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Empirical Test of the Impact of R&D Expenditures on the Price-to-Earnings Ratios of Photovoltaic Enterprises

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Abstract

Amidst China's "dual carbon" goals and accelerating global technological evolution, photovoltaic (PV) enterprises are intensifying their research and development (R&D) investments to secure advantages in technological pathways and cost competitiveness. However, the capital market has historically shown divergence in its valuation of R&D expenditures: R&D can be perceived as an investment to build technological moats or interpreted as "hollow storytelling" that inflates valuations. The Price-to-Earnings Ratio (PER) is a crucial metric for stock valuation. Therefore, this paper utilizes A-share listed PV companies as samples to construct a panel fixed-effects model to examine the impact of R&D expenditure ratio on PER, and further investigates lagged effects and heterogeneity. The results indicate a significant positive correlation between R&D expenditure ratio and PER, and the R&D expenditure ratio from the previous period also shows significant positive influence, suggesting a certain delay in the recognition of R&D value. The positive impact of R&D on PER is stronger within the high R&D group, while it is not significant in the low R&D group. The conclusion for state-owned enterprise samples is unstable due to limited sample size. This paper discusses the aforementioned findings from the perspectives of industry cycles and information environments, and provides implications for corporate R&D resource allocation and investor valuation recognition.

Keywords

Photovoltaic Enterprises; R&D Investment; PER; Fixed Effects; Heterogeneity.

1. Introduction

The photovoltaic industry occupies an important place in China's energy transition and green development. In recent years, firms in the sector have expanded both capacity and R&D at a fast pace, making innovation increasingly central to competition. The strategic rationale is straightforward: higher cell conversion efficiency, lower manufacturing costs, better process yields, and improved material and production systems can all create a competitive advantage. The valuation consequences are less straightforward. Investors may regard high R&D expenditure as evidence of growth potential and technological barriers, and therefore assign a higher valuation. When industry conditions weaken, expected profits fail to materialize, or R&D is inefficient, the same expenditure may instead be viewed as a burden on earnings or as a narrative-driven bubble. Because policy, technological change, and strong cyclicality interact closely in this industry, the relationship between R&D investment and market valuation deserves separate examination [1].

Against this background, the paper asks whether the R&D expense ratio of photovoltaic firms is priced as a technological moat or as a capital-market bubble. The empirical analysis addresses three questions. First, does R&D investment have a statistically significant effect on PER, and what are the direction and magnitude of that effect? Second, does the market

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recognize the value of R&D with a lag? Third, does the relationship differ with firms' R&D intensity, valuation level, or ownership type?[2].

These questions are especially relevant for photovoltaic firms. Compared with a broad manufacturing sample, this sector is more exposed to price swings and policy changes, while PER itself reacts strongly to temporary earnings fluctuations and shifts in market expectations. The analysis therefore uses firm fixed effects to absorb unobserved company characteristics that do not change over time. It is then extended with a lagged R&D term and grouped regressions so that the baseline result can be examined across time and across different types of firms.

2. Literature Review and Research Hypotheses

Existing studies provide two main points of departure. One body of research examines whether R&D expenditure is value relevant and how investors respond to it. A second body of research considers the determinants of valuation multiples, especially PER. In the first strand, R&D is generally treated as an investment in intangible capabilities rather than as an ordinary current cost. Its benefits may appear in later profitability, stronger technological barriers, and a more durable competitive position. Chinese studies have therefore focused on corporate performance, innovation output, and market value, and have found that the effect of R&D can vary with thresholds, firm conditions, and the information environment. The PER literature, by contrast, emphasizes earnings, expected growth, risk, size, financial leverage, and industry cycles as major sources of variation in valuation multiples.

For photovoltaic companies, these two strands point to an ambiguous valuation effect. When R&D leads to faster technological iteration or measurable cost and efficiency gains, investors have grounds to assign stronger growth expectations and a higher PER. During an industry downturn or a period of intensified competition, however, R&D expenditure may add to current cost pressure and may be followed by a lower valuation. The accounting treatment also matters. Although R&D expense reduces current profit when it is recognized, its economic function is closer to investment in an intangible asset because it may support future cash flows and sustained competitive advantages. Prior research generally reports a positive association between R&D investment and firm value, but the size and even the direction of that association depend on governance, absorptive capacity, R&D efficiency, and external conditions. On this basis, the following hypotheses are proposed [3].

H1: For photovoltaic enterprises, the R&D expense ratio is significantly and positively related to PER; an increase in R&D investment is associated with a higher market valuation.

H2: The effect of R&D investment on PER is lagged; the previous-period R&D expense ratio continues to affect current PER significantly.

H3: The relationship between R&D expenditure and PER differs across firms. The positive effect is stronger among high-R&D enterprises and weaker or insignificant among low-R&D enterprises.

Evidence from fixed-effects panel threshold models further suggests that the effect of R&D investment on firm outcomes is not necessarily linear; it may change when R&D intensity moves from one interval to another [4].

Studies of dual-threshold effects also find different responses for current and lagged growth. This provides a basis for expecting valuation responses to R&D to be both state dependent and delayed [5].

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3. Study Design

3.1. Sample and Data Sources

The sample consists of A-share companies classified under the Shenwan second-level industry 'Photovoltaic Equipment'. ST firms are excluded, and firm-year observations are collected for 2018-2024. The initial panel contains 378 observations for 54 companies. The number used in each regression is smaller after observations with missing variables are removed and, for the lagged model, consecutive-year data are required. The benchmark regression contains 313 valid observations, while the lagged specification contains 259. The dataset includes PER, the R&D expense ratio (RD), indicators of profitability and growth, firm size, leverage, and ownership structure [6,7].

3.2. Variable Definitions

(1) Dependent variable: PER, the price-to-earnings ratio, which represents the market valuation level.

(2) Core explanatory variable: RD, defined as R&D expenditure divided by operating revenue. It measures the intensity of a firm's R&D investment.

(3) Control variables:

- TAG: total asset growth rate, used to represent a firm's future expansion and growth potential;
- SGR: sustainable growth rate, capturing endogenous growth under the firm's existing financial policies;
- SIZE: firm size, measured in this paper as the logarithm of total assets;
- LEV: leverage ratio, reflecting financial leverage and financial risk;
- TOP1: the shareholding percentage of the largest shareholder, used to represent ownership concentration and governance structure.

The heterogeneity tests further divide firms into high- and low-R&D groups, high- and low-PER groups, and different ownership categories.

3.3. Model Specification

(1) Baseline Model (Fixed Effects):

$$PER_{(i,t)}=\alpha+\beta\cdot RD_{(i,t)}+\gamma\cdot Controls_{(i.t)}+\mu_i+\varepsilon_{(i,t)} \tag{1}$$

The fixed effects for firms are used to control for unobservable factors at the firm level that do not change over time.

(2)Lagged effects model:

$$PER_{(i,t)}=\alpha + \beta\cdot RD_{(i,t-1)} + \gamma\cdot Controls_{(i.t)}+\mu_i+\varepsilon_{(i,t)} \tag{2}$$

To test the market's delayed response to R&D value.

(3) Heterogeneity Model: Estimate the benchmark model by grouping firms based on dimensions such as R&D intensity, PER levels, and ownership structure, then compare differences in β.

3.4. Data Cleaning and Sample Selection Rules

The same cleaning rules are applied across the panel specifications so that the regression results can be reproduced. Stock codes and fiscal years are first standardized to ensure that each firm-year observation is matched uniquely. PER, RD, and the main control variables are

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then checked for missing values, and incomplete observations are removed. A lagged R&D observation is retained only when the same company has data for at least two consecutive years, which explains the smaller sample in the lagged regressions. Finally, implausible observations, including extreme growth rates, are reviewed. Where necessary, they are truncated or reported together with comparison results based on alternative treatment rules in the robustness tests.

4. Empirical Findings and Analysis

4.1. Descriptive Statistics and Multicollinearity Test

Table 1 reports the descriptive statistics. The benchmark sample contains 313 observations. PER has a mean of 37.669 and a standard deviation of 38.706, with values ranging from -21.372 to 111.696. RD averages 0.041, or approximately 4.1%, and its standard deviation is 0.021. The dispersion in RD shows that firms differ in R&D intensity, while the much wider spread in PER is consistent with the industry's sensitivity to market conditions and expectations. Table 2 presents the VIF results. The values are low for all explanatory variables, and the mean VIF is 1.340. Multicollinearity is therefore unlikely to be a serious problem in the baseline specifications.

Table 1. Descriptive Statistics of Key Variables

Variable	Obs	Mean	Std.Dev.	Min	Max
per	313	37.669	38.706	-21.372	111.696
rd	313	0.041	0.021	0.013	0.081
tag	313	0.306	0.344	-0.101	0.987
sgr	313	0.067	0.097	-0.116	0.208
size	313	22.917	1.054	21.443	24.717
lev	313	0.516	0.161	0.225	0.733
top1	313	30.8	11.971	14.44	50.02

Note: The variables are defined in Section 3.

Table 2. Multicollinearity Test (VIF)

Variable	VIF
size	1.530
sgr	1.510
tag	1.400
lev	1.340
rd	1.150
top1	1.100
Mean VIF	1.340

Note: The VIF and Mean VIF values for each variable in the report are used to test for multicollinearity.

4.2. Baseline Regression: The Effect of the R&D Expense Ratio on PER

Table 3 reports the baseline estimates. Column (1) includes RD and firm fixed effects only, while control variables are added step by step in columns (2) to (4). Across the specifications, the coefficient on RD ranges from 344.102 to 504.995 and is significant at the 5% level in most columns. Firms with a higher R&D expense ratio therefore tend to have a higher PER. In column (4), for example, the RD coefficient is 474.403. Because RD is expressed as a ratio, a one-percentage-point increase in RD is associated, other things being equal, with an increase of approximately 4.744 in PER. The magnitude is economically meaningful, and the result

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supports H1: the capital market generally attaches a valuation premium to R&D investment by photovoltaic firms.

The control variables add useful context. SGR is significantly positive in some specifications, which is consistent with growth expectations playing an important role in PER. LEV is significantly negative in column (4), indicating that greater financial risk can reduce valuation multiples. TOP1 is not significant in that column, so the benchmark model does not show a clear valuation effect from ownership concentration.

Table 3. Base Regression Results (Dependent Variable: PER)

Variable	**(1)**	**(2)**	**(3)**	**(4)**
rd	344.102*	504.995**	477.396**	474.403**
tag	15.054	-2.558	-3.748	-0.659
sgr		178.288***	181.784***	174.759***
size			-6.977	0.001
lev				-65.398**
top1				-0.349
Firm FE	YES	YES	YES	YES
N	313	313	313	313
R2	0.223	0.312	0.320	0.333

Note: Standard errors are shown in parentheses; * p<0.1, ** p<0.05, *** p<0.01.

4.3. Lagged Effect: Delayed Pricing of R&D Investment

The lagged results are reported in Table 4. To allow for the time required for R&D output to emerge and be recognized by investors, the model uses the one-period lag of R&D investment, L.RD. Its estimated coefficient ranges from 503.521 to 532.254 and is significant at the 5% level. Previous-period R&D intensity is therefore positively associated with current PER. This result supports H2 and indicates that the market does not incorporate R&D value immediately. Recognition may develop as firms disclose technological progress and as product upgrades and profit realization become observable.

Table 4. Regression Results for Lagged R&D Expenditure Ratio (Dependent Variable: PER)

Variable	**(1)**	**(2)**	**(3)**	**(4)**
L.rd	521.080**	532.254**	522.163**	503.521**
tag	-0.402	-12.416	-12.830	-8.760
sgr		156.747***	153.632***	145.621***
size			6.520	9.323
lev				-48.097
top1				-0.207
Firm FE	YES	YES	YES	YES
N	259	259	259	259
R2	0.351	0.407	0.409	0.414

Note: Significance labels are the same as in Table 2.

4.4. Heterogeneity Analysis

This study conducts grouped regression analyses based on R&D intensity, PER levels, and ownership structure to examine whether the 'R&D-valuation' relationship varies across different firm characteristics Heterogeneity results are reported in Tables 5–7. Specifically, Table 5 shows that the RD coefficient is significantly positive only for the high-RD subsample, while it becomes insignificant for the low-RD group. Table 6 indicates that splitting the sample

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by valuation level (high vs. low PER) does not yield a statistically significant RD effect in either subsample, suggesting that R&D intensity alone does not directly account for cross-sectional differences in high valuations. Table 7 further reports the ownership-based regressions; due to the small SOE subsample and the lack of firm fixed effects in that split, the SOE estimates should be interpreted cautiously, and the non-SOE results serve as the main reference.

Table 5. Regression by Group: Based on R&D Intensity (High/Low R&D)

Variable	**High R&D Group**	**Low R&D Group**
rd	586.119*	-208.455
tag	-6.437	-8.481
sgr	112.903	241.330***
size	-1.659	8.284
lev	-60.001	-97.246*
top1	-0.255	-0.421
Firm FE	YES	YES
N	135	164
R2	0.591	0.395

Table 6. Grouped Regression: By PER Level (High/Low PER)

	(1)	(2)
Variable	(High PER)	(Low PER)
rd	104.418	194.965
	(225.160)	(107.016)
tag	-3.494	2.677
	(4.335)	(3.963)
sgr	-387.299***	133.168***
	(42.032)	(16.445)
size	-16.023**	3.164
	(5.121)	(3.028)
lev	96.570***	-3.691
	(20.384)	(13.035)
top1	-1.806***	-0.023
	(0.386)	(0.319)
_cons	465.421***	-76.715
	(106.335)	(66.990)
Firm FE	YES	YES
N	132	170
R^2	0.769	0.793
adj. R^2	0.612	0.685

Note: Groups are classified as high/low PER based on the median PER; significance labels follow the same convention.

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Table 7. Regression by Ownership Type (State-Owned/Non-State-Owned)

	(1)	(2)
Variable	State-Owned	Non-State-Owned
rd	-653.263	331.508
	(3345.575)	(263.063)
tag	251.467*	-12.374
	(124.347)	(7.371)
sgr	212.086	141.860**
	(111.983)	(48.272)
size	277.297*	1.146
	(142.330)	(4.517)
lev	-1.0e+03*	-53.294*
	(518.907)	(26.464)
top1	-13.215*	-0.588
	(6.745)	(0.450)
_cons	-5.4e+03*	36.976
	(2742.677)	(113.492)
Firm FE	No	No
N	25	288
R^2	0.699	0.388
adj. R^2	-0.032	0.216

Note: The state-owned subsample is small, so its estimates should be interpreted cautiously. Significance symbols follow Table 3.

(1) Grouped by R&D intensity: In the high R&D group, the R&D coefficient is 586.119 and significant at the 10% level. In the low R&D group, the R&D coefficient is -208.455 and not significant. This suggests that the benefits of R&D investment are more likely to be realised by firms with 'higher R&D intensity and more intense technological route competition', thereby supporting Hypothesis H3.

(2) PER grouping: The R&D coefficients for both the high- and low-PER groups are insignificant. This suggests that R&D investment itself does not necessarily explain 'high valuation' when companies are grouped by valuation quantiles. A more reasonable interpretation is that the ability of the market to price R&D may require further discussion in conjunction with factors such as profit realisation, industry cycle position and the information environment.

(3) Grouped by ownership structure: The state-owned enterprise (SOE) group had a small sample size (N = 25) and the model did not include firm-specific effects. This led to unstable coefficient estimates. Therefore, conclusions should be interpreted with caution. The R&D coefficient for the non-SOE group is 331.508, which is positive but has weak significance. This suggests that ownership structure may influence R&D efficiency and market expectations through governance mechanisms and resource acquisition capabilities. However, further testing with a larger sample size and more granular classification is required.

5. Discussion and Implications

The overall results indicate a stable positive correlation between the R&D expense ratio and the price-earnings ratio (PER), with a pronounced lag effect. This phenomenon can be understood from three perspectives. Firstly, the photovoltaic industry is a cutting-edge sector characterised by rapid technological iteration. In order to sustain efficiency gains and cost reduction capabilities and expand new business lines, investment in R&D often serves as a critical driver. During market upturns or technological breakthroughs, the market is more willing to pay for 'technology options', thereby driving up PER. Secondly, the value of R&D is not immediately apparent upon investment. It becomes apparent gradually through product iterations, yield improvements and cost reductions. Disclosure follows its own rhythm and financial data lags behind, meaning that R&D expense ratios from the previous period remain significant. Thirdly, heterogeneous results remind us that the valuation boost from R&D isn't universally accessible. It is more prevalent among high-R&D groups. In other words, 'strong R&D' companies are more easily recognised by the market and are more likely to command valuation premiums.

(1) Management implications: Shifting from 'input intensity' to 'input quality'. This study finds that the ratio of R&D expenditure correlates positively with valuation, and that this effect is more pronounced among high-R&D enterprises. This suggests that companies should maintain the level of R&D investment while also improving R&D efficiency and the verifiability of outcomes. R&D can be effectively translated into cost reduction and efficiency gains by optimising project portfolios, tackling critical processes, and strengthening equipment-material coordination. At the same time, companies should improve the clarity and transparency of R&D disclosures. This includes sharing information on R&D strategy, phased outcomes, efficiency metrics and core patents, helping the market to identify effective R&D.

(2) The Temporal Dimension of Valuation: The Practical Significance of Lag Effects'. The continued importance of R&D investment during the lagging period suggests a delayed response from capital markets to the value of R&D. Companies should therefore place greater emphasis on medium- to long-term R&D planning and avoid making frequent adjustments to investment based on short-term profit fluctuations. Meanwhile, investors can focus on aligning R&D with subsequent operational metrics, such as gross profit margin, unit costs, product mix and order fulfilment, to assess its potential to drive sustained improvements in cash flow.

(3) R&D Insights from a Cyclical Perspective: Premium Valuation Is Not Absolute. The photovoltaic industry exhibits strong cyclicality, with PER being sensitive to profit fluctuations. R&D premiums manifest differently across various phases. During upward cycles, the market is more willing to assign high valuations based on technological prospects; in downward cycles, cash flow and financial stability become paramount, with high leverage significantly suppressing valuations. While maintaining continuous R&D efforts, companies must strictly control capital expenditures and safeguard cash flow security to avoid amplifying risks through the combination of high R&D spending and high leverage.

(4) Implications for Future Research: Refining the “Input-Output-Valuation” Analysis Chain. This paper measures R&D solely through input intensity. Subsequent studies should incorporate additional output and mechanism variables to construct a more comprehensive analytical framework, distinguishing between “technology premium” and “cyclical premium.” Metrics such as patent quality, technological breakthroughs, cost improvements, and industry pricing could be integrated to enhance explanatory power.

6. Conclusion and Research Limitations

Using panel data for A-share photovoltaic enterprises, this paper examines the relationship between the R&D expense ratio and PER. The estimates show a significant positive relationship, and the one-period lag of RD is also significant. The relationship is more pronounced among firms with high R&D intensity. These findings are consistent with the view that a technological moat can support a valuation premium, but they also show that the premium is conditional on industry conditions and the information environment during the sample period.

The study has three main limitations:

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(1) The study relies primarily on PER as its valuation measure. Because PER is highly sensitive to earnings volatility, it may become unstable when the industry enters a downturn or a company records a temporary loss; extreme or negative values can result.

(2) The sample treats photovoltaic enterprises as a single group, even though the industry chain is heterogeneous. Polysilicon and wafer producers, module manufacturers, inverter firms, and auxiliary-material suppliers differ in their R&D patterns, profit models, and exposure to the cycle. Pooling them may conceal structural differences among these segments.

(3) Firm fixed effects and lagged terms address firm-level unobserved heterogeneity and reverse causality only to a limited extent, so endogeneity remains. Firms with higher valuations may have easier access to financing and may therefore increase R&D investment. Unobserved factors, including managerial competence, may also affect both R&D and valuation and are not fully controlled for in the current model.

These limitations suggest three directions for future research. First, the valuation metric system could be broadened and robustness tests could be conducted with multiple methods. Second, the analysis could distinguish segments of the photovoltaic value chain and different phases of the industry cycle, which would help separate technology premiums from cyclical premiums. Third, institutional variables such as the information environment and corporate governance could be added, or quasi-natural experiments could be used to strengthen causal identification. These extensions would allow the central financial-economics question of how capital markets price corporate R&D investment to be examined more systematically.

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