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Carbon Policy Effect: Dual Carbon Strategy on Profitability of Manufacturing Enterprises

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Abstract: The manufacturing industry is a major contributor to the carbon emissions of China. Studying the changes in the profitability of manufacturing enterprises is conducive to observing the impacts and focuses that the "dual carbon" goal brings to manufacturing enterprises,thereby better facilitating the achievement of the "dual carbon" goal.This paper organizes a total of 18,329 sample data from 3,061 manufacturing enterprises in China.It shows that the"dual carbon"policy significantly improved the profitability of enterprises located in regions with well-established low-carbon pilot programs. Then, it's also found that strategy has a positive effect on profitability for enterprises which belong to the eastern region, non-high polluting industries,or with high ownership concentration. Lastly,it's also discovered that there is a mediating effect of "dual carbon"strategy which helps to better understand the impact mechanism of improving profitability for manufacturing enterprise under the pressure of regulation.

Keywords: "Dual carbon" strategy, Enterprise profitability, Mediating effect.

1. Introduction

As the world's largest manufacturing country, the development of manufacturing enterprises in China has also encountered new challenges in line with the requirements of a low-carbon economy. As the most prominent sector in China's carbon emissions, the manufacturing sector accounts for more than half of the country's total emissions. Therefore, the carbon emission reduction effect of manufacturing enterprises is directly related to the effectiveness of China's carbon emission reduction and the realization of the "dual carbon" goal.

In the study of policies, Tan Xianchun et al. (2022) summarized 168 policies around low-carbon development in China during the period of 2007-2021, and found that compared with the previous implementation of low-carbon policies relying on administrative orders, market-oriented means have now become an important direction, especially through fiscal policy. Currently, the assessment of corporate profitability is generally integrated into the DuPont Analytical Management System, which is designed to realize targeted analysis through the detailed deconstruction of profitability indicators and in-depth analysis of various key elements affecting corporate profitability. The system can meet the needs of operators, investors, financial practitioners and other stakeholders for performance assessment through accounting analysis. In addition, another perspective for assessing the profitability of an enterprise focuses more on the efficiency and quality of the enterprise's own financial operations, especially in terms of financial performance, which focuses on measuring its profitability by examining the enterprise's financial performance, such as financial performance, which is mainly reflected in indicators such as Return on Assets (ROA), Return on Equity (ROE), and so on. Different indicators used can also affect the results of empirical research. Some scholars' statistics on the literature using corporate financial performance as the object of research from 1972 to 2012 found that most of the literature used the accounting indicators of return on assets (ROA), return on equity (ROE), and return on sales (ROS) as financial performance measure. Secondly, Tobin's Q, which represents market indicators, is used as a financial performance measure. However, using stock return as a financial performance indicator, the empirical results are in the opposite direction compared to the above measures.

This paper is an empirical study based on the theme of the impact of the "dual carbon" target on the profitability of listed manufacturing enterprises, which can be roughly divided into five parts: the first part is the introduction, which will mainly introduce the "dual carbon" target proposed to solve the outstanding problems of resource and environmental constraints, and the literature review. The second part introduces research hypothesis. The third part is variables and model. The fourth part is the empirical analysis. The fifth part is the research conclusion.

2. Research Hypothesis

Before the dual carbon goals, China had already begun to implement a low-carbon pilot city policy. A total of 74 cities were selected as low-carbon pilot cities, of which 40 regions implemented well according to a report announced by government in 2023.So it is beneficial to observe the difference between the profitability of manufacturing enterprises in low-carbon pilot areas and other regions to observe whether the profitability of manufacturing enterprises registered in low-carbon pilot cities will be affected by the "dual carbon" goal.

According to the spillover effect, the "dual-carbon" goal, as an environmental requirement with corresponding policies to help realize it, can be used as an environmental regulation policy to study its impact on corporate profitability. One dimension of environmental regulation that should not be overlooked in different regions is whether local governments are inclined to adopt strategic environmental policies in order to pursue economic growth and achieve good results. In light

of the current widespread environmental pollution challenges, academic studies have shown that local governments exhibit a "downward competition" or "race to the bottom" in environmental regulation in order to attract mobile resources and stabilize local resources. This view, however, is incomplete. However, this view is incomplete. Regions are at different levels of development, and even if they are equally motivated by the need to attract liquid resource. However, for those regions that are already on the path of transformation and upgrading, it is more likely that they will exhibit a "race to the bottom" in terms of environmental regulation in order to attract highly mobile resources that prefer a high-quality ecological environment. The Race to the Top in terms of environmental regulation.

Therefore, based on the above analysis, we propose Hypothesis 1.

H1: The profitability of manufacturing firms domiciled in good low-carbon pilot cities is positively affected by the "dual-carbon" target.

3. Variables Definitions and Model

3.1. Data Sample

Our sample is comprised of listed manufacturing firms on the Shanghai Stock Exchange (SHSE) and Shenzhen Stock Exchange (SZSE) during the period 2014–2022. In addition, in order to eliminate the possible bias of outliers on the results of the empirical analysis, this paper implements the two-sided truncation at the 1% level for the selected variables so we get a final sample of 18329 observations.

We select the manufacturing enterprises with reference to the 2012 version of the industry classification of the Securities and Exchange Commission (SEC). After the above screening, this paper selects 1995 A-share manufacturing enterprises listed in Shanghai and Shenzhen as the research object of this paper. In addition, in order to eliminate the possible bias of outliers on the results of the empirical analysis, this paper implements the two-sided truncation at the 1% level for the selected variables. After rigorous screening and processing of the data with the help of Stata17.0 statistical software, 18,329 valid observations were finally obtained. The enterprise data used in this study are obtained from the China Stock Market&Accounting Research (CSMAR) system. All the data are cross-checked for consistency.

3.2. Variables

3.2.1. Dependent Variable: ROA

Currently, the assessment of corporate profitability is generally integrated into the DuPont Analytical Management System. Besides, literates used the accounting indicators of return on assets (ROA), return on equity (ROE), and return on sales (ROS) as financial performance to measure the profitability of enterprises. We use ROA to be a dependent variable on the behalf of profitability.

3.2.2. Control Variables

Following prior studies, we control for a vector of firm characteristics shown to affect profitability. The

control variables include construction in progress, total assets, variety of operating expenses, investments, environmental information score, R & D (research and development). Moreover, we add Area and Policy dummies to control for whether the manufacturing enterprise is located in an excellent low-carbon pilot city and dynamic changes in the low-carbon environment to enterprises during the sample period, respectively. $\mathrm{Area}_{i,t}$is the place of registration of the enterprise i in year t. If it is in a low-carbon pilot city with excellent assessment results, the value is 1; otherwise, it is $0.\mathrm{Area}_{i,t}$ The time of the "dual carbon" policy shock is set to 2020, where Policy is 1 when the year is 2020 and later, and 0 before 2020. $\mathrm{Control}_{i,t}$ are control variables, which are variables that are controlled at the firm level and at the yearly level, and include variables as shown in Table 1 which provides definitions of all variables used in our analysis.

Table 1. Meaning of main variable symbols

Variables	Definitions
LnCS	Take the natural logarithm for construction in progress (CS)
LnTA	Take the natural logarithm of the total assets (TA)
MA	Ratio of management expenses to operating income
SALE	Ratio of selling expenses to operating income
RD	Ratio of R&D expenses to operating income
OPER	Ratio of operating costs to operating revenues
RATIO	Ratio of environmental investment to total assets
FR	Ratio of finance costs to operating income
RE	Difference between current assets and current liabilities to total assets
FA	Ratio of net fixed assets to total assets
ROIC	Ratio of investments to total assets
DEBT	Ratio of total liabilities to total assets
LNFO	Taking the natural logarithm of a firm's environmental information score
LA	Ratio of return on investment to capital invested in the enterprise
TQ	Market capitalization to total assets
PE	Ratio of stock price to per share
OC	Sum of shareholdings of the company's top five largest shareholders

3.3. Model

In order to better observe the impact of the "dual-carbon" policy on the profitability of listed manufacturing enterprises whose registered place is a good low-carbon pilot city and solve the multicollinearity problem, this paper sets up the model as follows:

$$\mathrm{ROA}_{i,t} = \beta_0 + \beta_1 \mathrm{DID} + \beta_2 \mathrm{Control}_{i,t} + \varepsilon_{i,t} \quad (1)$$

Where DID replaces $\mathrm{Area}_{i,t} \times \mathrm{Policy}_{i,t}$, β_1 represents regression coefficients, $\varepsilon_{i,t}$is an error term.

4. Empirical Analyses

4.1. Descriptive Statistics

From the statistics in Table 2, we can observe that the average value of the coefficient of the excellent low-carbon pilot cities (parea) is 0.392, which indicates that about 39.2% of the cities in the sample selected for this paper performed well in the implementation of the low-carbon pilot policy and received excellent ratings in the assessment report. It is particularly noteworthy that after the "dual carbon" target was proposed and implemented, 17.5% of the enterprises were still registered in these low-carbon pilot cities with excellent performance, a phenomenon that fully illustrates that only a small number of cities have demonstrated good implementation and demonstration effects in the low-carbon pilot policy. In addition, the sample mean of return on assets (ROA) is 0.0409, and its standard deviation is 0.0714,

however, from the huge gap of nearly 0.7 between the maximum value and the minimum value, we can infer that there are more significant differences in ROA among different manufacturing enterprises.

Table 2. Descriptive Statistics for Key Variables

variant	quantities	average value	(statistics) standard deviation	minimum value	maximum values
DID	18,329	0.175	0.380	0	1
parea	18,329	0.392	0.488	0	1
RATIO	18,329	0.0804	0.0989	0	0.598
RE	18,329	0.0547	0.0744	-0.443	0.288
ROA	18,329	0.0409	0.0714	-0.473	0.239
ROIC	18,329	0.0552	0.0881	-0.709	0.308
OPER	18,329	0.933	0.162	0.523	2.594
SALE	18,329	0.0796	0.0987	0.00105	0.546
MA	18,329	0.0802	0.0568	0.00792	0.442
FR	18,329	0.0107	0.0273	-0.0829	0.212
LNFO	18,329	2.273	0.872	0	3.738
LnCS	18,329	18.23	3.726	0	23.65
LnTA	18,329	22.10	1.142	19.95	25.82
ROE	18,329	0.0233	1.120	-76.76	5.307
LnIR	18,329	-1.533	1.937	-13.816	15.280
LnPE	18,329	3.885	1.030	-5.375	7.514
DEBT	18,329	0.395	0.234	0.00906	8.009

4.2. Multivariate Results

Table 3. Regression results of ROA, ROE, TQ

	(1)	(2)	(3)
VARIABLES	ROA	ROE	TQ
DID	0.001*	0.046*	0.014*
	(1.84)	(1.87)	(1.69)
LnCS	-0.000	0.003	-0.006***
	(-0.34)	(0.51)	(-6.22)
LnTA	-0.001**	-0.005	-0.072***
	(-2.45)	(-0.10)	(-22.17)
MA	0.051***	-0.248	1.453***
	(7.62)	(-0.58)	(23.98)
SALE	0.003	-0.344	0.274***
	(0.45)	(-0.38)	(9.67)
OPER	-0.044***	-0.043	-0.050*
	(-11.60)	(-0.07)	(-1.73)
RATIO	0.000	0.157**	0.006
	(0.34)	(2.16)	(0.18)
FR	-0.225***	-3.503**	-1.933***
	(-16.00)	(-2.03)	(-14.63)
ROIC	0.705***	-1.113	-2.815***
	(61.35)	(-0.51)	(-18.77)
LNFO	-0.000**	0.024	0.007*
	(-2.07)	(1.26)	(1.93)
LA	-0.008***	3.776***	-0.137***
	(-4.89)	(2.66)	(-8.63)
LnPE	-0.003***	0.139***	0.179***
	(-8.18)	(3.18)	(54.65)
LnIR	0.000**	-0.005	0.003**
	(2.55)	(-1.05)	(2.15)
Observations	18,329	18,329	18,329
Number of id	3,061	3,061	3,061
R-squared	0.967	0.154	0.423

Table 3 reports the regression results of the effect of good low carbon pilot cities on the profitability of manufacturing enterprises under the "dual carbon" policy. The results show that the regression coefficient of DID of the cross term is significantly positive at the 10% significance level, which indicates to a certain extent that manufacturing enterprises registered in good low-carbon pilot cities under the "dual-carbon" policy improve their profitability, confirming Hypothesis 1: the profitability of manufacturing enterprises registered in good low-carbon pilot cities will be positively affected by the "dual-carbon" target. As mentioned above, under the implementation and promotion of the "dual-carbon" policy, enterprises in good low-carbon pilot cities to a certain extent demonstrate the importance they attach to the environment and can better develop under the environmental regulation policy. Besides, we use ROE and TQ (Tobin's Q Ratio) to replace ROA measuring the profitability of manufacturing enterprises in Table 3.

Columns (2) and (3) in Table 3 report the empirical results of ROE (return on equity) and TQ, respectively. The regression coefficients of the "dual-carbon" dummy variable (DID2) on ROE and TQ are 0.046 and 0.014, respectively, which have a positive effect on the two explanatory variables. The regression coefficient of DID2 on ROE is 0.046, and the regression coefficient of TQ is 0.014, which is a positive effect on these two explanatory variables at the significant level of 10%, and the significance of the empirical results is not different from that of Table 3-4, which indicates that the conclusion of this paper is robust. Column (3) in Table 3-7 reports the empirical results of using PE (price-earnings ratio) as an alternative explanatory variable, which shows a negative effect at the 5% significance level. The reason may be that PE (price-earnings ratio) represents the meaning of how many years a company's profitability can be fully recovered, and in this part of the calculation, the company's net assets, performance growth rate, and the assumption that the company has been running smoothly, have not been taken into account. In this part of the calculation, the net assets and performance growth rate of the enterprise are not taken into account, and it is only assumed that the enterprise has been operating smoothly, and when the manufacturing enterprise is hit by the type of environmental policy impacts such as the "dual-carbon" target, the operation of the enterprise in a certain period of time is unstable, and in addition, the profit level of the enterprise will be reduced as a result, therefore, when PE is used as an explanatory variable it will have a negative impact. After replacing the explanatory variables, hypothesis 1 is verified: the profitability of manufacturing enterprises whose registered place is located in good low-carbon pilot cities will be positively affected by the "dual-carbon" target, and passes the robustness test, and it can be considered that hypothesis 1 is valid.

4.3. Robustness Test

After a basic empirical analyse and replace dependent variable, we do some other robustness tests, such as parallel trend test, placebo test, and PSM-DID procedure to make sure the robustness of the results.

4.3.1. Parallel Trend Test

This paper adopts the Difference-in-Differences (DID) method as a research tool which requires to satisfy the parallel trend assumption. That means the experimental group is unaffected by the policy in the first period and the policy is in effect from the second period, while the control group is unaffected by the policy throughout the study period. We use

the graphical method (see Figure 2) to verify the hypothesis of parallel trends in the sample data, and accordingly assess the effects of dynamic policies at the city level. By looking at Figure 2, we can clearly see that the confidence interval of the regression coefficients consistently encompasses a value of 0 in the six years before the official implementation of the "dual-carbon" policy, a phenomenon that suggests that urban enterprises in the experimental group and the control group did not show significant differences in profitability during this period. However, from the beginning of the first year of policy implementation, the confidence intervals of the estimated coefficients presented in Figure 1. no longer include a value of 0, a shift that strongly supports the parallel trend hypothesis.

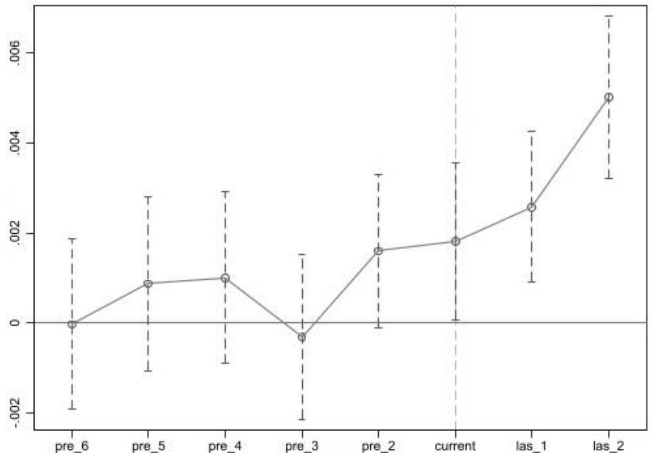

Figure 1. Parallel Trend Test Plot

4.3.2. Placebo Test

The placebo test can be chosen to randomize the experimental group, typically by randomly selecting individuals as the treatment group and repeating it 500 or 1,000 times to see if the coefficients are significantly different from the baseline estimates. If it is not significant, it can indicate the robustness of the original policy effect. In this section, the interaction term is randomly selected 500 times, and Figure 2. is obtained. From the figure, it can be seen that the scatters are concentrated around 0 and far away from the true value, and the vast majority of scatters are located on the level of the solid line at p=0.1, which indicates that the vast majority of the estimated coefficients are not significant at the 10% level, which implies that the effect of the "dual-carbon" policy on manufacturing firms grouped by information disclosure degree in Hypothesis 1 is not significant. This implies that the policy effect of the "dual carbon" policy in Hypothesis 1 on manufacturing firms grouped by the degree of information disclosure is not affected by other unobserved factors.

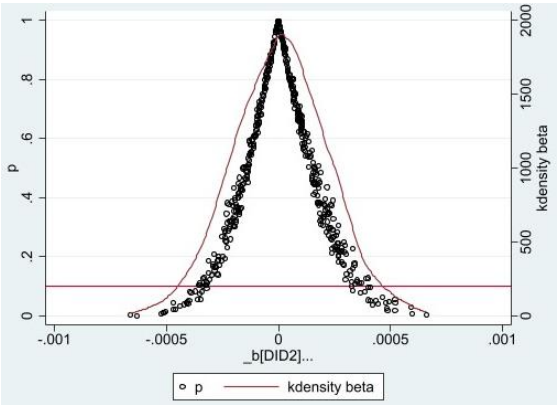

Figure 2. Scatterplot of p-value for information disclosure test

4.3.3. PSM-DID

In order to mitigate the endogeneity problem triggered by sample selection bias, this paper draws on previous scholars' research methods. In this paper, we adopt the PSM-DID method to conduct the robustness test. Specifically, we first utilize the "dual-carbon" policy as the explanatory variable and perform logit regression analysis on the control variables to calculate the propensity score. Subsequently, we apply a 1:1 nearest-neighbor matching strategy to screen out the non-pilot cities with the closest propensity scores, and use them as the new control group sample.

In order to test whether the matching results are effective in balancing the data, the pstest command is used in this section for analysis. The test results of the balance hypothesis, while Figure 2. visualizes the test of the balance hypothesis in the form of a scatter plot. According to these results, we can observe that after the application of the propensity score matching (PSM) method, the absolute value of the t-value shows a tendency to decrease, and at the same time, the absolute value of the standardized deviation of each variable is also reduced to varying degrees, and these deviation values are all controlled within the range of 10%. This result indicates that there is no longer a significant difference between the means of the experimental group and the control group in terms of the matching variables, thus strongly proving that we have effectively solved the endogeneity problem of the sample and successfully passed the consideration of the balance test.

Then we use the PSM sample to re-estimate model (1), we observe that the coefficient estimate of the difference-in-differences (DID) is 0.001 and exhibits statistical significance at the 10% significance level, which reveals that the coefficient estimate of DID is 0.085 and is significant at the 5% significance level. The above empirical results not only strongly verify the correctness of H1.

5. Conclusion

This paper regards the "dual carbon" policy as a "natural experiment", utilizes the financial data of China's Shanghai and Shenzhen A-share A-share main board manufacturing industry listed companies during the period from 2014 to 2022, and explores the impact mechanism of the "dual carbon" policy on corporate profitability with the help of the double-difference model. Double carbon" policy on corporate profitability. In order to ensure the robustness of the research results, this paper also implements a placebo test for the sample, and conducts a series of rigorous robustness tests by replacing the core indicator variables, using PSM propensity score matching and other methods. The main findings are as follows:

The implementation of the "dual-carbon" policy has significantly improved the profitability of manufacturing enterprises located in good low-carbon pilot cities. The introduction of this policy has created unprecedented opportunities and challenges for local governments and enterprises. In response to environmental regulations, companies have accelerated the pace of low-carbon transformation, realized green production, and invested more in innovation to improve their productivity. At the same time, local governments are fully supporting the transformation and upgrading of enterprises by introducing tax subsidies and attracting foreign investment, ultimately contributing to a significant increase in corporate profitability.

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