*sustainability*

MDPI

*Article*

# Influencing Factors of Enterprise R&D Investment: Post-Subsidy, Sustainability, and Heterogeneity

**Yabin Yu * and Qian Xu**

College of Economics & Management, China Jiliang University, Hangzhou 310018, China; xuqian@cjlu.edu.cn
* Correspondence: yabinyu@cjlu.edu.cn

**Abstract:** Sustainable innovation is an important factor for enterprises to obtain core competitiveness in modern society, and only continuous R&D investment can ensure the smooth progress of enterprise innovation. Therefore, this study uses the post-subsidy data of enterprise R&D investment released by Hangzhou Science and Technology Bureau to explore the influencing factors of R&D investment and its sustainability by Chinese high-tech enterprises. In contrast to previous research which mainly focused on the pre-subsidy, this study focuses on the post-subsidy policy of R&D investment sustainability. Empirical analysis methods, such as cross-sectional linear regression and the propensity-score-matching method, were used to draw the following conclusions: (1) The quantity and sustainability of R&D investment of enterprises are obviously unbalanced among regions. Regions where high-tech enterprises are concentrated have higher levels of R&D investment and sustainability than other regions. (2) Under different scales, there are significant differences in the amount and sustainability of R&D investment. Large enterprises have stronger R&D investment strength, while small enterprises have stronger R&D investment willingness. However, the effect of scale on R&D investment will be reduced by regional factors. (3) The evaluation of high-tech enterprises and the enterprises' R&D investments affect each other. (4) The sustainability of enterprise R&D investment will be affected by enterprise heterogeneity factors, and in turn, the sustainability of enterprise R&D investment will also affect the amount of enterprise R&D investment. Based on the results, the study provides suggestions for the government to make more targeted policies.

**Keywords:** R&D investment; post-subsidy; sustainability; heterogeneity; China; high-tech enterprises



**Citation:** Yu, Y.; Xu, Q. Influencing Factors of Enterprise R&D Investment: Post-Subsidy, Sustainability, and Heterogeneity. *Sustainability* **2022**, *14*, 5759. https://doi.org/10.3390/su14105759

Academic Editor: Antoni Sánchez

Received: 17 March 2022
Accepted: 7 May 2022
Published: 10 May 2022



## 1. Introduction

Nowadays, without pursuit of scientific and technological progress, enterprises are easily eliminated by the market. Additionally, the amount of R&D investment is an important indicator of the degree of emphasis on technology development. On the one hand, the R&D investment behavior of enterprises is driven by the companies' internal cultures and development strategies; on the other hand, it is also encouraged by the external policy environment.

As a very common policy incentive tool, government subsidy can guide market behavior pertinently. Although tax incentives can help enterprises improve productivity in the long run [1], compared with indirect policies, such as R&D tax incentives, policies that directly help enterprises solve financial problems are more direct and effective [2]. For example, the funding of R&D investment for enterprises can be effective support, especially for small and medium enterprises with financial constraints.

However, R&D funding can also be divided into pre-subsidy and post-subsidy. In the past, most of the research was based on pre-subsidy (provide funding based on the enterprises' qualifications), which is a kind of traditional government subsidy and might crowd out the private innovation input of enterprises [3]. Some enterprises carry out speculative R&D behavior to obtain funding, and such speculative R&D behavior does not substantially help the enterprise to innovate. For some entrepreneurs, such pre-subsidies

might be just start-up capital for business and are not actually applied to substantive innovation. To be more precise, it is also necessary to distinguish between the total R&D investment of enterprises and the net investment excluding the government-funded part [4]. In contrast, post-subsidies (provide funding depending on R&D expenditure already invested by the enterprises) used for enterprise R&D investment avoids the occurrence of speculation to some extent. At the same time, the limited research focuses on the sustainability of R&D investment. The study bridges the research gap to explore the sustainability and heterogeneous influencing factors of enterprises' R&D investment by studying the post-subsidy data of high-tech enterprises' R&D investment published by Chinese government.

The following sections will be arranged as follows: the second section is literature review and hypothesis proposal, the third section is the description of data sources and research methods, the fourth section is the statistical analysis of model results, and the last section is the conclusion on the impact of enterprise R&D investment, as well as the application suggestions for enterprises and governments.

## 2. Conceptual Framework and Hypothesis Development

R&D is the most direct tool to promote enterprise innovation and progress. However, R&D investment cannot bring short-term benefits and is often limited by enterprises' financial difficulties and concerns about the exclusivity of research results [2]. Common R&D incentive policies can be divided into direct funding and tax incentives [1]. However, traditional funding policies might crowd out enterprises' R&D investments [3]. At the same time, more targeted environmental policies will affect enterprises' green innovation, but the policy effect will be affected by enterprise heterogeneity [5,6].

Research shows that industrial structure among different regions will have an impact on enterprises' R&D investments [7]. The innovation capacity of regions with more private enterprises is stronger than regions with more state-owned enterprises [8]. In addition, government funding will also increase the innovation gap between different regions [9].

**Hypothesis 1 (H1).** *The enterprise region will affect the R&D investments of enterprises (enterprises in high-tech development zone will have more R&D investments).*

Large-scale enterprises have more innovation resources, and the degree of R&D investment will be less dependent on government subsidies [10]. However, smaller enterprises will limit their R&D investments due to financial constraints [11].

**Hypothesis 2 (H2).** *Enterprise size will affect the R&D investment of enterprises (larger enterprises will have more R&D investments).*

The innovation level and the degree of knowledge absorption and utilization will impact the R&D investment level of the enterprise [12]. And the stability of corporate executives will also affect the enterprise R&D investment through the internal R&D environment [13]. At the same time, the ownership will also influence the enterprise R&D investment [14]. In fact, in the rating of high-tech enterprises, the requirements for R&D investment is different by technology levels.

**Hypothesis 3 (H3).** *R&D investments of different technology levels of high-tech enterprises have significant differences (higher technology level enterprises will have more R&D investments).*

Previous studies mostly studied enterprises' R&D investments from the static perspective, but the dynamic effect (ex. frequency) of enterprises' R&D investments also deserves attention [14]. The sustainability of R&D investments will be affected by trade credit, especially for small enterprises with financial constraints [15]. Sometimes, whether an enterprise can sustainably invest in R&D depends on its cash flow condition [16,17]. When cash flow is volatile, the investment decision on R&D will become cautious [18]. Conversely, the

R&D investment of an enterprise will also affect its own cash holding [19]. Continued R&D investment can also help enterprises boost their profitability under economic crisis [20]. Therefore, in addition to the study of influencing factors, the research will also carry out a multidimensional analysis on the sustainability of enterprise R&D investment.

**Hypothesis 4a (H4a).** *The sustainability of enterprise R&D investment is influenced by enterprise heterogeneous factors (region/size/type).*

**Hypothesis 4b (H4b).** *The sustainability of the enterprise R&D investment will further stimulate the enterprise R&D investment.*

To better demonstrate the research framework of the study, we draw the Figure 1 below.

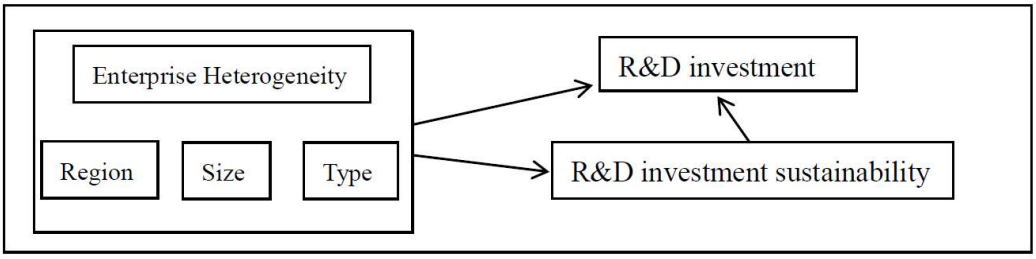


**Figure 1.** Research Conceptual Framework.

## 3. Data and Method

### *3.1. Data Sources*

The research data in the study are from the 2017–2018 Publication List of R&D Investment of Small, Medium and Micro (enterprises with less than 10 employees or less than RMB 500,000 annual income) Enterprises in Hangzhou and the 2019–2020 Publication list of R&D Investment of High-Tech Enterprises in Hangzhou, issued by Hangzhou Bureau of Science and Technology. The publication content lists the R&D expenditure data of small, medium, and micro enterprises in Hangzhou from 2016 to 2018, as well as the R&D expenditure incremental data of high-tech enterprises in Hangzhou from 2019–2020. In this way, 1010 valid samples of 2017 and 1018 of 2018 were obtained. Taking 2017 and 2018 as the benchmark years, 177 samples of 2016 and 425 samples of 2019 were matched. However, due to the influence of the COVID-19 pandemic on the economy in 2020, the matching samples in 2020 largely declined. Therefore, the data from 2016 to 2019 are used for the analysis below.

### *3.2. Variable Measurement*

#### 3.2.1. Dependent Variable

Enterprise R&D investment (R&D) refers to the capital invested by an enterprise to research and develop new technologies [21]. Generally, the data of R&D is stated and disclosed in the financial reports of enterprises.

R&D investment sustainability (Sus) refers to the sustainability of enterprise R&D investment [14]. Generally, at least three years can be regarded as "sustainable". In this way, Sus is measured as increased investment in R&D for three consecutive years out of four years. We select the sample enterprises that increased R&D investments for three consecutive years from 2016–2018 or 2017–2019 as 1, and the remaining enterprises were marked as 0.

#### 3.2.2. Independent Variables

Region (region) refers to the geographical location of an enterprise. In this study, it is the administrative division in which the enterprise is located. We record the enterprises in BJ and YH, the high-tech development zone, as 1, and the enterprises in other regions as 0.

Enterprise scale (size) in the study divided the sample enterprises into two groups: enterprises above designated size (marked as 0) and enterprises below designated size (marked as 1), according to the enterprises' annual output or main business income.

Enterprise type (type): The samples in this study are all high-tech enterprises, but they can be divided into various types of technology-related enterprises, according to different technology levels. We record the "national high-tech enterprises" and "provincial science and technology SMEs" as 1 and the others (such as city/star-up technology enterprises) as 0.

### *3.3. Model Set*

As the dependent variables are continuous variables, and the independent variables are multiple classification variables, cross-sectional linear regression analysis was first applied in the study to test whether enterprise R&D investment is affected by region, size, and type.

$$\ln RD_i = \alpha + \beta_1 Region_i + \beta_2 Size_i + \beta_3 Type_i + \varepsilon_i \quad (1)$$

To further test the joint influence of heterogeneity factors on enterprise R&D investment, the interaction terms of region and size (ReSi) are added to build the model 2. Additionally, since the enterprises in the sample are all technology-related enterprises with different technology levels, the differentiation of type is not as significant as region and size, so no interaction term related to type is added to the model (2).

$$\ln RD_i = \alpha + \beta_1 Region_i + \beta_2 Size_i + \beta_3 Type_i + \beta_4 ReSi_i + \varepsilon_i \quad (2)$$

In addition, another research focus of the study is the factors affecting the sustainability of R&D investment. According to Hypothesis 4a, the sustainability of enterprise R&D investment may be affected by heterogeneous factors, such as region, size, and type of enterprise; thus, model (3) is established. Besides, according to Hypothesis 4b, the sustainability of R&D investment may further affect the enterprise's R&D investment. Therefore, the sustainability of R&D investment is put into the model as an independent variable, and model (4) is established.

$$Sus_i = \alpha + \beta_1 Region_i + \beta_2 Size_i + \beta_3 Type_i + \varepsilon_i \quad (3)$$

$$\ln RD_i = \alpha + \beta_1 Sus_i + \beta_2 Region_i + \beta_3 Size_i + \beta_4 Type_i + \varepsilon_i \quad (4)$$

In the above models, i represents each sample enterprise; RD stands for R&D investment; region represents the location of an enterprise; size indicates the enterprise scale; type indicates the technology title type of the enterprise; ReSi represents the interaction terms of "region and size"; Sus represents the sustainability of enterprise R&D investment; $\alpha$ is the intercept that does not vary with individuals; $\beta$ is the parameter to be estimated; $\varepsilon$ is the error term that follows the normal distribution.

## 4. Results

### *4.1. Descriptive Statistics of Main Variables*

From Table 1, we can find that enterprises' R&D investments from 2016 to 2018 are in a state of continuous growth, both average and maximum. Although the statistics of 2019 show the incremental values of enterprises' R&D investments, it also proves the sustainability of enterprises' R&D investments from another aspect. The remaining four variables Sus, region, size, and type are all dichotomous variables.

**Table 1.** Descriptive statistics of main variables.

| Variable | Mean | SD | Min | *p*50 | Max |
|---|---|---|---|---|---|
| 16R&D | 319 | 389 | 0 | 207 | 3007 |
| 17R&D | 349 | 446 | 0 | 202 | 4082 |
| 18R&D | 677 | 685 | 84.30 | 474 | 7903 |
| 19R&D Increase | 391 | 409 | 50.10 | 247 | 2832 |
| Sus | 0.517 | 0.500 | 0 | 1 | 1 |
| Region | 0.545 | 0.498 | 0 | 1 | 1 |
| Size | 0.755 | 0.430 | 0 | 1 | 1 |
| Type | 0.883 | 0.321 | 0 | 1 | 1 |

### *4.2. The Model Results of Heterogeneous Influencing Factors*

First, from an overall perspective (Table 2), no matter the region, size, or type of enterprise, it has a significant impact on R&D investment of enterprises. In addition, the model results of the years 2016 to 2019 are basically consistent, which also verifies the robustness of the model. Further, the coefficients of each independent variable show the influence of each heterogeneous factor.

**Table 2.** Cross-sectional linear regression for R&D investment.

| Variable | (1) 16R&D | (2) 17R&D1 | (3) 18R&D2 | (4) 19R&D3 |
|---|---|---|---|---|
| Region | 90.785 | 120.671 *** | 71.356 *** | 68.674 * |
| | (1.61) | (2.94) | (2.68) | (1.67) |
| Size | −345.132 *** | −553.404 *** | −365.486 *** | −193.397 *** |
| | (−5.04) | (−11.62) | (−11.84) | (−3.77) |
| Type | - | 1.041 | 72.084 * | 5.686 |
| | - | (0.02) | (1.76) | (0.10) |
| Constant | 538.579 *** | 1027.875 *** | 522.768 *** | 500.725 *** |
| | (8.31) | (13.84) | (10.86) | (6.89) |
| Observations | 179 | 1018 | 1018 | 425 |
| R-squared | 0.129 | 0.119 | 0.127 | 0.036 |

*t*-statistics in parentheses *** $p < 0.01$, * $p < 0.1$.

The first is the regional effect. Region 0 others works as the control group. The R&D investment of Region 1, the high-tech development zone (BJ and YH), is significantly different from that of the control group, indicating that there is a substantial difference in R&D investment among the different regions. The positive coefficient shows that the R&D investments of enterprises in high-tech regions are more than that in other regions. That is to say, the high-tech development zone does positively promote the R&D investments of enterprises.

The second is the size effect. Compared with Size 0 big, Size 1 small also has a significant difference in R&D investment, indicating that enterprise size is indeed an important factor affecting enterprise R&D investment. But the coefficient is negative, which means that small enterprises invest less in R&D than large enterprises, consistent with our traditional logic. R&D investment is a very considerable expenditure. The larger the enterprise, the more economic strength it has to invest in R&D.

Finally, there is the type effect. Compared with Type 0 "other enterprise", Type 1 national high-tech enterprise and provincial science and technology SMEs have significant differences in R&D investment. These two groups of companies, as relatively advanced technology enterprises, spend more on R&D than the rest of the enterprises. As the enterprises in the sample are varying high-tech enterprises, the differences are within the categories. Except for the 2018 result, the type effect is not very significant.

To further compare the joint influence of region and size on enterprise R&D investment, the interaction terms of region and size are added into the model. We can find that in model (5)–(8) in Table 3, the coefficients of interaction term Resi are all negative. Therefore,

compared with small-scale enterprises, large-scale enterprises do have stronger economic strengths to invest in R&D, but the effects will be reduced by regional factors. It might be the scale effect brought by industrial clusters. When small enterprises are concentrated in the regions with preferential policies, they will be able to stimulate more innovation enthusiasm and investment of small enterprises, whether it is the industry pressure from competitors or the regional effect of incentive policies.

**Table 3.** The interaction effect of heterogeneous factors.

| Variable | (5) 16R&D | (6) 17R&D1 | (7) 18R&D2 | (8) 19R&D3 |
|---|---|---|---|---|
| Region | 295.735 ** | 309.293 *** | 235.987 *** | 200.748 ** |
| | (2.46) | (3.74) | (4.42) | (2.19) |
| Size | −220.011 ** | −439.569 *** | −266.131 *** | −108.306 |
| | (−2.34) | (−6.84) | (−6.40) | (−1.47) |
| Type | - | −3.622 | 68.014 * | 1.004 |
| | - | (−0.06) | (1.67) | (0.02) |
| ReSi | −261.896 * | −250.015 *** | −218.215 *** | −165.089 |
| | (−1.93) | (−2.63) | (−3.55) | (-1.61) |
| Constant | 449.952 *** | 954.177 *** | 458.443 *** | 441.518 *** |
| | (5.69) | (12.05) | (8.96) | (5.43) |
| Observations | 179 | 1018 | 1018 | 425 |
| R-squared | 0.147 | 0.125 | 0.138 | 0.042 |

*t*-statistics in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

### *4.3. The Description of R&D Investment Sustainability*

With 2017 and 2018 as the base years, the data of 2016 and 2019 were matched respectively to obtain 177 samples in 2016 and 425 samples in 2019. From 2016 to 2018, 177 enterprises were continuously listed, accounting for 17.4%. Of those, the ranking of 62 companies in 2017 go up compared with that in 2016, rising between 5~352. From 2016 to 2019, 76 enterprises were continuously listed, accounting for 7.5% of the total sample. It shows that the listed companies still have a lot of space for progress in sustainable R&D investment.

By region, in Figure 2 of the whole sample, the number of listed high-tech enterprises in the BJ district is the highest, and the YH district ranks the second. However, in Figure 3 of enterprises with sustainable R&D investment from 2016 to 2019, the YH district ranks first, which reflects that enterprises in the YH district have a relatively better sustainability of R&D investment.

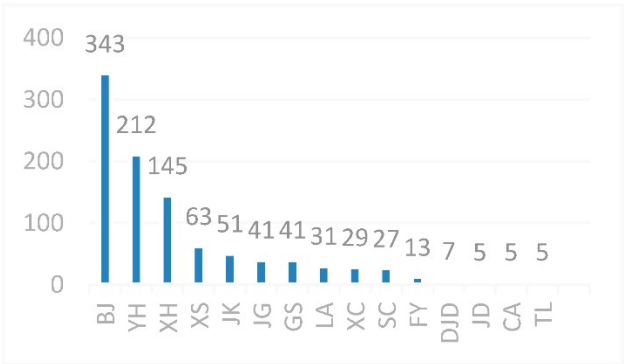


**Figure 2.** Whole sample total by region.

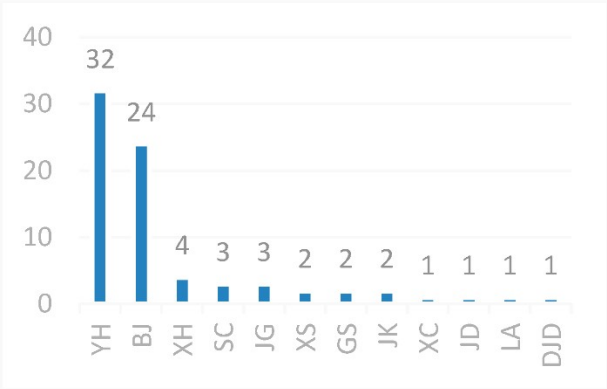


**Figure 3.** Sustainable sample by region.

In terms of scale, as the research samples in the study are from the list of "small, medium, and micro enterprises in Hangzhou", in general (Figure 4), the proportion of enterprises below designated size reaches 76%, and this proportion continues to rise to 87% in the samples of continuous investment from 2016 to 2019 (Figure 5). It proves that enterprises below designated size are active subjects of R&D activities in the market.

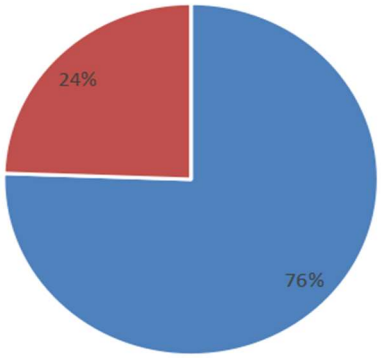


**Figure 4.** Whole sample by size.

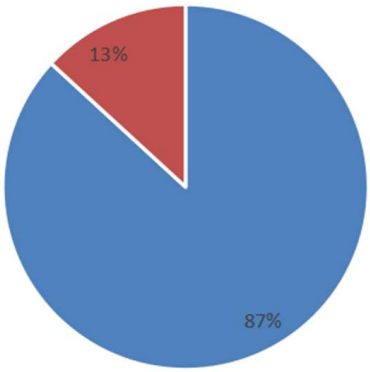


**Figure 5.** Sustainable sample by size.

In terms of enterprise types, national high-tech and provincial science and technology SMEs account for 88% of the total (Figure 6), and enterprises sustainably investing in R&D from 2016 to 2019 are both of these two types (Figure 7). It shows that the evaluation of high-tech enterprises also plays an important role in promoting the sustainable R&D investments of enterprises.

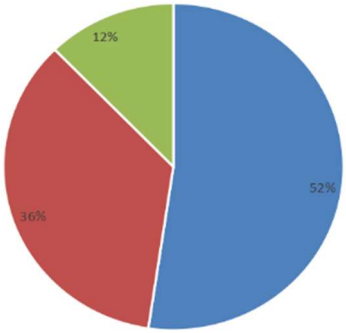


**Figure 6.** Whole sample by type.

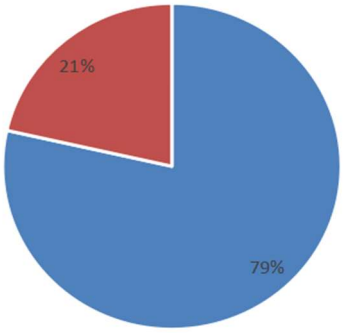


**Figure 7.** Sustainable sample by type.

### *4.4. The Model Results of R&D Investment Sustainability*

To analyze the impact of enterprise heterogeneous factors on the sustainability of R&D investment more rigorously, the study adopts cross-sectional linear regression to test. And since the dependent variable is a dichotomous variable, negative binomial regression is further used to verify the robustness. As can be seen from the results in Table 4, both cross-sectional linear regression (see (9) in Table 4) and negative binomial regression (see (10) in Table 4) have reached a relatively consistent conclusion: enterprise location and enterprise scale have a significant positive impact on the sustainability of R&D investment. Specifically, enterprises in high-tech development zones are more likely to invest sustainably in R&D, which is inseparable from regional support policies. On the other hand, compared with the stability of large enterprises, small enterprises are in a stage of rising development. As a new force in the market, sustainable R&D investment is an important path for the sustainable development and expansion.

**Table 4.** Regression for R&D investment sustainability.

| Variable | (9)<br>Reg-Sus | (10)<br>NB-Sus |
|---|---|---|
| Region | 0.114 *** | 0.224 ** |
| | (3.62) | (2.49) |
| Size | 0.119 *** | 0.251 ** |
| | (3.26) | (2.25) |
| Type | 0.040 | 0.077 |
| | (0.82) | (0.56) |
| Constant | 0.329 *** | −1.054 *** |
| | (5.78) | (−6.22) |
| Observations | 1018 | 1018 |
| R-squared | 0.027 | |

*t*-statistics in parentheses, *** $p < 0.01$, ** $p < 0.05$.

Conversely, we also want to know whether the sustainability of R&D investment further influences the amount of enterprise R&D investment. To answer the question, we

divided the sample enterprises into two groups based on whether the R&D investment of enterprises has sustainability and conducted regression respectively. As can be seen from the results in Table 5, although the model coefficients in 2017 and 2018 are slightly different, the coefficient directions and significance of all variables are consistent, indicating the robustness of the model. In general, the sustainability of enterprise R&D investment can significantly affect the enterprise R&D investment. In addition, among the enterprises that sustainably invest in R&D, the large-scale enterprises located in high-tech development zones with higher technological rating levels are more likely to increase R&D investment, which forms a virtuous cycle.

**Table 5.** Regression for R&D investment by sustainability.

| | (11) 17R&D1 | | (12) 18R&D2 | |
|---|---|---|---|---|
| **Variable** | **NON** | **SUS** | **NON** | **SUS** |
| Region | 96.040 * | 109.773 * | 40.613 | 71.450 * |
| | (1.72) | (1.83) | (1.22) | (1.77) |
| Size | −499.390 *** | −669.096 *** | −311.510 *** | −473.767 *** |
| | (−8.18) | (−9.10) | (−8.52) | (−9.54) |
| Type | −97.346 | 84.973 | −2.950 | 135.575 ** |
| | (−1.14) | (0.93) | (−0.06) | (2.20) |
| Constant | 1001.233 *** | 1134.596 *** | 491.063 *** | 623.252 *** |
| | (10.34) | (10.08) | (8.47) | (8.20) |
| Observations | 492 | 526 | 492 | 526 |
| R-squared | 0.122 | 0.140 | 0.130 | 0.159 |

*t*-statistics in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

### *4.5. The PSM Test of R&D Investment Sustainability*

To further verify the reverse impact of sustainability of R&D investment on enterprise R&D investment, this part adopts the non-parametric estimation method propensity-score-matching (PSM) to test. The enterprises without sustainable R&D investments are taken as the control group, and the enterprises with sustainable R&D investments are taken as the treatment group to compare the differences in R&D investment between the two groups. Since the probability distribution of the treatment group and the control group is difficult to keep consistent, the counterfactual framework is constructed with the method of Rosenbaum and Rubin [22]. In addition, the similar control group enterprises are matched as far as possible for the treatment group enterprises through the method of PSM.

As shown in Table 6 and Figure 8, all observed values are within the range of common values and do not lose any samples. In addition, balance tests for independent and control variables are required prior to PSM estimation. The results of Table 7 and Figure 9 show that the %bias decreases to 0 after matching, and the t value is very significant, which greatly reduces the total bias of matching. However, it is closely related to the fact that all the variables involved are classified variables. Therefore, we believe that the matching effect between the treatment group and the control group is satisfactory and can be used to explain the differences in R&D investments of enterprises.

**Table 6.** PSM results.

| | **Common Support** | |
|---|---|---|
| Treatment assignment | On support | Total |
| Untreated | 492 | 492 |
| Treated | 526 | 526 |
| Total | 1018 | 1018 |

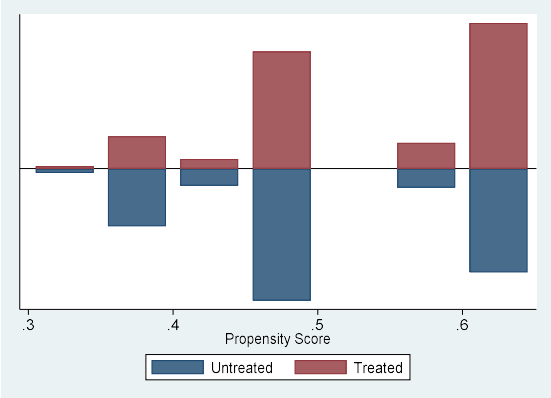


**Figure 8.** Common range of propensity scores.

**Table 7.** Balance test before and after co-variable matching.

| Variable | Unmatched Matched | Mean Treated | Mean Control | %Bias | %Reduct Bias | *t*-Test *t* | *t*-Test *p* > *t* | V(T)/ V(C) |
|---|---|---|---|---|---|---|---|---|
| region | U | 0.60646 | 0.47967 | 25.6 | | 4.0900 | 0.0000 | |
| | M | 0.60646 | 0.60646 | 0 | 100 | 0.0000 | 1.0000 | |
| size | U | 0.80418 | 0.70325 | 23.6 | | 3.7700 | 0.0000 | |
| | M | 0.80418 | 0.80418 | 0 | 100 | 0.0000 | 1.0000 | |
| type | U | 0.88593 | 0.88008 | 1.8 | | 0.2900 | 0.7720 | |
| | M | 0.88593 | 0.88593 | 0 | 100 | 0.0000 | 1.0000 | |

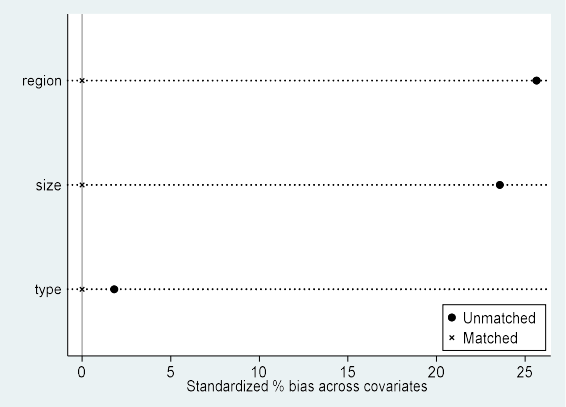


**Figure 9.** Matching validity test.

After obtaining effective matching samples, the nearest neighbor (1:4) matching is adopted to measure the impact of sustainable R&D investment on enterprise R&D investment. As it reveals from the results in Table 8, there is a significant positive difference between the treatment group and the control group (ATT = 3.75, DIFF = 127.944), indicating that sustainable R&D investment can effectively promote enterprise R&D investment. To ensure the reliability of the results, we also used the matching method of nearest neighbor 1:4 + caliper 0.05 to estimate, and the obtained results are consistent with the demonstration of Table 8, proving the robustness of the model. Besides, by further testing the data of 2018, we can see from Table 9 that the conclusion is similar to the analysis of 2017, with a slight difference in value. All in all, companies that continue to invest in R&D are more likely to invest more in R&D.

**Table 8.** The treatment effect of PSM (detail).

| Variable | Sample | Treated | Controls | Difference | S.E. | T-Stat |
|---|---|---|---|---|---|---|
| rd1 | Unmatched | 738.374925 | 610.4311 | 127.9438 | 42.80652 | 2.99 |
| | ATT | 738.374925 | 573.1362 | 165.2387 | 44.07436 | 3.75 |

**Table 9.** The treatment effect of PSM (general).

| Variable | (13) 17R&D | (14) 18R&D |
|---|---|---|
| _treated | 127.944 *** | 116.821 *** |
| | (42.807) | (27.762) |
| Constant | 610.431 *** | 288.878 *** |
| | (30.770) | (19.956) |
| Observations | 1018 | 1018 |
| R-squared | 0.009 | 0.017 |

Standard errors in parentheses *** $p < 0.01$.

## 5. Conclusions and Discussion

### *5.1. Conclusions*

As can be seen from the data analysis results above, enterprise heterogeneous factors such as region and enterprise scale and type, are indeed important factors affecting enterprise R&D investment and have a significant impact on the sustainability of enterprise R&D investment. In turn, the sustainability of enterprise R&D investment will further influence enterprise R&D investment.

First, due to the agglomeration of high-tech enterprises in different regions, there exists in the quantity and sustainability of R&D investment of enterprises an obvious imbalance among regions. Compared with other regions, regions where high-tech enterprises gather are more impressive in the amount and sustainability of R&D investment, which may be closely related to regional support policies [23], such as more subsidies in the high-tech development zone and competitor pressure [24]. Hypotheses 1 and 4a are verified, which is consist with the previous pre-subsidy study [9].

Secondly, enterprise size will certainly affect the R&D investment of the enterprise. Large high-tech enterprises have the strength of sustainable investment, while small high-tech enterprises have the demand of sustainable investment, which is different from the previous study with the pre-subsidy [25,26]. There are significant differences in the amount and duration of R&D investments at different scales. But the size effect is undermined by the regional effect. For small enterprises in high-tech development zones, with more subsidies, it is better to carry out sustainable R&D investment. Hypotheses 2 and 4a are tested.

In addition, although the sample enterprises are all technology-related enterprises, the specific high-tech levels and categories are still different. There are significant differences in the amounts of R&D investment among enterprises of different high-tech categories. The national high-tech and provincial science and technology SMEs are obviously better in the sustainability of R&D investment, which also reflects the mutual influence between enterprise rating and enterprise R&D investment. With higher technology ratings, these types of high-tech enterprises have more resources for subsidies to invest on R&D [27]. Hypotheses 3 and 4a are verified.

Finally, the sustainability of enterprise R&D investment can further promote enterprise R&D investment. Both statistical regression analysis and non-parametric estimation confirm this conclusion. On the one hand, we know that R&D is a long-term process. Additionally, the sunk cost is very high for enterprises that sustainably invest in R&D, so these enterprises need to continue investing. On the other hand, it is the sustainable R&D investment that enables enterprises to enjoy more preferential policies, such as high-tech enterprise rating and corresponding financial subsidies. The enterprises are more willing to continue to

invest on the basis, thus, forming a virtuous cycle. Hypothesis 4b is tested, which provides a new perspective compared with the pre-subsidy study [28].

### *5.2. Policy Implications*

The analysis results show that it is necessary to formulate policies regarding local conditions (ex. regions, enterprise scales and types) to guide enterprises to invest in R&D efficiently and sustainably.

Firstly, different regional R&D investment incentive policies can be applied among different regions. Because the number of high-tech enterprises in different regions is unbalanced, the demand for R&D incentive in different regions is not consistent as well. Therefore, in addition to unified policies at the national level, local policies at the regional level are more conducive to guiding enterprises to invest in R&D. Especially in regions where high-tech enterprises gather, such targeted post-subsidy policies will have a more significant effect. Targeted government funding can indeed produce an obvious market effect on enterprises' R&D investments [29].

Secondly, differentiated R&D investment incentive policies should be built for enterprises of different scales. Enterprises of different sizes also have different incentive modes for R&D investment, some of which are mainly cooperation and supplemented by support, while others may be mainly supported and supplemented by cooperation [30]. For example, large-scale enterprises can get support from tax incentives for R&D investment, but the taxable revenue of small-scale enterprises is limited. The incentive effect of taxes to small-scale enterprises may be limited, while government subsidies may be more effective. Compared with other policy instruments, it shows that government subsidies to independent high-tech SMEs can help them more effectively [31]. However, government subsidies can also be divided into pre-subsidy and post-subsidy. The sample data in the study is from the list of government post-subsidy policies, reflecting the feasibility of post-subsidy in a practical operation.

In addition, rating enterprises is also an effective method to encourage enterprise R&D investment. On the one hand, enterprises need to meet the corresponding R&D investment requirements to obtain the various titles of high-tech enterprises. On the other hand, when enterprises sustainably invest in R&D, it can also help enterprises better meet the evaluation standards of corresponding technology-type enterprises. The two are mutual causation, forming a virtuous circle and producing a positive R&D investment spillover effect. Once entering such a virtuous cycle, enterprises will continue to invest in R&D; otherwise, the conversion cost will be very high [32].

Finally, regarding the limitations of the study, although the paper has conducted an initial study on the influencing factors of enterprises' sustainable R&D investments, due to the short period of post-subsidy policy implementation and the impact of the special event of COVID-19, there is still a lot of research space in the future. For example, under the natural experiment of COVID-19, whether the sustainable R&D investments of enterprises will be affected and how to respond in terms of policies are possible research areas. We will pay close attention to long-term R&D investment sustainability in the future.

**Author Contributions:** Conceptualization, Y.Y.; data curation, Y.Y. and Q.X.; formal analysis, Y.Y.; funding acquisition, Y.Y.; methodology, Y.Y. and Q.X.; software, Q.X.; validation, Y.Y.; visualization, Q.X.; writing—original draft, Y.Y.; writing—review and editing, Y.Y. and Q.X. All authors have read and agreed to the published version of the manuscript.

**Funding:** We appreciate the reviewer's comments. This work was supported by 2019 Hangzhou soft science project "Analysis and research on innovation and R&D investment of Hangzhou science and technology enterprises" (20190834M11-2), the Hangzhou philosophy and social science planning project "Research on the mechanism of different tax policy tools on innovation quality of Hangzhou manufacturing enterprises" (Z19JC046), the National Social Science Foundation of China (21BJY222), and the Key Program for Youth in Major Humanities and Social Sciences in Zhejiang Universities (2021QN078).

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** The data presented in this study are available on request from the corresponding authors.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References


1. Minniti, A.; Venturini, F. The long-run growth effects of R&D policy. *Res. Policy* **2017**, *46*, 316–326.
2. Martinsson, G. What promotes R&D? Comparative evidence from around the world. *Res. Policy* **2017**, *46*, 447–462.
3. Marino, M.; Lhuillery, S.; Parrotta, P.; Sala, D. Additionality or crowding-out? An overall evaluation of public R&D subsidy on private R&D expenditure. *Res. Policy* **2016**, *45*, 1715–1730.
4. Kiman, K.; Jongmin, Y. Linear or Nonlinear? Investigation an Affect of Public Subsidies on SMEs R&D Investment. *J. Knowl. Econ.* **2021**. [CrossRef]
5. Li, X.; Xiong, Q.Y. Phased Impacts of China's Dual-Credit Policy on R&D. *Front. Energy Res.* **2021**, *9*, 694338.
6. Su, W.; Song, X.; Guo, C. Research and development investment and operational performance of listed small and medium-sized enterprises in China. *Appl. Econ.* **2020**, *52*, 5936–5948. [CrossRef]
7. Aarstad, J.; Kvitastein, O.A. Enterprise R&D investments, product innovation and the regional industry structure. *Reg. Stud.* **2019**, *54*, 366–376.
8. Yang, C.; Lee, C.; Lin, C.A. Why does regional innovative capability vary so substantially in China? The role of regional innovation systems. *Asian J. Technol. Innov.* **2012**, *20*, 239–255. [CrossRef]
9. Li, J.; Wu, X. Research on the Impact of Government R&D Funding on Regional Innovation Quality: Analysis of Spatial Durbin Model Based on 283 Cities in China. *Complexity* **2021**, *2021*, 2217588.
10. Yu, F.; Guo, Y.; Lettic, F.; Barnes, S.J. Regional anti-corruption effort, political connections and firm innovation effort: Evidence from China. *Bull. Econ. Res.* **2018**, *71*, 18–32. [CrossRef]
11. Broome, T.; Moore, W.; Alleyne, P. Financing constraints and the R&D decision in the Caribbean. *Entrep. Reg. Dev.* **2018**, *30*, 964–986.
12. Zhao, Y.; Song, X. How Should the Chinese Government Invest R&D Funds: Enterprises or Institutions? *Comput. Econ.* **2018**, *52*, 1089–1112.
13. Xiong, R.; Wei, P.; Yang, J.; Cristofini, L.A. Impact of top executive turnover on firms' R&D investment: Evidence from China. *Innov. Organ. Manag.* **2020**, *23*, 400–424.
14. Chen, X.; Xie, E.; Van Essen, M. Performance feedback and firms' R&D frequency: A comparison between state-owned and private-owned enterprises in China. *Asian Bus. Manag.* **2021**, *20*, 221–258.
15. Chen, L.; Chen, Z.; Li, J. Can Trade Credit Maintain Sustainable R&D Investment of SMEs?—Evidence from China. *Sustainability* **2019**, *11*, 843.
16. Kang, T.; Baek, C.; Lee, J. The persistency and volatility of the firm R&D investment: Revisited from the perspective of technological capability. *Res. Policy* **2017**, *46*, 1570–1579.
17. Xue, J.; Yip, C.K.; Zheng, J. Innovation capability, credit constraint and the cyclicality of R&D investment. *Econ. Lett.* **2021**, *199*, 109705.
18. Beladi, H.; Deng, J.; Hu, M. Cash flow uncertainty, financial constraints and R&D investment. *Int. Rev. Financ. Anal.* **2021**, *76*, 101785.
19. Magerakis, E.; Gkillas, K.; Floros, C.; Peppas, G. Corporate R&D intensity and high cash holdings: Post-crisis analysis. *Oper. Res.-Ger.* **2021**. [CrossRef]
20. Dimitropoulos, P.E. R &D investments and profitability during the crisis: Evidence from Greece. *R&D Manag.* **2020**, *50*, 587–598.
21. Javeed, S.A.; Latief, R.; Jiang, T.; Ong, T.S.; Tang, Y. How environmental regulations and corporate social responsibility affect the firm innovation with the moderating role of Chief executive officer (CEO) power and ownership concentration? *J. Clean Prod.* **2021**, *308*, 127212. [CrossRef]
22. Rosenbaum, P.R.; Rubin, D.B. Constructing a Control Group Using Multivariate Matched Sampling Methods That Incorporate the Propensity Score. *Am. Stat.* **1985**, *39*, 33–38.
23. Xu, J.; Wang, X.; Liu, F. Government subsidies, R&D investment and innovation performance: Analysis from pharmaceutical sector in China. *Technol. Anal. Strateg. Manag.* **2021**, *33*, 535–553.
24. Yang, C.; Lai, J. Influence of Cross-Listing on the Relationship between Financial Leverage and R&D Investment: A Sustainable Development Strategy. *Sustainability* **2021**, *13*, 10341.
25. Boeing, P.; Eberle, J.; Howell, A. The impact of China's R&D subsidies on R&D investment, technological upgrading and economic growth. *Technol. Forecast. Soc. Chang.* **2022**, *174*, 121212.
26. Busom, I.; Corchuelo, B.; Martínez-Ros, E. Tax incentive . . . or subsidies for business R&D. *Small Bus. Econ.* **2014**, *43*, 571–596.
27. Pan, X.; Pan, X.; Wu, X.; Jiang, L.; Guo, S.; Feng, X. Research on the heterogeneous impact of carbon emission reduction policy on R&D investment intensity: From the perspective of enterprise's ownership structure. *J. Clean. Prod.* **2021**, *328*, 129532.

28. Busom, I.; Corchuelo, B.; Martínez-Ros, E. Participation inertia in R&D tax incentive and subsidy programs. *Small Bus. Econ.* **2017**, *48*, 153–177.
29. Hottenrot, H.; Lopes-Bento, C. (International) R&D collaboration and SMEs: The effectiveness of targeted public R&D support schemes. *Res. Policy* **2014**, *43*, 1055–1066.
30. Zhu, L.; Luo, J.; Dong, Q.; Zhao, Y.; Wang, Y.; Wang, Y. Green technology innovation efficiency of energy-intensive industries in China from the perspective of shared resources: Dynamic change and improvement path. *Technol. Forecast. Soc. Chang.* **2021**, *170*, 120890. [CrossRef]
31. Czarnitzki, D.; Delanote, J. R&D policies for young SMEs: Input and output effects. *Small Bus. Econ.* **2015**, *45*, 465–485.
32. Liu, D.; Li, Z.; He, H.; Hou, W. The determinants of R&D smoothing with asset sales: Evidence from R&D-intensive firms in China. *Int. Rev. Econ. Financ.* **2021**, *75*, 76–93.