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Research on the Coupling Coordination Relationship between Internal R&D and External R&D of Manufacturing Industry: An Empirical Study of Shandong Province, China

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Abstract. Based on the statistical data of Shandong manufacturing industry from 2009 to 2017, the coupling coordination degree model of physics was used to measure the coupling degree of internal and external R&D. The result shows that coupling coordination between R&D and external R&D in Shandong manufacturing industry is low. There are significant differences between 27 sub-industries. According to the results, this paper proposes the countermeasures and provides some suggestions for R&D investment.

Introduction

Manufacturing industry is the basis and core of industrial development, and its degree of development has become an important indicator to measure the competitiveness of a country[1]. "Made in China 2025" proposes that we take the road of innovation-driven development for building a strong manufacturing country,, and we need to improve the manufacturing innovation system that combines enterprises as the mainstay, market-oriented, and the combination of government, industry, and research. Whether it can lead the independent research and development of enterprises and fully rely on external enterprises, universities and scientific research institutions to implement collaborative innovation has become the key to gaining competitive advantage.

Therefore, in order to further promote the manufacturing industry to become stronger and bigger, and to play its leading role in the national economy, it is necessary to conduct research on the effective integration of internal R&D and external R&D, which not only helps to understand the current development status, but also contributes to promote the rapid and healthy development of the industry.

Literature Review

Internal R&D is an important source of core competitiveness. The unique knowledge and technology barriers have established a solid barrier for industrial development. Resource-based theory believes that internal R&D can condense more knowledge, strengthen existing knowledge and technology, and enrich the industrial resource pool based on existing knowledge capabilities. Internal R&D investment is the main factor for the formation of innovation capability [2]. With the addition of different R&D subjects, it has injected new vitality into R&D. Under the technology and knowledge base of internal R&D, following the existing knowledge and technology track [3] , external R&D can continue to make breakthroughs, and in this process, the degree of trust between the various entities is deepening, laying the foundation for the next stage of external R&D. As the main source of core competitiveness in the industry, internal R&D can effectively improve the ability of internal and external knowledge integration, and play an obvious role in external R&D.

External R&D cooperation can be combined with core technologies and core products that promote internal R&D [4], and external R&D brings a multi-party information base. According to the theory of absorptive capacity, the absorption of new knowledge can make industry become more creative and competitive. The external R&D cooperation process will bring a new knowledge base, and the heterogeneity of knowledge can enrich the original information resources to a certain extent, which

strengthens the depth and breadth of knowledge accumulation. On this basis, it continuously integrates knowledge and industry resources. At this time, the addition of external R&D will reduce the pressure of internal R&D, acquire more resources, then reduce the cost and risk of R&D units and maximize the effectiveness of R&D.

For the relationship between internal R&D and external R&D, domestic and foreign scholars have conducted a series of studies, mainly in the following aspects:

First, independently study the two modes and their effects. For example, the empirical study of Mata (2013) shows that internal R&D and external R&D strategies have different effects on the distribution of returns[5]. Bai et al. (2014) considered that internal R&D, external collaborative R&D and foreign capital introduction are three typical R&D modes, and studied the impact of different modes on technological innovation and the differences between different regions[6]. Similarly, Jiang et al. (2015) measured the performance of internal R&D and external R&D and regional differences based on high-tech industry data[7].

Second, focus on the complementary relationship between the two models. Some scholars have analyzed the relationship and its strength, such as Yu et al (2014, 2015) find that there is an interactive relationship between internal R&D and external R&D based on panel data of high-tech industries, but the coordination level needs to be improved[8-9]. In addition, some scholars also explore the influencing factors of such relationships, such as Fan (2011), based on the data of Guangdong industry-university-research institute, the research shows that there is a complementary relationship between R&D and industry-university-research cooperation within enterprises, and it is affected by R&D investment density[10]. Similarly, empirical studies by Chen et al. (2013) show that there is a complementary and coordinated relationship between internal R&D and external enterprises'cooperative innovation, which is affected by absorptive capacity, while there is no complementarity between internal R&D and university or R&D institution's cooperative innovation[11].

Third, comprehensively analyzes of the substitution and complementarity of the two models. Zhen et al. (2013) pointed out that there is a complementary and substitutive relationship between internal R&D and external R&D, so enterprises must find the best R&D expenditure[12]. In addition, some scholars have discussed the influencing factors of this relationship, Yuan et al.(2012) find that when the technological innovation capability is weak, internal R&D and industry-university-research cooperation have substitution, when the technological innovation capability exceeds a certain limit, they are complementary[13]. Subsequently, the case study of Liu Wei et al. (2012) also shows that with the improvement of technological capabilities of enterprises, there are three stages of substitution-complementation-substitution relationship between internal R&D and industry-university-research cooperation[14]. Similarly, John et al. (2012) based on panel data of pharmaceutical companies shows that internal R&D and external R&D are complementary when internal R&D investment is high, while internal R&D and external R&D are substitutive when internal R&D investment is low[15]. In addition, the study of Lotka-Volterra model of Hu et al. (2014) also shows that the substitution or complementarity between independent R&D and industry-university-research within enterprises is influenced by the maximum innovation revenue and strong competition[16].

In summary, previous scholars have done a lot of research on the complex relationship between internal R&D and external R&D, which provides a reference for follow-up research. Different from previous studies, this study analyzed the coupling degree between internal R&D and external R&D from a systematic point of view, understood the interaction between internal R&D and external R&D in manufacturing industry, enriched the relevant literature, and proposed countermeasures based on the results, so as to promote the healthy development of manufacturing industry.

Research Method

Coupling theory was initially mainly applied in the field of physics, and in recent years it has been gradually applied in the field of social science. Coupling refers to the interaction between two or more internal elements or modes of motion, which results in a coordinated and symbiotic dynamic association [17]. The coupling of internal and external R&D refers to the interaction between internal R&D system

and external R&D system, resulting in complementary advantages and further promoting the positive overall relationship.

Efficacy Function

We suppose $u_i(i=1,2,\cdots,n)$ is the ordering parameters of internal R&D and external R&D, and μ_{ij} means indicator j of parameters i, its value is $X_{ij}(j=1,2,\cdots,m)$. α_{ij}, β_{ij} are maximum and minimum values of system critical points, respectively. The efficacy is

$$u_{ij}=\begin{cases}(X_{ij}-\beta_{ij})/(\alpha_{ij}-\beta_{ij}), u_{ij}\ has\ positive\ effect\\(\alpha_{ij}-X_{ij})/(\alpha_{ij}-\beta_{ij}), u_{ij}\ has\ negative\ effect\end{cases} i=1,2,...,n;\ j=1,2,...,m \quad (1)$$

In the above equation, u_{ij} is the level of satisfaction of the indicators $(0\le u_{ij}\le 1)$. The linear weighted sum method is used to calculate the total contribution of the order degree with each order parameter, that is:

$$u_i=\sum_{j=1}^{m}\lambda_{ij}u_{ij},\ \sum_{j=1}^{m}\lambda_{ij}=1,\ i=1,2,...,n;\ j=1,2,...,m \quad (2)$$

In the formula above, λ_{ij} is the weight of the various indicators of subsystems and can be obtained by variation coefficient method.

Coupling Coordination Function

If the system includes only two elements, then the coupling degree model of multiple elements interplay is:

$$C=\left\{(u_1\times u_2)/[(u_1+u_2)^2]\right\}^{1/2} \quad (3)$$

In this study u_1 is the internal R&D and u_2 is the external R&D. Coupling degree (C) could be divided into three levels: the low level $(0<C\le 0.3)$, the moderator level $(0.3<C\le 0.7)$ and the high level $(0.7<C<1)$.

In order to reflect the effectiveness, we modify the coupling degree to evaluate the mutual coupling coordination degree (H), which is expressed as:

$$H=(C\times F)^{1/2} \quad (4)$$

$$F=\alpha u_1+\beta u_2 \quad (5)$$

F is the integrated harmonic index. α, β are undetermined coefficients. In this paper, we think that Internal R&D and external R&D are equally important, so take $\alpha=\beta=0.5$. Coupling coordination can be carried out four levels: the low level $(0<H\le 0.4)$, the moderate level $(0.4<H\le 0.6)$, the high level $(0.6<H\le 0.8)$ and the extreme level $(0.8<H<1)$.

Empirical Analysis

Date

Based on the data of industries above the scale of Shandong Statistical Yearbook from 2009 to 2017, according to the needs and characteristics of the study, the incomplete sub-industries were excluded, and 27 sub-industries including agricultural and sideline food processing industry were selected to ensure the consistency and availability of the data. The internal R&D system is expressed by internal R&D expenditure, including basic research expenditure, applied research expenditure and experimental research expenditure. The external R&D system uses external expenditure of R&D funds, including expenditure on domestic research institutions, domestic universities and overseas expenditure.

Result

In this paper, Stata15 is used to measure the degree of coupling and coordination between internal R&D and external R&D. The broken-line diagrams of R&D coupling degree and R&D coupling coordination degree of 27 sub-industries above the scale of Shandong Province are obtained (Fig. 1). As a whole, Internal and external R&D coupling degree is very high, but there is a phenomenon of uneven sub-industry coupling degree, and the difference between different years will increase.

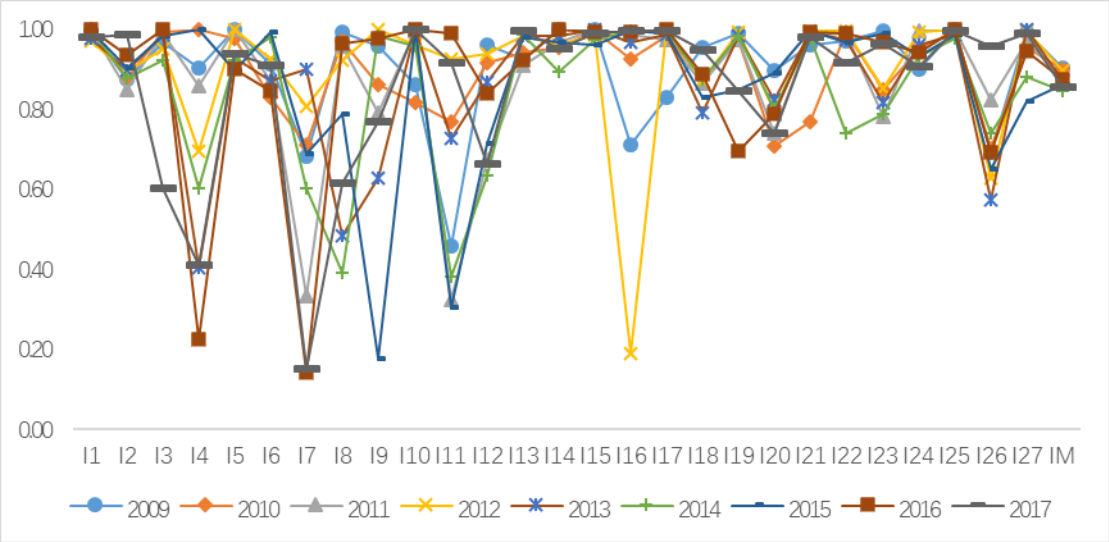

Fig.1 The degree of coupling of internal R&D and external R&D in Shandong manufacture industry

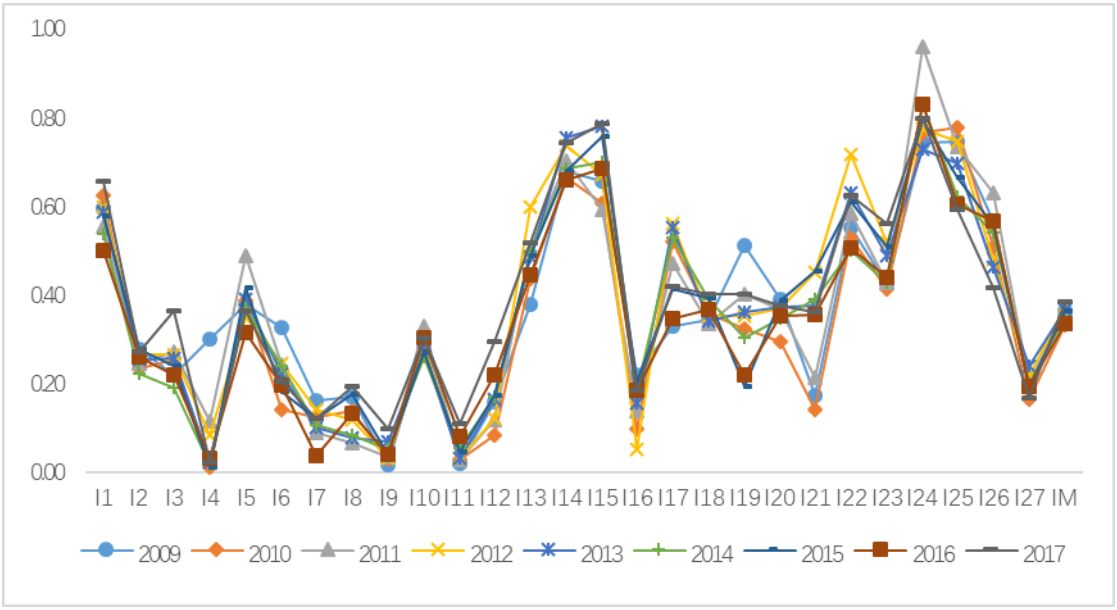

Fig.2 The degree of coupling coupling coordination of internal R&D and external R&D in Shandong manufacture industry

Considering that only relying on the coupling degree will lead to misleading judgment and draw a pseudo conclusion that the degree of coordinated development of the system is higher, this paper carries out the analysis of the coupling coordination degree of internal and external R&D. Through the correction of the coupling coordination, it is found that the overall coupling of internal and external R&D of industries above the scale in Shandong Province is in a state of low coordination and coupling, and the gap between sub-industries becomes very obvious, among which tobacco industry is the most sub-sectors such as tobacco products industry (I4) and furniture manufacturing (I9) are in a low coupling state, while chemical raw materials and chemical products manufacturing (I14) are in a highly coordinated state, transportation equipment manufacturing (I24) is basically In an extremely coupled coordination state.

Summary

Based on the physics coordination degree model and the manufacturing data of Shandong Province, this paper analyzes the coupling relationship between internal R&D and external R&D. The research results show that the coupling coordination between R&D and external R&D in Shandong manufacturing industry is low. Degree coupling coordination state indicates that in the process of internal R&D and external R&D investment, we should pay attention to the interaction relationship of them. Based on this, the following countermeasures are proposed:

First, based on the correlation between internal and external R&D, in R&D activities, we should pay attention to balance the relationship between internal R&D and external R&D, and find a balance between the two to maximize output. Second, in the internal and external R&D linkage, we must focus on communication and internal and external communication, maintain knowledge flow, information flow, capital flow, etc., so that internal and external R&D coupling outputs can flow and drive upstream and downstream enterprises. Third, the government, enterprises, research and development institutes, etc. can rely on their own advantages to carry out joint research and development, and focus on the key problems in the process of industry. At the same time, we must continuously strengthen internal research and development, then develop core competitiveness.

In addition, there are some limitations in the study. It is only validated by the data of industries above the scale of Shandong Province, the best situation of the internal and external R&D coupling coordination degree is not further analyzed. It does not further analyze the impact of R&D coupling on industrial upgrading. In the follow-up study, more in-depth research will be carried out on the above issues, and relevant research will be continuously enriched to provide guidance for industrial development.

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