R&D Investment Leap and Green Innovation Performance in Heavily Polluting Enterprises

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Abstract. Based on the dual innovation theory, The empirical part of this article is tested using Stata 16.0, the panel model are used to verify the impact of R&D investment leap on green technology innovation and the mediating effect of dual innovation ambidexterity. The results show that: (1) R&D investment leap has a significant positive impact on green technology innovation. (2) Innovation ambidexterity plays a partially mediating role between R&D investment leap and green technology innovation.

Keywords: R&D investment leap; Green innovation performance; Dual innovation balance

1 Introduction

Green technology innovation is of great significance to the sustainable development of enterprises and the environment, especially for heavily polluting enterprises, to get rid of high energy consumption and high pollution industry attributes and production models through green technology innovation is the focus of their future development process. However, how to speed up the green technology upgrade of enterprises while ensuring the normal operation of heavily polluting enterprises has always been an urgent problem to be solved to achieve the goal of green transformation.

This paper introduces the dual innovation balance to establish a new conceptual framework to explore the impact of R&D investment leap and dual innovation balance on green technology innovation, so as to provide decision-making reference for the green development of heavy polluting enterprises.

2 Research Hypothesis

Based on life cycle theory, technology life cycle can be divided into the development, validation and application, mature, and degenerate five stages [1]. In technology development period, enterprises need to introduce external knowledge and related technical personnel, which cause the significant increase in of R&D input [2], tilting re-sources to green technology research and development, so as to speed up the green technology innovation output. In the mature stage of technology, the marginal diminishing effect

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reduces the conversion efficiency of R&D investment, so it is not in the interests of enterprises to continue to add funds, and R&D investment decreases significantly compared with that in the early stage. At this time, enterprises focus more on improving existing green technologies through exploitative innovation.

R&D investment leap means that the organization can make corresponding organizational structure, resource allocation and value adjustment in time with environmental changes. The flexible transformation shows that enterprise has the high strategic flexibility and coordination ability [3], which maximizes the utilization of resources by the enterprise and indirectly increases the supply of resources, which is beneficial for the organization to carry out dual innovation at the same time and improve duality. The balance of innovation, and exploratory and exploitative innovation can also promote each other, which further improves the balance of dual innovation.

Exploratory innovation often leads to failure and produces a "failure trap", while exploitative innovation often achieves early success and strengthens continuing along the original path, resulting in a "success trap"[4]. Therefore, it is necessary to balance the relationship between exploratory innovation and exploitative innovation to promote green technology innovation. Therefore, it is proposed that:

H1: R&D investment leap has a positive impact on green technology innovation;

H2: R&D investment leap positively affects the dual innovation balance;

H3: Dual innovation balance positively affects green technology innovation;

H4: Dual innovation balance mediates the relationship between R&D investment leap and green technology innovation.

3 Research Design

3.1 Sample selection and data processing

Sample selection.

Based on the industry codes of the "Classification Index of Listed Companies" revised by China Securities Regulatory Commission in 2012 and previous studies on heavy polluting enterprises [5], this paper finally identified a total of 16 subsectors as heavy polluting industries, and selected A-share listed companies in related industries as the research objects of this paper.

In order to ensure sufficient sample size, the time interval of this study is set as 2012-2017. After eliminating ST, ST* enterprises and enterprises with missing or incomplete data, 59 heavily polluting enterprises that meet the screening conditions are finally determined. The data are mainly from GTA database and Patsnap database, and supplemented with corporate social responsibility reports.

Variable design.

The specific data sources, index setting and processing methods in this paper are as follows:

(1) Green technology innovation: In this paper, the sum of the number of green invention patents and green utility model patents of listed companies is used as the measurement index of green technology innovation.

(2) R&D investment leap: Based on the research of Wu Jianzu and Xiao Shufeng [2], the maximum value of residual in the time trend is obtained by GARCH model to measure R&D investment leap.

(3) Dual innovation balance: refer to previous studies [6-7], to calculate the enterprise dual balance based on patent data. In this paper, invention patents are classified as exploratory innovation (TS), and the sum of utility model and design patents is classified as explosive innovation (LY). Finally, the innovation balance index (ZS) is calculated. The calculation formula is:

$$TS = \text{Invention patent} / (\text{Invention patent} + \text{utility model} + \text{design}) \quad (1)$$

$$LY = \text{utility model patent} + \text{design patent} / (\text{invention patent} + \text{utility model} + \text{design}) \quad (2)$$

$$ZS = 1 - | TS - LY | \quad (3)$$

(4) Other variables. In this paper, the asset-liability ratio, profit rate and enterprise size are introduced into the model as control variables. A brief statistical description is shown in Table 1 below.

Table 1. Variable definitions and descriptive statistics

Index	Variable Sign	Mean	S.D.
Green technology innovation	Gpat	2.49	6.56
R&D investment leap	Leap	0.12	2.39
Dual innovation balance	ZS	0.46	0.32
Profit rate	Profitability	0.06	0.50
Asset-liability ratio	Dta	0.55	0.20
Enterprise size	Scale	22.57	1.40

Original: Author

Panel data stationarity test.

In order to avoid spurious regression, it is necessary to conduct unit root test on panel data. Homogeneous panel unit root test (BT test) and heterogeneous panel unit root test (Fisher-ADF test and Fisher-PP test) are used in this paper, and the specific results are shown in Table 2. After testing with three different methods, it can be found that both homogeneous panel unit root test and heterogeneous panel unit root test significantly reject the null hypothesis of the existence of unit root, which further indicates that the variable series selected in this paper is stationary.

Table 2. Panel unit root test results

Variable	Ht test	Fisher-ADF test	Fisher-PP test
Gpat	-14.76***	28.30***	9.99***
Leap	-3.32***	68.12***	35.50***
ZS	-10.71***	33.51***	21.07***
Profitability	-49.80***	54.01***	8.28***
Dta	-2.20**	10.56***	10.62***
Scale	-2.73***	20.18***	2.60***

Original: Author

Note: ***, ** and * respectively indicate that they pass the test at the significance level of 1%, 5% and 10%, as shown in the following table.

3.2 Regression Analysis

In order to verify the proposed hypothesis, this study constructed multiple regression equations to verify the hypothesis and controlled for the individual firm fixed effects. The estimated results are shown in Table 3. Model 3 shows that R&D investment leap has a positive impact on green technology innovation (β=0.148, P<0.01), the main effect hypothesis H1 was verified.

According to the estimation results of Model 1 and Model 4, the leap in R&D investment has a significant positive impact on the dual innovation balance (β=0.019, P<0.1), dual innovation balance has a significant positive impact on green technology innovation (β=0.712, P<0.01), hypothesis H2 and H3 have been verified. On the premise that H2 and H3 are established, it can be seen from Model 5 that R&D investment leap and dual innovation balance jointly positively affect green technology innovation (β1=0.145, β2=0.594, P<0.01). Moreover, the positive effect of R&D investment leap on green technology innovation is significantly weakened due to the existence of dual innovation balance (β=0.145<0.148), indicating that dual innovation balance plays a partial mediating role between R&D investment leap and green technology innovation. Hypothesis H4 is verified.

Table 3. Panel regression results

Variable	ZS	Gpat			
	Model 1	Model 2	Model 3	Model 4	Model 5
Leap	0.019*		0.148***		0.145***
ZS				0.712***	0.594***
Profitability	-0.042*	-0.082	-0.075	-0.137	-0.116
Dta	-0.116	-1.850***	-0.912	-2.860***	-1.890***
Scale	-0.180***	0.639***	0.508***	0.626***	0.385**
Fixed effect	firm	firm	firm	firm	firm

Original: Author

Note: ***, ** and * respectively indicate that they pass the test at the significance level of 1%, 5% and 10%, as shown in the following table.

4 Main research conclusions

In the context of tighter resource and environment constraints, the transformation of heavily polluting enterprises is an urgent and realistic research topic. In this paper, R&D investment leap, dual innovation balance and green technology innovation are included in the unified analysis framework, and the mechanism of R&D investment leap on green technology innovation is explained objectively. The following conclusions are obtained: (1) R&D investment leap has a positive impact on green technology innovation; (2) Dual innovation balance partially mediates the relationship between R&D investment leap and green technology innovation.

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