

The Effect of AIoT on the Total Factor Productivity: The Case of China in The Past Decade

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Abstract: This paper introduces the economic significance of AIoT technology, especially the impact on TFP. The impact of AIoT technology development on TFP growth rate in China is empirically studied then by selecting the relevant data in recent ten years. Economic theories have confirmed the positive impact, while the empirical analysis of this paper also reveals that the marginal benefit of AIoT investment is not ideal sometimes even though the technology investment has increased.

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1 Introduction

IoT (Internet of Things) is defined as the realization of a society in which a large number of various things are connected to the Internet and smoothly transmit large amounts of information with each other, thus forming the foundation of people's lives and economic activity. AIoT, integrating AI (Artificial Intelligence) and IoT, is an advanced type of IoT, called the third wave after the development of computer and Internet.

AIoT makes home appliances and IT devices people-oriented and user-friendly by connecting them to the cloud and giving them AI capabilities. AI can analyze and learn people's routines and preferences and thus provide them with appropriate services and suggest ways to use products. Similarly, for the manufacturing industry, by optimizing manufacturing facilities and working procedure, AIoT would

promote the rise of TFP (Total Factor Productivity) as a consequence.

In the AIoT era, both consumer and industrial sectors are facing new opportunities, thus attracting the attention of the investors and government regulators of China. From 2005 to 2019, 1718 investment and financing events occurred in the field of AIoT, with a total financing amount of 191.9 billion yuan, with a growth rate of 73 percent. According to the database of iResearch, the AIoT application penetration rate on public safety and government services of China is predicted to reach 70% in 10 years.

There is no doubt that AIoT will increase TFP in theory. However, in the recent decade of AIoT development in China, what is the actual impact? In this paper advances on two fronts would be made. First, a specific theory of the impact of AIoT on production would be forged. It's not simply plugging something into computers or other AIoT devices and achieving service quality or efficiency gains. Instead substantial changes have been done in the manufacturing environment of artificial intelligence and interconnection of all things. Second, empirical analysis would be adopted to verify the theory given above, and find out the reason if there were a conflict.

2 Frameworks

2.1 Tfp Growth Rate

TFP, which is defined as the output that can be obtained by a given unit of factor combination, plays an important role in the growth theory. Therefore, it has been studied at both the micro and macro levels:

The former focuses on the study of TFP growth rate, while the latter is more inclined to study how to maximize TFP by advances in technology or rational resource allocation between industries.

To find out how TFP changes, in addition to the DEA (data envelopment analysis) method and the SFA (stochastic frontier analysis) method at the microscopic level, macroeconomists have also put forward many important theories, in which the most representative ones are Solow growth model, Solow residual value and macro growth accounting system (Abramovitz, 1956; Solow, 1957). According to Solow's model, economic growth can be decomposed into the growth of capital, labor factors and "Solow residual value", and then the contribution rate of different factors in economic growth can be calculated. The growth of "Solow residual value" reveals the TFP growth rate. After that, Dale W. Jorgenson and Zvi Griliches have successively integrated investment theory, index Number theory, national income accounting system and enterprise theory into the growth accounting framework, and defined the Divisia Index as the TFP growth rate.

TFP growth rate at the macro level has attracted more attention in China, as Huang Yongfeng (2002), Sun Linlin and Ren Ruoen (2005), Guo Qingwang and Jia Junxue (2005) have all carried out relevant researches. They also tried to use the production frontier method to measure the TFP index of macro or sector, in general, by taking the enterprise or region as the efficiency and TFP index measurement unit to measure the efficiency and TFP index and obtaining the TFP index of the industry sector or economy by using a weighted average.

From the perspective of supply side and growth function, factors determining growth potential can be simplified as factor input (including labor, capital, etc.) and TFP. This paper will focus on studying the effect of technological progress on TFP at the macro level.

2.2 Substitution Effect and Pervasiveness Effect of AIoT

"Computers everywhere except in the productivity statistics." Robert Solow wrote in the New York Times in 1987. This remark was later called "Solow Paradox". Since then, many economists have carried out a lot of empirical research to test the "Solow

paradox". It is believed that the impact of AIOT on the economy will shake up this paradox.

AIoT is extremely comprehensive and has a huge capacity, including AI, SI (System Integration), cloud computing and IoT, factors almost deeply integrated with other industries. At present, AIoT is in a state of multi-level and fragmentation, being applied on various requirements through 2B (B2B, Business to Business), 2C (B2C, Business to Customer), 2G (B2G, Business to Government) and so on.

Since AIoT's own technological progress and productivity improvement will reduce the cost and price of AIoT products, it would cause substitution effect in the consumption and investment fields. AIoT, along with the sharing economy which continues to expand the scope of business, has gradually changed people's views on consumption. The progress of AIOT technology and its scale effect will reduce the price of related products, affect consumer preference, and finally enhance its substitution effect. AIoT products are high-tech products with high added value and unlimited market potential, therefore investment in its technology research and development is widely regarded as promising, especially as its costs continue to fall.

On the other side, with the characteristics of universality and permeability, AIoT can be widely applied in various fields of economy and society, so as to enhance the synergy between factors in the production process and reduce the market failure caused by information asymmetry and then improve TFP. The interaction with 5G, and the proposal of the concept of smart home and smart city, confirm the continuous expansion of AIoT industrial ecology coupled with its stronger pervasiveness effect.

3 Empirical Methods and Results

3.1 Data Description

The data for this article comes from the National Bureau of Statistics of China, the China Academy of Information and Communication Technology (CAICT), and the Ministry of Industry and Information Technology of China. The data from 2010 to 2019 have been chosen, because the development of the Internet of Things in China basically stagnated before then. The following data will be involved (Table 1).

Table 1. The data from 2010 to 2019 have been chosen, because the development of the Internet of Things in China basically stagnated before then

VARIABLE	UNIT	MEANING
N	million	Number of AIoT connections.
PG/JG/SG/CG	million	The number of primary school/ junior high school / senior high school / college or above graduates.
CPI		Consumer price index.
FAPI		Fixed asset investment price index
ERD	billion	Expenditure on research and experimental development.
IOVSE	trillion	Industrial output value of state-owned enterprises.
GIOV	trillion	Gross industrial output value.
Y	trillion	GDP.
K	trillion	Investment in fixed assets throughout society.
L	million	Quantity of employment.

3.2 Data Processing

In order to obtain TFP, the Solow model is used in this paper to perform a simple calculation of the Solow residual value, and then the growth rate of TFP is obtained, denoting RTFP, whose principle is:

$$RTFP = \frac{\dot{A}}{A} = \frac{\dot{Y}}{Y} - a \cdot \frac{\dot{K}}{K} - b \cdot \frac{\dot{L}}{L}, (a = 0.3, b = 0.7)$$

As for the development of AIoT, it is quite reasonable to use number of AIoT connections. to describe its specific situation, which has been recorded as N.

In addition, there is a clear correlation between education and productivity, so it is necessary to include education as a control variable when discussing TFP. As for the measurement of education, this paper follows the method in the existing literature and USES the weights of 6, 9, 12 and 16 years, respectively, to make a weighted average of the number of graduates with primary school, junior high school, senior high school and college or above in that year, and records the results as E:

$$E = \frac{6 \cdot PG + 9 \cdot JG + 12 \cdot SG + 16 \cdot CG}{43}$$

Since AIoT technology is inseparable from R&D (Research and Development), and the expenditure input of R&D will directly and indirectly affect TFP, it is also necessary to take the expenditure on research and experimental development as the control variable. In order to eliminate the influence of price, this paper calculates the average CPI and fixed asset investment price index to represent the price level, and records the ERD after excluding price influence as RD.

The economic institution under government

intervention will affect the development of industry through affecting social investment and enterprise financing. Because most AIoT enterprises are small or medium-sized innovative enterprises, to which the government's policy support is very important, it is essential to introduce institutional factors into the model. The Institution index, measuring institutional factors, is defined by the proportion of the industrial output value of state-owned enterprises (IOVSE) in the gross industrial output value (GIOV), denoting II:

$$II = \frac{IOVSE}{GIOV}$$

3.3 Empirical Methods

In order to test the impact of AIoT on TFP, this paper, referring to Ahmed, Elsadig and Musa (2010), establishes the data model as follows:

$$\ln RTFP = \alpha + \beta \ln N + \gamma E + \delta RD + \varepsilon II + \varepsilon$$

Adding time subscript, it becomes:

$$\ln RTFP_t = \alpha + \beta \ln N_t + \gamma E_t + \delta RD_t + \varepsilon II_t + \varepsilon_t$$

After the first order difference, the data model becomes:

$$\begin{aligned} \ln RTFP_t - \ln RTFP_{t-1} &= \beta(\ln N_t - \ln N_{t-1}) + \gamma(E_t - E_{t-1}) + \delta(RD_t - RD_{t-1}) \\ &+ \varepsilon(II_t - II_{t-1}) + (\varepsilon_t - \varepsilon_{t-1}) \end{aligned}$$

Because compared with other factors, education level and policy factors are always stable, which has little significance for the first-order difference between the two factors. This function ends up being like:

$$\begin{aligned} \ln RTFP_t - \ln RTFP_{t-1} &= \beta(\ln N_t - \ln N_{t-1}) + \gamma E + \delta(RD_t - RD_{t-1}) + \varepsilon II + (\varepsilon_t - \varepsilon_{t-1}) \end{aligned}$$

At this point, the left-hand side of the equation explains the change in the growth rate of TFP as dependent variables, while the right-hand side of the

equation explains the growth rate of IOT connectivity, current education level, R&D expenditure growth and institutional factors respectively as independent

variables. All five variables are statistically stable. The results are obtained after regression:

VARIABLE	COEFFICIENT
$\ln N_t - \ln N_{t-1}$	-0.48**
E	0.21***
$RD_t - RD_{t-1}$	-0.45*
II	-0.06***

Key: *— $p < 0.1$, **— $p < 0.05$, ***— $p < 0.01$

D Empirical Conclusion

Firstly, the coefficient of institutional factors is -0.06, which means that when the proportion of the industrial output value of state-owned enterprises in the gross industrial output value changes by 16.67 percentage points, the change of TFP growth rate will change by 1 percentage point in reverse. However, in the past decade, the biggest interannual change of institutional factors was 10.49% in 2013. Therefore, it can be considered that the impact of institutional factors on TFP growth rate is very small.

In addition, the results showed that increased education led to increased TFP growth which was not controversial at all, while IOT connectivity and R&D spending prevented further growth which means the marginal benefit of AIoT investment kept decreasing. The latter doesn't make sense in theory, thus there must be something wrong that leads to the paradox. Xiao Liping (2018) has pointed out that the driving force of Internet technology to promote TFP is mainly from technical efficiency rather than technological progress, which has been confirmed in his empirical analysis of China's provincial panel data on computer technology. For this study, AIoT is undoubtedly a kind of technological progress, but its technical efficiency remains to be studied. Besides, irrational pursuit of popular industries or technologies is an important reason for the waste of technology investment.

4 Conclusions

It is theoretically feasible for AIoT technology to promote TFP growth rate. But in the empirical analysis of China's data in recent ten years, the opposite results are presented. IOT connectivity and R&D spending, representing the investment in the construction and development of AIoT technology, both prevented further growth of TFP growth rate, as a probable consequence of low technical efficiency

and unreasonable investment allocation.

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