

Impact of Industrial Internet Platform Development on Total Factor Productivity of Enterprises

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Abstract: At present, the rapid development of industrial internet platform has gradually become an important driving force for the high-quality development of enterprises. Based on the current situation of industrial internet development in Shandong province, the impact of industrial internet platform development on total factor productivity of enterprises was investigated. It is found that the development of industrial internet platforms significantly improves the total factor productivity level of enterprises, and this finding still holds after robustness tests and detailed analysis. Mechanism analysis shows that business process management optimization of industrial internet platforms is conducive to promoting total factor productivity of enterprises. At the same time, under the network effect of the industrial internet platform, promoting the construction of two integration has promoted the total factor productivity of enterprises, according to the age test of enterprises, the longer the survival time of enterprises, the more mature the development of market mechanism, and the more obvious the promoting effect.

1. Introduction and Literature Review

1.1 Introduction

Industrial internet is an important direction for future economic development. Industrial internet is a new infrastructure that integrates the new generation of information and communication technology with industrial economy, and realizes the layout of multiple elements and the whole industrial chain through the integrated connection of people, machines, things and systems, while the development of industrial internet is also a national strategy. In November 2021, the Ministry of industry and information technology issued the "14th five-year plan for the development of deep integration of informatization and industrialization", proposing to promote the development and application of industrial internet platforms as a key element of the 14th five-year plan's development strategy for the integration of two industries. Among them, the industrial internet platform is the center of gravity of the industrial internet, the core of all industrial elements, but also the whole industrial chain and value chain of the whole connection, integration and deployment, is the key point of digital transformation and upgrading of manufacturing industries. Industrial internet platforms have achieved popularity and wide application, showing significant application value, and their contribution to economic growth is becoming more and more evident, gradually becoming a major kinetic energy and new engine to prompt enterprises to achieve high quality. In

2020, the industrial internet platform will play an indispensable role in supporting the prevention and control of COVID-19 emergencies, helping to connect the supply and demand of materials, and promoting the reproduction of enterprises^[1].

As an important indicator of high quality, total factor productivity is the inexhaustible force for continuous economic growth^[2], and improving the total factor productivity of enterprises has become the key grasp to achieve high quality development. Focusing on the enterprise level, the total factor productivity of enterprises is generally used to portray the high quality development of enterprises. The development of industrial Internet platform penetrates deeply into each production link of enterprises, breaks the shackles of traditional factor market, and provides technical support to the digital and intelligent development of enterprises, which is conducive to promoting the quality and efficiency of enterprise production^[3]. As a form of deep integration between industrial parks and the new generation of information technology, how effective is the industrial internet platform in practice? Does it successfully achieve the purpose of promoting the total factor productivity of enterprises? What are the mechanisms affecting the total factor productivity of enterprises? All these questions need to be answered. The study of this issue is not only a major concern of academic research and policy stakeholders today, but also a question of the dynamics of the sustainable improvement of enterprise total factor productivity and thus the realization of high-quality development.

Using the OP method and the development level of industrial internet in Shandong province, this paper investigates the impact of industrial internet platform development on enterprise total factor productivity and its transmission mechanism. While promoting the construction of industrial internet, Shandong province also takes it as an important cornerstone and key path for the digital transformation of manufacturing industry, and promotes the integration of applications to accelerate to high-level and multi-field deepening, which is conducive to a deep understanding of the impact of the development of industrial internet platform on the productivity of enterprises. At the same time, the research in this paper also provides empirical evidence and corresponding policy references for promoting the high-quality development of industrial internet and enhancing the total factor productivity of enterprises in the context of economic high quality.

1.2 Literature Review

1.2.1 Industrial Internet Platform Related Research

The internet, as an important engine of social development, has created a new economic and social development model. Most domestic studies on industrial internet platforms focus on macro analysis summarizing the development path of industrial internet platforms and the application value, and a few scholars develop from the perspective of internetization. A study by Shen, Guobing and Yuan, Zhengyu (2020)^[4] using data from Chinese industrial firms found that internetization of firms has a significant enhancing effect on innovation capability, and further study found that internetization can improve the possibility of exporting by firms through innovation as a mechanism. He, Xiaolong et al. (2021)^[1] analyzed the current situation of industrial internet platform applications and finally found that the overall level of platform applications is seriously polarized, and there is still room for industrial equipment to go to the cloud with great difficulty as well as business to cloud rate. Chen Wu et al. (2022)^[5] provide a deep integration of the enabling nature of industrial internet platforms and provide practical optimization suggestions for the future development and implementation of industrial internet platforms in China based on the current architecture of industrial internet platforms.

1.2.2 Total Factor Productivity Related Studies

Total Factor Productivity, or TFP for short. In recent years, with the popularity and widespread use of digital technology, digital technology development has gradually become the main driver of total factor productivity in manufacturing enterprises^[6], its status and importance are gradually coming to the fore. Song, Qinghua et al. (2022)^[7] used the input-output method to measure the level of industry digitization and analyzed the impact of industry digitization on the total factor productivity of enterprises and the mechanism of action. Zhao, Chenyu et al. (2021)^[8] sorted out the inner mechanism of digital transformation to enhance total factor productivity of enterprises at the level of theoretical foundation and empirically demonstrated the impact of digital transformation on total factor productivity of enterprises.

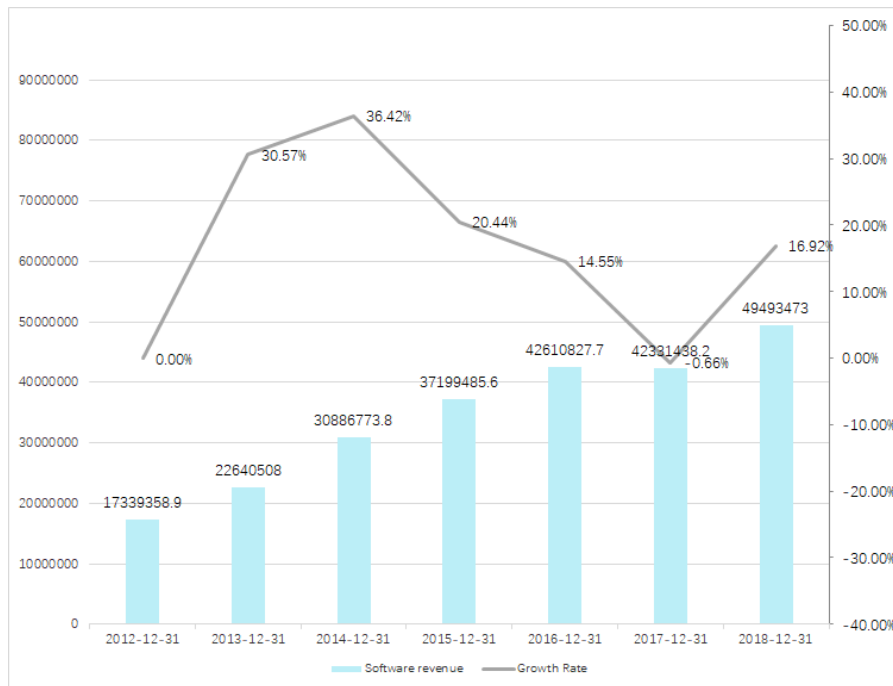
1.2.3 Literature Review

By summarizing the literature related to industrial internet platforms and total factor productivity, it is easy to find that the relevant research on industrial internet at home and abroad has been fully developed, but the research results of industrial Internet platforms on total factor productivity of enterprises at the overall level are still inadequate. So, do industrial Internet platforms promote the growth of total factor productivity of enterprises? What is the process mechanism of this promotion effect? Existing studies have not yet provided clear explanations for the above questions. In view of this, this paper will use the OP method to estimate the effect of industrial Internet platforms on enterprise total factor productivity based on the current development of Internet in Shandong Province, using data from the database of Chinese industrial enterprises, in order to precisely identify the causal relationship between industrial Internet platforms and enterprise total factor productivity changes.

2. Current Status of Internet Development in Shandong Province

2.1 Rapid Growth of Industry Scale

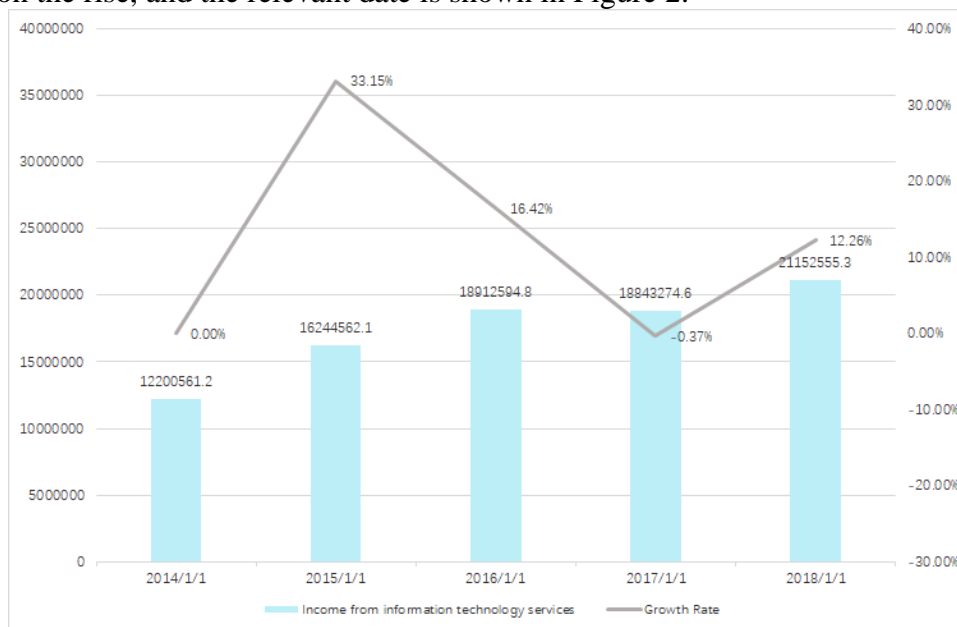
Software application and service industry is a strategic core and key industries related to the overall national economic and social development, at the same time, the information technology industry in Shandong province to achieve strong development, showing vitality, scale and quality of simultaneous improvement, and the relevant date is shown in Figure1. Generally speaking, from 2012 to 2018, the average revenue of software business in Shandong province is 34643123.6. From the peak and valley values of the data, it can be seen specifically that in these years, the maximum value of software business income in Shandong province reached 49493473. In 2018, the value of software business revenue in Shandong province was 49493473, which was 42331438.2 in the same period of 2017. Compared with the same period in 2017, it increased by 7162034.8, a year-on-year growth of 16.92%, and the growth rate was 17.58% higher than the previous year. The average growth rate was 19.71%, and the highest growth rate was 36.42%. According to the statistical data of Shandong province's software business income from 2012 to 2018, from the perspective of the rate of change, we can generally see that since 2012, Shandong province's software business income has experienced a certain degree of growth, in 2018 compared with 2012, an increase of 32154114.1.



Data source: National Bureau of Statistics.

Figure 1: Software Business Revenue Size and Growth Rate, 2012-2018

With the development of economy and society, in the society of big data, people pay more and more attention to the software revenue of embedded system in Shandong Province. According to the latest statistics derived from the Bureau of Statistics, the software business income in Shandong province is on the rise, and the relevant date is shown in Figure 2.



Data source: National Bureau of Statistics.

Figure 2: Information Technology Services Revenue Size and Growth Rate, 2014-2018

Between 2014 and 2018, the information technology service revenue of Shandong province has grown significantly and is in the middle to upper position in 2018 when compared horizontally with the data of the same period in various provinces across the country. Compared with the historical

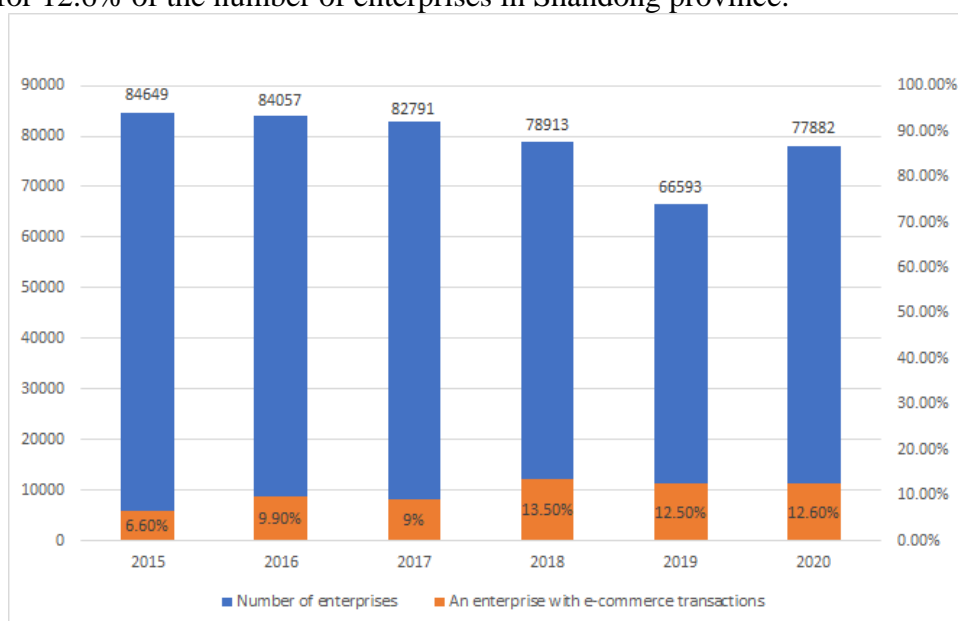
data, the information technology service income of Shandong province in 2018 is 21152555.3, the index in the same period of 2017 is 18843274.6, compared with the same period of 2017 increased by 2309280.7, a year-on-year growth of 12.26%, the growth scale is strong, the growth rate is 12.63% higher than the previous year. From 2014 to 2018, the information technology service income of Shandong province changed from 12200561.2 to 21152555.3, and the average of the information technology service income of Shandong province was 17470709.6, with an average growth rate of 15.37%.

2.2 Aggregate Development Trend

Shandong province bureau of industry and information technology released the list of provincial digital economy parks in Shandong in 2021. It includes Qingdao Guanggu software park, Qingdao Tianan digital city, China Chuanhua SCO international logistics port digital economy park and Linyi Longhu software park. Weifang software park won the 2021 Shandong province brand technology enterprise incubator, the number of software parks is gradually increased, the scale is gradually expanded, and the development environment is further optimized.

2.3 Emerging Businesses Flourish

The relevant data is shown in Figure 3, the data of Huajing industry research institute shows that there are 77,882 enterprises in Shandong province in 2020, accounting for 6.9% of the number of enterprises in the country, of which there are 9,777 enterprises with e-commerce trading activities, accounting for 12.6% of the number of enterprises in Shandong province.



Data source: National Bureau of Statistics, compiled by the China Institute of Industrial Research.

Figure 3: The number of enterprises and the proportion of e-commerce enterprises in Shandong Province, 2015-2020

2.4 Strong Support for the Integration

Many well-known domestic enterprises and many software products with excellent market applications were exhibited, such as Longchamp ERP, oriental electronics production monitoring and management system, which greatly promoted the transformation and upgrading of traditional

industries. During the "13th five-year plan" period, industrial enterprises above the scale in Shandong province implemented more than 70,000 technical transformation projects, opened 51,000 5G base stations, full coverage of urban 5G network, more than 226,000 cloud enterprises. Many key backbone enterprises are leading the development of high-end, intelligent and green, and the intelligent manufacturing index ranks the first in the country, the product structure is constantly optimized and the quality is constantly improved. Haier Kaos and Longchao Yunzhou have been selected as the first 10 domestic "dual-process" industrial internet platforms, making great progress in building a strong manufacturing province.

3. Theoretical Mechanisms

The industrial internet platform is the center of gravity of the industrial internet and is the complete penetration and configuration hub for the entire industrial elements, the overall industrial chain and the entire value chain. It is the starting point of digital change in the manufacturing industry, but also the key to the development of industrial internet innovation, the power of change brought by the industrial internet platform has become an important factor in the transformation and development of data-driven systems. The industrial mechanism model drives economic transformation through big data as well as artificial intelligence technology to achieve total factor productivity improvement of enterprises, with three main mechanisms of business process management, empowering enterprise transformation and upgrading, and integration of two. The mechanism is illustrated in Figure 4.

3.1 Accelerate and Optimize Business Process Management

The industrial internet platform improves enterprise total factor productivity by accelerating the optimization of business process management. Technically speaking, the industrial internet platform is divided into three layers: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Software as a Service (SaaS)^[9]. On the one hand, the booming development of industrial internet platforms has given rise to the integration of various layers, links and elements of the platform, which greatly promotes the platform's business process management capabilities. On the other hand, the industrial internet platform can connect the business processes inside and outside the enterprise^[10], changing the embedded links of the value chain thereby improving the development of total factor productivity of the enterprise. In addition, enterprises can achieve accelerated optimization of business process management by strengthening infrastructure and system metrics assessment. First, the infrastructure provides the necessary tools for business process management, allowing people to break away from traditional models and management standards and become "enablers" of management capabilities. Comprehensively promote the construction of 5G networks and digital infrastructure, accelerate the layout of industrial business processes, promote efficient data transmission, and facilitate the rapid flow of various innovation factors^[11]. Secondly, the most important part of the business process management system indicators are business process organizers and participants. The implementation of business process management relies on the many organizers and participants in the enterprise, whose main responsibility is to design and continuously optimize processes, and all change actions must be implemented by employees, so organizational participants are an indispensable part of accelerating the optimization of business process management. With the development of innovative optimization of enterprise business processes, the efficiency of resource allocation of enterprises is continuously improved, the production model of enterprises and the operational efficiency of industrial internet platforms are optimized, which in turn promotes the development of total factor productivity of enterprises^[8,12].

3.2 Drive to Empower Enterprises to Transform and Upgrade

Industrial internet platform-driven empowerment of enterprise transformation and upgrading to improve enterprise total factor productivity. On the one hand, the development of industrial internet platform can lead to the diversified development trend of industrial APP. The essence of industrial APP software is a formatted industrial application, and based on the consistency index, an industrial application that can be quickly reused and popularly conveyed after the industrial technology elements are wrapped and positioned to promote the revitalization of traditional industries. traditional industrial software procedures are huge and cumbersome business processes make coordination between elements impossible, while industrial APP software uses micro-services and integrates the relationship between elements in a combinatorial way to achieve optimal distribution. Industrial internet platform can realize industrial APP innovation application, deep development and mining of big data, and finally refining, extracting, processing and aggregating data to realize the ultimate export product application of industrial Internet platform value. The industry-specific application-oriented market environment not only stimulates the formation of an entire ecosystem of social resources, but also promotes digital systems from independent dedicated systems to deep integration. On the other hand, the industrial internet platform relies on big data and the internet and other technologies to make the communication between industrial enterprises, research institutions and universities more convenient and close, to continuously improve the depth and breadth of research on the core problems of enterprises, to provide power support for enterprise R & D innovation, and then improve the R & D innovation capability of enterprises^[13]. At the same time, in the era of transformation of new industrial enterprises, innovation and research and development capabilities have become the core competitiveness of today's industrial enterprises to enhance the innovation capabilities into the platform management system, improve the level of science and technology, and drive the development of total factor productivity of empowered enterprises.

3.3 Integration of Industrialization and Industrialization

The huge network effect brought by the application of industrial internet platform will accelerate the process of integration of two^[14], the ultimate goal is to achieve an increase in total factor productivity of the enterprise. On the one hand, from the perspective of market mechanism, the development of industrial internet platform makes the market competition faced by enterprises gradually expand, and under the strong competitive pressure, enterprises must catch up with competitors through technological innovation. The integration of information technology and industrial technology allows the flexibility and modularity of information technology to effectively retrieve market demand information, identify differentiated demand distribution states, adjust and change overall strategies over time as well as intelligent strategies, and effectively reduce communication costs and operational risks^[15-16], achieve total factor productivity improvement of enterprises. On the other hand, from the perspective of internal drive, culture is a high-level level of value co-creation in industrial internet platforms^[17], enterprise culture seems to be unrelated to the integration of two, but it is closely related. The development of the integration of two cannot be separated from the support of enterprise culture, and the development of the integration of two can shape the excellent enterprise culture, which is an important condition for the successful development and application of the integration system of two and has a soul. Industrial integration is supported by a cultural system through the transformation and upgrading of traditional technologies, the overall improvement of technological levels, the creation of highly efficient business results and products, the reduction of marginal costs, the effective reorganization of corporate business processes, and the advancement of production technologies to make product quality more secure. With the deepening of the integration of the two, on the basis of technology

and industry integration, business integration, product integration and derivatives will further develop, continuously improving technical efficiency, platform efficiency, business efficiency and even social efficiency, and the integration of the two will eventually realize the transformation of social and economic operation mode, which will eventually lead to the improvement of total factor productivity of enterprises.

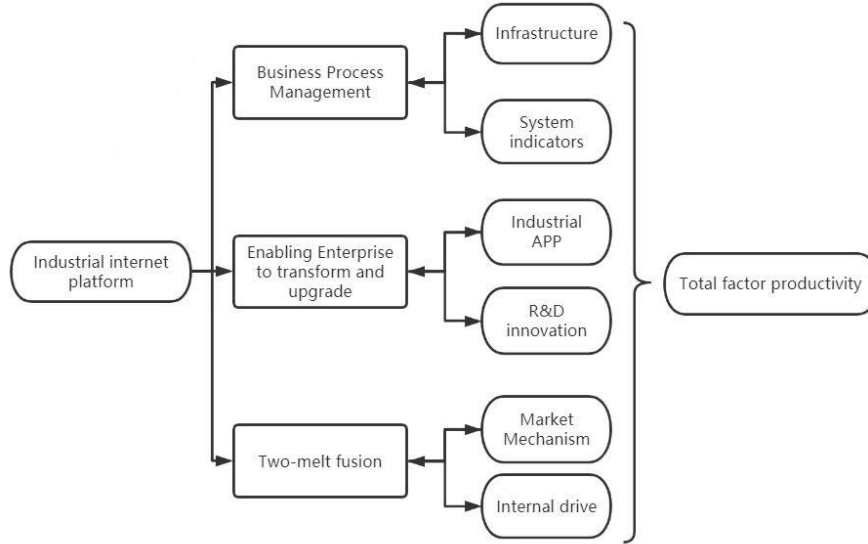


Figure 4: Enabling mechanism of industrial internet platform

4. Empirical Testing

4.1 Benchmark Model Setting

To examine the impact of digital economy development on the total factor productivity of enterprises, the following benchmark regression model is constructed in this paper:

$$TFP_{ijt} = \alpha_1 + \alpha_2 Digital_{ijt} + \sum \alpha_k M_{ijt} + \sigma_{ar} + \sigma_{in} + \sigma_{ye} + \xi_{ijt} \quad (1)$$

Among them, i indicates a self-employed company, j indicates the city where the company is located, t indicates year, $\sigma_{ar}, \sigma_{in}, \sigma_{ye}$ denote the unobservable region, industry and year disturbance terms, respectively, ξ_{it} is the random perturbation term. In the model, the core coefficients of interest in this paper are α_2 , if significantly positive then the theoretical mechanism hypothesis is supported.

4.2 Variable Descriptions and Data Sources

The explanatory variable of this paper is the total factor productivity of the firm (LS), the calculation method is Olley-Pakes (OP) calculation method. The core explanatory variable is the level of digital development ($Digital$), use the level value of the city where the company is located, the city digital infrastructure index and digital industry development index were obtained by using the entropy value method. In this paper, we set the set of control variables, mainly including: Business age (Age), expressed as the difference between the current year and the year when the business opened + 1; Enterprise scale ($Sale$), measured using the logarithmic form of corporate operating income; Profitability ($Prof$) measured using the ratio of total enterprise profit to industrial

value added; Capital-output ratio (Ky) measured using the proportion of total enterprise fixed assets to industrial value added.

Data source, corporate-level data from 2012-2019 Guotaian database (CSMAR), research subjects are Chinese listed companies in Shanghai and Shenzhen A-shares; City-level data use the 2012-2019 *China City Statistical Yearbook*. The statistical description of each variable is shown in Table 1.

It can be seen from Table 1 that the minimum value of the digitalization level of the explanatory variables is 0.09, the maximum value is 6.97, and the mean value is 0.29. Therefore, it can be inferred that there are great differences in the digitalization level of different cities in China. The minimum value of the explained variable TFP was 10.56, the maximum value was 17.10, and the mean value was 14.84, indicating that different enterprises had great differences in total factor productivity.

Table 1: Statistical description of the full sample variables

Variables	Number of samples	Average value	Standard deviation	Minimum value	Maximum value
Total Factor					
Productivity(TFP)	115305	14.84	1.08	10.56	17.10
Digitalization Level($Digital$)	115305	0.29	0.18	0.09	6.97
Enterprise Scale($Scale$)	115305	10.97	11.02	0	19.31
Profitability($Prof$)	115108	0.23	0.25	-0.69	0.90
Debt Ratio($Debt$)	115108	0.57	0.41	0	3.10
Capital to output ratio(Ky)	115261	1.46	1.19	0	9.76

Data source: matched enterprise database.

4.3 Empirical Regression Results

In this paper, we first conduct Hausman test on equation (1), and the results strictly reject the original hypothesis, so we choose the panel fixed-effects model to complete the benchmark regression, and the results are shown in Table 2. The results show that improving the level of urban informatization and the size of the Internet will significantly benefit firms in improving total factor productivity, which is consistent with the previous analysis of the theoretical mechanisms. And the extent of this boost is more obvious for larger enterprises.

From the results of the control variables, the regression coefficient of enterprise size is 2.098, which has passed the significance test of 1%, indicating that the larger the enterprise size, the more conducive to development, and thus improve the total factor productivity. It can be seen that at the present stage, the level of informatization and the scale of the internet are constantly making efforts to promote the improvement of the total factor productivity of enterprises. At the same time, the new generation of technology represented by the internet continues to improve, promoting enterprises to take the road of innovation, so as to achieve rapid development of enterprises. The regression coefficient of profit rate is 21.620, which is significantly positive, indicating that the development potential of enterprises is more conducive to the improvement of the total factor productivity of enterprises. The asset-liability ratio is significantly negative, indicating that excessive asset-liability ratio will affect the vitality of enterprises and is not conducive to the improvement of the total factor productivity of enterprises. The coefficient of capital output ratio is positive, indicating that a higher capital output ratio is conducive to the improvement of total factor productivity of enterprises.

Table 2: Empirical regression results

	Baseline	regression	Robustness tests	Fine-grained analysis	
	results		2SLS Estimated	Longer business age	Short business age
<i>TFP</i>	2.290*** (0.081)		3.651*** (0.270)	3.818*** (0.150)	2.248*** (0.082)
<i>Sale</i>	2.098*** (0.029)		3.010*** (0.029)	-3.410*** (0.068)	-4.046*** (0.030)
<i>Prof</i>	21.620*** (0.216)		19.782*** (0.216)	-53.376*** (0.398)	-45.589*** (0.221)
<i>Debt</i>	-3.279*** (0.183)		-3.283*** (0.183)	0.407 (0.398)	4.176*** (0.187)
<i>Ky</i>	1.305*** (0.034)		1.456*** (0.034)	-2.633*** (0.072)	-1.457*** (0.035)
<i>_cons</i>	13.257*** (2.324)		13.691*** (2.247)	10.351*** (0.858)	11.810*** (2.331)
Regional Effect	Yes		Yes	Yes	Yes
Industry Effect	Yes		Yes	Yes	Yes
Year Effect	Yes		Yes	Yes	Yes
Observations	115108		115108	25922	89186
	0.457		0.421	0.433	0.491

Note:***, **, *indicates significant at 1%, 5%, and 10% statistical levels, respectively; Robust standard errors are reported in parentheses.

5. Conclusion

In this paper, by analyzing the current situation of industrial internet development in Shandong province, examining the impact of industrial Internet platform development on the total factor productivity of enterprises, the following main conclusions were obtained: Firstly, the analysis of the theoretical mechanism shows that the business process management optimization of the industrial internet platform is conducive to promoting the total factor productivity of enterprises, infrastructure, business equipment, business organization and management system indicators, it helps firms to increase total factor productivity; Secondly, under the network effect of industrial internet platform, promote the integration of the two construction to promote the total factor productivity of enterprises. Sub-firm age tests show that the longer a firm survives the more mature the development of market mechanisms and the more pronounced the promotion effect.

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