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Research on the innovation efficiency evaluation of Unicorn Enterprises in Anhui Province based on the three-stage DEA model

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ABSTRACT

Unicorns, as unlisted start-ups valued at more than $1 billion, have a significant impact on economic development and industry innovation. However, they also face problems such as unclear innovation paths and rigid business models, which can lead to lower user satisfaction and lower market value. The article begins with determining the importance of unicorns in the global economy, and points out that the efficiency of technological innovation transformation is the key to measuring their success. Then, the innovation efficiency of unicorn enterprises is evaluated through the three-stage DEA model, and 11 A-share unicorn concept listed companies in Anhui province are empiranalyzed. The research results show that different enterprises differ in the efficiency of scientific and technological innovation, and some enterprises such as COWA ROBOT and INNOTRON MEMORY performing well in pure technical efficiency and scale efficiency. Other companies need to further improve in technology application and scale management. In addition, the research also put forward countermeasures and suggestions such as promoting regional linkage and innovation resource sharing, optimizing government support policies and building an efficient scientific and technological innovation service system, so as to improve the transformation efficiency of scientific and technological innovation achievements of unicorn enterprises.

KEYWORDS

DEA model; Unicorn enterprise; Enterprise innovation efficiency evaluation

1. INTRODUCTION

American investor Irene Lee originally introduced the concept of a "unicorn" to describe private startups that are valued at $1 billion or more and were founded for less than 10 years ago. Unicorn enterprises are not only the embodiment of regional innovation strength, but also a hot topic of management science research. Through disruptive technological progress and business model innovation, these enterprises can optimize the industrial structure, integrate the use of resources, and play a key role in China's economic development and industry innovation. However, under the appearance of rapid growth and high valuation, unicorns are also faced with problems such as unclear direction of innovation and adhering to traditional business models. These problems may lead to the decline of user satisfaction, and the replacement of original products or services by competitors, thus reducing the market value of the enterprise. How to build a competitive advantage in the market is an urgent problem to be solved when studying the growth of unicorn enterprises. Therefore, in order to enhance the innovation ability of unicorn enterprises in China, it is particularly important to evaluate the innovation efficiency of listed companies in line with the concept of unicorn.

2. LITERATURE REVIEW

As a model of innovation and growth, unicorns play an increasingly important role in the global economy. They are often defined as unlisted startups valued at more than $1 billion, which tend to be disruptive in technological innovation and business models. In the development process of unicorn enterprises, the transformation efficiency of scientific and technological innovation achievements is one of the key indicators to measure their success.

The transformation efficiency of scientific and technological innovation achievements of unicorn enterprises is affected by many factors. First of all, the internal management mechanism and innovation culture of enterprises have a significant impact on the transformation of achievements. Zhou and Tong (2017) showed that an open innovation environment and an efficient R & D management process can accelerate the commercialization of scientific and technological achievements. In addition, the interaction between enterprises and the external environment, such as the cooperation with universities and research institutions, is also a key factor to improve the transformation efficiency.Li et al.(2018) has emphasized the role of industry-university-research cooperation in promoting the transformation of scientific and technological achievements. Government policy also plays an important role in the transformation of scientific and technological innovation achievements of unicorn enterprises. Policy tools such as tax incentives, R & D subsidies, and intellectual property protection can encourage enterprises to increase R & D investment and promote the transformation of scientific and technological achievements. According to the Wang et al.(2019) research, government funding for science and technology projects can effectively reduce the r & d risks of enterprises and improve the success rate of scientific and technological innovation.

However, there are also some challenges in the transformation process of scientific and technological innovation achievements. For example, the market acceptance degree, the stability of the capital chain, and the matching degree between the technology and the market demand are all important factors affecting the conversion efficiency. In addition, unicorns may face management challenges during their rapid growth, which may also affect the sustainability of their technological innovation and the efficiency of achievement transformation. In order to improve the efficiency of the transformation of scientific and technological innovation achievements, strengthen the internal R & D project management of enterprises, establish a cross-departmental innovation team, and obtain new technology and market information through external cooperation. In addition, building an ecosystem that supports innovation, including venture capital, incubators and accelerators, is also an important way to promote the transformation of scientific and technological achievements.

In general, the transformation efficiency of scientific and technological innovation achievements of unicorn enterprises is a complex process affected by multi-dimensions and multiple factors. Through the comprehensive consideration of internal management, external cooperation, government policies and market factors, the transformation of scientific and technological achievements can be promoted more effectively, so as to promote the continuous innovation and economic growth of enterprises. Future research can further explore the differentiated strategies and best practices of unicorn enterprises in different industries and at different stages of development in the transformation of scientific and technological innovation achievements.

3. CONSTRUCTION OF EFFICIENCY EVALUATION MODEL AND INDEX SYSTEM

3.1. Study Methods

In this paper, the three-stage DEA model is used to analyze the innovation efficiency of unicorn enterprises, exclude the influence of environmental effect and random error on the efficiency value,

and show the efficiency level of each decision-making unit more truly. The model is divided into the following three stages:

3.1.1. Stage 1: BCC model

Considering the factor of constant scale reward, Banker, Chaenes, Cooper and other scholars found that adding constraints to CCR model can exclude the situation of constant scale reward, that is, DEA-BCC model. The model formula is as follows:

$$\min[\theta - \varepsilon(\sum_{i=1}^{n} s_i^- + \sum_{r=1}^{s} s_r^+) \quad] \tag{1}$$

$$\text{s.t.} \quad \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta x_{ij_0}, i \in (1,2,\cdots,m) \tag{2}$$

$$\sum_{j=1}^{n} Y_{rj}\lambda_j - s_r^+ = \theta y_{rj_0}, r \in (1,2,\cdots,s) \tag{3}$$

$$\sum_{j=1}^{n} \lambda_j = 1 \tag{4}$$

$$\theta, \lambda_j, s_i^-, s_r^+ \geq 0, j = 1,2,\cdots,n \tag{5}$$

s_i^-, $s_r^+ X_{ij_0} Y_{rj_0} j_0 ij\theta s_i^- s_r^+$ In the above equation, the relaxation variable, m and s are the number of input and output indicators, are the first loser and the first output item of the first decision unit. Where 0 is the pure technical efficiency of the decision unit DMU. If DMU is highly effective when =1, =0, =0, the output is the best after the optimal combination; that is, the technical efficiency is the best; when =1, =0, or =0, the DMU is weak DEA, and the relative comprehensive efficiency is weak. If 0 <<1, the DMU is DEA invalid, and the closer to 1, the closer the efficiency is to the effective.$\theta s_i^- s_r^+ \theta\theta$

3.1.2. Stage 2: Regression results of the SFA model

(1) For regression with SFA, include relaxation variables as dependent variables and environmental variables as independent variables, and the model is established as follows:

$$S_{ni} = f^n(z_i;\beta^n) + v_{ni} + u_{ni}, n = 1,\cdots,N, i = 1,\cdots,I \tag{6}$$

$f^n(z_i;\beta^n)$To determine the feasible relaxation front, it is the coefficient to be estimated and the error mixing term.$\beta^n v_{ni} + u_{ni}$

(2) Finally, adjust the input variables to keep all DMUs in the same external environment. The adjustment formula is as follows:

$$x_{ni}^A = x_{ni} + [\max\{z,\beta^n\} - z_i\beta^n] + [\max\{v_{ni}\} \quad -v_{ni}], n = 1,\cdots,N, i = 1,\cdots,I \tag{7}$$

$x_{ni}^A x_{ni}$This neutralization represents the number of adjusted and pre-adjusted inputs, respectively. $[\max\{z,\beta^n\} - z_i\beta^n][\max\{v_{ni}\} \quad -v_{ni}]$ For adjustment for environmental variables, all DMUs are at the same luck level.

3.1.3. Stage 3: adjusted DEA model analysis

$x_{ni}^A x_{ni} y_{ni}$The adjusted input data replaces the original input data, and the output is still the original output data, and it is brought back into the BCC model. Actual efficiency values for the removal of environmental effects and statistical noise.

4. EMPIRICAL ANALYSIS

4.1. Samples, Variables, and Data Description

This study will be 2020, with reference to the Wind financial terminal definition of unicorn enterprises and the relevant information in the annual report of listed companies, selected the directly or indirectly hold unicorn shares investors, or to the unicorn enterprise provide products, services and solutions suppliers, these companies usually have high technical threshold or launched a disruptive products. The research finally locked 11 listed companies in Anhui province that meet the concept of A-share unicorn as the analysis object. In terms of data collection, the patent information comes from the patent retrieval system of the State Intellectual Property Office, the per capita GDP data of the region is taken from the National Bureau of Statistics, the foreign direct investment data is consulted to the statistical yearbooks of each province, and the other required data are obtained through the annual reports of listed companies. In this paper, the DEAP 2.1 software was used for the specific analysis.

4.2. Variable Selection

(1) Input variables

Assessing and analyzing the innovation performance of listed unicorns is a dynamic process involving many factors, which requires a comprehensive consideration of multiple dimensions, such as human resources, capital input and material resources. In this study, we selected the size of the R & D team, R & D investment, and physical assets as key indicators to measure the level of investment of these listed unicorns in innovation.

R & D team size: We take the number of R & D personnel of the enterprise as the key indicator to measure its human resource input, which reflects the talent reserve and professional ability of the enterprise in scientific and technological innovation.

R & D capital investment: the total amount of funds invested in R & D activities is taken as the index of the capital dimension, which reflects the financial support and investment intensity of enterprises for innovation activities.

Fixed assets: The scale of fixed assets is selected as the representative of material resources input, which indicates the accumulation of physical assets. These assets may include laboratory equipment, production facilities, etc., and are critical to innovation activities.

(2) Output variables

Innovation output indicators include both knowledge output and economic output. Knowledge output is measured by the number of patents granted, the total economic output profit and the main business income.

Number of patents: The number of patents is a direct indicator to measure the achievements of enterprise innovation activities, which reflects the number of new technologies, new inventions or new designs produced by enterprises in a certain period of time. Patent not only represents the innovation ability of an enterprise, but also is an important symbol of its technical strength and market competitiveness.

Total profit: the total profit is the financial result of an enterprise in a certain accounting period, which reflects the profitability and economic benefits of the enterprise. High total profit usually means that enterprises can effectively translate their innovations into economic value, thus achieving good market returns.

Main business income: Main business income refers to the total income obtained by an enterprise from its core business activities. This index can reflect the growth of the market size and market share

of enterprises, and is an important basis for evaluating the acceptance degree of enterprise innovative products or services in the market.

Table1. Variable Definition

Variable type	Variable names	variable symbol
input variable	R&D Staff	People
	R&D Expenditures	ten thousand yuan
	Fixed Assets	ten thousand yuan
	Patents	items
Output variables	Total Profit	ten thousand yuan
	Main business income	ten thousand yuan

5. ANALYSIS OF THE EMPIRICAL RESULTS

In the process of analyzing the scientific and technological innovation efficiency of 11 unicorn enterprises in Anhui Province, this study uses DEAP 2.1 software to evaluate the comprehensive performance of these enterprises in the transformation of scientific and technological achievements:

(1) Comprehensive efficiency: As a key evaluation index, the comprehensive efficiency comprehensively reflects the resource utilization and allocation efficiency of unicorn enterprises in Anhui Province in the process of transformation of scientific and technological achievements. This index provides us with in-depth insight into the overall efficiency level of scientific and technological achievements. Numerically, the comprehensive efficiency is reflected in the product of pure technical efficiency and scale efficiency, thus reflecting the overall performance of enterprises in scientific and technological innovation activities.

(2) Pure technical efficiency: This index focuses on evaluating the efficiency of the use of scientific and technological resources under the established technical level. It is influenced by multiple factors, such as enterprise management level, technology maturity and professional ability of r & d team. The efficiency of pure technology directly determines whether enterprises can realize the optimal utilization of resources in the process of scientific and technological innovation.

(3) Scale efficiency: Scale efficiency focuses on the impact of the enterprise scale on the transformation efficiency of its scientific and technological achievements, and reveals the difference between the production efficiency of the enterprise under the existing scale and the production efficiency under the theoretical optimal scale. By optimizing the scale efficiency, enterprises can maintain or improve the efficiency of their technological innovation while expanding their scale.

The DEA model of input-oriented and variable scale reward adopted in this study calculates the transformation efficiency of scientific and technological achievements of 11 unicorn enterprises in Anhui Province, and the relevant results are summarized in the table below.

Table2. Changes in Transformation Efficiency of Scientific and Technological Innovation Achievements of 11 Unicorn Enterprises in Anhui Province, 2018-2021

Corporation	Techch	Pech	Sech	Return on scale
YINGFA GROUP	0.672	1	0.672	drs
COWA ROBOT	1	1	1	-
JIANA	0.646	1	0.646	drs
INNOTRON MEMORY	0.721	1	0.721	-
Nexchip	0.224	1	0.224	drs
VITAL	0.182	0.428	0.461	drs
Xunfei Healthcare	0.262	0.781	0.301	irs
ORIGIN CUANTUM	0.486	0.824	0.877	irs
CHIP MORE	0.273	0.742	0.437	drs
CIQTEK	0.664	0.938	0.664	-
NuVolta	0.736	0.602	0.736	ins

DEAP 2.1 software is used to calculate the innovation efficiency of 11 unicorn listed companies in 2020. From the scores of Techch (technology change efficiency), Pech (pure technology efficiency) and Sech (scale efficiency), we can see the differences in the efficiency of technological innovation of different enterprises. For example, COWA ROBOT, INNOTRON MEMORY and CIQTEK showed high pure technical efficiency and scale efficiency, indicating that they make effective use of technological resources at the current scale. Most enterprises' pure technology efficiency is the same as the scale efficiency score, which may indicate that these enterprises have reached a certain balance in technology application and scale management. However, for Nexchip, VITAL, Xunfei Healthcare, ORIGIN QUANTUM and CHIP MORE, pure technical efficiency is lower than scale efficiency, which may mean that despite their low application efficiency in technology, there is still room for improvement in scale management. At the same time, we can see the status of different enterprises in terms of scale return. For example, enterprises with drs (increasing scale return) may need to scale up to improve the efficiency of unit cost, while enterprises with irs (diminishing scale return) may need to optimize the scale to avoid cost inefficiency.

6. COUNTERMEASURES AND SUGGESTIONS

After an in-depth analysis of the scientific and technological innovation efficiency of the 11 unicorn enterprises in Anhui Province, this study puts forward the following three countermeasures and suggestions to promote the improvement of the transformation efficiency of the scientific and technological innovation achievements of these enterprises:

6.1. Promote Regional Linkage and The Sharing of Innovation Resources

Unicorn enterprises in Anhui province should deepen their cooperation with neighboring provinces and jointly build a regional innovation community. This requires further expansion of the scope of cooperation on the existing basis, including but not limited to the Yangtze River Delta, the central region and even other provinces in the country. Through the establishment of regional innovation alliance, the comprehensive sharing of R & D resources, market information and policy orientation will be realized. At the same time, enterprises should be encouraged to carry out deeper technical exchanges and talent flow, such as promoting the rapid dissemination of knowledge and technology by exchanging technical teams, conducting joint research and development projects, and holding regular technical seminars. In addition, enterprises should also actively participate in the formulation of regional innovation policies, and provide corporate perspective suggestions and feedback for the optimization of regional innovation environment.

6.2. Optimize the Government Support Policies to Stimulate the Innovation Vitality of Enterprises

The government should further increase its support for scientific and technological innovation and provide more comprehensive and precise policy support for unicorns. This includes more research and development funding, especially for innovative projects with strategic significance and market potential. At the same time, the government should further improve the preferential tax policies, reduce the r & d costs of enterprises, and encourage enterprises to increase their R & D investment. In addition, the government should also set up innovation funds and incentive mechanisms to encourage enterprises to increase investment in R & D and attract and cultivate more high-level R & D talents. The government can also provide policy consultation, market access support and other services to help enterprises better grasp the market dynamics and improve the commercialization capacity of innovation results.

6.3. Build an efficient Scientific and Technological Innovation Service System

Unicorn enterprises in Anhui province should strengthen the cooperation with universities and research institutions to build an innovation system integrating industry, university and research. This requires enterprises to establish closer cooperative relations with universities and research institutions, such as promoting the rapid transformation of scientific research achievements through jointly building joint research and development centers, technology transfer offices and post-doctoral workstations. At the same time, enterprises should actively participate in the establishment and improvement of scientific and technological innovation service platforms, use these platforms to obtain the latest scientific research achievements and market dynamics, and accelerate the commercialization process of scientific and technological achievements. In addition, through these platforms, enterprises can also connect with domestic and foreign innovation resources, expand international cooperation, and enhance their international competitiveness. The government should also play an active role in this process, such as promoting the construction and development of scientific and technological innovation service platform by means of providing financial support and policy guidance.

Through the implementation of the above countermeasures, the unicorn enterprises in Anhui province will be able to go further on the road of scientific and technological innovation, and make greater contributions to the economic development of the region and even the whole country. At the same time, these countermeasures will also help to solve the problems existing in the transformation of current scientific and technological innovation achievements, such as low technical efficiency, insufficient research and development funds, etc., so as to realize the benign interaction between scientific and technological innovation and economic and social development. Through continuous efforts and innovation, unicorns in Anhui province are expected to become an important force driving China's scientific and technological innovation and economic development.

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