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# Are R&D subsidies effective? The effect of industry competition

*Xin Xiang*

**Abstract**
In this study, the author explores the effect of industry competition on public R&D subsidy effectiveness. He finds a non-linear threshold effect of industry competition on R&D subsidy effectiveness. Specifically, R&D subsidy effectiveness reaches its peak when industry competition lies between two estimated thresholds.

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**Keywords** Industry competition; R&D subsidy; complement effect; threshold regression

**Authors**
*Xin Xiang, Macau University of Science and Technology, Macau, China, xiangxinmacau@163.com*

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# 1 Introduction

The private R&D investment is crucial to ensure a country's economic growth, and the country typically encourages the private R&D investment through R&D subsidies. For instance, some tax preferential policies in China allow additional deductions for the R&D expenditure. However, arguments about R&D subsidy effectiveness are controversial. On the one hand, the R&D subsidy provides firms with public financing and induces firms to increase their private R&D spending (Bronzini and Piselli, 2016). On the other, cheap public funds may crowd out private funds, since firms tend to apply for the subsidy rather than raise funds in imperfect capital markets (Carboni, 2011). Thus, to what extent the subsidy benefits R&D activities is still a question. In this paper, I expand existing literature by examining the extent to which the R&D subsidy encourages private R&D spending and how R&D subsidy effectiveness is determined by industry competition.

Up to date, little attention has been paid to competition's effect on R&D subsidy effectiveness, while the link between competition and the R&D expenditure has been fully discussed. First, traditional arguments dating back to Schumpeter (1934) note that low competition increases the probability that the monopoly rent benefits R&D activities, so firms in less competitive industries, which are rewarded by monopoly profits, tend to invest more in R&D activities (Schumpeter, 1934; Aghion et al., 2005). Thus, it is reasonable for me to expect that firms facing less industry competition would have strong innovation incentives and then take fully advantage of public R&D grants. Second, arguments based on the "escape competition" theory predict a positive effect of industry competition on private R&D spending. These arguments note that firms in competitive industries face more similar production costs. R&D activities aimed at decreasing production costs reward firms with post-innovation rents and help firms to escape from competition, so firms in competitive industries tend to invest more in R&D (Aghion et al., 2005, 2009). The escape competition effect spurs firms' innovation incentives, and then I could expect that the public subsidy would be efficient at increasing private R&D spending when firms faced intense industry competition. However, neither predictions has been examined.

In this study, I first investigate the extent to which the R&D subsidy encourages private R&D spending and find that the subsidy can complement private R&D spending to some degree. As to the effect of competition on subsidy effectiveness, the relationship between them points to a presence of non-linear threshold effect. That is, the escape-competition effect leads the complement between public and private funds to increase when competition intensifies to reach a threshold; whereas the Schumpeterian effect induces the complement to increase when competition lessens to reach another threshold level.

# 2 Policy background and methodology

## 2.1 R&D subsidy policies in China

This paper discusses competition's effect on R&D subsidy efficiency. R&D subsidy policies typically reflect the government priority, and a certain kind of firm is always selected as a target. So, it is necessary to introduce R&D subsidy policies in China. R&D subsidy policies in China are complex, and the most famous nationwide policy is the additional deduction for R&D expenditures policy, which began in 1996. This policy allows entities that have established a sound accounting system such as state-owned, private and foreign enterprises, research institutions and universities to enjoy 50% additional deductions, and allows small high-innovation firms to enjoy 75% additional deductions for the R&D expenditure. That is, for ordinary enterprises, 100 Yuan R&D expenditures can be treated as 150 Yuan and deduct from the income when calculating the enterprise income tax. For small high-innovation firms, the additional deduction will be 75 Yuan, and high-innovation firms are identified as those that are operated in high-innovation industries including electronic information, aeronautics and astronautics, modern transportation, modern agriculture, medical and medicine, new material, new energy and so on. The policy of 75% additional deductions for the R&D expenditure will be extended to ordinary firms in 2018. The additional deduction policy enables a wide range of firms that have engaged in R&D activities to benefit from tax preferences, and the identification of high-innovation industries is not strict so that many industries can be treated as high-innovation ones and enjoy 75% additional deductions. However, a drawback of this policy is that it is difficult for government to recognize a reasonable R&D expenditure, and the requirement of establishing an expense recognition process may be costly. Zhang et al. (2015) introduce another nationwide subsidy policy "innovation funds". The "innovation funds" policy provides small and median innovation firms with three kinds of subsidies: the direct subsidy, the interest subsidy and the capital investment. Firms in 8 high-tech industries including electronics, medical and medicine, new material, environmental protection and modern agriculture get priority in applications. Only a small range of firms thus can benefit from the "innovation funds" policy, and "innovation funds" may not be as efficient as the additional deduction policy. As indicated by Zhang et al. (2015), the "innovation funds" policy seems to be less efficient than expectation. In general, nationwide subsidy policies benefit a wide range of industry firms, and these generalized preferences can encourage all kinds of research activities no matter the research is a process or a basic one. This may be because the distinction between process and basic research spending is costly.

In addition to nationwide policies, provinces have their own R&D subsidy policies. For example, Guangdong province provides an additional R&D subsidy for firms operated in Guangdong. Specifically, the subsidy equals R&D expenditures time 10% when R&D expenditures are smaller than 5 million Yuan, while the subsidy equals 500 thousand plus R&D

expenditures minus 5 million when R&D is larger than 5 million Yuan. Shandong province provides 10% additional subsidies for R&D expenditures that have already been subsidized by the additional deduction policy. Cities even have their independent R&D subsidy policies. For instance, in 2018, Futian district Shenzhen city provides less than 3 million Yuan subsidies for firms whose R&D expenditures are greater than 500 thousand Yuan. These policies often concentrate public funds on a certain kind of R&D activity such as patent application. For instance, the subsidy detail of the sample firms shows a wide range of subsidy sources, such as the R&D worker's training subsidy, the patent application subsidy and the interest subsidy and so on. In general, firms can receive a wide source of R&D subsidies in China. In this case, the R&D subsidy becomes a possible financing channel through which firms can support their R&D activities, and the most crucial problem is that public financing may substitute or complement private one.

## 2.2 The data

My dataset comes from China Stock Market & Accounting Research Database. I exclude financial firms because of their special financial leverage. Firms that have missing values for financial data and those with at least two years deficits are also excluded from my sample. After these cleaning steps, I use a balanced panel of 901 publicly traded firms in China among 135 industries based on the classification of China's Securities Regulation Commission over the period 2000–2016. The final dataset includes 15317 firm-year observations.

## 2.3 Dependent variables

I use two proxies to measure the R&D expenditure. As mentioned by Gonzalez and Pazo (2008), an efficient public programme would complement private R&D spending and induce private spending even beyond the subsidy. I first use the internal R&D expenditure, which subtracts the government subsidy from total R&D expenditure, to measure the amount of private R&D spending (Clausen, 2009). The subsidy programme would be efficient if the subsidy could induce firms to obtain R&D financing through private means, and the internal R&D expenditure would be high in this case. The other proxy is simply the total R&D expenditure, which measures both public and private funds. Table 1 shows that the mean level of the internal R&D spending to sales ratio is 0.199, and the sample mean of the total R&D spending to sales ratio is 0.366.

## 2.4 Independent variables

The primary focus of this paper is competition's effect on R&D subsidy efficiency, so I include the public subsidy obtained to support private R&D programmes in my regressions (Lee, 2011). The public subsidy is typically operated through both fiscal and tax incentive channels. Fiscal incentive is the most common form of the public subsidy, but fiscal grants benefit firms only if the R&D project is expected to be valuable. Thus the allocation of public funds is likely to be subject to the "pick the winner" criteria. Tax incentive, by contrast, exhibits a more random process because tax burden, which is influenced by the amount of R&D expenditures, is reduced automatically (Bronzini and Piselli, 2016). Thus, a small number of studies address the selection bias problem by including tax incentive programmes only (Czarnitzki et al., 2011; Cappelen et al., 2012). In my study, public subsidies include both fiscal and tax grants, since fiscal benefits are also crucial parts of public subsidies (Berube and Mohnen, 2009). In robustness check, I correct the potential selection bias problem by employing the industry mean and the one year lag[1] of firm subsidies as instrumental variables.

As to industry competition, I employ two competition proxies in my regressions. The first one is simply the Herfindahl index of firm sales for each industry. The Herfindahl index measures the distribution of industry firm sales, and a higher Herfindahl index of firm sales usually indicates a lower competition environment. For robustness, I repeat my analysis by using an industry median of firms' profit margin as another competition proxy. The profit margin is measured as an operating income to sales ratio, in which the operating income equals the operating revenue minus the operating expenditure. Firms facing less competition typically earn a higher profit margin than the firms facing intense competition do. In this case, a higher profit margin indicates a lower industry competition. Table 1 shows that the sample mean of the Herfindahl index is 0.136 and the mean of the industry profit margin is 0.064.

## 2.5 Control variables

I first include the natural logarithm of total assets as a control variable. Total assets are often used to control for the firm size, which may have possible influences on firms' R&D incentives (Hyytinen and Toivanen, 2005; Meuleman and De Maeseneire, 2012). I also use the natural logarithm of sales to control for the sales scale, and use the change in sales over a fiscal year to capture the sales growth. Sales are considered to influence firms' willingness to develop new products (Ernst et al., 2010). I also control for the financial leverage, and use the debt to asset ratio to measure the financial leverage. The financial leverage changes firms' financing ability and influences their R&D incentives (Cai and Zhang, 2011; Sasidharan et al., 2015). In Table 1,

[1] Thanks for reviewer's suggestion of using the lag subsidy as instrument.

the sample mean of the natural logarithm of total assets is 21.683. The mean of the sales scale and sales growth are 20.901 and 0.204 respectively. As to the financial leverage, the mean of the debt to asset ratio is 0.534.

*Table 1*: Summary statistics

| Variables | Obs. | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Internal R&D expenditure to sales ratio | 15317 | 0.199 | 1.201 | -5.594 | 20.326 |
| Total R&D expenditure to sales ratio | 15317 | 0.366 | 1.386 | 0 | 25.725 |
| Natural log of individual firms' subsidy | 15317 | 7.436 | 8.034 | 0 | 20.160 |
| Industry mean of individual firms' subsidy | 15317 | 11.026 | 7.408 | 0 | 19.002 |
| HHI | 15317 | 0.136 | 0.152 | 0.02 | 1 |
| Industry median of individual firms' profit margin | 15317 | 0.064 | 0.063 | -0.105 | 0.345 |
| Assets | 15317 | 21.683 | 1.315 | 18.977 | 25.528 |
| Sales | 15317 | 20.901 | 1.932 | 17.072 | 25.095 |
| Original value of Sales | 15317 | $4.89\times10^{9}$ | $1.77\times10^{10}$ | -3599547 | $7.46\times10^{11}$ |
| Sales growth | 15317 | 0.204 | 0.637 | -0.659 | 4.08 |
| Debt ratio | 15317 | 0.534 | 0.26 | 0.078 | 1.94 |

## 2.6 The model

In order to estimate the effect of industry competition on R&D subsidy efficiency, I modify the empirical model suggested by Clausen (2009). The empirical model is defined as:

$$R\&D_{i,t} = \beta_1 + \beta_2 Subsidy_{i,t} I\left(Com_{j,t} \leq \alpha_1\right) + \beta_3 Subsidy_{i,t} I\left(\alpha_1 < Com_{j,t} \leq \alpha_2\right) + \beta_4 Subsidy_{i,t} I(Com_{j,t} > \alpha_2) + \beta_x X_{i,t} + \varepsilon_{i,t} \qquad (1)$$

in which *i* denotes firm *i*, *t* denotes year *t* and *j* reflects industry *j*. R&D denotes the internal R&D spending to sales ratio, and I employ the total R&D spending to sales ratio as another innovation proxy. All of the R&D ratios are calculated by multiplying the original ratios by 100. Subsidy denotes the natural logarithm of the government subsidy allocated to individual firms. For robustness, I use the industry mean and the one year lag of firm subsidies as Subsidy instrument variables. Com denotes two competition variables mentioned above. X is a vector of control variables mentioned in Section 2.3.

I use the threshold regression approach developed by Hansen (1999) to estimate the equation. Hansen (1999)'s methodology allows an examination for the existence of competition thresholds in explaining R&D subsidy effectiveness. This method first gives some potential competition thresholds beyond which R&D subsidy effectiveness changes drastically, and then estimates subsidy effectiveness separately for each competition threshold level. In addition, Hansen (1999)'s methodology addresses the firm fixed effect by employing a data transformation. This transformation, which avoids the estimation of so many dummy variable parameters, involves subtracting the time-mean of each firm entity away from the variable's values.

# 3 Empirical results

## 3.1 Summary statistics

Table 1 presents summary statistics of main variables. The sample mean of the internal R&D expenditure to sales ratio is 0.199, which is slightly lower than the sample mean of the total R&D expenditure to sales ratio. The internal R&D reflects firms' willingness to use private financing channels such as loans, the equity and the internal cash to support their R&D programmes, while the total R&D expenditure reflects both private and public financing channels. This is why the sample mean of the internal R&D spending ratio is smaller than the mean of the total R&D spending ratio. However, both the internal and the total R&D spending ratio are small. Ma et al. (2014) find that more than 50% Chinese manufacturing firms engaged in R&D from 2002 to 2004. However, if we turn to the entire A-share market, which includes all kinds of industries such as the real estate, the agriculture and the media, the average R&D spending to sales ratio is only 1.406 %[2]. The sample employed in this paper is a subset of the A-share market, which only includes firms that continued as a going concern from 2000 to 2016, that is the sample firms are quite mature. Mature firms typically have a stable profit so their R&D incentive may not be as high as that of young firms.

The sample mean of the natural log of individual firms' R&D subsidy is only 7.436, while the sample mean of the industry subsidy (11.026) is higher. However, both firm and industry R&D subsidies are lower than those presented in previous studies, such as Clausen (2009) indicates that the mean of the natural log of the close to market subsidy is 1938.9 in Norway. In addition, the sample mean of HHI is 0.136 and the minimum value of HHI is only 0.02. These two figures are quite small, indicating that industry sales are not concentrated into one or two firms. The sample mean of the industry profit margin is even smaller than 10%, and the largest

[2] This figure is calculated by using the R&D expenditure and sales of firms in Chinese A-share market, and data is from Bloomberg database.

industry median of the profit margin is only 34.5%. These statistics also indicate that industry competition is so high that firms can only receive a low profit margin.

### 3.2 Determination of the threshold number

Table 2 shows results of the determination of the threshold number. I determine the number of thresholds by estimating the baseline model allowing for one, two or more competition thresholds. According to Aghion et al. (2005)'s study, the relationship between competition and firms' innovation incentives is an inversed-U shape. Since efficiency of public R&D grants depends on firms' innovation incentives, the relationship between competition and R&D subsidy efficiency is also non-linear and exhibits at least two cut-points.

In Table 2, both threshold parameters and their confidence intervals have been estimated. The competition variable in columns (1) and (2) is the Herfindahl index of industry firm sales. In column (1), all of the threshold parameters ($\hat{\alpha}_1$= 0.0396 and $\hat{\alpha}_2$ = 0.0706) lie within their 95% confidence intervals, suggesting that both $\hat{\alpha}_1$ and $\hat{\alpha}_2$ in column (1) are statistically significant. These results also indicate that the relationship between the R&D subsidy and the private R&D investment can be estimated in three stages, and R&D subsidy's effect on private R&D spending will change drastically when competition reaches the two thresholds. The threshold parameters in column (2) (0.0396 and 0.0706) also lie in their 95% confidence intervals, indicating that competition exhibits two statistically significant cut-points when explaining the effect of subsidies on total R&D spending. The competition proxy in columns (3) and (4) is the industry median of individual firms' profit margin. Results in columns (3) and (4) also exhibit two statistically significant thresholds, which are in line with our expectation. I also find that some of the thresholds are close to each other, such as the thresholds in column (4) (0.0434 and 0.0491). Table 1 shows that the sample mean of industry profit margin is 0.064, and even the largest threshold in column (4) (0.0491) is smaller than the sample mean. This result indicates that R&D subsidy's effect changes more quickly when market competition becomes weaker. This may show that most of the Chinese firms, especially some small firms, are not willing to engage in innovation. Technologies employed by industry firms are similar to each other, and market competition becomes intense. However, firms that tend to improve technologies that are widely used by competitors will benefit more from R&D activities.

I sequentially carry out the LM test, and the bootstrapped P-value is reported in Table 3. In columns (1) to (4), all of the P-values in single threshold tests are smaller than 1%. These results indicate that competition has at least one cut-point when describing the relationship between the R&D subsidy and private R&D spending. Then I conduct double threshold tests and find that P-values in double threshold tests are also smaller than 1%, suggesting that two competition thresholds are also acceptable. However, when LM tests extend to third-level tests the results are no longer statistically significant, indicating that two cut-points are more proper.

*Table 3*: Tests for threshold effect : P-values from LM tests

| Threshold | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Single | 0.000*** | 0.000*** | 0.000*** | 0.000*** |
| Double | 0.000*** | 0.000*** | 0.000*** | 0.000*** |
| Triple | 0.940 | 1.000 | 0.637 | 0.567 |

Notes: * Significant at 10%; ** significant at 5%; *** significant at 1%

*Table 2*: Threshold estimates [95% confidence intervals]

| Threshold | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| First ($\hat{\alpha}_1$) | 0.0396 | 0.0396 | 0.0434 | 0.0434 |
| | (0.0383-0.0402) | (0.0383-0.0402) | (0.0303-0.0445) | (0.0303-0.0445) |
| Second ($\hat{\alpha}_2$) | 0.0706 | 0.0706 | 0.0516 | 0.0491 |
| | (0.0686-0.0709) | (0.0686-0.0709) | (0.0511-0.0524) | (0.0487-0.0497) |

Notes:(i) The threshold estimates refer to the level of competition variables; (ii) Confidence intervals are reported in parentheses

## 3.3 The effect of competition on R&D subsidy effectiveness

Table 4 shows the regression results for the effect of competition on R&D subsidy effectiveness. For the internal R&D measure, coefficients for the R&D subsidy variable (Subsidy) in columns (1) and (3) are positive and significant at 1%, indicating that the subsidy increases the amount of private internal R&D spending. These results are in line with Carboni (2011)'s work which demonstrates that the perfect crowding-out between public and private financing should be rejected, and public grants enhance the probability that innovation firms get access to market financing to some degree.

Consistent with my prediction, the relationship between competition and R&D subsidy efficiency points to an existence of non-linear threshold effect. Specifically, Subsidy's coefficients for second-level regressions in columns (1) and (3) are the largest (0.045 and 0.057), indicating that firms that lie between the two critical values of industry competition ( $\hat{\alpha}_1$ and $\hat{\alpha}_2$ ) are more likely to use public funds to complement their internal R&D spending. Economically, 100% increases in the R&D subsidy induce firms to increase 0.045 % of their internal R&D to sales ratio in column (1) and 0.057 % of the R&D ratio in column (3). Specifically, if firms received average 100 Yuan subsidy before, an extra 100 Yuan subsidy now may lead to average 0.045% increases in their internal R&D to sales ratio in column (1). Since the sample mean of sales is $4.89\times10^9$ Yuan in Table 1, the average increases in R&D spending will be 2.2 million Yuan. This effect seems small, but it constitutes 22.613% of the sample

*Table 4:* The impact of industry competition on R&D subsidy effectiveness

| Variable | (1) HHI-internal | (2) HHI-total | (3) Margin-internal | (4) Margin-total |
|---|---|---|---|---|
| Subsidy | | | | |
| I(Com $\leq \hat{\alpha}_1$) | 0.010*** | 0.031*** | 0.026*** | 0.056*** |
| | (3.19) | (9.29) | (15.45) | (29.85) |
| I($\hat{\alpha}_1$<Com $\leq \hat{\alpha}_2$) | 0.045*** | 0.077*** | 0.057*** | 0.089*** |
| | (20.24) | (31.03) | (18.30) | (25.93) |
| I(Com>$\hat{\alpha}_2$) | 0.014*** | 0.036*** | 0.009*** | 0.024*** |
| | (9.56) | (21.25) | (5.17) | (12.74) |
| Constant | -1.493*** | -2.575*** | -1.630*** | -2.718*** |
| | (-5.94) | (-9.23) | (-6.44) | (-9.70) |
| Firm fixed effect and control variables | Yes | Yes | Yes | Yes |
| $\hat{\alpha}_1$ | 0.039 | 0.039 | 0.043 | 0.043 |
| $\hat{\alpha}_2$ | 0.076 | 0.076 | 0.049 | 0.051 |
| $R^2$ | 0.046 | 0.120 | 0.049 | 0.128 |
| Obs. | 15317 | 15317 | 15317 | 15317 |

Notes: This table presents results of industry competition's effect on R&D subsidy effectiveness. Internal R&D spending to sales ratio is employed in columns (1) and (3), while total R&D spending to sales ratio is used in columns (2) and (4). Subsidy denotes individual firms' R&D subsidy. Com denotes the Herfidahl index of firm sales for each industry in columns (1) and (2), and the industry median of firms' profit margin in columns (3) and (4). The firm fixed effect has been already addressed by using Hansen (1999)'s methodology. $\hat{\alpha}$ denotes two thresholds. T-statistics are given in parentheses. *, ** and *** denote significant at 10%, 5% and 1% level, respectively.

mean of the internal R&D spending ratio (0.045÷0.199). That is, 100 Yuan sales include nearly 0.2 Yuan internal R&D spending at the beginning, but 100 Yuan subsidy increases lead to average 0.045 Yuan increases in internal R&D spending. The increases constitute 22.5% of original average spending. The similar effect can also be found in column (3).

In contrast, the coefficients for first-level regressions are 0.010 in column (1) and 0.026 in column (3), and the coefficients for third-level regressions are 0.014 and 0.009. All of these coefficients are smaller than those in second-level regressions. In column (1), 100% increases in subsidy lead to merely 0.010% increases in internal R&D ratio in the first-level regression, and the increases constitute only 5.025% of the sample mean of the internal R&D ratio (0.010÷0.199). This result is 0.035% lower than that in the second-level regression (0.045%-0.010%). In addition, 100% increases in subsidy result in 0.014% increases in internal R&D ratio in the third-level regression. This effect constitutes only 7.035% of the sample mean of the internal R&D ratio (0.014÷0.199), and is 0.031% lower than that in the second-level regression (0.045%-0.014%). The similar effect could also be found in regressions in column (3).

The results in Table 4 also indicate that the complement between the subsidy and the internal R&D spending ratio increases when industry competition intensifies to reach the threshold $\hat{\alpha}_2$, even if the initial level of competition is low. This finding coincides with the escape competition theory suggested by Aghion et al. (2005). In addition, the degree to which the R&D subsidy complements the internal R&D spending ratio increases when competition lessens to reach another threshold ($\hat{\alpha}_1$), while the initial level of competition is high in this case. This result could be explained by increased monopoly profit.

In fact, industry competition can be influenced by R&D activities of industry firms. Specifically, industry competition is intense when industry firms share similar technologies, and similar technologies lead products that are sold in the market to possess similar qualities. The price that sellers can charge their customers then decreases until the marginal profit equals zero. This would explain why firms earn a lower profit margin in a competitive market. However, if a small range of firms tend to advance existing technologies, they will have opportunities to increase the profit they earn, and the market competition then becomes less intensive. In this case, innovation activities that enable firms to charge a profit will lead industry competition to decrease, and the low competition level will be a consequence of industry firms' innovation activities.

In term of R&D subsidy policies, it is reasonable to assume that R&D subsidies can lead the private R&D investment to increase when subsidized firms have incentives to engage in innovation activities. Since innovation activities result in decreases in industry competition, R&D subsidies will be more efficient when subsidized firms are in less competitive markets. Results in this section indicate that the complementary effect of the R&D subsidy is stronger when subsidized firms are in less competitive industries. When considering subsidy policies in China mentioned in section 2, subsidy policies in China always select high-innovation firms as targets. For instance, the additional deduction policy provides small high-innovation firms with 75% additional deductions, and firms in eight high-tech industries have priorities when applying for "innovation funds". High-innovation firms may have willingness to do innovation, and innovation itself may lead the market competition to be less intensive. This may give a policy explanation of my results: subsidy policies in China select high-innovation firms as subsidized firms and high-innovation firms are always operated in less competitive industries, so results in this section show that subsidies are more efficient when firms face less intensive market competition.

The innovation proxy in columns (2) and (4) is the total amount of funds devoted to R&D projects. The coefficients of Subsidy in columns (2) and (4) are also positive and significant at 1%, indicating subsidy's positive effect on total R&D spending. The largest coefficient of Subsidy in columns (2) and (4) lie in second-level regressions (0.077 and 0.089), suggesting that the complement effect of public funds tends to reach its peak when subsidized firms lie between the two competition thresholds. In addition, the coefficients of Subsidy in column (2) and (4) (0.077 and 0.089) are higher than those in column (1) and (3) (0.045 and 0.057). This may be because firms use public funds as a critical channel of R&D financing, and the R&D subsidy in turn could lead to higher increases in total R&D spending than those in private spending.

## 3.4 Robustness tests

So far, I have demonstrate the complementary effect of individual firms' R&D subsidy on R&D spending. However, subsidy policies always select high-innovation firms in high-innovation industries. For example, some policies require the subsidy equals a percentage of the R&D expenditure so that high-innovation firms can receive more subsidies. In this case, the subsidy will be influenced by some factors that are determined by R&D spending, and these factors will lead to endogeny. In order to address the potential endogenous problem, I introduce an instrument variable—the industry mean of individual firms' R&D subsidy—into my regressions. That is, I regress the industry subsidy on the two R&D proxies. The instrument should relate to individual firms' R&D subsidy but do not be influenced by individual firms' R&D expenditure. R&D subsidy policies are often conducted in an industry level, and industries that are considered as conducting valuable R&D programmes are more likely to receive subsidies, thus individual firms' R&D subsidy relates to the industry subsidy. However, the R&D expenditure has a small influence on industry-level variables such as industry R&D subsidy. This is because R&D spending of firms accounts for only a small proportion of industry R&D, but industry R&D has a direct impact on other industry-level variables. For some industries, the largest value of the individual to industry R&D spending ratio is smaller than 10%, and some small firms even do not contribute to the industry R&D expenditure.

After using the industry subsidy, each column in Table 5 reports two possible competition thresholds ($\hat{\alpha}_1$ and $\hat{\alpha}_2$), and competition thresholds are quantitatively similar to those in Table 3. In LM tests, all of the P-values in single and double threshold tests are smaller than 10%, indicating that competition exhibits two cut-points. When considering the effect of the subsidy on R&D spending, the largest coefficient of the industry subsidy also lies in second-level regressions in Table 5. For example, in column (2) of Table 5, the coefficient 0.103 indicates that 100% increases in R&D subsidy result in 0.103% increases in R&D spending. This effect constitutes 51.759 % of the sample mean of the internal R&D ratio (0.103÷0.199).

Table 6 employs the one year lag of individual firms' R&D subsidy as the instrument that is I regress the one year lag of the firm subsidy on the R&D expenditure. In Table 6, except for results in column (4), each column indicates that the positive effect of the subsidy on the R&D expenditure reaches its peak when competition lies between the two thresholds. In general, after using instrument variables to address the potential endogenous problem, our main findings are strongly held.

*Table 5*: Other R&D subsidy proxies: the industry mean of the R&D subsidy

| Variable | (1) HHI-internal R&D | (2) HHI-total R&D | (3) Margin-internal R&D | (4) Margin-total R&D |
|---|---|---|---|---|
| Tests for threshold | | | | |
| Single | 0.017** | 0.053* | 0.000*** | 0.000*** |
| Double | 0.040** | 0.063* | 0.003*** | 0.000*** |
| Triple | 0.470 | 1.000 | 0.773 | 0.7133 |
| Threshold estimate | | | | |
| First($\hat{\alpha}_1$) | 0.0396 | 0.0459 | 0.0434 | 0.0456 |
| | (0.0383-0.0402) | (0.0396-0.0480) | (0.0420-0.0445) | (0.0451-0.0462) |
| Second($\hat{\alpha}_2$) | 0.0706 | 0.0706 | 0.0491 | 0.0491 |
| | (0.0679-0.0709) | (0.0686-0.0709) | (0.0487-0.0497) | (0.0487-0.0497) |
| Estimated variables | | | | |
| Subsidy | | | | |
| I(Com $\leq \hat{\alpha}_1$) | 0.015*** | 0.036*** | 0.026*** | 0.048*** |
| | (5.43) | (13.42) | (15.15) | (25.86) |
| I($\hat{\alpha}_1$<Com $\leq \hat{\alpha}_2$) | 0.046*** | 0.103*** | 0.044*** | 0.074*** |
| | (16.88) | (24.67) | (16.46) | (20.30) |
| I(Com >$\hat{\alpha}_2$) | 0.017*** | 0.035*** | 0.012*** | 0.023*** |
| | (12.71) | (22.45) | (7.35) | (12.91) |
| Constant | -2.302*** | -4.266*** | -2.472*** | -4.733*** |
| | (-9.68) | (-16.01) | (-10.31) | (-17.64) |
| Firm fixed effect | Yes | Yes | Yes | Yes |
| $R^2$ | 0.041 | 0.104 | 0.042 | 0.102 |
| Obs. | 15317 | 15317 | 15317 | 15317 |

Notes: This table also reports regressions of the public subsidy on the private R&D expenditure, which are influenced by industry competition. The subsidy proxy (Subsidy) in this table is the industry mean of individual firms' R&D subsidy. R&D spending ratios, competition variables (Com) and control variables are the same to those in table 4. The firm fixed effect has already been addressed by using Hansen (1999)'s methodology. $\hat{\alpha}$ denotes two thresholds. T-statistics are given in parentheses. *, ** and *** denote significant at 10%, 5% and 1% level, respectively.

*Table 6*: Other R&D subsidy proxies: one year lag of the R&D subsidy

| Variable | (1)<br>HHI-internal R&D | (2)<br>HHI-total R&D | (3)<br>Margin-internal R&D | (4)<br>Margin-total R&D |
|---|---|---|---|---|
| Tests for threshold effect | | | | |
| Single | 0.020** | 0.010** | 0.000*** | 0.000*** |
| Double | 0.000*** | 0.000*** | 0.020** | 0.000*** |
| Triple | 0.673 | 0.383 | 0.713 | 0.923 |
| Threshold estimate | | | | |
| First($\hat{\alpha}_1$) | 0.0592 | 0.0592 | 0.0516 | 0.0682 |
| | (0.0530-0.0602) | (0.0588-0.0602) | (0.0513-0.0524) | (0.066-0.069) |
| Second($\hat{\alpha}_2$) | 0.0399 | 0.0399 | 0.0428 | 0.0494 |
| | (0.0386-0.0411) | (0.0386-0.0411) | (0.0420-0.0435) | (0.0488-0.0498) |
| Estimated variables | | | | |
| Subsidy | | | | |
| I(Com $\leq \hat{\alpha}_1$) | 0.006* | 0.023*** | 0.025*** | 0.058*** |
| | (1.79) | (6.46) | (13.17) | (29.71) |
| I($\hat{\alpha}_1$<Com $\leq \hat{\alpha}_2$) | 0.060*** | 0.092*** | 0.045*** | 0.027*** |
| | (18.20) | (25.15) | (14.49) | (10.81) |
| I(Com >$\hat{\alpha}_2$) | 0.015*** | 0.034*** | 0.005** | 0.001 |
| | (9.12) | (18.49) | (2.54) | (0.37) |
| Constant | -1.446*** | -2.392*** | -1.366*** | -2.412*** |
| | (-4.91) | (-7.25) | (-4.62) | (-7.33) |
| Firm fixed effect and control variables | Yes | Yes | Yes | Yes |
| $R^2$ | 0.034 | 0.082 | 0.038 | 0.095 |
| Obs. | 14416 | 14416 | 14416 | 14416 |

Notes: This table also reports regressions of the public subsidy on the private R&D expenditure, which are influenced by industry competition. The subsidy proxy (Subsidy) in this table is the industry mean of individual firms' R&D subsidy. R&D spending ratios, competition variables (Com) and control variables are the same to those in table 4. The firm fixed effect has already been addressed by using Hansen (1999)'s methodology. $\hat{\alpha}$ denotes two thresholds. T-statistics are given in parentheses. *, ** and *** denote significant at 10%, 5% and 1% level, respectively.

# 4 Conclusion

This study estimates the impact of industry competition on R&D subsidy effectiveness. I provide solid evidences for the complement effect of public R&D support, while the impact of this effect differs among competition levels. Specifically, the degree to which the public subsidy complements private financing increases when competition intensifies to reach a threshold level, and the complement effect increases again when competition lessens to reach another threshold after which competition becomes less pronounced.

This study contributes to existing literature by shedding light on the relationship between industry competition and effectiveness of public R&D support. Most studies focus on R&D subsidy efficiency, but few researches show that subsidy efficiency differs among industries. In addition, this paper adds to market competition studies. Market competition impacts firms' financial plans (Xu, 2012; Chang et al., 2015), but its impact on R&D subsidy effectiveness has seldom been discussed. Findings in this paper indicate that industry competition appears as an important determinant of R&D subsidy effectiveness. This paper also has some drawbacks that point to a way for further studies. First, subsidy data is general so that the subsidy itself only reflects a financing channel through which firms support their R&D activities. However, R&D subsidies are a set of institution-incentive policies. The allocation of subsidies depends on government priorities, and the relationship between industry competition and R&D subsidy efficiency may reflect a result of the design of policies. So, an investigation based on a certain subsidy policy may be helpful in explaining empirical results. Second, R&D spending could break down into several parts such as basic research, process research and product development spending. Since different kinds of researches may exhibit different levels of investment requirement, the "complementarity" effect may differ among research types. However, the distinction between different types of R&D spending may be difficult.

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