bias suggests that the matching procedure is effective.[14] The mean absolute bias in the matched sample is only 2.518, whereas it is 31.714 in the unmatched sample. Based on the suggested criterion proposed by Sianesi (2004), we checked 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 lower panel of Table

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

5, the pseudo-R^2 approaches a value close to zero in the propensity score estimation that uses recipient firms and 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. To sum up, 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 reduce sampling selection bias arising from observable differences between the treatment and control groups, while suffering the serious drawback that it does not control for the unobservable characteristics across firms that may exist between recipients and non-recipients of R&D tax credits. One advantage of our dataset is that it contains the amounts of R&D tax credits, enabling us to examine the marginal rather than the treatment effects of R&D tax credits on R&D activities of firms. Thus, we further include the taxation remit of R&D tax credits and employ the IV technique based on the panel data model to examine the marginal effect of tax credits on R&D expenditures of firms in Taiwan.

5.1 Empirical Specification and Estimation Techniques

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

$$\begin{aligned} \ln RD_{it} = {} & \beta_0 + \beta_1 \ln RDTAX_{it} + \beta_2 \ln SIZE_{i,t-1} + \beta_3 AGE_{it} + \beta_4 \ln KL_{i,t-1} \\ & + \beta_5 PROFIT_{i,t-1} + \beta_6 \ln EXP_{i,t-1} + u_i + \varepsilon_{it} \end{aligned} \tag{4}$$

The dependent variable $\ln RD_{it}$ denotes the logarithm of R&D spending of firm *i* in year *t*. Both theoretical and empirical studies have identified various determinants of explanatory variables. Because this study examines the marginal effect of R&D tax credits on R&D expenditure of firms, 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 three firm characteristics and two performance variables, namely, firm size (ln*SIZE*), firm age (*AGE*), capital intensity (ln*KL*), profitability (*PROFIT*), and exports (ln*EXP*). To avoid the potentially endogenous problem in explanatory variables, all variables except for firm age enter the equation in the form of lagged one-year.

The size of a firm is measured by the logarithm of employment. Large firms typically have obvious advantages in terms of their ability to support R&D. The famous Schumpeter hypothesis indicates that firms wielding monopolistic power (larger firms) tend to engage in innovation, a hypothesis supported by many empirical studies.[15] Alternatively, Audretsch and Acs (1991) found 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 firm age on R&D, there is a potential learning-by-doing effect on innovation and incumbent firms have an advantage over their younger counterparts in terms of R&D management. Alternatively, younger firms are possibly more R&D-intensive to obtain superior technological competitiveness. The term ln*KL* denotes capital intensity of a firm, measured as the logarithm of physical capital per employee. A firm with higher capital intensity typically engages in more R&D to improve its production process in Taiwan (Yang *et al*, 2009). This study observed a positive association between capital intensity and R&D.

Previous literature has widely studied innovation financing.[16] Thus, a firm's profitability (*PROFIT*) is also included to measure the availability of internal financial resources and is expected to have a positive effect on firm innovation. The trend towards globalization and the small open economy of Taiwan provides firms more opportunities to acquire technological knowledge through knowledge spillovers in international markets

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[15] For example, please see Lerner (1995) and Hall and Ziedonis (2001).
[16] As for the importance of financing on firms' R&D, please see Hall (2002) for a comprehensive survey.

and to enhance their additional R&D activity. The exporting decision is probably due to self-selection that firms with a higher technological level or productivity select to enter international markets. We therefore included exports (ln*EXP*) as an explanatory variable.

5.2 Estimation Results

One econometric problem encountered in the estimation procedure is the endogenous causality between R&D tax credits and R&D investment, which is why we previously adopted the PSM approach. The Wu-Hausman test was employed to detect the existence of endogeneity. If no endogeneity was found, we then employed the panel fixed effects model to deal with unobserved firm heterogeneity. Consequently, when endogeneity is detected, the generalized method of moment (GMM) approach provides an alternative technique. Using an adequate instrumental variable (IV) to deal with the endogenous variable, this approach provides asymptotically efficient estimators as those obtained using GMM (Harris, 2005). That is, this approach provides asymptotically efficient estimators, even under the heteroscedasticity across firms and autocorrelation of disturbances within firms over time.

The test results indicate an endogenous causality between R&D tax credits and firm's R&D investment for the entire sample of electronics firms and non-electronics firms.[17] Therefore, we adopted the instrumental variable technique to conduct empirical estimation for the entire sample and two sub-samples. We adopted the "lagged one-year unused R&D tax credits (UNTAXC)" as the instrumental variable for R&D tax credits, as it can capture the long-run effect of R&D tax credit, say over five years, on R&D expenditure. Accordingly, we use the F-test developed by Staiger and Stock (1997) to assess the effectiveness of the instrumental variable. However, the statistical test reveals that the instrumental variable is effective for only the entire sample and subsample of electronics

[17] To save space, this study does not show the estimation results of the Wu-Hausman test, but are available upon request from the authors.

firms.[18]

As the IV is ineffective for subsample of non-electronics firms, we thus employ the Arellano-Bond GMM to implement the estimation, in order to obtain efficient estimates. As indicted in the bottom of Table 6, all statistics do not reject the null hypothesis at the 10% statistical level, suggesting there is no over-identifying. Table 6 reports a series of estimates of the R&D equation specified in Equation (4). The left panel displays estimates obtained from the IV estimator of panel fixed model, whereas the right panel of Table 6 demonstrates results obtained using the GMM.[19]

[Insert Table 6 approximately here]

To what extent does the R&D tax credit stimulate private R&D expenditure? We first looked at the variable of concern in this study: R&D tax credits. In the Panel IV estimator, the estimated coefficients for ln*RDTAX* is positive and statistically significant at the 1 % statistical level for the whole sample and electronics firms, after controlling for other potential influences. This result is consistent with previous findings for the PSM estimates that R&D tax credits do encourage firms to increase their R&D investment. The estimated elasticity of R&D with respect to R&D tax credits is 0.302 for all firms and 0.370 for electronics firms. While the estimated elasticity of R&D tax credits on R&D expenditure for non-electronics firms is much lower and statistically insignificant, this result suggests that the tax policy is more relevant to R&D expenditures of electronics firms, consistent with that for previous PSM estimates.

The GMM estimates in columns (4)-(6) of Table 6 show the same result that R&D tax credit variable is associated with a significantly positive coefficient for only the whole sample and electronics firms. As the GMM approach is first-difference estimation, the

[18] We have been also adopted tax credit with one-year lag as the instrument variable. This F-test suggests this instrument variable is effective for various sample groups. While we reach similar results, it captures only a short-run effect and will be inadequate when R&D tax credit has a long-term effect on R&D expenditure. Thanks one anonymous referee pointing out this limitation of this instrumental variable.

[19] The GMM approach is first-difference estimation, while we remain to denote the variable name in the level form in Table 6.

associated magnitude, 0.080, in column (4) suggests that a 1% increase in tax credit leads to 0.08% growth on the R&D expenditure growth. This R&D growth-enhancing effect is stronger for the electronics firms, as shown in column (5). Compared with results obtained using the PSM that neither handle endogeneous problem in current level estimation and nor control for the unobservable characteristics across firms, the GMM estimates suggest that R&D tax credit overall exhibit a significant influence on R&D growth, especially for electronics firms.

Despite that the estimated elasticity of R&D with respect to R&D tax credits is considerable in columns (1) and (2), it is more crucial to evaluate the marginal effect of R&D expenditure effectuated by the R&D tax credit. That is, "to what extent do tax credits induce firms' R&D investment?" Using the estimated elasticity and mean values of both R&D expenditure and R&D tax credits to implement the calculation, we found that a one dollar taxation remit of R&D tax credit induces 0.094 dollars more of R&D expenditure for the entire sample, on average. Because the R&D expenditure of electronics firms is more sensitive to the R&D tax credit, the calculated marginal effect of R&D tax credits reaches a higher effect of 0.120, suggesting the corresponding shares of induced R&D spending range from 9.4% to 12.0%. The R&D preferential policy of a tax credit has indeed induced additional R&D investment undertaken by firms in Taiwan, while the R&D-enhancing effect is much lower compared with experiences in developed countries surveyed by Hall and Van Reenen (2000). This casts the susceptive view regarding the effectiveness of R&D tax credit policy from the view of public finance.

Regarding the influences of other observed characteristics, few variables are associated with a significant coefficient, as the influential effect is primarily dominated by the one-year lagged R&D expenditure. We then focus on discussing the results of panel IV estimates. The positive effect of firm size on R&D expenditure supports the Schumpeter hypothesis that large firms (with market power) are more inclined to have the wherewithal to exploit innovations. Younger electronics firms tend to appear a higher R&D growth, as the coefficient of firm size is significantly negative in column (5). While capital intensity is not a crucial factor of innovation propensity overall, it is interestingly to show a significantly positive and negative for electronics and non-electronics firms, respectively. Profitability is significantly associated with a positive coefficient for only non-electronics firms, verifying the importance of internal finance on R&D activity. However, profitability does not seem to be a key factor of R&D expenditure in the electronics industry. The possible interpretation is that R&D activity seems to become a necessary input in the technologically dynamic industry. The coefficients of exports are positive and significant at the 1 % statistical level in columns (1) and (2), lending support to the importance of international linkages in domestic R&D activity.

5.3 Evaluation of Potential Policy Reform

The R&D tax credit of the SUI is planned to terminate at the end of 2009; therefore, whether Taiwan should continue to encourage R&D activity in firms by legalizing a new policy measure of R&D tax credit arises as a public concern in Taiwan. Facing the uncertainty of new R&D policy, do firms change their R&D behavior to respond to R&D tax credit along with the approaching SUI expiration? This unique and interesting analysis can provide insightful policy implications not previously investigated in the literature. Because the SUI allows R&D engaging firms to use up tax credits within five years, this study further employs the OLS to estimate Equation (4) for sub-samples of various time spans, in order to obtain R&D elasticity with respect to R&D tax credits. Table 7 displays a series of estimates.

[Insert Table 7 approximately here]

The year-by-year estimates on elasticity of R&D with respect to R&D tax range between 0.116 and 0.141 and exhibit a slightly increasing trend during the 2002-2005 period.[20] As for estimates using various time periods, the estimated elasticity of R&D with respect to R&D tax credits remains similar, hovering between 0.119 and 0.135. Specifically, estimates obtained base on time span of two-year and three-year suggest an increasing elasticity. It implies that firm attitude toward R&D tax credit becomes more aggressive along with the approaching expiration of SUI. This finding is reasonable that firms tend to appropriate the benefits of tax credits before this SUI expires, as whether the following statue can being legislated is uncertain. On the other hand, this finding seems to lend a supportive view on the efficacy of policy measure.

To summarize, the above analyses provide strong evidence of the positive effect of R&D tax credits on private R&D. Because the way in which R&D elasticity is calculated differs from that in Bloom *et al*. (2003), we cannot directly compare the effect of tax incentives on the level of R&D expenditure in Taiwan with that in OECD countries. However, the estimated marginal R&D-inducement effect catalyzed by tax incentives is low after considering endogeneity and firm heterogeneity. This result suggests that the government should carefully evaluate an R&D encouragement policy, if they plan to continue to encourage and promote private R&D using this policy tool.

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 newly industrialized economies (NIEs) and developing countries. Taiwan has been one of the most successful NIEs in the world in innovative performance over the past two decades, particularly in the technological field of electronics. One possible reason is that the government has adopted long-standing tax incentives to foster private R&D. Economists have traditionally been skeptical of the efficacy of any fiscal provisions. Is the

[20] As the explanatory variables enter equation (4) in the form of lagged one-year, it causes the loss of one year data. Thus, the year-by-year estimations contain only four years.

R&D tax credit really an effective mechanism for encouraging firms to invest more in R&D? This issue is particularly important to Taiwan, because the tax credit policy that forms part of the SUI will expire at the end of 2009. The government must decide in the near future whether to extend the tax credit policy or change it in part, if not completely.

This paper evaluates the effect of tax credits on R&D activity in Taiwan that differs from previous studies focused on estimating tax price elasticity of R&D based on R&D cost. We first adopt the propensity score matching method to simulate the scenario of how the treatment of R&D tax credits affects R&D activity of firms. The PSM approach helps to correct the selection bias that previous studies inadequately address. Secondly, to control for unobservable firm heterogeneity between treated and control groups which may affect R&D activity, this study employs both techniques of panel instrumental variable and GMM to estimate the influences of tax credits on R&D expenditure and its growth.

Using a panel dataset of 576 enterprises listed on the Taiwan Stock Exchange over the 2000-2005 period, our empirical findings are summarized as follows. First, the PSM estimate shows that R&D tax credits induce a higher (53.8%) R&D expenditure, on average. This suggests that there is no crowding-out effect of public R&D support on private R&D, whereas there is a positive effect of R&D tax credits on private R&D. On the other hand, the growth level estimation of PSM demonstrates also a positive influence of tax credits on R&D expenditure growth, while this enhancing effect is not statistically significant. Secondly, the R&D-inducement effect of tax credits was found to differ between electronics and non-electronics firms. Specifically, this treatment effect is much stronger for electronics firms such that the recipients of R&D tax credit experience a higher (16.9%) growth of R&D investment and a higher (71.8%) R&D expenditure than those they do lacking this policy instrument. Alternatively, we do not find significant treatment effects on R&D expenditure and growth brought about by the R&D tax credit for non-electronics recipients. Third, estimates obtained using IV technique involving the panel data model show that the elasticity of R&D with respect to the taxation remit is 0.302 on average. The induced R&D expenditure effectuated by tax credits accounts for 9.4% to 12.0% of R&D for the sample firms. Moreover, estimates obtained using GMM lend the similar finding that tax credits do have a R&D growth-enhancing effect, particularly for electronics firms. This suggests that tax credits have a moderate effect on private R&D in Taiwan. Finally, the R&D elasticity of tax credit tends to increase slightly along with the approaching expiration of SUI. It suggests that firms prefer to appropriate the benefit of policy measure and lends supportive evidence on the effectiveness of R&D tax credits.

Based on the above analyses, this study derives several policy implications. First, as this study overall finds a significantly positive R&D-inducement effect of R&D tax credits, the R&D preferential policy is deemed an effective policy tool for fostering private R&D activity, thereby supporting previous aggregate evidence. Secondly, as the marginal R&D-inducement effect facilitated by tax credit is relatively limited, whether this policy tool continues to be implemented after the SUI expires is worth careful evaluation, as the problem of fiscal deficit has seriously worsened in Taiwan in recent years.[21] Third, because the effect of R&D tax credits differs between electronics and non-electronics firms, the government should devise ways to adjust the taxation reduction rate for R&D investment across industries. Finally, due to the limitation of using LMEs, this study cannot examine the criticism that SMEs have difficulty qualifying for tax credit. This issue is worth further investigation.

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[21] After the previous version of this study being carried out, the new Statute of "Industrial Innovation Statute (IIS)" went into effect on October 2010. In the IIS, a firm can credit only 15 % of R&D expenditures against the amount of profit-seeking enterprise income tax payable within the coming one year.

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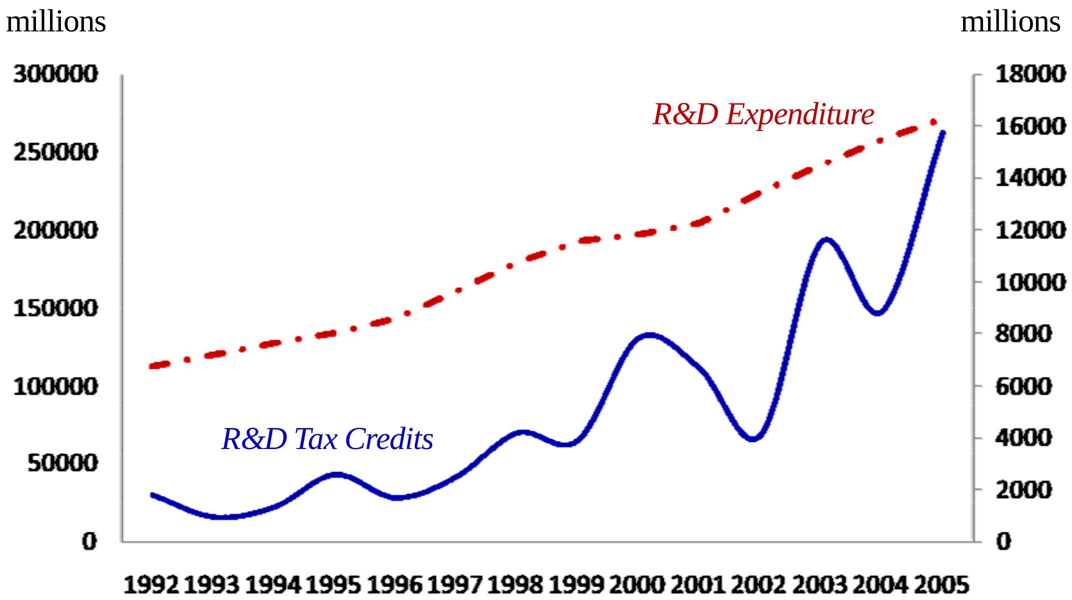
Figure 1   R&D Expenditure and R&D Tax Credits, 1992-2005



Data Source: Indicators of Science and Technology, Taiwan, various issues. Yearbook of Tax Statistics, Taiwan, various issues. All figures are real value using 2001 as the base.

Table 1 Variable Definitions and Basic Statistics 2001-2005

Variables	Definition	All Firms	Electronics	Non-Electronics
G_RD	Growth rate of R&D expenditure (%)	9.820	24.597	-6.701
		(165.699)	(151.230)	(179.212)
RD	R&D expenditure (NT$ million)	250.760	408.863	71.542
		(840.635)	(1112.915)	(209.137)
RD2	Lagged two-year R&D expenditure (NT$ million)	200.198	305.269	73.221
		(703.770)	(916.436)	(223.127)
RDTAX	R&D tax credits (NT$ million)	87.357	133.377	18.502
		(572.610)	(726.193)	(147.542)
RDTAX1	Lagged one-year R&D tax credits (NT$ million)	76.464	115.238	18.390
		(529.093)	(668.731)	(154.988)
UNTAXC	Lagged one-year unused R&D tax credits	314.510	496.325	98.006
		(1928.887)	(2501.479)	(785.516)
D_RDTAX	Dummy variable	0.431	0.657	0.175
	A firm with R&D tax credits =1	(0.495)	(0.475)	(0.380)
SIZE	Firm Size: number of employees	1043.856	1171.201	899.504
		(2083.331)	(2472.033)	(1515.667)
AGE	Firm Age: surveyed year minus the starting year	23.593	17.686	33.013
		(12.312)	(9.040)	(10.895)
KL	Capital intensity: the ratio of fixed capital to employee	4.606	2.740	6.722
	(NT$ million per employee)	(9.598)	(4.923)	(12.678)
PROFIT	Profitability: ratio of profit to sales (%)	19.327	20.139	18.406
		(15.941)	(16.397)	(15.362)
PROFIT(t-1)	Lagged one-year profitability (%)	20.009	21.083	18.807
		(15.628)	(16.350)	(14.692)
EXP(t-1)	Lagged one-year export value (NT$ million)	6096.217	9711.045	2101.486
		(221763.35)	(28979.44)	(6247.271)
OBS	Sample size	2588	1375	1213

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

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

	All firms		Electronics firms		Non-electronics firms	
	User	Non-user	User	Non-user	User	Non-user
R&D expenditure (NT$ million)	424.359	119.146	493.435	246.543	129.807	59.203
Growth of R&D	21.77%	0.83%	23.63%	26.456%	13.94%	-11.07%
Number of employees	1298.989	850.427	1307.777	909.070	1261.519	822.833
Firm age	19.904	27.271	16.698	19.584	33.528	32.844
Capital intensity (NT$ million)	2.826	5.956	2.582	3.043	3.864	7.327
Number of observations	1116 (43.12%)	1472 (56.88%)	904 (65.75%)	471 (34.25%)	212 (17.48%)	1001 (82.52%)

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

	All Firms	Electronics	Non-Electronics
lnRD2	0.115***	0.208***	-0.053**
	(0.016)	(0.021)	(0.021)
lnSIZE	0.093*	0.136**	0.121*
	(0.049)	(0.054)	(0.074)
AGE	-0.019***	-0.108***	0.063***
	(0.005)	(0.006)	(0.006)
lnKL	0.040	-0.961***	0.486***
	(0.117)	(0.130)	(0.168)
PROFIT	0.018***	0.014***	0.006
	(0.003)	(0.004)	(0.006)
CON	-3.142***	1.301***	-6.128***
	(0.496)	(0.480)	(0.704)
Industry dummy	Yes		
Time dummy	Yes	Yes	Yes
Pseudo R^2	0.176	0.280	0.118
Log likelihood	-1250.773	-1061.463	-610.213

Notes: (1). Figures in parentheses are standard errors. (2). ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 4 Treatment Effect of R&D Tax Credits

	R&D Growth	RD
	(1)	(2)
All Firms	0.156	0.538***
	(1.56)	(2.72)
Electronics	0.169	0.718***
	(1.59)	(3.50)
Non- Electronics	0.049	0.233
	(0.42)	(1.00)

Notes: (1). Figures in parentheses are t-values. (2). *** represents statistical significance at the 1% level. (3). The propensity score function includes lnRD2, lnSIZE, AGE, lnKL, PROFIT, time dummy and industry dummy.

Table 5 Matching Covariates Balancing Property – Kernel

		Mean		t-test		Standardized Bias	
Variables	Sample	Treated	Control	t	p>|t|	% bias	|bias|
lnRD2	Unmatched	9.451	8.772	4.09	0.000	17.4	78.2
	Matched	9.496	9.348	0.84	0.402	3.8	
lnSIZE	Unmatched	6.325	6.050	5.84	0.000	23.2	68.2
	Matched	6.342	6.430	-1.79	0.074	-7.4	
AGE	Unmatched	19.904	27.272	-14.80	0.000	-62.7	94.4
	Matched	20.695	21.108	-0.88	0.377	-3.5	
lnKL	Unmatched	3.1201	3.296	-8.75	0.000	-35.2	88.3
	Matched	3.127	3.148	-0.98	0.326	-4.1	
PROFIT	Unmatched	21.319	17.816	5.57	0.000	22.4	92.8
	Matched	21.393	21.142	0.35	0.724	1.6	
				|bias| summary statistics:		BEFORE	AFTER
				Mean		31.714	2.518
				Std. Dev.		33.310	2.214
				Maximum		113.668	7.372
				Minimum		3.865386	.0825251
				Pseudo R2		0.159	0.002
				LR test p-value		0.000	0.776

Notes: (1). The p-value of the t-test represents the equality of means in the treated and control groups. (2). % bias is the standardized bias as suggested by Rosenbaum and Rubin (1985) reported together with the achieved percentage reduction in |bias|.

Table 6 R&D Effects of R&D Tax Credits

	IV estimator of Panel Fixed Model			Arellano-Bond GMM		
	(1) All Firms	(2) Electronics	(3) Non- Electronics	(4) All Firms	(5) Electronics	(6) Non-Electronics
lnRD(t-1)				0.691***	1.165***	0.078
				(0.119)	(0.144)	(0.140)
lnRDTAX	0.302***	0.370***	0.086	0.080**	0.116***	-0.022
	(0.084)	(0.097)	(0.283)	(0.032)	(0.032)	(0.042)
lnSIZE(t-1)	0.649***	0.426***	0.996***	0.587**	0.219	1.144**
	(0.122)	(0.139)	(0.259)	(0.235)	(0.268)	(0.543)
AGE	-0.022	-0.016	-0.024	-0.041	-0.097*	-0.070
	(0.015)	(0.018)	(0.016)	(0.037)	(0.053)	(0.060)
lnKL(t-1)	-0.061	0.508**	-1.240***	0.496	0.670	0.537
	(0.204)	(0.254)	(0.427)	(0.422)	(0.462)	(1.063)
PROFIT(t-1)	-0.001	-0.009	0.026**	-0.006	-0.009	-0.019
	(0.006)	(0.007)	(0.013)	(0.007)	(0.008)	(0.015)
lnEXP(t-1)	0.123***	0.167***	0.073*	0.004	-0.061	0.033
	(0.027)	(0.035)	(0.0445)	(0.037)	(0.049)	(0.052)
F	52.63***	31.57***	6.10			
Sargan(P-value)				0.133	0.431	0.312
# of obs.	2588	1375	1213	2588	1375	1213

Notes: (1). Figures in parentheses are standard errors. (2). ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. (3). F statistic is the weak IV test. The null hypothesis is rejected when F value is larger than 10, indicating that the adopted IV is effective. (4). Sargan test is for test the over-identifying restrictions. The null hypothesis is not rejected when p-value is not less than 1%, indicating that the adopted IV is valid.

Table 7 R&D-Inducement Effects of R&D Tax Credits in Various Time Span

	2002	2003	2004	2005
Year by year	0.116	0.130	0.128	0.141
Two year		0.119	0.128	0.135
Three year			0.121	0.132
Four year				0.126