Measurement and Comparison of IoT Technology Gap between China, the United States, EU, Japan, and South Korea

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Abstract. This article aims to measure the technological gap of the Internet of Things (IoT) in the new technological revolution and propose policy recommendations for optimizing innovation routes. To this end, this paper establishes a technology gap test model through the indices of paper activity power, paper influence, patent activity power, patent influence, and patent market power, at the same time, the Gordon method is used to standardize scoring, in order to clarify the fine-grained technology gap between China, the United States, Europe, Japan, and South Korea in the field of the Internet of Things. Through comparative research, it has been found that China's IoT technology innovation is in a paralleling competitive stage with Europe, America, Japan, and South Korea, but there are issues such as weak international competitiveness. Therefore, policy recommendations for optimizing innovative routes are proposed for problem research, in order to provide support for relevant research and policy decisions.

Keywords: IOT; Measurement of technology gap; Intellectual Property Index; Innovation Leap.

1. Introduction

The leading technologies of the new technological revolution, represented by artificial intelligence, big data, cloud computing, the Internet of Things, 3D printing, intelligent robots, etc., accelerate integration and innovation, profoundly and widely change human production and lifestyle, and technological innovation paradigms. The Internet of Things, as the core, instrumental, and fundamental technology linking the integration and innovation of the above pioneering technologies, has become a key area of international development. China has the overwhelming majority of research papers and patents applications in this field, and there are divergent views at home and abroad as to whether China's technology level is following, running alongside or leading. Therefore, it is an important prerequisite to scientifically measure the technology gap and identify problems for healthy development.

2. Literature review

There are many studies in the early stage that used differences in production efficiency or per capita GDP to replace technological disparities, which are easy to operate but not close to the objective level of technology. However, Intellectual property statistics can better reflect the technological status of countries in the world. The Global Innovation Index, EU Innovation Scoreboard, OECD Statistics and Technology Indicators have adopted patent and paper indicators, driving the measurement of technological disparities through intellectual property to become the mainstream of research.

The measurement of technology gap in international relevant literature is mostly based on paper and patent data, as shown in Table 1. Data statistics and mathematical methods are similar, and econometric models mainly use index types, such as innovation index, patent index, or RCA index. The decomposition formula uses various relationships between a certain part of the data and the total amount of each layer, such as the relationship between a certain technology patent and the patent population, and the relationship between high cited papers and the total amount of papers, to illustrate the relationship between quantity and quality with the highest total quantity but not high rating. The above literature lacks technical fine-grained decomposition, and lacks sufficient exploration of paper

and patent quality issues, which hinders the effective implementation of academic support for the new catch-up strategy.

Table 1. Representative literature on technical measurement

Literature	Literature	Patent	Paper	statistical model
Global Innovation Index (GII)	WIPO, CU, INSEAD	√	√	$\ln\left[\frac{(\max \times f-1)(econmy\ value-\min)}{\max-\min}\right]$
European Innovation Scoreboard (EIS)	EU	√	√	(1) $z_{ij}=\frac{x_{ij}-\bar{x}_j}{s_j}$; (2); $s_d=\sqrt{\frac{1}{n}\sum_{j=1}^{n}\left(d_{i0}-\overline{d_0}\right)^2}$
Measuring patent quality: indicators of technological and economic value	OECD	√		(1) $\beta_{ij}=\frac{T_{ji}^n}{T_i^n}$; (2) $G_x=1-\sum_{j=1}^{M_i}\left(\frac{1}{N}\sum_{i=1}^{N}\frac{T_{ji}^n}{T_i^n}\right)^2$
Three characteristics of technology competition by IoT-driven digitization	Sang-Jin Ahn	√	√	(1) $HHI=\sum_{i=1}^{m}S_i^2=\sum_{i=1}^{m}\left(\frac{N_i}{N}\times 100\right)^2$; (2)$C_i=\frac{2e_i}{k_i(k_i-1)}$
Ubiquitous technologies and 5G development. Who is leading the race?	Parcu P, et al	√		$RCA_{ct}=\left(\frac{P_{ct}/P_c}{P_c/P}\right)$

3. Method

Empirical method: Paper Activity Index, Paper Citation Index, Patent Activity Index, Patent Citation Index, and Patent Market power Index were used to measure the patent and paper data of IoT technology in China, the United States, EU, Japan, and South Korea from 2008 to 2021, retrieved from web of science and WIPO, CNIPA, USPTO, EPO, JPO and KIPO. The measurement results were then scored on a percentage scale using the Gordon model, on this basis, the technical gap comparison curve is formed by the scores of each year.

4. Measurement and Demonstration

The measurement results of the gap in IoT technology are shown in Figure 1. The relative score of 100 points based on the highest technology country's Internet of Things technology level in the United States, 93.8 points for EU, 89.7 points for Japan, 79.5 points for South Korea, and only 62.4 points for China. It was a turning point for China's rapid growth in 2014, starting from 66.9 points, as shown by the Z-line in Figure 1, with an annual growth rate of 6% rapidly rising and catching up. From the years of breaking the 60point mark, South Korea was in 2009, while China was in 2018, 9 years later than South Korea. From the latest round of years that crossed the 90point line, in the EU, 2018 was the year, 2019 was the year for South Korea, and 2020 was the year for China, which is only one or two years behind the level of the EU and South Korea. In 2021, China's IoT technology score reached a historical high of 93.2 points, with the EU scoring 95.5 points, Japan scoring 89.6 points, and South Korea scoring 93.5 points. This indicates that the IoT technology gap among the five major economies has converted into a narrow range of nearly 10 points, presenting a typical characteristic of the paralleling operation stage. The overall pattern indicates that China's Internet of Things technology has entered a historic new stage of paralleling development with EU, the United States, Japan, and South Korea.

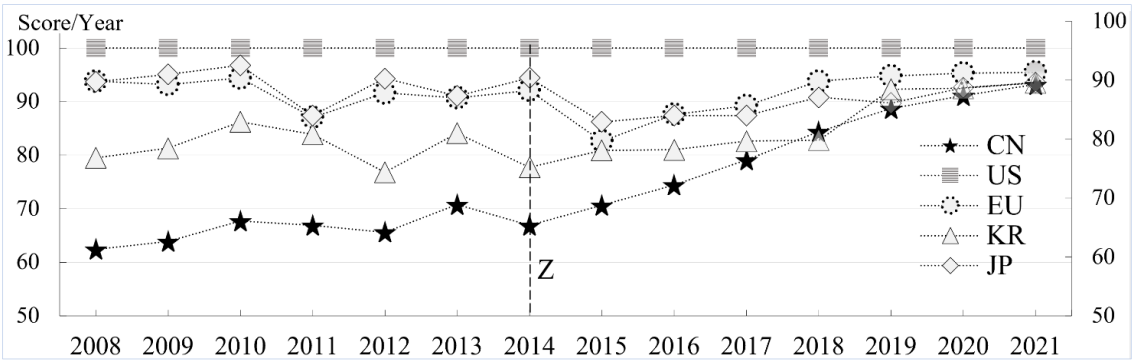

Fig. 1 The Catch-up Curve for Convergence of IoT Technology Gap

5. Basic Cause Deconstruction

The quality analysis of technology patent data mainly focuses on the number of IP5, patent families, and domestic and foreign structures. The IP5, also known as the Five Intellectual Property Offices of China, the United States, Europe, Japan, and South Korea, is the world's largest intellectual property office, representing more than 80% of global patents and patent families. Patent families, which are a collection of equally prioritized patent documents protecting the same invention across IP institutions and geographies, are more technologically competitive than non-family patents. The structure of domestic and foreign patents has multiple perspectives. Generally, only domestic nationals with domestic patents in this office or too few foreign patents of domestic nationals lack international competitiveness. If there are too few domestic patents of domestic nationals in this office or too many foreign patents of foreign nationals in this office, it indicates a lack of local independent innovation leadership.

The analysis finds that the basic pattern of Chinese patents is that local nationals only account for the absolute majority of domestic patents in CNIPA, while foreign patents are too few, indicating a strong local innovation leadership and relatively insufficient international competitiveness. Global IP5 patents for IoT technologies, except for China, the ratio of patents filed abroad to domestic patents in other economies is approximately 50%. The patents filed by Chinese people abroad account for only 6.3% of the total number of patents filed by Chinese people and only 5.4% of the patents filed abroad by all countries, which is one of the reasons why there is still a technology gap despite the fact that China has the largest number of patents in total. However, this indicator is much higher in the United States than in other economies, reaching 41.1%, indicating its strong international competitiveness.

6. Conclusion and Propose

Based on intellectual property data and technology gap measurement indicators, this article measures and scores the gap in the Internet of Things technology in the new technology revolution between China, the United States, Europe, Japan, and South Korea, and analyzes the innovation ecosystem. The following conclusions are drawn.

Firstly, with the advent of the new technological revolution, a window of new technological opportunities has emerged; Secondly, China has accumulated innovative energy and conditions for innovation leap through a long-term process of following and running, and the overall technology level is gradually approaching Japan, South Korea, Europe and America. With 2014 as the turning point, China's technology imitation process has reached the "boundary of the trap", and the characteristics of paralleling running are prominent, marking the overall entry into a stage of paralleling competition and cooperation with major economies; Thirdly, China has encountered a comprehensive technological blockade, political suppression, and economic sanctions imposed by technological hegemony, with challenges and opportunities coexisting; Fourthly, in response to the strategic opportunity period of the new technological revolution, China has proposed and

implemented a transformation strategy of technology from following to paralleling or leading, introduced a series of policies to develop IoT technology, and formed a positive institutional window and continuously expanding demand window. At present, the decisive factor in accelerating the narrowing of the technological gap mainly depends on the understanding and response to the problems and challenges faced in the paralleling competition and cooperation stage. The most fundamental is that only by promoting comprehensive system ecological optimization of technological and social innovation, and comprehensively raising China's innovation energy level to a critical mass, can we achieve leapfrog leadership.

The following proposal is proposed for this purpose.

Promote the transformation of the digital economy and digital society, systematically optimize the allocation of top-level design, legal norms, cultural confidence, educational reform, and social systems, and shape new driving forces and advantages for development through a new national system; Optimize the environment and innovate policies to cultivate a talent highland with world-class education, livability, innovation, and charm, gathering global talents to cultivate high skilled talents; On the basis of the advantages of IoT research and development in Chinese universities and research institutions, we will focus on developing leading large enterprises and chain owners with basic and innovative capabilities to participate in the balance of international technological hegemony giants, while cultivating globally influential specialized, refined, and innovative "little giants" and unicorn enterprises; By leveraging the collaborative innovation system of "government, people, industry, academia, and research" and the strategic strategy of independent technological innovation, we aim to seize the leading position in key core technological innovation at the high-end of the industrial value chain, strive to optimize the global layout of patent pools, patent families, patent alliances, domestic patents, cooperative patents, IP5 patents, and international patents, increase the discourse power of technological standards, and accelerate the expansion of the proportion of standard essential patents, forming an excellent mechanism for the innovation of intellectual property strategy, and transitioning to become a world power in the Internet of Things.

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