Examining the Post-Print New Economy from the Perspective of Information Technology Development Trends

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Abstract

In the process of achieving economic transformation and industrial upgrading, whether new technologies can form new drivers and whether these new drivers can propel a new economy has become a matter of widespread concern for government departments, industry, and academia. The article assesses the prospects and risks of the new economy from the perspective of information technology development trends, pointing out that information technology will be the primary driver for developing the new economy in the next 15-20 years; that human-cyber-physical integrated intelligent technology is the most pioneering new technology; and that for nurturing new drivers of economic growth, technological accumulation is as important as technological innovation. China' s industrial control sector suffers from weak technological accumulation; the state should increase investment in science and technology for the intelligent industrial control field and vigorously cultivate scientific and technological talent in industrial control.

Full Text

Judging the New Economy from the Perspective of Information Technology Trends

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Abstract

In the process of economic transformation and industrial upgrading, whether new technologies can form new drivers of growth and subsequently propel the new economy forward has become a widespread concern among government, industry, and academia. This paper analyzes the prospects and risks of the new economy from the perspective of information technology trends, arguing that information technology will be the primary driver for developing the new economy over the next 15-20 years; that Human-Cyber-Physical ternary intelligence represents the most leading-edge new technology; and that for cultivating new economic drivers, technology accumulation is as important as technological innovation. Since China' s industrial control field suffers from weak technology accumulation, the nation should increase investment in intelligent industrial control R&D and vigorously cultivate scientific and technological talent in this domain.

Keywords: information technology, Human-Cyber-Physical ternary intelligence, technology accumulation, industrial control

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In recent years, the vigorous development of the new economy has raised hopes. Among the world' s top ten platform economies, China occupies three positions (Alibaba, Tencent, Baidu). In 2016, China' s service sector contributed 58.2% to national economic growth, 20.8 percentage points higher than the secondary industry. On the other hand, in 2016, the value-added of high-tech industries accounted for only 12.4% of industrial enterprises above designated size, indicating that the industrial structure dominated by traditional industries has not fundamentally changed and that the incremental growth of the new economy cannot yet offset the downward adjustment of traditional sectors. Faced with this mixed situation, many remain skeptical about whether new technologies can create new drivers and whether these drivers can power the new economy. How should we understand the opportunities and risks in developing the new economy?

We believe that new technologies are the primary force for developing the new economy, and that a rational judgment about its prospects can be made from information technology trends. What technologies will mainly drive industrial upgrading in the next 10-15 years? Why can Human-Cyber-Physical ternary intelligence promote economic transformation? How can independently developed new technologies truly become new drivers of economic development? Answering these questions is essential for correctly understanding the new economy.

1. Information Technology is the Main Driver for Developing the New Economy in the Next 15-20 Years

1.1 Information Technology Will Continue to Play the Leading Role

Given that Moore' s Law is approaching its limits, communication technology is nearing the Shannon limit, and considering the internet bubble at the turn of the century, many scholars in the early 21st century predicted that information technology had essentially completed its historical mission of driving economic development and that the first half of the 21st century would belong to biotechnology. However, over the past decade, cloud computing, the Internet of Things, big data, and artificial intelligence have emerged in successive waves, demonstrating the continued vitality of information technology and its ongoing role in leading global economic development.

Since World War II, the foundational technological inventions supporting long waves of world economic development have been the electronic digital computer, transistor, integrated circuit, optical fiber communication, wireless communication, Internet, and World Wide Web. Since the WWW, although new terms such as cloud computing, the Internet of Things, and big data have continuously emerged, no fundamental invention comparable to the above technologies has appeared. New technologies like brain-inspired computing and quantum computing cannot form new economic drivers in the short term. It generally takes 20–30 years from basic invention to major economic impact, so the next more vigorous economic long wave may not arrive until after 20 years. The next two decades will likely be a periodic recession phase of the economic long wave, which according to historical patterns should also be a period of intensive fundamental inventions. Since history provides only 4–5 sample data points for economic long waves, long-wave theory in economics may not serve as a reliable basis for predicting economic trends, though the judgment that the world economy develops cyclically should be reliable.

The international community calls this pattern the law of accelerating returns in technological evolution, where so-called accelerating returns refer to the accelerating enhancement of technology' s driving force on the economy. The Stone Age evolved over tens of thousands of years, the printing press took a century to spread, while WeChat on mobile networks required only a few years to achieve universal adoption.

1.2 The Depth and Breadth of Information Technology Development

Assessing the development trend of information technology requires considering at least two dimensions: depth and breadth. In terms of depth, according to McKinsey' s 2013 technology forecast, by 2025 the industries likely to generate economic benefits of $5–10 trillion will still be information industries such as mobile Internet, intelligent software systems, cloud computing, and the Internet of Things. In biotechnology, only next-generation genomics might reach $1 trillion, while advanced materials would be less than $0.5 trillion and renewable energy less than $0.3 trillion [1]. This judgment is shared not only by McKinsey but also by many technologists and economists: the potential of information technology has not been fully realized, while gene, biotechnology, and nanotechnology are still in gestation. Information technology will remain the dominant force for the next 15 years or even longer.

From the breadth perspective, historically major fundamental inventions such as the steam engine, internal combustion engine, and alternating current required long periods of technical improvement and diffusion before generating huge economic benefits, and information technology should be no exception. Information technologies like the WWW have undergone more than 20 years of diffusion and accumulation, making the first half of the 21st century the golden age for information technology to improve productivity. Major technology applications often follow two successive S-curves, with the second S-curve having a longer lifecycle and stronger economic driving force [3]. Most information technologies today will follow the second S-curve development trend in the next 20 years, characterized mainly by technological improvement and extensive penetration. In other words, over the next 10–20 years, the greatest contributions to the economy may not come from newly invented major technologies but from new products integrating information technology into various industries, new business models providing personalized products and services on demand, and new patterns of cross-industry chain integration. For the information age, the popularization and penetration of information technology still have a long way to go—current applications are only equivalent to the steam engine era of the Industrial Revolution.

1.3 The New Economy is Essentially a Transition from Industrial Economy to Information Economy (Digital Economy)

Many equate the new economy with strategic emerging industries, believing that only industries within the national designated scope count as new economy. This is a misunderstanding. The new economy has broader connotations, including using information technology to upgrade and transform traditional industries. The U.S. "New Economy Index" includes the proportion of farmers using the Internet to conduct agricultural operations as one of its 25 indicators measuring new economic development. The World Economic Forum' s 2016 Digital Transformation Initiative pointed out that from 2016 to 2025, digital transformation across industries is expected to create $100 trillion in social and enterprise value (primarily social value), with the automotive, consumer goods, electricity, and logistics sectors alone accounting for over $20 trillion in potential cumulative value [4]. The prospects for digital technology upgrading traditional industries are extremely bright.

China has 150 million manufacturing workers, compared with only 14 million in the United States and 9 million in Japan. China has over 140,000 machinery suppliers, five times the number in Japan, making the significance of China' s manufacturing upgrading extraordinary. The high-tech transformation of manufacturing is essentially the deep integration of information technology and manufacturing technology. In the past, products were called machines or electrical appliances; in the future, most products will be "networked devices." So-called intelligent manufacturing involves not only the informatization of manufacturing processes but more importantly, making manufactured products network-enabled, data-driven, and intelligent. The i5 intelligent machine tool from Shenyang Machine Tool Group, which leads global intelligent manufacturing, exemplifies this trend.

The new economy is essentially a transition from industrial economy to information economy (digital economy). Current GDP statistics cannot accurately reflect the development of the digital economy. The sharing advocated by the digital economy, consumer surplus brought by user experience, free open-source software, and user-to-user transactions are not counted in GDP. Many foreign institutions and scholars are exploring more suitable statistical methods for the digital economy. The popular notion that China' s economic new normal is L-shaped, with stable growth of around 6% for the next decade, reflects industrial economy thinking. Even with 6% or lower GDP growth, the actual connotation of the digital economy has changed substantially.

2. The Most Leading New Technology is Human-Cyber-Physical Ternary Intelligence

Many new technologies drive the new economy, but we believe the most leading one is Human-Cyber-Physical ternary intelligence, abbreviated as ternary intelligence, also known as Human-Cyber-Physical computing. Emerging around 2010, its main characteristic is intelligent universal connectivity—interconnection between things, between things and people, integrating intelligence into everything, and achieving seamless integration of informatization and industrialization. Traditional artificial intelligence aims to give computers human-like intelligence, with intelligent computing processes limited to cyberspace, representing one-dimensional computing. Ternary intelligence extends computing processes from cyberspace to include human society (people), cyberspace (machines), and the physical world (things), forming a three-dimensional world. Intelligent computing occurs within this ternary world, representing ternary computing. Both the physical world and human society are objects and executors of intelligent computing processes.

The essence of ternary intelligence is to optimize material and energy movement in the physical world and production-consumption activities in human society through information transformation, providing higher-quality products and services, making production and consumption processes more efficient and intelligent, thereby promoting the digital transformation of economy and society. Ternary computing was identified as a major IT trend by the Chinese Academy of Sciences in 2009 [5]. Related concepts include the Internet of Everything (IoE) [6], Seamless Intelligence [7], Cyber-Physical Systems [8], and "Internet Plus." Ternary intelligence can be understood as seamless intelligent computing technology atop the Internet of Everything, requiring new core technologies and ecosystems.

2.1 Ternary Intelligence Will Continue and Enhance Internet Development Momentum, Accelerating Industrial Upgrading and Transformation

Over the past 15 years, the information industry has been the main driver of China' s economic and social development. According to Forbes Global 2000 rankings, in 2007 Lenovo, Alibaba, and Tencent ranked 1338th, 1863rd, and 1905th respectively—positions near the bottom. By 2016, these three companies had risen to 840th, 174th, and 201st, showing remarkable Chinese corporate progress within nine years amid the mobile Internet wave. Ternary intelligence is built upon mobile Internet and will continue and strengthen this powerful momentum formed over the past decade.

In 2016, China had 16 information industry companies in the Global 2000 list; adding Huawei (a non-public company) makes 17 companies achieving $431.7 billion in sales and $50.6 billion in profit. The United States had 74 companies on the list, achieving $1,582.1 billion in sales and $211.3 billion in profit (Table 1). Chinese information industry companies' average profit margin was 11.73%, higher than the average for all Chinese companies in the Global 2000 (10.19%) but lower than U.S. information industry companies (13.36%). Chinese companies' profits were only 24% of U.S. companies' , far below the China-U.S. GDP ratio (61%). If in 15 years the China-U.S. information industry profit ratio could synchronize with the GDP ratio, or if Chinese information industry companies' 2030 sales revenue could reach U.S. companies' 2016 levels, there remains 3–4 times growth potential.

These data also reflect weaknesses in China' s information industry. First is the "top-heavy" structure: China' s information services sector has developed well, but software and hardware remain weak. Second is strong consumption-side but weak supply-side: Chinese companies have achieved rapid growth by leveraging China' s large mobile Internet user base ("netizen dividend"), but hardware, software, and services for producers (enterprises) have grown slowly. Third is the lack of core technologies: among Global 2000 companies, the United States has 14 chip companies and 14 software companies, while China has none.

Over the next 15 years, as we face the evolution from mobile Internet to intelligent universal connectivity, we should attach great importance to the emerging market of ternary intelligence. According to various industry estimates, by 2030 there will be hundreds of billions to trillions of sensors and tens of billions of edge devices globally, each requiring new processor chips, operating systems, development environment software, and new usage models. The intelligent universal Internet has not yet formed monopolies, so developing ternary intelligence in China can not only continue and enhance Internet development momentum in products and services but also fill gaps in core hardware and software technologies.

2.2 Five Key Aspects of Ternary Intelligence

Developing ternary intelligence requires integrating existing technologies such as cloud computing, big data, mobile Internet, and the Internet of Things, breaking through new scientific and technological challenges, and achieving usage model and business model innovation. The following five key scientific and technological aspects are essential:

(1) **Computer Science for Ternary Intelligence**: Extending traditional computer science limited to cyberspace to the ternary world of humans, machines, and things, including ternary computability theory, modular architecture for ternary intelligent systems, complexity characterization of user experience, scientific representation of seamless intelligence, and easy-to-use natural interaction interfaces.

(2) **Edge Computing Ecosystem**: The industrial ecosystems for desktop Internet and mobile Internet have matured, with desktop Internet dominated by the x86+Windows+Linux ecosystem and mobile Internet by the ARM+Android+iOS ecosystem. The edge computing system has not yet developed a dominant ecosystem or stabilized, presenting a major challenge to develop an edge computing ecosystem supporting billions of devices.

(3) **Energy-Efficient Intelligent Computing Platforms**: Ternary intelligence requires computing capabilities improved by a thousand times compared with today' s systems while maintaining the same energy consumption. Learning from nature and integrating specialized and general-purpose components through new technologies such as self-adaptation and reconfigurability is a feasible route to constructing energy-efficient intelligent computing platforms. An example is the Cambrian deep learning processor supported by the CAS Strategic Priority Program, which achieves a thousand-fold improvement in performance-power ratio compared with general-purpose processors.

(4) **Trusted Internet**: As ternary intelligence more directly involves human society and the physical world, network information security becomes more urgent and important. We must develop an intelligent universal Internet that encourages openness and sharing while ensuring information security and user privacy and accepting lawful government regulation. A harmonious ternary environment satisfying these conditions is called Trusted Internet. The recently emerging blockchain technology is one of the foundational technologies for building Trusted Internet and deserves high attention [9].

(5) **Identity Federation**: The intelligent universal Internet will generate many entities requiring naming, covering people (users), machines (devices, data, and services in cyberspace), and things (objects in the physical world). How to enable users to conveniently use all devices and intelligent

services through a single identity is a new challenge. Currently, user identities are forcibly bound to a specific vendor' s account platform; the ideal scenario is for each user to have a "national information account" that can access any authorized service anytime, anywhere.

3. Cultivating New Driving Forces Requires Adhering to Independent Innovation and Technology Accumulation

New technologies do not automatically transform into productive forces. The transformation from knowledge to actual productive forces generally requires four stages: (1) discovering new knowledge through scientific research; (2) converting knowledge into new technologies that meet application needs through invention; (3) transforming technologies into new products and services through technological innovation and beginning to enter the market; and (4) continuously improving and enhancing product and service market competitiveness through application. From scientific knowledge to technology, from technology to product, and from product to market, each step must cross a "valley of death." There are no shortcuts across this valley—only the ability for independent innovation can succeed. While it is often said that core technologies cannot be bought, what truly cannot be purchased is the capability for independent innovation. Core technologies supporting the new economy can only be obtained through enhanced independent innovation capabilities.

Innovation-driven development has become a national strategy, yet we often neglect the importance of technology accumulation when implementing this strategy. In reality, technology accumulation is as important as technological innovation. A key factor in economic growth is the increase in knowledge stock, and for both enterprises and individuals, knowledge growth depends on technology accumulation through continuous innovative practice. China' s high-speed rail success is hailed as a model of "introduction, digestion, absorption, and re-innovation," but we should not forget that China has been engaged in railway locomotive R&D since the 1950s. Through the tempering of research projects such as the "China Star," the CRRC Corporation had already established solid technological reserves.

Some of China' s strategic emerging industries have developed rapidly while others have not, partly due to differences in technology accumulation across sectors. Railway locomotive manufacturing has relatively solid technology accumulation, but the industrial control field (including operation control for high-speed rail and aviation) has extremely weak technology accumulation. According to 2014 statistics from the Ministry of Industry and Information Technology, 900 large-scale industrial control systems across 22 industries in China were mostly provided by foreign manufacturers, especially programmable logic controllers (PLCs), where foreign companies occupy over 94% of the market share. Because domestic enterprises in the industrial control field struggle to imitate foreign products, foreign companies do not need to apply for patent protection for their product sales in China. The number of patents applied for by foreign companies in China has long remained at about 10% of the total patents in this field (compared with 43% in communications and computer fields). Under the current situation of strong national support for intelligent manufacturing and "Internet Plus," and in the process of achieving intelligent universal connectivity, increasing R&D investment in the industrial control field and consolidating technology accumulation in this area are particularly important.

Consolidating technology accumulation must start with education. China' s talent cultivation in industrial control far from meets market demand. Almost no university has offered courses related to PLC technology, and the information technology talent needed for equipment manufacturing has not been included in the shortage talent catalogs of many provinces and cities.

One path to accumulating technology to cross the valley of death while cultivating innovative talent is to actively participate in international communities for open standards, open-source software, and hardware, striving to initiate and lead several core technology and platform ecosystem open-source communities. We should aim to cultivate 2,000 core community volunteers within the next few years—engineers recognized and trusted by global peers who have write access to community standard documents and software/hardware source code. With nearly ten million software engineers in China, targeted talent policies should be formulated to encourage them to contribute more to global communities.

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