

The Impact of R&D Investment on Innovation-driven Efficiency-Based on the Application of Input-output Theory in Financial Analysis Teaching

Mingyao Hu ^{a, *}, Ming Fang ^b

School of Management, Wuhan University of Technology, Wuhan, China

^a hmy@whut.edu.cn, ^b fxlasting@aliyun.com

*Correspondence Author

Abstract. This article applies the input and output theory to the empirical teaching of financial analysis. Based on data from 2013-2018 of high-tech enterprises in Hubei Province, this paper conducts an empirical study on the impact of R&D investment on various aspects of innovation-driven efficiency. This paper constructs a DEA model, uses DEAP2.1 software to calculate the innovation-driven efficiency of an enterprise, and discusses the impact of R&D investment on enterprise technical efficiency and scale efficiency. Establish a multiple regression model and use Stata software to study the impact of R&D investment intensity and R&D personnel investment intensity on the efficiency of corporate innovation-driven.

Keywords: input-output theory, R&D investment, innovation drives efficiency, high-tech enterprises.

1. Introduction

As far as financial accounting is concerned, the input-output theory is a reasonable theory, which reasonably quantifies the input resources and output resources in the operation of business entities, and uses mathematical methods to study the relationship between input and output. This is a reasonable theory of accounting and economics. The academic field provides quantitative research methods for input and output analysis. This article applies the input-output theory to the teaching of financial analysis.

Innovation refers to the activities of high-tech enterprises for technological innovation and the development of new technologies and new products. It can be divided into three major aspects: knowledge, management, and science and technology. Innovation has led the world trend. We need to study how innovation promotes social and economic development. The most important part of innovation-driven development is to use science and technology to drive development. The role of traditional population, labor, resources and energy is limited. The basic goal of innovation is to drive economic and social development, not to innovate vigorously for the purpose of publishing high-level academic papers. R&D investment is the starting point for all innovation activities. As an innovative province, Hubei Province attaches great importance to R&D investment and technological innovation. Therefore, based on Hubei Province's R&D investment and innovation-driven efficiency as the research object, grasping the specific situation of the implementation of the innovation-driven strategy of the innovative province is of great significance to our country's innovation-driven development strategy.

Based on the above status, this paper grasps the direct impact of R&D investment on the innovation-driven efficiency of high-tech enterprises, and puts forward decisions and suggestions on rational use and effective planning of R&D investment, so that enterprises can improve their performance and innovation efficiency while also driving their own innovation. National development is more efficient.

2. Theoretical framework and hypotheses development

2.1 Current hypothesis of R&D investment on enterprise innovation-driven efficiency

Liu Xueyao and Zhang Min (2017) pointed out that the R&D investment of listed companies has a negative effect on the economic situation of the company, and there is no obvious lag effect [1]. R&D activities are an uncertain and high-risk activity for high-tech companies. For companies, backward R&D investment does not have a positive impact on the company's innovation-driven efficiency, but will cause redundant R&D resources. Based on the above situation, this article proposes the following assumptions:

Hypothesis 1: R&D investment is current to the innovation-driven efficiency of enterprises.

2.2 The impact of R&D investment on the redundancy of enterprise innovation-driven efficiency

As a high-tech enterprise with active R&D activities, the intensity of R&D investment must be relatively large. Whether it is capital investment or personnel investment, the enterprise has carried out a certain degree of allocation. However, the redundancy of resources is inevitable, so it is necessary to understand what is the status of the redundancy of high-tech enterprises, what is the degree, and the development trend in comparison. Hubei Province is in the forefront of major innovation provinces, and its investment in R&D funds and personnel resources is relatively large, and there are also many innovative activities. Therefore, the redundancy situation in this province should be relatively optimistic. Li Yanping (2016) pointed out that there is insufficient investment in innovation resources. In the Yangtze River Economic Zone, the investment of innovative talents and capital is insufficient, which limits regional development, and most companies fail to realize the urgency and necessity of innovative activities [2]. Based on the above information, this article proposes the following assumptions:

Hypothesis 2: R&D investment has a redundant impact on the efficiency of enterprise innovation-driven, but more of it is insufficient output.

2.3 The impact of various types of R&D investment intensity on innovation-driven efficiency

Capital investment and personnel investment in R&D investment is an indispensable and important component of the innovation development system. Since the proposal of the innovation-driven development strategy, R&D funds and personnel input have also been included in the research on innovation-driven development. Because of regional development, the impact of R&D resources on innovation activities varies. Xu Huanzhang (2019) pointed out that R&D investment has a positive correlation with corporate performance [3]. Lin Yaling (2019) pointed out that Hebei Province needs to increase R&D investment, and R&D expenditures and R&D personnel investment have a driving effect on the economic development of the province[4]. However, many studies believe that the intensity of R&D investment in some regions has a negative impact on innovation efficiency and business performance.

Based on this, this article proposes the following assumptions:

Hypothesis 3: The intensity of R&D investment has a positive impact on the efficiency of enterprise innovation-driven.

Hypothesis 4: The investment intensity of R&D personnel has a positive impact on the efficiency of enterprise innovation-driven.

3. Method

3.1 Sampling and Data Collection

The research sample data of this paper is downloaded from the Guotaian database and the official websites of the Shenzhen Stock Exchange and the Shanghai Stock Exchange, using the original data

of the high-tech listed companies in Hubei Province from 2013 to 2018, and processing the relevant data through DEAP2.1 and STATA16.0. Valid data and processing samples. After the above processing, this article has obtained 48 effective sample enterprises of high-tech listed companies in Hubei Province, with a total of 288 effective samples, as panel data for the following empirical analysis.

3.2 Variable selection and definition

Dependent variable: Innovation Driven Efficiency (IDE). The acquisition of this indicator needs to be measured, not directly available. This paper selects the output-oriented DEA-BCC model based on the input-output theory to calculate, and the calculated pure technological innovation efficiency represents the innovation-driven efficiency of the enterprise.

Test variable: Based on previous research results, this paper divides R&D investment into two parts to consider, R&D capital investment and R&D human resource investment. Based on this, the indicators of these two parts are selected as the measurement of R&D investment indicators.

R&D investment intensity (RDI): This study uses the ratio of the current corporate R&D expenditure to the company's total operating income to measure. This indicator will indicate the amount of capital investment in enterprise R&D funds.

R&D personnel input intensity (RPI): This study uses the ratio of the number of enterprise R&D personnel to the total number of enterprise employees to measure. This indicator will indicate the company's R&D investment in human resources.

Control variables: Government subsidies (GS). Innovation output (PA). Company size (SIZE). Financial leverage (FL). Ownership concentration (OC). Company growth (GO). Dummy variables of the nature of the enterprise (SOE). Area dummy variable (AREA). Scale dummy variable (SIZEFENZU).

3.3 Model

1) DEA calculation model

Assuming there are N decision-making groups, there are m kinds of input variables and n kinds of output variables, then the input and output variables of the j-th decision-making unit are:

$$x_j = (x_{1j}, x_{2j}, \dots, x_{mj})^T \quad (1)$$

$$y_j = (y_{1j}, y_{2j}, \dots, y_{nj})^T, j=1, 2, \dots, N \quad (2)$$

The model should add a weighted number to integrate the input and output indicators. Because there are many input and output indicators, they cannot be added together for measurement and comparison. Set v as the weight of the input index and u as the weight of the output index, then the weight vectors are:

$$v_j = (v_1, v_2, \dots, v_m)^T \quad (3)$$

$$u_j = (u_1, u_2, \dots, u_{nj})^T, j=1, 2, \dots, N \quad (4)$$

Then we can define a function (5):

$$IDE = \frac{x^T y_i}{v^T x_j} = \frac{\sum_{k=1}^S u_k y_{kj}}{\sum_{i=1}^m v_i x_{ij}} \quad (5)$$

2) Regression model

This article uses a multiple regression model to analyze the impact of R&D investment and R&D personnel investment on the efficiency of enterprise innovation-driven.

$$IDE = \beta_0 + \beta_1 RDI + \beta_2 RPI + \beta_3 GS + \beta_4 PA + \beta_5 SIZE + \beta_6 FL + \beta_7 OC + \beta_8 GO + \varepsilon \quad (6)$$

β represents the regression coefficient. The Y value of the above model is the efficiency IDE driven by the explanatory variable innovation, and the X value is the explanatory variable RDI and RPI and the control variable government subsidy GS, innovation output PA, and enterprise scale. SIZE, financial leverage FL, equity concentration OC, and corporate growth GO.

4. results

4.1 Descriptive Analysis of Variables in DEA Model

Table 1 shows the descriptive statistics of the logarithm of the input and output indicators used to calculate the innovation-driven efficiency.

Table 1. Descriptive statistics of input and output indicators of DEA model (logarithm)

index	type	variable	N	mean	sd	min	max
Input	Human resources	Technical staff	288	5.62	1.09	3.00	8.75
	Financial resources	R & D spending	288	17.9	1.21	15.61	21.66
Output	Innovation output	patent application	288	2.30	1.38	0	5.81
	Economic output	Operating income	288	21.11	1.33	18.79	23.97

The following is a descriptive analysis of the panel data of the relevant variables involved in the regression model:

Table 2. Descriptive statistical analysis of regression model variables

VARIABLES	N	mean	sd	min	max
CODE	288	24.50	13.88	1	48
YEAR	288	2,016	1.711	2,013	2,018
IDE	288	0.953	0.0425	0.821	1
RDI	288	5.912	5.130	0.180	27.51
RPI	288	20.65	13.97	0.770	59.53
GS	288	13.74	5.846	0	20.23
PA	288	26.13	48.54	0	333
SIZE	288	21.76	1.296	15.01	24.48
FL	288	41.27	21.96	3.344	95.94
OC	288	0.514	0.174	0.175	1.000
GO	288	19.26	41.97	-56.35	308.2
CODE	288	24.50	13.88	1	48

4.2 DEA results and regression results analysis

This section summarizes and analyzes the results calculated by the software on the DEA model and regression model.

1) The current impact of R&D investment on the efficiency of enterprise innovation drive

In the results calculated by the DEA model, we put the 6-year input and output of 48 samples in the current period, and put the 5-year input in the case of a 1-year lag, and calculate the innovation-driven efficiency of the T0 period and the T1 period respectively. The change value. Table 3 shows the innovation-driven efficiency of enterprises in T0 and T1 periods from 2013 to 2018.

Table 3. Innovation-driven efficiency of listed high-tech companies in Hubei Province

mean	TE		PTE		RTS	
	T0	T1	T0	T1	T0	T1
2013	0.928	0.928	0.954	0.957	0.972	0.970
2014	0.925	0.944	0.953	0.964	0.970	0.979
2015	0.928	0.919	0.954	0.944	0.973	0.974
2016	0.922	0.868	0.946	0.931	0.976	0.932
2017	0.939	0.944	0.958	0.959	0.981	0.985
2018	0.936		0.952		0.982	
mean	0.930	0.921	0.953	0.951	0.976	0.968

The value of pure technical efficiency is lower than scale efficiency, which proves that we need to make certain technological progress to improve the overall efficiency of innovation. When output lags for one year, technical efficiency, pure technical efficiency, and scale efficiency are lower than the current efficiency. It proves that the current R&D investment has a greater impact on the innovation output and economic benefits of enterprises, leading to greater innovation-driven efficiency. Therefore, hypothesis one holds.

2) The redundant impact of R&D investment on innovation-driven efficiency

Table 4 is the classification of the scale efficiency of each decision-making unit of the sample companies in the current period and the lagging period. Scale benefits are divided into constant scale benefits (DRS), increased scale benefits (IRS) and reduced scale benefits (CRS).

Under the five-year innovation-driven situation of the 48 samples of high-tech listed companies in Hubei Province, half of the cases were insufficient output. It is necessary to expand the scale of R&D investment and enhance technological progress. In some cases, there is redundancy in R&D investment resources, and investment needs to be reduced. Therefore, Hypothesis 2 holds.

Table 4. Proportionally categorize sample companies' economies of scale in T0 and T1 periods

mean	T0 (288)			T1 (240)		
	DRS	IRS	CRS	DRS	IRS	CRS
2013	4	29	15	4	32	12
2014	5	34	9	13	28	7
2015	6	33	9	10	31	7
2016	11	21	16	4	39	5
2017	18	22	8	21	17	10
2018	16	19	13			
sum	60	158	70	52	147	41
ratio	20.83%	54.86%	24.31%	18.06%	51.04%	14.24%

3) Regression analysis of various types of R&D investment intensity on innovation-driven efficiency

Table 5. The impact of R&D funds and personnel input on the efficiency of enterprise innovation

VARIABLES	IDE
RDI	-0.005*** (-11.41)
RPI	0.000 (1.59)
GS	-0.000 (-1.45)
PA	0.000*** (10.30)
SIZE	-0.011*** (-5.88)
FL	0.000** (1.99)
OC	0.028** (2.48)
GO	-0.000 (-1.06)
Constant	1.199*** (28.11)
Observations	288
R-squared	0.481
F test	0
r ² a	0.466
F	32.30

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

This paper selects the fixed effects regression model and uses STATA16.0 software for data processing, and the following Table 5 is the result of software analysis.

According to the following information, it can be seen that the investment of R&D funds has a significant negative correlation with the efficiency of corporate innovation-driven, which is consistent

with the results of correlation analysis. It means that as the company's capital investment increases, the company's innovation-driven efficiency becomes lower. Based on the results of hypothesis 2, enterprises generally have insufficient innovation output, so the capital investment of enterprises does not constitute a positive impact on innovation driving, and there is a relatively slight negative impact. Due to the greater uncertainty and high risk of R&D activities, this situation is allowed. Therefore, Hypothesis 3 does not hold. Under the comprehensive effect of various indicators of the enterprise, the investment of R&D personnel is positively related to the efficiency of enterprise innovation driving, but the significance is not strong.

4.3 further research

According to the conclusion that hypothesis 3 is not true and hypothesis 4 is not significant, the sample is grouped and regressed, and grouped and regressed according to the nature of ownership, region and size.

Table 6. Grouped regression results

variable	IDE					
	State-owned enterprise	Non-state-owned enterprise	Wuhan area	Non-Wuhan area	Large-scale enterprise	Small-scale business
RDI	-0.004 ***	-0.004 ***	-0.004 ***	-0.013 ***	0.005 ***	0.003 ***
t	0.001	0.000	0.000	0.002	0.001	0.001
RPI	0.001 **	-0.000 *	0.000 **	-0.000	0.000	-0.000 **
t	0.000	0.000	0.000	0.000	0.000	0.000
GS	0.000	-0.001 *	-0.001	-0.000	-0.001 **	-0.000
t	0.001	0.000	0.000	0.000	0.000	0.000
PA	0.000 ***	0.001 ***	0.000 ***	0.001 ***	0.000 ***	0.001 ***
t	0.000	0.000	0.000	0.000	0.000	0.000
SIZE	0.005	-0.020 ***	-0.018 ***	-0.004	-0.005	-0.013 ***
t	0.004	0.002	0.002	0.004	0.003	0.003
FL	-0.000	0.000	0.000 ***	-0.001 ***	0.000 **	-0.000 *
t	0.000	0.000	0.000	0.000	0.000	0.000
OC	0.042 **	0.021 *	0.006	0.056 ***	0.016	0.051 ***
t	0.018	0.013	0.013	0.021	0.021	0.013
GO	0.000	0.000	-0.000	-0.000 **	-0.000	-0.000 **
t	0.000	0.000	0.000	0.000	0.000	0.000
_cons	0.852 ***	1.400 ***	1.337 ***	1.097 ***	1.049 ***	1.244 ***
	0.084	0.046	0.049	0.082	0.077	0.072
Obs.	118	170	168	120	155	133
R-squared	0.418	0.649	0.640	0.440	0.548	0.542
F test	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
r2 a	0.4185	0.6494	0.6395	0.4401	0.5479	0.5424
F	9.80	37.27	35.26	10.91	22.12	18.37

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

It can be seen that under different grouping conditions, the impact of R&D investment intensity on innovation-driven efficiency still shows a significant negative correlation and consistent with the overall regression results, which proves that whether it is state-owned or non-state-owned, Wuhan or

non-Wuhan area, The scale is still a small-scale enterprise, and the impact of R&D investment intensity on the efficiency of enterprise innovation-driven development is pessimistic. Hypothesis 3 does not hold under any circumstances. The investment of R&D personnel in non-state-owned enterprises and small-scale enterprises is significantly negatively correlated with innovation-driven efficiency. But the results in non-Wuhan area are not significant. The impact of R&D personnel investment intensity on innovation-driven efficiency in state-owned enterprises, Wuhan area and small-scale enterprises is positively correlated, and the results in state-owned enterprises and Wuhan area are significant. For state-owned and high-tech companies in Wuhan, Hypothesis 4 is established.

5. Conclusions

A. The impact of R&D investment on innovation-driven efficiency is current. In other words, compared with the lagging investment, the current R&D investment has a greater impact on the current innovation-driven efficiency in all aspects. This means that the backward input has little effect on later innovation output and economic benefits.

B. The research results show that more than half of high-tech enterprises in Hubei Province are in a state of increasing scale efficiency, which means that the output of enterprises is insufficient, and more R&D investment is needed to make technological progress, and produce more innovation output and economic benefits. At the same time, some enterprises are in the stage of reducing economies of scale, indicating that their investment is redundant. These enterprises should focus on the integration and allocation of investment resources to achieve the best scale.

C. Enterprise patent output has a significant positive impact on R&D investment, which means that innovation output has a greater impact on the efficiency of enterprise innovation-driven. This proves that high-tech enterprises in Hubei Province can not only focus on the investment of R&D resources, but also need to improve their own innovation-driven development capabilities through technological progress, and put some resources in the stage of achievement transformation.

References

- [1] Lin B, Luan R . “Are government subsidies effective in improving innovation efficiency? Based on the research of China's wind power industry” [J]. *Science of The Total Environment*, 710.
- [2] Li Yanping, Mao Yanbin, Shi Yao. “Research on the Evaluation of Innovation-driven Development——Taking the Middle Reaches of the Yangtze River Economic Belt as an Example” [J]. *Science and Technology Progress and Policy*, 2016, 33(22):103-108.
- [3] Xu Huanzhang, Guo Qianwen, Wang Yi. “Research on the relationship between R&D investment, ownership structure and corporate performance” [J/OL]. *Finance and Accounting Newsletter*: 1-9[2020-01-15]. <https://doi.org/10.16144/j.cnki.issn1002-8072.20191209.001>.
- [4] Lin Yaling, Zheng Yanan. “Evaluation of Innovation Driven Efficiency Based on ECM——Taking a Province as an Example” [J]. *Finance and Economics*, 2019(02):131-133.