The effect of the degree of marketisation on the innovation efficiency of manufacturing enterprises

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Abstract. To investigate the impact of the degree of marketisation on the innovation efficiency of manufacturing enterprises. Taking the financial report data of 3300 listed manufacturing companies and the total marketisation index of their regions as samples from 2012 to 2021, the two-stage DEA model is used to calculate the innovation efficiency of the target manufacturing enterprises, and the total marketisation index of the enterprises and their regions as well as the relevant control variables are added. Empirical analyses were conducted using StataMP18 software. The results show that there is an inverted U-shaped relationship between the degree of marketisation and enterprise innovation efficiency, and enterprise absorptive capacity plays a positive moderating role to a positive moderating role between the marketisation process and innovation efficiency. The conclusions can enrich the theory of enterprise innovation environment driving and innovation transformation capacity, and provide management and policy insights for manufacturing enterprises' innovation efficiency improvement from the aspects of enterprise and government.

Keywords: Degree of marketisation; innovation efficiency; absorptive capacity.

1 Introduction

In the process of deepening marketisation, the market system has been continuously improved, and enterprises can obtain a good competitive environment to improve the innovation problem of enterprises[1]. The degree of marketisation also enhances market competition with government competition, and these factors can force firms to increase their investment in innovative activities[2]. It has been shown that when there is a positive correlation between the degree of marketisation and the risk appetite of firms, they are more motivated to invest in innovations characterised by high investment risk and long payback periods than when there is a low degree of marketisation[3]. In addition, absorptive capacity relates to a firm's ability to internalise external information and knowledge resources and apply them to the firm's innovation needs, and is largely decisive for innovation efficiency[4].

In order to explore the influence relationship between the degree of marketisation and the innovation efficiency of manufacturing enterprises, and the mechanism of absorptive capacity in the role between the two. The empirical analysis is based on the

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data of 3,300 listed manufacturing enterprises and the total marketisation index of the region where they are located from 2012 to 2021. The conclusions of the study are conducive to helping enterprises adjust their innovation strategies according to the degree of marketisation, optimise internal innovation mechanisms and processes, strengthen market competitiveness in order to improve competitiveness and innovation efficiency, and promote the high-quality development of manufacturing enterprises.

2 Theoretical Analysis and Hypothesis

2.1 Degree of Marketisation and Innovation Efficiency of Manufacturing Firms

Some studies have found that with deepening marketisation. On the one hand, the degree of distortion in factor markets will be alleviated, which will improve the efficiency of resource allocation by enterprises[5]. On the other hand, with the deepening of marketisation, the degree of product market development will be improved, which will promote the enhancement of enterprise innovation capacity[6]. However, it has also been pointed out that too much marketisation will increase competition in the market, which will reduce the level of trust between firms and increase the likelihood of misallocation of resources, and at the same time cause firms to reduce their investment in innovative projects with long payback periods, inhibiting the development of innovation[7].

To sum up, in the early stage of market reform, the pressure of competition will stimulate the innovation enthusiasm of enterprises, prompting them to increase their R&D investment to enhance technology and product innovation. At the same time, along with the advancement of marketisation, government intervention will be reduced and the relevant market system will be improved, which will also enhance the innovation efficiency of enterprises. However, with the deepening of marketisation, enterprises may pay more attention to short-term benefits and reduce innovation activities that require long-term investment due to the deviation of resource allocation and the intensification of competition, which will have a negative impact on innovation efficiency. Based on the above analysis, the following research hypotheses are proposed:

H1:There is an inverted U-shaped relationship between the degree of marketisation and innovation efficiency.

2.2 Firm Absorptive Capacity and Innovation Efficiency

Absorptive capacity improves the efficiency of access to innovation resources, and in a highly marketised environment, firms with stronger absorptive capacity are better able to access and integrate external resources, thereby accelerating the transformation of innovation results[8].Other studies have subdivided absorptive capacity into potential absorptive capacity and actual absorptive capacity. Potential absorptive capacity refers to the ability of an enterprise to identify and accept external knowledge resources effectively. If an enterprise has strong potential absorptive capacity, it can obtain more information and knowledge resources from the market[9]. Accordingly, an enterprise's ability to digest, understand and internalise external knowledge is defined as the actual

absorptive capacity. The actual absorptive capacity of an enterprise can help it to collect knowledge resources efficiently in a complex environment, and to obtain new knowledge elements through the secondary construction of knowledge resources, so as to enhance its innovative capacity[10].

To sum up, absorptive capacity can help enterprises deal with complex market environment and acquire knowledge resources with potential value. In addition, enterprises can make use of absorptive capacity to obtain new knowledge combinations and innovation paths in the reorganisation of old and new knowledge resources, thus enhancing the innovation efficiency of enterprises. Based on the above analysis, the following hypotheses are proposed:

H2: Absorptive capacity can enhance the efficiency of firms' innovation.

2.3 Regulatory Role of Absorptive Capacity

The more mainstream view of the absorptive capacity of enterprises is based on the theory of dynamic capacity, which is regarded as a kind of dynamic capacity. That is, the ability to draw resources, especially knowledge resources, from the environment and internalise them into itself and apply them to the innovation, production and other practical activities of enterprises[11].Some scholars believe that the absorptive capacity of enterprises can promote the development of innovative activities of enterprises in the form of structural embeddedness, and it is recommended that enterprises make good use of the advantages of structural embeddedness to enhance the absorptive capacity of enterprises[12]. Absorptive capacity can prompt enterprises to effectively acquire and learn knowledge, improve the efficiency of R&D resource allocation, and then strengthen the communication and cooperation with external organizations to promote the frequency of innovation to meet the needs of marketisation[13].

In summary, absorptive capacity has a certain moderating role in the process of the influence of the degree of marketisation on the innovation efficiency of enterprises. Strong absorptive capacity enables enterprises to acquire innovation resources, cooperate, capture market demands and opportunities in the market more effectively, learn and adapt to market changes quickly, and thus improve innovation efficiency. Based on the above analysis, the following hypotheses are proposed:

H3:Firms' absorptive capacity positively moderates the effect of the degree of marketisation on firms' innovation efficiency.

3 Research Design

3.1 Data Sources

A sample of 3,300 listed manufacturing companies in 31 provincial-level administrative regions in China was collected from 2012 to 2021. The data on R&D investment, number of patent applications, and other measures of innovation efficiency and absorptive capacity are obtained from the CSMAR database. The original data on provincial GDP, total government expenditure, and other provincial market environment data are obtained from national databases and the China Marketisation Index database.

3.2 Definition of Variables

Explanatory Variables.

Degree of marketisation. The total marketisation index (N) measured by the China Sub-Provincial Marketisation Index Report was chosen to quantify the degree of marketisation in each province.

Explained Variables.

Innovation efficiency. The centralised two-stage DEA model is chosen to measure the efficiency, and the maximum possible value of the overall efficiency is taken as the innovation efficiency of the target manufacturing enterprises. Referring to previous research[14]and considering the relevance of indicators, the representativeness and availability of actual data and other factors to select indicators, the R&D input indicators are selected as R&D personnel (L), R&D investment (R&D), intermediate output indicators are selected as number of patent applications (PAT), increase in intangible assets (IMM), additional input indicators are selected as net fixed assets (FIX), number of employees (STA), and final output indicators are selected as operating revenue (INC), operating profit (POR), and final output indicators are selected as operating income (INC), operating profit (POR). STA), and the final output indicators are selected as operating income (INC) and operating profit (POR). There are extreme data such as zero value and negative value in the observed sample values, so the sample data are quantified. The correlation coefficient test of the two-stage input and output indicators using StataMP 18 shows that all the input and output indicators of the two stages of the sample company are significantly positively correlated at the 1% level, which satisfies the assumption of homoscedasticity, and therefore the selection of indicators is reasonable.

The measurement of the innovation efficiency of the target manufacturing enterprises refers to the centralised two-stage DEA model proposed by Liang et al[15], and establishes the following model:

$$E_1 = \frac{\sum_{d=1}^{a} w_d Z_{dj}}{\sum_{i=1}^{m} v_i X_{ij}} \tag{1}$$

$$\text{s.t.} \quad \frac{\sum_{d=1}^{a} w_d Z_{dj}}{\sum_{i=1}^{m} v_i X_{ij}} \le 1 \quad , \quad (v_i, \ w_d, \ q_h, \ u_r \ \ge 0, j = 01,2,3,\ldots,n \quad ,$$

$$E_2 = \frac{\sum_{r=1}^{c} u_r Y_{rj}}{\sum_{d=1}^{a} w_d Z_{dj} + \sum_{h=1}^{b} q_h P_{hj}} \tag{2}$$

$$\text{s.t.} \quad \frac{\sum_{r=1}^{c} u_r Y_{rj}}{\sum_{d=1}^{a} w_d Z_{dj} + \sum_{h=1}^{b} q_h P_{hj}} \leq 1 \quad , \quad (v_i, \ w_d, \ q_h, \ u_r \geq 0, j = 01,2,3,\ldots,n \ ), \tag{3}$$

$$E = E_1 \times E_2$$

where: j represents the number of decision-making units (DMU) (j=1, 2,..., n); X represents initial inputs, Z represents intermediate outputs, P represents additional inputs, and Y represents final outputs; each decision-making unit (DMU) has m initial inputs (X_{ij}, i=1, 2,..., m), a intermediate outputs (Z_{dj} , d = 1, 2, ..., a), b additional inputs (P_{hj}, h = 1, 2, ..., b), and c final outputs (Y_{rj}, r = 1, 2, ..., c); v_i, w_d, q_h, and u_r are the weight coefficients of X_{ij}, Z_{dj}, P_{hj}, and Y_{rj}, respectively.1 is the maximum possible value of the first stage efficiency; 2 is the maximum possible value of the second stage efficiency; and is the maximum possible value of the overall efficiency.

Moderating Variables.

Absorptive capacity. With regard to the quantification of the absorptive capacity (AB) of enterprises, some studies have shown that the process of enterprises using the absorptive capacity to transform knowledge resources into practical applications can be reflected by R&D activities, and the ability of enterprises to collect, transform and utilise knowledge and information resources is directly correlated with the R&D expenditure of enterprises. R&D expenditures and absorptive capacity tend to reflect a significant positive correlation, the more R&D expenditures, the stronger the absorptive capacity tends to be[16]. Therefore, drawing on the research of Yang Lin et al[17], the ratio of annual R&D expenditures to operating income is taken as the logarithm to measure the absorptive capacity of enterprises.

Control Variables.

In terms of control variables, drawing on previous studies related to market-oriented reforms and enterprise innovation, data on the level of regional economic development (GDP), government influence (Gov), education level (Edu), foreign trade level (Fore), and market structure (Mar) are collected in terms of the market environment[18]. The level of regional economic development is measured by the logarithm of the regional GDP of each region, the government influence is measured by the ratio of the total amount of government financial expenditures in the current period to the regional GDP of the current period, the education level is measured by the logarithm of the number of university students per 100,000 people in each region, the level of foreign trade is measured by the ratio of the total amount of regional imports and exports to the regional GDP, and the market structure is measured by the number of manufacturing enterprises above the size in the region. The market structure is measured by the logarithm of the number of above-scale manufacturing enterprises in the region. In addition, the enterprise itself collects data on enterprise size, age, growth, and debt ratio based on previous studies[19]. Where firm size is measured by taking the logarithm of the total assets of the firm, firm age is measured by the number of years the firm has been in existence,

firm growth is measured by the growth rate of the firm's operating income, and gearing is measured by the ratio of the total liabilities of the firm to the total assets of the firm.

3.3 Modelling

Benchmark Regression Model.

In order to test the theoretical hypothesis H2, the regression model of the impact of the degree of marketisation on the innovation efficiency of enterprises is constructed as shown in equation (1);

$$E_{it} = a_0 + a_1 N_{it} + \sum a_k Controlsit1_{it} + \sum a_l Controlsit2_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad , \quad (K=1, 2, \cdots, k; L=1, 2, \cdots, l) \tag{4}$$

In order to test the theoretical hypothesis H2, the regression model of the impact of firms' absorptive capacity on firms' innovation efficiency is constructed as shown in equation (2):

$$E_{it} = b_0 + b_1 N_{it} + \sum b_k Controlsit1_{it} + \sum b_l Controlsit2_{it} + \mu_i + \lambda_t + \varepsilon_{it} \text{, } (K=1, 2, \cdots, k; L=1, 2, \cdots, l) \tag{5}$$

Where: i denotes enterprise, t denotes time. E_{it} represents the innovation efficiency of enterprise i in period t; N_{it} represents the marketisation index of enterprise i in period t; AB_{it} represents the absorptive capacity of enterprise i in period t; Controls1 represents the control variables related to the market environment, which contains five control variables, i.e., the level of regional economic development (GDP), the influence of the government (Gov), the level of education (Edu), foreign trade level (Fore), and market structure (Mar); Controls2 represents the firm's own related control variables, containing four control variables, i.e., firm size (Size), firm age (Age), firm growth (Grow), and gearing ratio (Debt); μ_i and λ_t represent the individual and time fixed effects, respectively, and ε_{it} is the random perturbation term.

Moderating Effects Modelling.

In order to test the theoretical hypothesis H3, the moderating effect model of the moderating effect of the absorptive capacity of enterprises in the impact of the degree of marketisation on the innovation efficiency of enterprises is constructed as shown in equation (3).

$$E_{it} = c_0 + c_1 N_{it} + \sum c_k Controlsit1_{it} + \sum c_l \ Controlsit2_{it} + \mu_i + \lambda_t + \varepsilon_{it} \text{, } (K=1, 2, \cdots, k; L=1, 2, \cdots, l) \tag{6}$$

4 Results of Empirical Analyses

4.1 Descriptive Statistics

The mean, standard deviation and median of the variables involved in the study are shown in Table 1.

Table 1. Descriptive statistics of variables

Name	Size	average	standard	median
N	20469	9.750	1.605	10.05
AB	20469	0.840	0.045	0.847
E	20469	0.580	0.049	0.576
GDP	20469	10.680	0.702	10.750
GOV	20469	0.180	0.062	0.162
Edu	20469	7.950	0.235	7.920
Fore	20469	0.070	0.049	0.069
Mar	20469	9.880	1.031	10.208
Size	20469	12.760	1.153	12.604
Age	20469	17.740	5.494	18.000
Grow	20469	4.220	14.361	0.010
Debt	20469	0.390	0.197	0.377

4.2 Correlation Test of Variables

Due to the existence of extreme values in the data that may arise from measurement errors, anomalies, or other reasons, the data are shrink-tailed in order to reduce or eliminate the impact of extreme values in the data on data analysis and modelling, so as to improve the stability and predictive performance of the model. And correlation analyses were conducted on the main variables such as marketisation reform and the rest of the control variables. The results show that there is a significant correlation between the marketisation index, innovation efficiency, absorptive capacity and the control variables, thus providing preliminary support for the hypotheses; the remaining control variables pass the Spearman's two-tailed test, which also proves that the model conception is feasible.

4.3 Regression Analysis

Regression Analysis of Degree of Marketisation, Absorptive Capacity and Innovation Efficiency.

The regression results of the degree of marketisation and innovation efficiency are shown in Table 2, where the control variables are all significantly correlated and are not shown in the table for the time being. As shown in Model 1, the correlation coefficient of the degree of marketisation is 0.0078 ($p<0.01$) i.e. there is a significant positive correlation between the degree of marketisation and regional innovation efficiency. And in order to further verify the quadratic relationship between the marketisation index and innovation efficiency, the squared term of the marketisation index is introduced, as shown in Model 2, the coefficient of the primary term corresponding to the marketisation index is 0.0304 ($p<0.01$), and the coefficient of the secondary term is -0.0012 ($p<0.01$), which reveals that a significant inverted U-shape relationship is presented between the degree of marketisation and the innovation efficiency of manufacturing enterprises. Thus, hypothesis H1 is confirmed.

The regression results of absorptive capacity and innovation efficiency are shown in Model3, the corresponding coefficient is 0.2468 ($p<0.01$), which means that there is a significant positive correlation between absorptive capacity and innovation efficiency of manufacturing enterprises, thus confirming hypothesis H2.

Table 2. Regression analysis of marketability, absorptive capacity and innovation efficiency

	Model1	Model2	Model3
N_w1	0.0078***	0.0304***	
	(0.0004)	(0.0019)	
N2_w1		-0.0012***	
		(0.0001)	
AB_w1			0.2468***
			(0.0068)
_cons	0.0281***	0.0317***	-0.1219***
	(0.0013)	(0.0013)	(0.0180)
N	20469	20469	20469
adj. R^2	0.2648	0.2703	0.2995

A Test of the Moderating Effect of Firms' Absorptive Capacity on the Relationship Between Degree of Marketisation and Innovation Efficiency.

The results of the regression of the moderating effect of firms' absorptive capacity on the relationship between the degree of marketisation and firms' innovation efficiency are shown in Table 3. The control variables are all significantly correlated and are not shown in the table for the time being. From Model4, it can be seen that absorptive capacity has a negative moderating effect on innovation efficiency, but considering that it may be the effect of covariance between the independent variables, the data were decentred to improve the stability and interpretability of the model. The results after decentralisation are shown in Model5 The correlation coefficient of the independent

variable marketability is 0.0068 (p<0.01); the coefficient of the cross-multiplier term of marketability and absorptive capacity is 0.0182 (p<0.1) The results show that the absorptive capacity of enterprises positively moderates the relationship between the degree of marketability and innovation efficiency. However, considering the inverted U-shaped relationship between the degree of marketisation and innovation efficiency, the squared term of the marketisation index is introduced in Model6, and the same decentralisation process is carried out in Model7, and the results still show that the absorptive capacity of enterprises has a positive moderating effect on the degree of marketisation and innovation efficiency.

In summary, it is concluded that there is a positive moderating effect of enterprise absorptive capacity in the impact of the degree of marketisation on the innovation efficiency of enterprises, and hypothesis H3 is valid.

Table 3. Regression analysis of the moderating effect of absorptive capacity

	Model4	Model5	Model6	Model7
N_w1	-0.0085***		-0.0397*	
	(0.0030)		(0.0222)	
NAB_w1	0.0182***		0.0835***	
	(0.0035)		(0.0266)	
AB_w1	0.0744**		-0.2540**	
	(0.0328)		(0.1139)	
c_N_w1		0.0068***		0.0305***
		(0.0004)		(0.0019)
NAB_cw1		0.0182***		0.0835***
		(0.0035)		(0.0266)
c_AB_w1		0.2523***		0.2545***
		(0.0071)		(0.0071)
N2_w1			0.0014	
			(0.0013)	
N2AB_w1			-0.0031**	
			(0.0015)	
c_N2_w1				-0.0012***
				(0.0001)
N2AB_cw1				-0.0031**
				(0.0015)
_cons	0.1782***	0.3073***	0.3724***	0.3383***
	(0.0333)	(0.0230)	(0.0964)	(0.0230)
N	20469	20469	20469	20469
adj. R 2	0.3087	0.3087	0.3143	0.3143

Standard errors in parentheses

* p < 0.1, ** p < 0.05, *** p < 0.01

5 Conclusions

Based on the relevant data of 3,300 listed manufacturing enterprises from 2012 to 2021, the influential relationship between the degree of marketisation and the innovation efficiency of enterprises is analysed in detail, as well as the moderating effect of the absorptive capacity of enterprises on the relationship between the degree of marketisation and the innovation efficiency of enterprises. The specific research results are as follows:

(1) There is a significant inverted U-shaped relationship between the degree of marketisation and innovation efficiency. There is a great difference between the early stage and the late stage of marketisation reform. In the early stage of market-oriented reform, enterprises will face greater pressure and challenges in competition, which will stimulate enterprise innovation motivation to increase innovation investment and the introduction of R & D talent, and at the same time, as the degree of marketisation deepens to optimise the resource allocation mechanism, so that resources can flow more efficiently to the innovation activities, and therefore the innovation efficiency can be improved. However, as marketisation deepens, and competition intensifies, firms may focus more on short-term profits and neglect real technological innovation and high value-added innovation activities. At the same time, the further deepening of marketisation is often accompanied by an increase in net fixed assets and additional inputs such as employees, so that innovation efficiency is inhibited, and therefore the relationship between market reform and innovation efficiency shows an inverted U-shaped trend.

(2) Absorptive capacity has a promoting effect on innovation efficiency. Good absorptive capacity can help enterprises better introduce external innovations, including technology, management experience, market information and other intangible assets, and enhance innovation efficiency. It can also help enterprises better perceive the changes and needs of the market, timely adjust the innovation direction and strategy, and improve the relevance and market adaptability of innovation.

(3) In the influence of the degree of marketisation on the innovation efficiency of enterprises, the absorptive capacity of enterprises has a positive moderating effect. Enterprises with strong absorptive capacity can more effectively complete the transformation of external information and knowledge resources into internal innovation capacity. They are able to combine external knowledge with internal technological capabilities to create new technologies, products or services. By transforming intangible assets into tangible assets, they help firms to generate revenue and improve innovation efficiency.

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