A Review of Science, Technology, and Innovation: Connotation, Evaluation Model

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Abstract. The capacity of science, technology, and innovation has a significant impact on economic growth. A scientific and reasonable capability evaluation model is crucial for the implementation of national, industry, and enterprise science and technology strategies. The research topic of science, technology, and innovation capabilities, as well as evaluation models and methods, is the emphasis of this article. It systematically summarizes the relevant concepts and connotations of science, technology, and innovation, particularly independent innovation, original innovation, innovation cradle, and other related concepts. On this basis, the paper reviews the evaluation models and methods of scientific and technological innovation from academic, institutional, and corporate perspectives, summarizes relevant characteristics and insights, and proposes further research suggestions from the perspectives of indicator selection and weight determination.

Keywords: science; technology; innovation; capability evaluation model

1 Introduction

In the context of the new round of technological revolution and industrial transformation, significant scientific discoveries, important technological inventions, and the widespread application of new technological products have effectively promoted profound changes in production and lifestyle worldwide. Innovation in science and technology is essential for efficiently raising productivity [1]. For instance， climate change is forcing us to rethink the way we live and work, and net zero target is highly relay on the large-scale technologies. Furthermore, the emerging technologies, particularly digital technologies, are already part of everyday life in a society that is undergoing fundamental change [2-3].

For this reason, to promote scientific and technical innovation is one of the main national strategies of many nations, particularly wealthy nations. As a result, policy support for such innovation has expanded in the manufacturing, energy, digital, and other industries. Taking the UK as an example, Department for Business, Energy& Industrial Strategy released ‘UK Innovation Strategy Leading the future by creating it’, and reiterated their objective of making the UK a global science superpower, turning

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world-leading science and ideas into solutions for the public good. In terms of the United States, White House Office of Science and Technology Policy, United States Department of Energy, and United States Department of State have jointly released 'National Innovation Pathway of the United States', and proposed a threefold net-zero technology action plan, including innovations, demonstrate, and deployment, to support meeting the U.S. NDC and implementation of the Long-Term Strategy. The German Federal Government has released the 'Future Research and Innovation Strategy' to defend our technical leadership, to strengthen the transfer of research results into application, and to be open to new technologies.

Furthermore, science, technology, and innovation has also become an important research field in the academic community. Since Joseph Alois Schumpeter first introduced innovation into the economic system at the turn of the 20th century, theoretical research on innovation activities and performance, including connotation, mechanism, and innovation paradigm, as well as applied research, including evaluation models and case studies, has gradually enriched and promoted the formation and development of innovation theory. In the meanwhile, several featured articles of aforementioned topics have been published.

Aiming to provide a guide on the science, technology, and innovation, especially from the perspective of capacity evaluation models and approaches, the selected articles in this field are reviewed in this paper. Especially, the evaluation models and methods proposed in these articles are analyzed and categorized from different perspectives including scholars, organizations, and enterprises. The emphasis is also given on the key theoretical issues and challenges of evaluation models and approaches, which are extracted and discussed together with several suitable suggestions. Moreover, based on the review, this paper also provides several recommended research prospects for the guidance of further research in details.

2 Theories related to science, technology, and innovation

2.1 Concepts Related to science, technology, and innovation

Joseph Schumpeter is regarded as the father of innovation because of his original insights into the function of capitalist technical innovation in economic growth that laid the foundation for the early understanding of innovation. Schumpeter's innovation theory states that innovation is the process of establishing a new Production function, forming a new combination of production factors, putting a new combination of production factors, and putting a new combination of production conditions into production in order to produce new goods, generate new wealth, and earn excess profits. Modern statistical techniques were utilized in the 1970s by Mensch, Freeman, Clark, and others to support Schumpeter's position and advance novel hypotheses. Some classic theories have been further proposed, shown as Table I.

Table 1. Classic theories and point of view

Scholars	Sources	Main ideas
Joseph Schumpeter	Economic Development Theory	Innovation refers to the introduction of a new combination of production factors and conditions into the production system.
Utbach	Industrial Innovation and Technology Diffusion	The difference between invention or technological samples is that innovation is the actual adoption or first application of technology.
Peter F. Drucker	Innovation and Entrepreneurship	Innovation is a specific tool for entrepreneurship that can turn change into an opportunity and develop into different businesses or provide different services.

Innovation research started to move in two directions with the development of Schumpeter's innovation theory. One is the school of technological innovation, which has done extensive research on the topic from the viewpoint of the relationship between technological innovation and imitation, promotion, and transfer, and has developed certain representative theories. The institutional innovation school is a different type that combines innovation with institutions and researches the connection between institutional elements, technological innovation, and the financial gains of businesses, placing emphasis on the significance of institutional arrangements and innovation for economic development. As indicated in Table II, certain academics in China have also undertaken relatively extensive study on innovation models and have developed a number of representative innovation theories, including original innovation, independent innovation, comprehensive innovation, collaborative innovation, integrated innovation, etc., shown as Table II.

Table 2. Classic theories and point of view

Innovation theories	Main ideas
Original innovation	Inventive accomplishments that are ground-breaking, frequently disruptive, and often at the forefront of engineering practice, basic research, and technical advancement.
Imitation innovation	Integrating various individual and dispersed related technological achievements to achieve new products and industries.
Disruptive innovation	Successfully created goods, services, or business models fundamentally alter the needs of mainstream markets and upend the preeminent actors in those sectors.
Collaborative innovation	The complex organizational approach for innovation networks, which generates systematic and nonlinear effects through deep cooperation and resource integration between knowledge creators and technology innovators.

The ability to innovate in science and technology generally revolves around development goals, producing results through the efficient use of scientific and technological resources, coupling various links involved in scientific and technological innovation activities, and transforming them into both internal conditions and external manifestations of true productivity [4-6].

2.2 Concepts of independent innovation capability

Independent innovation, in general, refers to the creation of new goods and services by the use of one's own resources and skills to implement novel technology into production.

From the perceptive of innovation forms, independent innovation refers to a variety of innovation processes, the key ones being the original invention, the integrated innovation, and the introduction, digestion, absorption, and re-innovation in science and technology. Original invention is the cornerstone of autonomous creativity among them. Integrated innovation is the blending of diverse technologies to produce new goods and technologies and to bring them to market. Technology is introduced, digested, and absorbed by ongoing innovation built upon the existing framework [7].

Independent innovation, in terms of the innovation process, primarily involves scientific and technical innovation. The study of natural laws and the discovery of new ones is referred to as scientific innovation. Scientific innovation resembles fundamental research, with universities and research organizations serving as the primary sources of innovation. The transition of basic scientific research findings into technology is referred to as technological innovation. It is characterized by applied research, with firms serving as the primary source of innovation.

From the perspective of capability, independent innovation capability refers to the fundamental quality and responsiveness of mastering the value distribution process by effectively integrating and utilizing internal and external resources to achieve significant breakthroughs in key industrial technologies. The capacity to innovate autonomously is the outcome of a combination of several talents, including not only the ability of the innovation topic to master and utilize resources, but also the ability to make scientific and technical achievements.

2.3 Concepts of innovation cradle capability

There is no clear definition of the concept of innovation cradle capability. However, in the context of science, technology, and innovation, the innovation cradle capability can be viewed as the core competitiveness that drives technological change through forward-thinking and ground-breaking technological achievements. As a result, innovation cradle capability is a unique capacity that avoids the connotation of copycat innovation and stresses uniqueness and source.

Four dimensions—academic new ideas, scientific breakthroughs, technical innovations, and new industrial directions—comprise the particular traits of innovative methods. Among them, academic new ideas are forward-looking scientific ideas and are the embryonic stage of innovation. New technology innovations and new scientific discoveries are causally related to one another and reinforce one another. New technical innovations offer experimental tools and conditions for new scientific discoveries, while new scientific discoveries validate new technological innovations' scientific theories. The rear end of the innovation cycle and the crucial stage for scientific and technical innovation to demonstrate its viability is the new industrial direction. Additionally, it might inspire fresh intellectual concepts for use in business.

From a capability perspective, top-notch innovation cradle capability is reflected in the following aspects. In terms of scientific innovation, innovation cradle capability is reflected in having some world-class scientific research institutions, and the emergence of globally influential experts, scholars, and academic achievements in certain disciplines. In terms of technological innovation, innovation cradle capability is reflected in having leading technological products and continuously emerging leading enterprises with global competitiveness in certain industrial fields. In terms of industrial innovation, innovation cradle capability is reflected in the gathering of innovative entrepreneurs, and the continuous emergence of new benchmark enterprises with global influence in certain fields.

3 Innovation Capability Evaluation Model and Method

3.1 Academic Perspective

From a scholarly standpoint, the academic community now uses the input-activity-output model to evaluate the potential of innovation capability. As the first level evaluation dimension innovation index model, many scholars typically decompose the dimensions of innovation capability evaluation into input-capability, activity-capability, and output-capability. In their individual studies on technology innovation, some other scholars have not fully constructed indicator systems based on the input-activity-output model, but they have still made appropriate additions and deletions on this basis, and the fundamental concept of indicator system construction has not changed significantly. For instance, some references use four criteria to assess an enterprise's capacity for technological innovation: R&D investment ability, innovation output ability, sustained innovation ability, and innovation ecological environment capability [8].

Input, Activity, and Output Capabilities are the main Indicators for measuring scientific and technological innovation Capabilities [9]. According to the researches of the above scholars, regardless of the Perspective. Depending on the issue being researched, several other indicators may be chosen.

3.2 Institutional perspective

Numerous organisations now assess the capability for scientific and technical innovation at the national and regional levels. The Global Innovation Index Ranking List, which is sponsored by the World Intellectual Property Organization, Cornell University, and INSEAD, the Innovation Index, which is sponsored by Bloomberg, the European Innovation Scoreboard (EIS), published by the European Union, and the Global Competitiveness Report (GCR), which is sponsored by the World Economic Forum, are among the most well-known and reputable of these.

Take the World Intellectual Property Organization (WIPO) as an example, The Global Innovation Index Ranking List includes science and innovation investments, technological progress, technology adoption, and socioeconomic impact, to capture the innovation ecosystem performance of more than 100 economies and tracks the most recent global innovation trends.

In terms of the European Innovation Scoreboard, the evaluation model provides a comparative assessment of the Research and Innovation performance of EU Member States, other European countries, and regional neighbours. It helps countries assess the relative strengths and weaknesses of their national innovation systems and identify challenges that they need to address.

As another illustration, let's look at the World Economic Forum's annual Global Competitiveness Report (GCR), which analyses and assesses the economic performance of various nations. The GCR was first published in 1979. The Growth Competitiveness Index and the Business Competitiveness Index were the two key indices that made up early reports. The new Global Competitiveness Report evaluation approach is separated into four dimensions to include more influencing elements, including enabling environment, human capital, markets, and innovation ecosystem. Each dimension is made up of several indicators. The component of enabling environment encompasses four indicators: system, infrastructure, information and communication technology application, and macroeconomic stability. Two indicators are included in the human capital dimension: talent health and professional skills; four indicators are included in the market dimension: product market, labor market, finance system, and market size. Two metrics are included in the innovation ecosystem dimension: company vitality and innovation capabilities.

3.3 Corporate perspective

In addition to scholars and research institutions, enterprises have extensively conducted evaluation practices for scientific and technological innovation capabilities based on industry and enterprise characteristics, and established innovation evaluation models and corresponding evaluation methods from various perspectives, in order to steadily improve their scientific and technological innovation capabilities.

To achieve the integration of the evaluation model with the scientific and technological innovation strategy, Company A in China, using the power industry as an example, introduces strategic mapping tools from the perspective of the company's scientific and technological innovation strategy. The major three parts of the key success factors of strategic priorities are project management capability, achievement creation and application capability, and continuous scientific and technology innovation capability.

Taking the electronic information industry as another example, Company B in South Korean believes that the innovation process can be summarized as a practical model of accumulation (reserves), implementation (efficiency), and realization (benefits). In light of this, Company B in South Korean has created a workable index system for evaluating an organization's capacity for technological innovation. Improvements in personnel quality and learning capacity are among them; innovation implementation is primarily comprised of two aspects: research and development and production manufacturing. The effectiveness of new items' output and sales potential are the major indicators of innovation. Additionally, innovation in management capacities is integral to the entire process of innovation activities. In light of this, South Korean company B established an evaluation index system for enterprise technological innovation capability by breaking down its technological innovation capability into learning ability, research and development ability, manufacturing ability, marketing ability, output ability, and management ability.

Chinese Company C, in the fields of space technology, thinks that the technical innovation capability index model and the technical innovation maturity index model are the two components of the innovation index model. The technology innovation capability index model is used to rank the technological innovation capability of units at various levels, while the technology innovation maturity index model is used to identify the organizational maturity levels of various units within the group. These two evaluation models are focused on representing the rate of development and trend of new enterprise construction that is innovative in terms of time, the overall design and structure of new enterprise construction that is innovative in terms of space, and the size and effectiveness of new enterprise construction that is innovative in terms of quantity.

4 Conclusion

First, choosing indicators carefully and giving various indications varying weights can prevent one-sided evaluation outcomes because of the limits of a single indicator. The normative practice in international innovation evaluation is multi-indicator comprehensive evaluation. The more indicators you choose, however, is not always better. It is essential to carefully select a variety of indicators to accurately depict various innovation states when gauging a particular innovation dimension.

Second, the potential indicators should be the main consideration when choosing the assessment model's indicators. Some indicators that evaluate future development potential can be taken into consideration based on the analysis and evaluation of the existing or past innovation status to better reflect a country's innovation trends.

Thirdly, total and relative scales must be taken into account when selecting indicators, and both total and intensity indicators must be established in a reasonable manner. By including scale indicators that can indicate the influence of innovation in the assessment model, it will be possible to prevent some of the smaller evaluated items from occupying a dominant position in the evaluation findings for an extended period of time.

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