China Journal of Accounting Research 11 (2018) 367–384

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China Journal of Accounting Research

journal homepage: www.elsevier.com/locate/cjar

The effects and economic consequences of cutting R&D tax incentives

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ARTICLE INFO

Article history:
Received 15 May 2017
Accepted 11 July 2018
Available online 14 September 2018

Keywords:
R&D credit rate
R&D investment
Firm value

ABSTRACT

Research has documented the stimulating effect of R&D tax credits on R&D expenditure when enacting an R&D tax credit or raising the credit rate. However, the potential adverse effects and consequences of reducing R&D tax incentives remain unexamined. Using a cut in R&D tax incentives in Taiwan, we document the adverse effect of reducing the R&D credit rate on corporate R&D expenditure. The reduced R&D credit rate has a negative impact on the relation between corporate R&D expenditure and firm value. Our results highlight the adverse effects and economic consequences of reducing R&D tax incentives in an emerging economy.

1. Introduction

This paper investigates the effects and economic consequences of cutting research and development (R&D) tax credit rates. Prior research documents the positive effect of enacting R&D tax credits or increasing credit rates in spurring additional corporate investment in R&D (Gupta et al., 2011; Finley et al., 2015). The research, however, has not examined the effects of reducing R&D tax incentives on corporate R&D expenditure. Corporate R&D expenditure may be less responsive to a decrease than to an increase in credit rates, as competition within industries and commitment to long-term R&D plans may constrain firms from substantially reducing their R&D investment. Hence, whether reducing R&D tax incentives will result in firms decreasing their R&D investment remains an unanswered empirical question. Even less is known about the relationship between R&D spending and firm value after a reduction in R&D credit rates.

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☆ We are grateful for the helpful comments of Jeong-Bon Kim, Minghai Wei, Charles J.P. Chen, Feng Liu, Wen Chen (discussant), an anonymous referee and participants at the 2017 CJAR summer research workshop.

https://doi.org/10.1016/j.cjar.2018.07.003
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The purpose of this paper is to fill this gap by assessing the impact of Taiwan's tax policy on R&D investment. R&D investment is important for both technological innovation and the competitiveness of economy. On account of the external benefits of R&D investment, many countries provide R&D credits to stimulate R&D expenditure in the private sector. Even developed countries such as the United States, Canada and France continue to provide R&D tax credits for corporate R&D expenditure. Over the past three decades, Taiwan has implemented favorable tax measures to stimulate firms to invest in R&D. The statutory R&D credit rate was gradually increased to 35% and could be further raised to 50% if the firm's current-year R&D expenditure exceeded its average R&D expenditure for the two previous years. However, the generous R&D tax incentives were long criticized for causing enormous revenue loss and a deterioration in the fiscal budget. In response to this criticism, Taiwan enacted the Statute for Industrial Innovation (SII) in 2010 to replace the previous tax incentives and reduce the R&D credit to a flat rate of 15%. This marked the first time Taiwanese policymakers greatly reduced the tax incentive for firm R&D expenditure, in contrast to most tax incentives of emerging countries aiming to stimulate incremental corporate R&D spending. It is unclear whether this reduction adversely affected corporate R&D expenditure and the overall economy.

The focus of this paper is to assess the effects and economic consequences of reducing R&D tax incentives in emerging economies. Using a sample of Taiwanese listed and over-the-counter firms for the period 2006–2014, we find that firms significantly reduced their R&D spending in response to the decrease in R&D credit rate by the SII. Furthermore, the credit rate reduction shows a negative effect on the relation between corporate R&D spending and firm value, as measured by Tobin's Q. We also find that the negative effect is more salient in the high-tech sample. Taken together, the results provide evidence of adverse effects and economic consequences of cutting R&D tax incentives.

We perform various sensitivity tests and robustness checks that include constructing alternative samples, model specifications and proxies for the economic consequences in our sample. We find that our contrast sample of biologics companies did not exhibit adverse effects or economic consequences after implementation of the SII. Using market-adjusted stock returns as an alternative proxy for economic consequences, we find that implementation of the SII had a negative impact on the relation between corporate R&D spending and stock returns. Our results are robust to different model specifications using both panel data estimations and a difference-in-differences design. Furthermore, we hand-collect the actual R&D tax credit amount from financial statement footnotes as a proxy variable to examine the effect of reducing R&D credit on firm innovation output. Our results show reduced innovation output by companies after implementation of the SII. Finally, we find that implementation of the SII significantly reduced both firm R&D credits and government tax revenue loss.

Our study makes several contributions to the literature. First, we extend the previous research on the link between R&D tax credit incentives and firm R&D spending. While the literature documents a positive effect of R&D tax credits in stimulating additional R&D spending (Berger, 1993; Gupta et al., 2011; Finley et al., 2015), little is known about the adverse impact of reducing R&D tax credits on firm R&D expenditure. Our study fills this gap by using the unique setting of the Taiwanese tax reform to address this issue. Companies may not reduce their R&D spending after the credit rate is decreased because of the constraints of nontax factors such as industry competition and commitment to long-term R&D projects. Our results, however, show a significant decrease in corporate R&D spending after a reduction in the credit rate, suggesting that the adverse tax effects outweigh the nontax factors in firm R&D investment decisions. Furthermore, the results of this paper provide tax policy implications for emerging economies. Developing countries often use tax incentives to stimulate investment. R&D investment is critical for technological advancement in developing countries. The SII, however, marks the first time Taiwan cut the tax incentives for firm R&D spending. The adverse effect we document arising from this cut suggests that developing countries should carefully consider the economic consequences of tax policies for firm R&D investment. Our paper also adds to the literature on the economic consequences of reducing the R&D credit rate, as there is limited empirical evidence on the relation between R&D spending and firm value after a reduction in R&D credit rate. We show that reducing the credit rate has a negative effect on the relation between corporate R&D spending and firm value.

The remainder of the paper is organized as follows. Section 2 discusses the background and related literature and develops our testable hypotheses. Section 3 develops the research design. Section 4 presents and analyzes the empirical results. Section 5 discusses the sensitivity tests, and Section 6 concludes the paper.

2. Background, related literature and hypothesis development

2.1. Background on R&D tax credits in Taiwan

Like many developing countries or regions, Taiwan has long provided substantial tax incentives to promote industrial upgrading and stimulate firm R&D investment. The Statute for Upgrading Industries (SUI) was enacted on 1 January 1991, and was one of the most important tax incentives to promote investment in Taiwan. One of the SUI's most favorable tax incentives was its statutory base credit rate of 35%[1] for firm R&D expenditure and an incremental credit rate of 50% if the current year's R&D expenditure exceeded the average for the previous two years. This generous tax incentive raised considerable concern in Taiwan about its effectiveness in stimulating firm R&D investment. The government also cautioned about the growing loss of revenue from these tax incentives and urged that their effectiveness in stimulating the economy be evaluated using empirical evidence (Chen and Gupta, 2017). The SUI expired at the end of 2009, and the Taiwanese government replaced it with the Statute for Industrial Innovation (SII). The SII essentially abolished all tax incentives except for the R&D tax credit, which it reduced to a flat rate of 15% without any increments. This marked the first policy change for R&D tax incentives in Taiwan. Whether the reduced R&D tax incentive resulted in adverse effects on firm R&D spending has implications for developing countries when changing their tax incentive policy.

2.2. R&D investment

Although it is straightforward to predict that an R&D tax credit should result in increased R&D spending because the credit lowers the marginal cost of R&D investment, the research finds mixed evidence for the effectiveness of R&D credits in stimulating R&D spending (Berger, 1993; Bloom et al., 2002; Klassen et al., 2004).

Berger (1993) investigates the effects of R&D tax credits in the Economic Recovery Tax Act of 1981 (ERTA). Using a sample of 263 U.S. firms with data from 1975 to 1989, he finds that a tax incentive increases R&D spending. On average, R&D tax credits increased R&D intensity (measured as the ratio of R&D spending to sales) by 2.9% during 1981–1989. He also finds that R&D credit induced $1.74 in additional spending per dollar of forgone revenue during the period 1982–1985. These results suggest that the credit-induced R&D spending is higher than the loss of tax revenue. Swenson (1992) also examines the effectiveness of the tax credit for research and experimentation (R&E) expenditure using data from 1975 to 1988. The results indicate that while credit increased additional research spending, the effect of the credit was substantially mitigated by the impact of net operating loss carryforwards and low growth opportunity. Bloom et al. (2002) examine the impact of fiscal incentives on the level of R&D investment. Using a sample of nine OECD countries over a 19-year period (1979–1997), they find that tax incentives are effective in increasing R&D intensity. They find that a 10% fall in the cost of R&D stimulates an R&D rise of just over 1% in the short run and almost 10% in the long run.

Klassen et al. (2004) examine the effectiveness of R&D tax incentives by comparing the R&D decisions of firms from Canada and the United States. These two countries have different R&D tax policies. In Canada, all R&D expenditure qualifies for a tax credit, while the U.S. tax credit applies only to incremental R&D expenditure. Using a matched sample of Canadian and U.S. firms reporting an R&D expense of at least 0.5% of sales between 1991 and 1997, they find that the Canadian incentive produced on average $1.30 per dollar of tax revenue forgone compared with $2.96 in the U.S. The results indicate that applying a credit only to incremental R&D expenditure provides a larger incentive for firms. In our study, the SUI provides a statutory base credit rate of 35% for firm R&D expenditure and an incremental credit rate of 50% for the excess of

[1] The effective base credit rate was 30% in 2008.

current year's R&D expenditure over the average for the previous two years. Hence, Taiwan's R&D credit is structured to combine the strict incremental credit in the U.S. and the straight credit in Canada, offering a unique setting to examine firm responses to the policy of cutting R&D tax incentives.

Prior research documents the stimulating effects of R&D credit stemming from the Omnibus Budget Reconciliation Act of 1989 (OBRA89). In the U.S., R&D credits have been incremental in nature, implying that companies must spend more in the current year than a given base amount to get the credit. OBRA89 replaced the moving average base for the computation with a fixed percentage base. Gupta et al. (2011) examine this change in the computation of the credit enacted in OBRA89 using a sample of 2540 firms for the period 1981–1994, and find that while overall firm eligibility declined after OBRA89, eligibility increased for firms in high-tech industries. They also find that the median R&D spending of high-tech (other) companies that qualified for the credit increased by approximately 15.9% (9.4%) between 1986 and 1989 and 1990–1994, and the R&D tax credit induced approximately $2.08 of additional spending per dollar of forgone Treasury revenue in the post-OBRA89 period.

After enactment of the OBRA, an important design change was the enactment of the Alternative Simplified Credit (ASC) in 2007. This did not replace the OBRA credit regime, but provided firms with a choice between two credit-calculation methods. Beginning in 2007, companies had the option each year of choosing between the OBRA89 and ASC methods, depending on which would generate the larger tax benefit.[2] Finley et al. (2015) find that the ASC design dramatically increased firm eligibility for R&D tax credits, inducing approximately $2.26 additional R&D spending per dollar of forgone tax revenue.

Rao (2016) investigates the U.S. federal R&D tax credit data from 1981 to 1991 and finds that a 10% reduction in the user cost of R&D led the average firm to increase its R&D intensity by 19.8% in the short run. In the long run, the average company faced the adjustment costs and further increased its spending over time.

Using data from Taiwan, Wang and Chen (2000) examine the effectiveness of the SUI's R&D investment tax credits, personnel training and the establishment of international brand names. Using linear structural relations (LISREL) to analyze 161 questionnaire samples, they find that tax credits positively impacted firm R&D expenditure and established international brand names. Yang et al. (2012) use a sample of manufacturing firms listed on the Taiwan Stock Exchange (TSE) during 2001–2005, and find that R&D tax credits positively influenced R&D spending and growth, especially for electronics companies.

Chen and Li (2017) find the reduced credit rate by the SII have an adverse effect on the R&D spending of growth companies, financially-constrained companies and electronics companies.[3] Further, the disallowing R&D credits of carrying forward into next four years results in less volatility in changes in firms' R&D spending.

Bloom et al. (2002) find that a 10% decrease in the cost of R&D investment stimulated an additional 1% of R&D investment in the short run and 10% in the long run. Intuitively, a reduction in the R&D credit rate should lead firms to undertake R&D spending. However, there may be restrictions on the scaling back of R&D spending. First, R&D projects are carried out on a long-run basis. Second, competition within industries drives the need for innovation. Under the SUI, if a firm invested $100 in R&D it could receive a tax credit of $35; under the SII, it could receive a credit of only $15, increasing the net R&D investment cost from $65 to $85, a net RD investment increase of $20.[4] Thus, *ceteris paribus*, we expect the increase in the marginal investment cost of R&D to reduce the optimal R&D expenditure level. A reduction in firm R&D after SII would suggest that the negative effect arising from cutting the R&D incentive exceeds the cost of scaling down a firm's R&D investment, and therefore that the firm reduces its R&D spending. Thus, we state our first hypothesis as follows.

H1: *Ceteris paribus*, corporate R&D expenditure decreases after implementation of the Statute for Industrial Innovation.

[2] Under OBRA89, the base amount is a fixed function of the firm's historical R&D intensity, and the increased R&D intensity in the current period determines the credit amount. Under the ASC, the base amount is a rolling average of the firm's prior three years of R&D expenditure, irrespective of sales, where R&D expenditure in the current year relative to the prior three years determines the credit amount. The statutory rates are 20% under OBRA and 14% under ASC.

[3] They, however, did not examine the overall effect of the SII on the structural change in firms' R&D expenditures.

[4] Still, there is a $15 difference in net R&D costs under the SUI and the SII, given the effective credit rate of 30% in 2008 under the SUI.

2.3. The economic consequences of cutting R&D tax incentives

R&D is a major source of competitive advantage for most companies. Although a high level of R&D intensity does not guarantee the generation of successful innovation and enhanced firm performance, companies that invest heavily in R&D are more likely trying to compete on the basis of innovativeness (O'Brien, 2003; Lin et al., 2006). Czarnitzki et al. (2011) investigate the impact of R&D tax credits on the innovation activities of Canadian manufacturing firms, and conclude that tax credits lead to additional innovation. Capon et al. (1990) find a positive association between research and development expenditure and performance. Research also finds that the frequency of patent citations and R&D spillovers are positively and significantly related to firm value (Chin et al., 2006).

As prior studies suggest a positive relation between R&D and firm value, we expect this positive relation to be weakened by the SII cut in R&D tax incentives due to the resulting structural change in R&D costs. Before implementation of the SII, the SUI provided substantial R&D tax incentives to subsidize firm R&D expenditure, effectively reducing after-tax R&D costs. The R&D tax incentives of the SUI included (1) a statutory base credit rate of 35% for all qualifying R&D expenditure, and (2) an additional credit rate of 15% for a firm's current-year R&D spending over its prior two-year R&D average expenditure.[5] The SII, however, reduced the R&D credit rate to a flat rate of 15% without any incremental credit. This reduction in R&D tax incentives might have resulted in an upward structural shift in after-tax R&D costs for firms, as the reduced base credit rate proportionately increased after-tax R&D costs and the elimination of incremental credit further increased after-tax R&D costs for firms with greater R&D expenditure, potentially reducing the value of innovative R&D output. Hence, we expect the reduction in the R&D credit rate by the SII to adversely affect the relation between corporate R&D expenditure and firm value. Therefore, we propose our second hypothesis as follows.

H2: *Ceteris paribus*, the implementation of the Statute for Industrial Innovation has a negative effect on the relation between corporate R&D expenditure and firm value.

3. Data and research design

3.1. Data and sample selection

Our sample companies consist of the non-financial companies listed on the Taiwan Stock Exchange (TSE) and Over-the-Counter Market (OTC). We exclude biologics firms from our test sample because they are not affected by the implementation of the SII.[6] We use biologics firms as a contrast sample for additional analysis. Prior research finds that high-tech firms are more likely to qualify for the R&D tax credit than non-high-tech firms (Gupta et al., 2011). We thus separately conduct the test on a subsample of high-tech firms, including those in the semiconductor, computer and peripheral equipment, optoelectronic, and communications and Internet industries.

Our sample period consists of the four years before implementation of the SII (2006–2009) and five years afterwards (2010–2014). For the initial sample, we exclude firm-years with missing data on variables included in the regression model. The final sample consists of 10,523 firm-year observations. Table 1 reports the industry distribution of the sample firms: electronics firms (industry codes 24–31) account for about 54.78% of the sample, reflecting the importance of Taiwanese electronics industry in the global electronics supply chain, and high-tech firms (industry codes 24–27) account for about 29.6% of the sample.

[5] Under the SUI, the R&D credit rate increased to 50% from the statutory base credit rate of 35% for the excess of a firm's current-year R&D spending over its previous two-year R&D average expenditure.

[6] Biologics companies continued to enjoy the R&D tax incentives as before through the Act for the Development of Biotech and New Pharmaceuticals Industry.

Table 1
Industry distribution.

Industry name	TSE industry code[a]	Sample observations	Percentage of observations
Cement	01	61	0.58%
Food	02	209	1.99%
Plastic	03	242	2.30%
Textile & Fiber	04	473	4.49%
Electrical Engineering & Machinery	05	551	5.24%
Appliance & Cable	06	128	1.22%
Glass & Ceramics	08	37	0.35%
Papermaking	09	62	0.59%
Steel & Iron	10	330	3.14%
Rubber	11	98	0.93%
Auto	12	45	0.43%
Construction	14	564	5.36%
Sea Transport	15	182	1.73%
Tourism	16	106	1.01%
Wholesale & Retailing	18	169	1.61%
Other	20	553	5.26%
Chemical	21	314	2.98%
Biotechnology & Medical Care	22	412	3.92%
Oil, Gas & Electricity	23	104	0.99%
Semiconductor	24	916	8.70%
Computer & Peripheral Equipment	25	841	7.99%
Optoelectronic	26	805	7.65%
Communications & Internet	27	554	5.26%
Electronic Components	28	1501	14.26%
Electronic Products Distribution	29	331	3.15%
Information Service	30	268	2.55%
Electronic-Other	31	549	5.22%
Cultural and Creative Industry	32	118	1.12%
Total		**10,523**	**100%**

[a] We define industries according to the TSE industry codes.

3.2. Econometric methods

To test our two hypotheses, we construct the following two regression models.

3.2.1. Empirical model of H1

Following prior studies (Gupta et al., 2011; Finley et al., 2015), we construct regression model (1) to test H1 as follows:

$$RDI_{it} = \alpha_0 + \alpha_1 DYEAR_t + \alpha_2 TobinQ_{it} + \alpha_3 CFShort_{it} + \alpha_4 mRDI_{jt} + \alpha_5 LagRDI_{it} + \alpha_6 ETR_{it} + \alpha_7 SIZE_{it} + \alpha_8 ROA_{it} + \alpha_9 DEBT_{it} + \alpha_{10} FIRMAGE_{it} + \alpha_{11} GDP_t + \sum_j Industry\ effects + \varepsilon_{it} \quad (1)$$

where
subscript: i = firm index, j = industry index, and t = year index;

RDI	=	R&D expenditure ÷ net sales;
DYEAR	=	a dummy variable equal to 1 if the firm-observation is in the period 2010–2014, and 0 otherwise;
TobinQ	=	Tobin's Q, measured as (market value of common shares outstanding + book value of preferred stock + long-term debt + short-term debt) ÷ total assets;

CFShort	=	cash flow constraints before R&D expenditure, measured as (dividends + cash flow from investing – cash flow from operations – R&D expenses) ÷ beginning-of-year total assets;
mRDI	=	the average *RDI* of the industry, measured as the mean *RDI* of all firms in firm i's industry;
LagRDI	=	the one-year lagged *RDI*;
ETR	=	effective tax rate before R&D, measured as (current expenses + R&D expenses × statutory corporate income tax rate) ÷ (pre-tax income + R&D expenses);
SIZE	=	the natural logarithm of total assets;
ROA	=	net income before R&D expenses ÷ total assets;
DEBT	=	total liabilities ÷ total assets;
FIRMAGE	=	the natural logarithm of firm age in years;
GDP	=	gross domestic product;
Industry effects	=	the industry dummies;
ε	=	residual term.

3.2.1.1. Dependent variable. The dependent variable *RDI* is R&D intensity defined as R&D expenditure divided by net sales. Following prior research (Berger, 1993; Gupta et al., 2011), we scale *RDI* by net sales to provide a comparable basis.

3.2.1.2. Independent variable. Our test variable *DYEAR* is equal to 1 for the years after enactment of the SII (i.e., 2010–2014), and 0 otherwise. As H1 hypothesizes that firm R&D expenditure decreased after the implementation of the SII, we expect the coefficient on *DYEAR*, α1, to be negative. As the SII essentially abolished all tax incentives but for the R&D tax credit and reduced the credit rate to a flat 15%, there may be a concern that the coefficient of *DYEAR* captures the SII effect rather than R&D credit change alone. We address this concern as follows. First, the SII also abolishes other investment tax credits, such as for investment in automatic-production and for pollution-prevention capital assets. However, there may be no direct correlation between firm R&D expenditure and capital asset investment, as firms usually determine their R&D and capital asset budgets as separate projects.[7] To the extent that R&D expenditure is not directly correlated with capital asset expenditure, the coefficient on *DYEAR* in the R&D regression model may not be severely confounded by the effect of capital asset investment. Second, under the SUI, the effective base credit rate for R&D investment was 30% in 2008 while the effective credit rate for capital asset investment was only a flat 5%. The effect of abolishing capital asset investment credit is thus likely to be much smaller than the reduction in the R&D credit rate under the SII.

3.2.1.3. Control variables. Control variables in our model generally follow prior studies for the determinants of *RDI* (Gupta et al., 2011; Chen, 2014; Finley et al., 2015). *TobinQ*, defined as the market value of equity plus the book value of debt divided by the book value of total assets, captures growth opportunities. Companies with greater growth opportunities may have more innovation projects and undertake more R&D spending. Swenson (1992) finds that the positive impact of R&D credit exists only for firms with high growth opportunities. Berger (1993) documents that companies with greater market-to-book ratios have higher R&D expenditure. Thus, the predicted coefficient on *TobinQ* (α2) is positive. *CFShort* is the measure of the cash flow constraint before R&D spending. Myers and Majluf (1984) propose a financing hierarchy suggesting that because of information asymmetry, companies prefer to finance R&D with funds generated internally rather than externally. Firms with higher financial constraints have fewer internally generated funds to invest in R&D spending. Thus, the predicted coefficient on *CFShort* (α3) is negative. We measure the availability of internal funds by including an estimate of a firm's cash flow shortfall before R&D spending, following Brown and Krull (2008). *CFShort* is used to test whether firms have enough cash flow from operations before

[7] For our sample, we find that the correlation coefficient between R&D expenditure and changes in fixed assets, both scaled by total assets, is only 0.02543, suggesting that firm R&D expenditure and capital asset investment are not strongly correlated.

R&D to pay for investments and dividends. R&D spending is an autoregressive process instead of a random walk process (Klassen et al., 2004); therefore, we include lagged R&D intensity (*LagRDI*). We also include *mRDI* to capture industry-specific factors that drive R&D expenditure. The effective tax rate before R&D spending (*ETR*) is used to control for the tax rate effect on the cost of R&D spending. *ETR* is defined as the sum of current tax expenses and R&D expenses multiplied by the corporate tax rate and divided by the sum of pre-tax income and R&D expenses. Firms with a higher *ETR* are likely to have higher R&D expenditure because of the reduced after-tax cost of R&D investment. Thus, we expect the coefficient on *ETR* to be positive. *SIZE*, defined as the natural logarithm of total assets, is used to control for the scale effect on R&D expenditure. Following prior studies, we have no predicted sign for *SIZE* (Gupta et al., 2011; Finley et al., 2015). *ROA* is defined as net income before R&D divided by total assets. As prior studies argue that unprofitable companies are more likely to experiment with innovative activity (Hitt et al., 1991), whereas another study argues that less profitable firms may reduce their R&D spending (Daellenbace et al., 1999), we make no prediction for firm *ROA*. *DEBT*, defined as debt to total assets, is a proxy for firm financial leverage. Companies with higher debt ratios may face higher costs of financial distress and thus limit risky expenditure such as R&D spending (Chen and Hsu, 2009). Thus, we expect the coefficient on *DEBT* to have a negative sign. *FIRMAGE* is defined as the number of years a company has been established. As prior research suggests that older companies have less incentive to invest in innovation (Lin et al., 2011), we expect the coefficient on *FIRMAGE* to be significantly negative. Finally, we incorporate gross domestic product, *GDP*, to control for changes in macroeconomic conditions that may influence the results of our analysis. We winsorize the dependent variable, *RDI*, and each of the continuous variables except for *ETR*[8] and *GDP*, at 1% and 99% to prevent outliers from unduly influencing the results. We also control for industry fixed effects in model (1).

3.2.2. Empirical model for H2

To test our H2, we construct regression model (2) to analyze the effect of SII implementation on firm value as follows:

$$TobinQ_{it} = \gamma_0 + \gamma_1 DYEAR_t + \gamma_2 RDI_{it} + \gamma_3 DYEAR_t \times RDI_{it} + \gamma_4 SIZE_{it} + \gamma_5 FIRMAGE_{it} + \gamma_6 DEBT_{it} + \gamma_7 PPE_{it} + \gamma_8 HHI_{ij} + \sum_j Industry\ effects + \varepsilon_{it} \quad (2)$$

where
subscript i = firm index, j = industry index, t = year index;

TobinQ	=	Tobin's Q, measured as (market value of common shares outstanding + book value of preferred stock + long-term debt + short-term debt) ÷ total assets;
DYEAR	=	a dummy variable that equals 1 if the firm observation is in the period 2010–2014, and 0 otherwise;
RDI	=	R&D expenditure ÷ net sales;
SIZE	=	the natural logarithm of total assets;
FIRMAGE	=	the natural logarithm of firm age in years;
DEBT	=	total liabilities ÷ total assets;
PPE	=	gross property, plant and equipment ÷ total assets;
HHI	=	the Herfindahl–Hirschman Index, computed as the sum of squared market share based on firm sales at the TSE industry code level;
Industry effects	=	industry dummies;
ε	=	residual term.

[8] Following McGuire et al. (2012), we winsorize *ETR* to the range between 0 and 1.

3.2.2.1. Dependent variable. As a proxy for firm value, we use Tobin's Q (*TobinQ*), measured as the sum of the market value of common shares outstanding, book value of preferred stock and long- and short-term debt divided by total assets, as used extensively in prior research (e.g., Shane and Klock, 1997; Bharadwaj et al., 1999; Chin et al., 2006).

3.2.2.2. Independent variables. We include *RDI* and *DYEAR*×*RDI* in Eq. (2). As we expect the reduction in R&D credit rate by the SII to have an adverse effect on the relation between corporate R&D expenditure and firm value, the predicted coefficient on *DYEAR*×*RDI* (γ_3) is negative.

3.2.2.3. Control variables. The control variables in our model generally follow prior studies of the determinants of firm value (Chin et al., 2006; Bharadwaj et al., 1999; Renders and Gaeremynck, 2012). We control for firm and industry characteristics in prior research that are correlated with firm value. We include firm size (*SIZE*), firm age (*FIRMAGE*) and leverage (*DEBT*). We also include capital intensity (*PPE*) and industry concentration (*HHI*). *PPE* is defined as the ratio of gross property, plant and equipment to total assets. As Renders and Gaeremynck (2012) find that the relationship between capital intensity and firm value is negative, we expect *PPE* to be negatively associated with *TobinQ*. The Herfindahl–Hirschman Index (*HHI*) is a measure of industry concentration, defined as the sum of squared market share based on firm sales in the TSE industry code level. Prior research suggests that industry concentration provides market power, which positively influences firm value (Domowitz et al., 1986). Therefore, we expect *HHI* to be positively associated with *TobinQ*. We winsorize the dependent variable, *TobinQ*, and each of the continuous variables at 1% and 99% to prevent outliers from unduly influencing the results. We also include dummies to control for industry fixed effects.

4. Results

4.1. Descriptive statistics and univariate analysis

Table 2 profiles the descriptive statistics of our sample firms for the selected variables. The means of *RDI* and *TobinQ* are about 0.034 and 1.247 for all firms and 0.066 and 1.407 for high-tech firms, respectively, indicating that high-tech firms have greater R&D expenditure and a higher market premium. Table 3 reports the Pearson and Spearman correlations between the selected variables included in the regression models. The correlations across the control variables are generally in line with economic intuition and with those found in prior studies. The correlation matrix, however, indicates a positive univariate relation between the dependent variables and our test variables, inconsistent with our prediction. As the univariate relations do not control for the effects of other factors, we conduct further multivariate regression tests.

4.2. Multivariate regression results

4.2.1. Test of the SII's effect on firm R&D intensity

Table 4 presents the regression results of model (1) separated into all firms and high-tech firms. The results for all firms show that the coefficient on *DYEAR* is negative and significant at the 1% level, supporting H1 that after implementation of the SII, Taiwanese companies reduced their R&D spending in response to the reduced R&D credit rate. The coefficients on *CFShort* and *Debt* are significantly negative, suggesting that firms with greater financial constraints and leverage tended to invest less in R&D spending, consistent with our prediction that firms tend to rely on internal funding for R&D spending because of the information asymmetry for R&D investment projects. The coefficients on *ETR* are significantly positive, consistent with the notion that firms with higher tax rates are more likely to invest in R&D to utilize greater R&D tax shields.

The results for high-tech firms show that the coefficient on *DYEAR* is also negative and significant at the 1% level, supporting H1. The magnitude of the coefficient on *DYEAR* for high-tech firms (−0.0139) is much larger than for all firms (−0.0055), suggesting that the adverse effect is more salient for high-tech firms, consistent with our conjecture. The coefficients on the control variables for high-tech firms are, in general, similar to those for all firms, consistent with our expectations. Overall, the results in Table 4 lend support to H1 that companies reduced their R&D expenditure after implementation of the SII.

Table 2
Descriptive statistics.

Variable	All firms N = 10,111			High-tech firms N = 3116		
	Mean	Std.	Median	Mean	Std.	Median
RDI	0.034	0.061	0.013	0.066	0.084	0.037
ΔRDI	0.001	0.016	0.000	0.003	0.029	0.000
TobinQ	1.247	0.874	0.998	1.407	0.961	1.122
CFShort	−0.006	0.126	−0.012	−0.031	0.128	−0.037
mRDI	0.036	0.035	0.024	0.069	0.033	0.058
LagRDI	0.033	0.057	0.013	0.063	0.078	0.036
ETR	0.133	0.157	0.114	0.140	0.160	0.123
SIZE	15.211	1.339	15.022	15.281	1.506	15.009
ROA	0.066	0.108	0.064	0.078	0.135	0.084
DEBT	0.360	0.171	0.347	0.329	0.167	0.311
FIRMAGE	3.176	0.495	3.219	2.869	0.471	2.890
HHI	0.003	0.013	0.000	0.001	0.007	0.000
GDP	16.444	0.074	16.445	16.447	0.074	16.445
RETURN	0.1270	0.557	0.001	0.107	0.616	−0.043
BE/ME	−0.147	0.710	−0.068	−0.309	0.706	−0.250
ME	14.897	1.408	14.724	15.144	1.525	14.959
PPE	0.199	0.174	0.150	0.186	0.169	0.131

Notes: We define the variables as follows: *RDI* is R&D expenditure scaled by net sales; *ΔRDI* is the change in the *RDI*; *TobinQ* is measured as (stock price × common shares outstanding + book value of preferred stock + long-term debt + short-term debt) ÷ book value of total assets; *CFShort* is cash flow constraints before R&D expenditure, measured as (dividends + cash flow from investing – cash flow from operations – R&D expenses) ÷ beginning of-year total assets; *mRDI* is the average *RDI* of the industry measured as the mean *RDI* of all firms in firm i's industry; *LagRDI* is the one-year lagged R&D intensity; *ETR* is the effective tax rate before R&D, measured as (current expenses + R&D expenses × statutory corporate income tax rate) ÷ (pre-tax income + R&D expenses); *SIZE* is the natural logarithm of total assets; *ROA* is net income before R&D expenses scaled by total assets; *DEBT* is total debt scaled by total assets; *FIRMAGE* is the natural logarithm of firm age in years; *HHI* is the Herfindahl–Hirschman index; *GDP* is the log of year t real gross domestic product; *PPE* is the ratio of gross property, plant and equipment to total assets; *RETURN* is the firm's market adjusted stock return from December of year t − 1 to December of year t; *BE/ME* is the natural log of the ratio of book equity to market equity for the fiscal year ending in year t − 1; *ME* is the natural log of the market capitalization at the end of year t.

4.2.2. The economic consequence of cutting R&D tax incentives: Firm value

Table 5 shows the regression results for model (2), with all firms and high-tech firms in columns 1 and 2, respectively. The results for all firms show that the coefficient on *RDI* is significantly positive, consistent with the notion that firms with a higher value tend to invest more in R&D. However, the coefficient on *DYEAR×RDI* is negative and significant (−2.1945, t = −4.37), lending support to H2, that implementation of the SII negatively impacted the relation between corporate R&D spending and firm value. The result for high-tech firms is also negative and significant at the 1% level, supporting H2. The signs of the coefficients of the control variables in Table 5 are, in general, consistent with our predictions. Overall, the results in Table 5 indicate that the reduced R&D credit rate had a negative impact on the relation between corporate R&D expenditure and firm value.

5. Sensitivity analyses

5.1. Balanced sample

A potential concern with our findings is that the sample composition in the pre- and post-SII periods might have changed. To address this concern, we form a balanced panel including only those firms present in our sample for the entire 9-year period. The results remain consistent with those in Tables 4 and 5.

Table 3
Correlation table (N = 10,111).

	RDI	*DYEAR*	*TobinQ*	*CFShort*	*mRDI*	*LagRDI*	*ETR*	*SIZE*	*ROA*	*DEBT*	*FIRMAGE*	*GDP*
Panel A: Model (1)												
RDI	1.000	0.041***	0.221***	−0.224***	0.543***	0.929***	0.136***	−0.206***	0.142***	−0.253***	−0.288***	0.044***
DYEAR	0.041***	1.000	0.013	0.080***	0.072***	0.057***	−0.077***	0.028***	0.001	−0.040***	0.112***	0.898***
TobinQ	0.221***	0.013	1.000	−0.012	0.187***	0.238***	−0.053***	−0.152***	0.015	0.034***	−0.204***	−0.029***
CFShort	−0.224***	0.080***	−0.012	1.000	−0.189***	−0.221***	−0.073***	0.063***	−0.229***	0.198***	0.056***	0.058***
mRDI	0.543***	0.072***	0.187***	−0.189***	1.000	0.536***	0.082***	−0.098***	0.151***	−0.203***	−0.403***	0.079***
LagRDI	0.929***	0.057***	0.238***	−0.221***	0.536***	1.000	0.130***	−0.212***	0.169***	−0.241***	−0.294***	0.049***
ETR	0.136***	−0.077***	−0.053***	−0.073***	0.082***	0.130***	1.000	−0.060***	0.169***	−0.101***	−0.068***	−0.067***
SIZE	−0.206***	0.028***	−0.152***	0.063***	−0.098***	−0.212***	−0.060***	1.000	0.136***	0.144***	0.206***	0.025**
ROA	0.142***	0.001	0.015	−0.229***	0.151***	0.169***	0.169***	0.136***	1.000	−0.307***	−0.122***	−0.026***
DEBT	−0.253***	−0.040***	0.034***	0.198***	−0.203***	−0.241***	−0.101***	0.144***	−0.307***	1.000	0.053***	−0.041***
FIRMAGE	−0.288***	0.112***	−0.204***	0.056***	−0.403***	−0.294***	−0.068***	0.206***	−0.122***	0.053***	1.000	0.104***
GDP	0.044***	0.898***	−0.029***	0.058***	0.079***	0.049***	−0.067***	0.025**	−0.026***	−0.041***	0.104***	1.000

	TobinQ	*DYEAR*	*RDI*	*DYEAR×RDI*	*SIZE*	*DEBT*	*PPE*	*FIRMAGE*	*HHI*
Panel B: Model (2)									
TobinQ	1.000	0.013***	0.221***	0.131***	−0.152***	0.034***	−0.039***	−0.204***	0.030***
DYEAR	0.013	1.000	0.041***	0.343***	0.028***	−0.040***	−0.059***	0.112***	−0.017*
RDI	0.221***	0.041***	1.000	0.776***	−0.206***	−0.253***	−0.077***	−0.288***	−0.078***
DYEAR×RDI	0.131***	0.343***	0.776***	1.000	−0.139***	−0.187***	−0.063***	−0.159***	−0.059***
SIZE	−0.152***	0.028***	−0.206***	−0.139***	1.000	0.144***	0.029***	0.206***	0.432***
DEBT	0.034***	−0.040***	−0.253***	−0.187***	0.144***	1.000	0.072***	0.053***	0.043***
PPE	−0.039***	−0.059***	−0.077***	−0.063***	0.029***	0.072***	1.000	0.088***	0.059***
FIRMAGE	−0.204***	0.112***	−0.288***	−0.159***	0.206***	0.053***	0.088***	1.000	0.121***
HHI	0.030***	−0.017*	−0.078***	−0.059***	0.432***	0.043***	0.059***	0.121***	1.000

*, ** and *** stand for significance at the 10%, 5% and 1% levels, respectively.

Table 4
Test of the SII effect on R&D expenditure.
$RDI_{it} = \alpha_0 + \alpha_1 DYEAR_t + \alpha_2 TobinQ_{it} + \alpha_3 CFShort_{it} + \alpha_4 mRDI_{jt} + \alpha_5 LagRDI_{it} + \alpha_6 ETR_{it} + \alpha_7 SIZE_{it} + \alpha_8 ROA_{it} + \alpha_9 DEBT_{it} + \alpha_{10} FIRMAGE_{it} + \alpha_{11} GDP_t + \Sigma_j Industry\ effects + \varepsilon_{it}$ (1)

	All Firms	High-Tech Firms
Constant	−0.4427*** (−3.79)	−0.7648** (−2.53)
DYEAR	−0.0055*** (−4.89)	−0.0139*** (−4.65)
TobinQ	0.0003 (0.58)	0.0012 (0.90)
CFShort	−0.0070** (−2.21)	−0.0112 (−1.39)
mRDI	0.2384*** (5.74)	0.3692*** (4.56)
LagRDI	0.9407*** (64.46)	0.9294*** (37.31)
ETR	0.0060*** (3.26)	0.0174*** (2.66)
SIZE	0.0001 (0.58)	−0.0002 (−0.48)
ROA	−0.0186*** (−4.44)	−0.0435*** (−3.94)
DEBT	−0.0131*** (−6.89)	−0.0305*** (−5.82)
FIRMAGE	−0.0006 (−1.36)	−0.0021** (1.98)
GDP	0.0265*** (3.70)	0.0472** (2.55)
N	10,111	3116
Industry effects	YES	YES
Adjusted R^2	0.8687	0.8321

This table presents the regression results of the SII effect on R&D expenditure. The *t*-statistics in parentheses are based on robust standard errors clustered at the firm level.
*, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.
See Table 2 for variable definitions.

Table 5
Test of the SII effect on the relation between corporate R&D expenditure and firm value.
$TobinQ_{it} = \gamma_0 + \gamma_1 DYEAR_t + \gamma_2 RDI_{it} + \gamma_3 DYEAR_t \times nRDI_{it} + \gamma_4 SIZE_{it} + \gamma_5 FIRMAGE_{it} + \gamma_6 DEBT_{it} + \gamma_7 PPE_{it} + \gamma_8 HHI_{ij} + \Sigma_j Industry\ effects + \varepsilon_{it}$ (2)

	All firms	High-tech firms
Constant	3.6661*** (9.85)	2.8265*** (4.93)
DYEAR	0.1191*** (5.20)	−0.1019* (−1.87)
RDI	3.4606*** (5.92)	3.4848*** (4.32)
DYEAR×RDI	−2.1945*** (−4.37)	−1.9678*** (−2.74)
SIZE	−0.1081*** (−4.93)	−0.0923** (−2.58)
FIRMAGE	−0.2071*** (−5.66)	−0.1604*** (−3.09)
DEBT	0.6614*** (5.04)	0.8749*** (3.33)
PPE	−0.3206*** (−3.10)	−0.2335 (−1.09)
HHI	7.9331*** (5.20)	11.8990** (1.98)
N	10,111	3116
Industry effects	YES	YES
Adjusted R^2	0.1376	0.1241

This table presents the regression results of the SII effect on the relation between corporate R&D expenditure and firm value. The *t*-statistics in parentheses are based on robust standard errors clustered at the firm level.
*, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.
See Table 2 for variable definitions.

5.2. Biologics firm sample

Biologics companies continued to enjoy the R&D tax incentives provided by the Act for the Development of Biotech and New Pharmaceuticals Industry, and were thus not affected by the reduced R&D credit rate under the SII, as the Act provides the same tax credit benefit as the SUI. We therefore use biologics firms as a contrast sample to conduct the sensitivity analysis.

Panels A and B of Table 6 present the regression results for models (1) and (2), respectively, using the biologics sample. In panel A of Table 6 the coefficient on *DYEAR* is negative but insignificant (0.1423, $t = -0.68$), and in panel B the coefficient on *DYEAR×RDI* is positive and insignificant (0.0403, $t = 0.15$). The results suggest that biologics companies, as a contrast sample, do not exhibit the adverse effects on R&D spending and firm value as do other firms after implementation of the SII.

5.3. The economic consequence of cutting R&D tax incentives: Stock returns

In addition to *TobinQ*, we use the market-adjusted stock returns as an alternative proxy for testing the effect of cutting R&D spending on firm value. Prior studies find that R&D intensity is positively associated with corporate stock returns (Chan et al., 2001; Eberhart et al., 2004). R&D activity represents an important corporate resource for enhancing firm value. We use the market-adjusted stock returns as the dependent variable and construct model (3) as follows:

$$RETURN_{it} = \beta_0 + \beta_1 DYEAR_t + \beta_2 RDI_{it} + \beta_3 DYEAR_t \times RDI_{it} + \beta_4 BE/ME_{i,t-1} + \beta_5 ME_{it} + \beta_6 ROA_{it} + \beta_7 DEB_{it} + \beta_8 SIZE_{it} + \sum_j Industry\ effects + \varepsilon_{it} \quad (3)$$

Our test variable is DYEAR×RDI in model (3). As we expect the reduction in the R&D credit rate under the SII to negatively affect the relation between corporate R&D expenditure and stock returns, the predicted coefficient on DYEAR×RDI (β_3) is negative. Following Li (2011), we also include BE/ME, ME and ROA in model (3). BE/ME is the natural log of the ratio of book equity to market equity for the fiscal year ending in year $t-1$. ME is the natural log of the market capitalization at the end of year t. ROA is defined as net income before R&D divided by total assets.

Table 6
Results of biologics sample.

	Biologics firms
Panel A: Test of the SII effect on R&D expenditure (model 1)	
Constant	−16.9464 (−1.05)
DYEAR	−0.1423 (−0.68)
TobinQ	0.0233 (0.57)
CFShort	0.1616 (0.74)
mRDI	0.2009 (1.38)
LagRDI	0.9694*** (10.32)
ETR	0.6394* (0.09)
SIZE	0.0715** (2.03)
ROA	−0.3727 (−1.07)
DEBT	−0.5823** (−2.57)
FIRMAGE	−0.0208 (−0.63)
GDP	0.9755 (0.99)
N	412
Adjusted R^2	0.7543
	Biologics firms
Panel B: Test of the SII effect on the relation between corporate R&D expenditure and firm value (model 2)	
Constant	4.7419* (1.95)
DYEAR	0.5176*** (3.66)
RDI	0.4081*** (2.90)
DYEAR×RDI	0.0403 (0.15)
SIZE	−0.1375 (−0.82)
FIRMAGE	−0.2711 (−1.59)
DEBT	−1.4182 (−1.41)
PPE	−0.1946 (−0.25)
HHI	13.4291 (0.30)
N	412
Adjusted R^2	0.2294

*, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.
See Table 2 for variable definitions.

Table 7 presents the results of model (3) separately for all firms and biologics firms. The results show that the coefficient on *DYEAR×RDI* for all firms is negative and significant (−0.2851, $t = -1.65$); however, the coefficient on *DYEAR×RDI* for biologics firms is negative but significant (−0.0445, $t = -0.830$). The results suggest that implementation of the SII negatively impacted the relation between corporate R&D spending and stock returns. However, biologics firms continued to enjoy the special tax incentive, and hence did not exhibit this adverse effect.

5.4. Test of the SII effect on firm innovation output

R&D is uncertain and consumes both money and time. However, R&D investment is essential for firms where innovation is pivotal. Because of the externality benefit of R&D investment, many countries provide R&D tax credits to stimulate R&D expenditure in the private sector. However, many countries grant tax credits only for *qualified* R&D expenditure that can lead to innovative output, and the expenditure must be reviewed by the tax authorities to qualify for the credit. Hence, R&D tax credits may, to some extent, reflect a firm's qualified innovative investment in R&D. Czarnitzki et al. (2011) conclude that tax credits lead to additional innovation output. Cappelen et al. (2012) also find that projects receiving tax credits result in the development of new production processes and to some extent new company products. These results imply that R&D tax credits may be positively related to firm innovation activity. We thus use the tax credit value as a

Table 7
Test of the SII effect on the relation between corporate R&D expenditure and stock returns.
$RETURN_{it} = \beta_0 + \beta_1 DYEAR_t + \beta_2 RDI_{it} + \beta_3 DYEAR_t \times RDI_{it} + \beta_4 BE/ME_{i,t-1} + \beta_5 ME_{it} + \beta_6 ROA_{it} + \beta_7 DEB_{it} + \beta_8 SIZE_{it} + \Sigma_j Industry\ effects + \varepsilon_{it}$ (3)

	All Firms	Biologics firms
Constant	0.3230*** (4.49)	0.3756 (1.39)
DYEAR	−0.0599*** (−5.83)	0.0197 (0.46)
RDI	−0.1672 (−1.00)	0.0659 (1.12)
DYEAR×RDI	−0.2851* (−1.65)	−0.0445 (−0.83)
BE/ME	0.6150*** (37.15)	0.6185*** (11.73)
ME	0.6205*** (36.70)	0.6140*** (10.61)
ROA	1.0447*** (18.22)	0.9910*** (4.24)
DEBT	1.2446*** (29.17)	1.0470*** (6.09)
SIZE	−0.6455*** (−38.15)	−0.6467*** (−10.42)
N	10,111	412
Industry effects	YES	NO
Adjusted R^2	0.4370	0.3963

This table presents the regression results of the SII effect on the relation between corporate R&D expenditure and stock returns. The *t*-statistics in parentheses are based on robust standard errors clustered at the firm level.
*, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.
See Table 2 for variable definitions.

proxy for innovation output. We hand-collect tax credit data from the income tax footnotes in financial statements, and define a firm with greater innovation output as one that qualifies for a tax credit. We then construct model (4) to test the impact of the SII on firm innovation output as follows:

$$CREDIT_{it} = \beta_0 + \beta_1 DYEAR_t + \beta_2 RDI_{it} + \beta_3 DYEAR_t \times RDI_{it} + \beta_4 SIZE_{it} + \beta_5 ROA_{it} + \beta_6 PPE_{it} + \beta_7 FIRMAGE_{it} + \beta_8 GDP_{it} + \sum_j Industry\ effects + \varepsilon_{it} \quad (4)$$

where CREDIT = 1 for firms with non-zero credit values. Other variables are defined as previously.

Consistent with our expectation, the untabulated results show that the coefficient on *DYEAR* is negative and significant at the 1% level, suggesting that implementation of the SII had a negative effect on firm innovation output.

5.5. The effect on government revenue

To examine the effect of the SII on government revenue, we provide the following two statistics: (1) the value of firm tax credits for the SUI and SII periods and (2) the amount of government tax revenue lost due to the SUI and SII.

We hand-collect the actual R&D tax credit value from the income tax footnotes in firm financial statements during our sample period. Panel A of Table 8 indicates that the mean R&D credit value for each firm-year observation for the SUI and SII periods is about NT$6,736,000 and NT$1,280,000, respectively. The statistically significant difference in the means of the credit value between the two periods (*t*-statistic = 8.36, *p*-value = 0.01) suggests that the actual R&D tax credits obtained by our sample firms were much lower in the SII period than in the SUI period.

Panel B of Table 8 outlines the yearly tax revenue loss from the SUI and SII based on the income statistics of Taiwan's Ministry of Finance. The statistics show a gradual increase in annual tax revenue loss during the SUI period from 2006 to 2009 from about NT$119.46 billion to NT$196.68 billion. In contrast, the SII period from 2010 to 2014 shows a gradual decrease from about NT$192.56 billion to NT$89.28 billion. Taken

Table 8
The SII effect on firm R&D credit and government tax revenue loss.

	SUI Period	SII period	*t*-test
Panel A: Firm R&D credit in the SUI and SII periods (in NT$ thousands)			
Mean R&D credit value	67,364	12,803	8.36***
	SUI period	SII period	
Panel B: Annual tax revenue loss from the SUI and SII (in NT$ thousands)			
		2010	192,556,095
2006	119,462,825	2011	160,659,273
2007	180,501,472	2012	114,537,979
2008	151,261,020	2013	100,815,504
2009	196,681,848	2014	89,282,026

*, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

together, the results show a significant reduction after implementation of the SII in both firm R&D credits and government tax revenue loss.

5.6. Control of firm-fixed effects and difference-in-differences test

Models (1) and (2) use panel data estimation to control for unobserved industry-fixed effects because while inter-industry differences in market structure, demand conditions and technological opportunity have critical effects on firm investment in R&D innovation, unobservable firm-specific characteristics such as corporate vision and strategy may also be important influences. Therefore, we conduct the following robustness tests.

5.6.1. Controlling for firm-fixed and year effects

We use the whole sample for the regression tests, including the biotechnology companies, a total of 10,523 firm-year observations.[9] Panels A and B of Table 9 present the results of the regression models for H1 and H2. The coefficients on *DYEAR* and *DYEAR*×*RDI* remain negative and significant in both panels A and B, consistent with H1 and H2 that corporate R&D expenditure decreases under the SII and that the SII negatively affects the relation between corporate R&D expenditure and firm value. The coefficients on other independent variables are qualitatively similar to the results in Tables 4 and 5.

5.6.2. A generalized difference-in-differences design

We conduct a difference-in-differences regression model (5) to analyze the different effects of the SII on firm value for biotechnology versus non-biotechnology firms. Biotechnology firms continued to enjoy a special tax incentive status and were unaffected by the SII's reduced R&D credit rate. Model (5) is stated as follows:

$$TobinQ_{it} = \alpha_0 + \alpha_1 DYEAR_t \times IND_j + \alpha_2 RDI_{it} + \alpha_3 SIZE_{it} + \alpha_4 FIRMAGE_{it} + \alpha_5 DEBT_{it} + \alpha_6 PPE_{it} + \alpha_7 HHI_{jt} + \sum_j firm\ effects + \sum_t Year\ effects + \varepsilon_{it} \quad (5)$$

where

subscripts i = firm index, j = industry index and t = year index. *DYEAR* is a dummy variable for years after the enactment of the SII, *IND* is a dummy variable for non-biotechnology firms and *DYEAR*×*IND* is the interaction term of *DYEAR* and *IND*. Because biotechnology firms are not affected by the enactment of the SII, we expect the coefficient on *DYEAR*×*IND*, α_1, to be negative.

Panel C of Table 9 presents the results of model (5). Consistent with our expectation, the coefficient on *DYEAR*×*IND* is negative and significant (−0.2806, $t = -2.02$), suggesting that non-biotechnology firms are more adversely affected by the SII than biotechnology firms.

[9] The sample has a total of 10,523 firm-year observations.

Table 9
Robustness tests.

Panel A: Test of the SII effect on R&D expenditure—Control for firm-fixed effects and year effects	
Constant	−0.1015 (−0.79)
DYEAR	−0.0040*** (−2.83)
TobinQ	−0.0018** (−2.17)
CFShort	0.0024 (0.71)
mRDI	0.0179 (1.62)
LagRDI	0.4930*** (11.3)
ETR	0.0049** (2.21)
SIZE	−0.0049** (−2.48)
ROA	−0.0602*** (−6.87)
DEBT	−0.0165*** (−3.07)
FIRMAGE	0.0120** (2.51)
GDP	0.0095 (1.22)
N	10,523
Firm effects	YES
Year effects	YES
Adjusted R^2	0.9095
Panel B: Test of the SII effect on the relation between corporate R&D expenditure and firm value—Control for firm-fixed and year effects	
Constant	−2.2754** (−2.22)
DYEAR	−0.1038*** (−4.65)
RDI	0.4363 (0.81)
DYEAR×RDI	−1.4349*** (−3.97)
SIZE	0.3623*** (5.34)
FIRMAGE	−0.5012*** (−3.86)
DEBT	−0.3317** (−2.24)
PPE	−0.2496 (−1.28)
HHI	4.9690 (1.22)
N	10,523
Firm effects	YES
Year effects	YES
Adjusted R^2	0.6780
Panel C: Difference-in-differences (Model 5)	
Constant	0.0354 (0.07)
DYEAR×IND	−0.2806** (−2.02)
RDI	−0.5680 (−1.07)
SIZE	0.3499*** (5.08)
FIRMAGE	−1.1750*** (−6.41)
DEBT	−0.3331** (−2.23)
PPE	−0.1824 (−0.94)
HHI	5.9085 (1.38)
N	10,523
Firm effects	YES
Year effects	YES
Adjusted R^2	0.6886

This table presents the regression results of the SII effect on R&D expenditure. The *t*-statistics in parentheses are based on robust standard errors clustered at the firm level. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively. See Table 2 for variable definitions.

This table presents the regression results of the SII effect on the relation between corporate R&D expenditure and firm value. The *t*-statistics in parentheses are based on robust standard errors clustered at the firm level.

This table presents the regression results of the different effects of SII on firm value for biotechnology and non-biotechnology firms. The *t*-statistics in parentheses are based on robust standard errors clustered at the firm level.

6. Conclusion

This study examines the effect of reducing the R&D tax credit rate in Taiwan on corporate R&D expenditure and the economic consequences arising from cutting the R&D tax incentive. Using Taiwanese firms listed on the TSE and OTC from 2006 to 2014, we find a significant reduction in firm R&D spending after implementation of the SII in response to the reduced R&D credit rate. Furthermore, we find an adverse impact of the increased after-tax R&D costs on the relation between corporate R&D spending and firm value. Moreover, we find reduced innovation output from companies after implementation of the SII, but not among biologics companies, which were unaffected by the reduced R&D credit rate. Finally, the income statistics show significantly reduced firm R&D credits and government tax revenue loss after implementation of the SII.

The results of this paper contribute to the tax policy debate about the pros and cons of R&D tax incentives. Developing countries or regions often use extensive tax incentives to attract foreign investment and stimulate innovation. However, concerns are often raised about the loss of tax revenue. Taiwan enacted the SII in 2010 to replace the previously abundant tax incentives, marking the first time policymakers in Taiwan greatly reduced tax incentives for firm R&D expenditure. Our paper provides evidence that the negative effect of cutting R&D incentives exceeds the cost to firms of scaling down their R&D investment. Our results have important implications for developing countries or regions evaluating the potential impact of changing their tax incentive policy.

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