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Analysis of the Effect of Digital Economy on Total Factor Productivity of Manufacturing Firms

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Abstract: The paper empirically evaluated the impact of the degree of metropolitan digital economy growth on the total factor output of businesses using panel data from manufacturing listed companies in Shanghai and Shenzhen A-shares from 2011 to 2019. It has been discovered that, first and foremost, urban digital economy growth can greatly improve business total factor output. After replacing the explanatory factors and central explanatory variables, the benchmark regression findings stay robust. Second, the impact mechanism test shows that metropolitan digital economy growth promotes company technological innovation, thereby increasing enterprise total factor output. Third, the sample is split into three samples in the eastern, central, and western regions, and the regressions are run independently in each. According to the analysis findings.

Keywords: Digital Economy, Total factor productivity of enterprises, Mechanism Analysis.

1. Introduction

As early as 1996, Negroponte's book "Digital Survival" elaborated on the idea that the digital economy can affect the level of economic development, demonstrating that advances in digital technology can lower the cost of information storage, reproduction, and dissemination, as well as improve the traceability of the content of innovative activities. In recent years, the growth of the digital economy has received national attention, with the 19th Party Congress report explicitly suggesting to "promote the profound merger of the Internet, big data, artificial intelligence and the real economy". Under the new double-cycle development pattern, the manufacturing industry is China's "ticket" to becoming a high-income country, the driving force of innovation-driven economic quality development, a powerful engine to drive employment to achieve common prosperity, and the fundamental plate to consolidate and enhance the industrial supply chain. In the future, we must unwaveringly stick to the manufacturing strategy, maintain the fundamental stability of the proportion of manufacturing industry, and consolidate and reinforce the basis of the real economy. The world is transitioning into a digital civilization, and the digital economy and finance will be the focal points of future global economic rivalry and cooperation. This social environment of rapid Internet development offers ideal circumstances for the growth of digital economy and finance, and industrial digitization has emerged as a critical field of digital technology development.

The policy implications and practical significance of this study can be summarized as follows: First, this paper studies the effect of digital technology development on the total factor productivity (TFP) of manufacturing enterprises, which can provide some theoretical basis and empirical reference for the formulation and implementation of development policies in the process of digital transformation of China's manufacturing industry; Second, this paper analyzes the direct and indirect mechanisms of the effect of digital economy development on the TFP of manufacturing enterprises in China, which has some practical significance for finding the path of TFP improvement among manufacturing enterprises in China; Third, the study of the heterogeneous effect of digital economy development level on the TFP of manufacturing enterprises can provide some practical significance for finding the path of TFP improvement among regions. Secondly, this paper analyzes the direct and indirect mechanisms of the impact of digital economy development on the TFP of manufacturing enterprises in China, which has some practical significance for finding the path of TFP improvement of manufacturing enterprises in China; Third, the study of the heterogeneous impact of digital economy development level on the TFP of manufacturing enterprises can provide some empirical evidence for the formulation of coordinated development policies between regions and reduce the development gap of manufacturing industries between different regions in China.

2. Literature Review

This paper examines the impact of the level of digital economy development on TFP of manufacturing enterprises in China from a micro perspective, and thus reviews and critiques the relevant literature from three perspectives: the impact of digital economy development and the impact of digital economy on manufacturing development.

A part of the literature explores the impact of the digital economy on technology-innovation. Negroponte argues that the application of digital technologies reduces the cost of storing, reproducing and transmitting information and enhances the traceability of content in innovation activities. [1]A similar view is shared by Yu et al. argue that emerging digital technologies have broken through the spatial, social and technological dimensions of innovation activities, lowered the threshold of innovation activities, and expanded the breadth and depth of digital innovation, which in turn has given rise to a number of new products and services. [2] Gruber et al. found that the benefits of broadband infrastructure deployment in Europe will outweigh the investment costs in the future, which helps to provide high-tech support for the whole EU or individual EU member states. [3] Xie et al. after considering factors such as endogeneity, found that the development of digital finance has a significant promotion effect on entrepreneurship. [4] A study by Wen et

al. showed that the development of the digital economy has promoted increased innovation capacity, but its potential has not yet been fully realized. [5]

There is also a part of literature that analyzes the impact of digital economy on social production. cardona et al. by summarizing previous studies found that ICT has given rise to the digital economy in the last 20 years and its development has had a significant impact on the way firms produce and provide goods and services and most studies found that ICT helps to increase firm productivity. [6] Koutroumpis et al. found that the deployment of broadband infrastructure delivers superior economic benefits compared to high technology across the EU or most individual member states. [3] He et al. further extended their research perspective and found that highly skilled employees and permanent employees can have complementary effects with ICT adoption in firms, thus significantly enhancing ICT productivity. [7] Qin et al. found that the digital economy promotes industrial structure upgrading through the paths of technological innovation and financial development. [8] Some scholars studied the impact of digital economy on manufacturing development from a macro perspective. Wei et al. based on provincial panels found that digital economy significantly promoted the high quality development of manufacturing industry. [9] While some scholars study the impact of digital economy on manufacturing development from a micro perspective. zhao et al. find that digital economy significantly contributes to the high-quality development of cities, while stimulating mass entrepreneurship is an important mechanism for digital economy to release the dividends of high-quality development. [10] Du et al. systematically examined the impact of urban digital economy on enterprise productivity in an inverted U-shape from a micro perspective, and found through heterogeneity analysis that the positive impact of digital economy on enterprise productivity was more significant in eastern regions, non-agricultural industries and medium and large enterprises. [11]

The existing literature provides a solid theoretical foundation for this study, and by combing the first studies, we can find that the existing studies have examined the measurement methods of digital economy and the impact of digital economy in various fields from multiple perspectives, and have achieved fruitful research results, but there are still some shortcomings. Firstly, few domestic and foreign studies have measured the level of digital economy development from a micro perspective, and thus the articles that study the level of digital economy development in cities on the TFP of manufacturing enterprises are even rarer. Second, there are few articles that directly study the impact of digital economy on the TFP of manufacturing enterprises, and the role of digital economy in improving the TFP of manufacturing enterprises has not been fully recognized. Therefore, this paper measures the development level of digital economy in cities and the TFP of manufacturing enterprises respectively, and on this basis, empirically investigates the impact of digital economy on the TFP of manufacturing enterprises, and examines the differences of the impact on different regions, and finally, digs deeper into the inner mechanism from the perspective of technological innovation.

3. Materials and Methods

3.1. Sample selection and data description

Using data availability as the benchmark, the panel data of manufacturing listed companies in Shanghai and Shenzhen A-shares from 2011-2019 were selected as the sample data set. The data were obtained from Wind database, CSMAR database, and China City Statistical Yearbook. The variables selected include: the explanatory variable, TFP (tfp), measured using principal component analysis; and the main explanatory variable, digital economy index (Dige), measured using generalized method of moments (GMM) method. Other control variables include, first, firm size (size), expressed using the logarithm of the firm's total assets. The larger the size of the firm, the more favorable its production scale and conditions are to enhance the level of technological innovation, thus positively contributing to TFP. Second, return on assets (roa), which is measured using the ratio of net profit to total assets. Third, labor productivity (lp), expressed using the ratio of revenue from main business to number of employees. Fourth, equity concentration (ec), expressed using the ratio of the shareholding of the first largest shareholder. Fifth, fixed assets share (pfa), which is measured in this paper using the ratio of net fixed assets to total assets. Sixth, enterprise age (age), which is expressed in this paper using the number of years the enterprise has been listed. Seventh, enterprise ownership (eo), state-owned enterprises take 1, non-state-owned enterprises take 0. Descriptive statistical characteristics of the sample are shown in Table 1.

Table 1. Descriptive statistics

Variable	Obs	Mean	Std.Dev.	Min	Max
Dige	11027	1.790686	2.258608	-1.304714	8.282353
tfp	11027	1.97	0.754	-3.002	7.37
Size	11027	8.321512	1.217665	2.596813	13.73149
roa	11027	0.0307732	0.418714	-30.68823	10.40092
Lp	11027	1.73463	18.30753	0.0072766	1426.665
Ec	11027	34.12132	14.38191	3	89.99
Pfa	11027	0.2329081	0.7396893	0.0000252	76.56212
Age	11027	10.49261	6.860509	2	30
eo	11027	0.3466038	0.4759098	0	1

3.2. Model setting

The following econometric model is set up to test the impact of digital economy development on TFP of manufacturing firms.

$$TFP_{it} = \beta_1 + \theta_1 Dige_{jt} + \lambda_1 X_{it} + \gamma_t + \mu_i + \varepsilon_{ijt}$$

where i, j, and t denote firm, city, and year, respectively. tfp is the core explanatory variable, denoting the TFP of firm i in year t; Dige is the core explanatory variable, denoting the

level of digital economic development of city j in year t; X is a set of control variables, denoting the value of control variables of firm i in year t; is a firm-varying year fixed effect; is a time-invariant industry fixed effect; denotes the random error term.

4. Empirical Results

4.1. Baseline return

This paper first examines the direct effect of the digital economy on TFP of manufacturing firms, and the regression results are shown in Table 2. On the basis of controlling for industry fixed effects and time fixed effects, the following table reports the effects of the digital economy on TFP of manufacturing firms before and after the inclusion of control variables, respectively. Column (1) shows the regression results without the inclusion of control variables, from which the regression coefficient of the main explanatory variable is 0.0407 and passes the test at the 1% level of significance. Column (2) adds the firm-level control variables such as firm size, labor productivity, and asset-liability ratio on this basis, and the regression coefficient of the core explanatory variable urban digital economy development level is significant at the 1% significance level, indicating that the development of digital economy significantly improves the TFP of manufacturing firms. Comparing columns (1) and (2), we can see that the regression coefficients of the core explanatory variables decrease and the regression fit increases after the inclusion of control variables, indicating that the model set in this paper fits the sample data better and the selection of control variables is more scientific and reasonable.

From the control variables, *size* increases the TFP of manufacturing enterprises, and the regression coefficient is 0.280, indicating that the TFP of enterprises increases by 0.280 units for each unit of increase in enterprise size. *lp* has a positive effect on the TFP of manufacturing enterprises and is significant, indicating that enterprises with higher labor productivity can usually fully coordinate the operation of various departments and thus improve the TFP of enterprises. It indicates that the stronger the concentration of equity, the higher the TFP of enterprises may be. the effect of *pfa* on enterprise TFP is not significant, which may be because, the fixed assets of manufacturing enterprises fail to realize quickly to meet the demand for capital in the flood of the development of digital economy, which affects the digital change of enterprises, and the impetus brought by the percentage of fixed assets to enterprise TFP is yet to be released.

Table 2. Baseline return

Variables	(1) *tfp*	(2) *tfp*
Dige	0.0407*** (0.00322)	0.0315*** (0.00276)
size		0.280*** (0.00805)
roa		0.118*** (0.0418)
lp		0.00655** (0.00307)
ec		0.00146*** (0.000425)
pfa		-0.0525 (0.0515)
age		0.00883*** (0.00117)
eo		0.0206 (0.0148)
Constant	1.895*** (0.00852)	-0.574*** (0.0635)
Observations	11,024	11,024
R-squared	0.345	0.522

Note: *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively, with robust standard errors between parentheses. The following tables use the same notations. This table takes into account control variables, Time-fixed effects, Industry-fixed effects and Area- year-fixed effects, which are the same in the following tables.

4.2. Robustness tests

In order to exclude the influence of other external factors not taken into account on the test and estimation results, and to examine whether the selection of indicators and the model construction are reasonable, this section will conduct robustness tests on the designed empirical model.

First, in order to avoid measurement errors caused by inappropriate measurement methods, the TFP of enterprises is re-measured by the LP method and the digital economy development index is re-measured by the principal component analysis method, and the regression analysis is re-run respectively. The results are shown in Table 3. Columns (1) and (2) report the regression results of the digital economy on the re-measured TFP of enterprises, and it is found that the regression coefficients of the core explanatory variables are 0.0438 and 0.0260 respectively, and both are significant at 1% significance level, and the direction of the coefficients is basically consistent with the baseline regression results, which indicates that the digital economy development has a

significant positive effect on the TFP of manufacturing enterprises. This verifies that the measure of TFP of enterprises in this paper is reasonable. Columns (3) and (4) report the regression results after re-measuring the digital economy development index. From the regression results, we can see that the digital economy still positively promotes the TFP of manufacturing enterprises. Columns (1)-(4) show that the regression coefficients of the core explanatory variables are still significantly positive after adding the control variables, but the magnitudes of the coefficients are reduced and the goodness of fit is increased, which further indicates that the control variables in this paper are more reasonably chosen.

Table 3. Robustness tests

Variables	(1) *tfp*1	(2) *tfp*1	(3) *tfp*1	(4) *tfp*1
Dige	0.0438***	0.0260***		
	(0.00412)	(0.00267)		
Score1			0.420***	0.346***
			(0.0366)	(0.0317)
size		0.547***		0.281***
		(0.00777)		(0.00805)
roa		0.103***		0.118***
		(0.0394)		(0.0417)
lp		0.00447*		0.00656**
		(0.00233)		(0.00307)
ec		0.00190***		0.00146***
		(0.000406)		(0.000425)
pfa		-0.0130		-0.0524
		(0.0360)		(0.0516)
age		0.00892***		0.00883***
		(0.00115)		(0.00117)
eo		0.0520***		0.0232
		(0.0146)		(0.0148)
Constant	4.133***	-0.568***	1.852***	-0.620***
	(0.0106)	(0.0604)	(0.0120)	(0.0637)
Observations	11,024	11,024	11,023	11,023
R-squared	0.371	0.722	0.344	0.522

4.3. Further testing

Based on Yu et al.'s study[12], this paper argues that digital economy development has the potential to enhance TFP of firms by promoting firm innovation, and therefore this paper tests the mechanism by developing the following mediating effect model.

$$Ino_{it} = \beta_0 + \beta_1 Dige_{jt} + \lambda X + \gamma_t + \mu_i + \varepsilon_{it} \quad (2)$$

$$TFP_{it} = \beta_0 + \beta_1 Dige_{jt} + \xi Ino_{it} + \lambda X_c + \gamma_t + \mu_i + \varepsilon_{it} \quad (3)$$

In the above model, Ino denotes technological innovation, and the ratio of R&D expenditure to total assets is used as a proxy variable to measure the level of technological innovation, and the meanings of other variables are consistent with (1). As shown in Table 4, digital economy development has a significant positive effect on firms' technological innovation, and the regression coefficient of dige is 0.100, indicating that digital economy development can promote the level of technological innovation. When ino is added to model (1), the level of technological innovation remains significantly positive. Meanwhile, the regression coefficient of the core explanatory variables is positively significant at 0.0270, which is smaller than the baseline regression result of 0.0315, indicating that the mediating effect does exist, and the mechanism of the effect of the digital economy on the TFP of enterprises is verified.

4.4. Heterogeneity analysis

The previous conclusion shows that the development of digital economy has a positive effect on the TFP of enterprises, and explores the path of the effect of digital economy on the TFP of enterprises, then whether there is a difference in the effect of digital economy development on the TFP of enterprises in different regions, which is further explored in this paper. In this paper, the 180 prefecture-level cities in the sample are divided into eastern, central and western regions, and the regression analysis is conducted separately. The regression results are shown in Table 5. In (1), the regression results for the eastern region, the coefficient of the core explanatory variable dige is 0.00570 and passes the test at the 5% significance level. The regression coefficient of dige is 0.0657 and passes the test at 1% significance level. In (3), the regression results for the western region show that the impact of digital economy development on TFP of enterprises is not significant. Comparing columns (1)-(3) it can be seen that the digital economy has the strongest impact on TFP of firms in the central region, followed by the eastern region and the weakest in the central region. This may be due to the fact that the central region is late in the development of digital economy compared to the eastern region, so there is still more room for the development level of digital economy in the central region. In contrast, the digital economy in the western region has no development advantage because of its geographical location and resource advantage, so the positive impact of digital economy on TFP of enterprises in the

western region is still not reflected.

Table 4. Mechanism analysis

Variables	(1) *ino*	(2) *tfp*
ino		0.0453*** (0.0158)
Dige	0.100*** (0.0160)	0.0270*** (0.00324)
size	-0.135*** (0.0491)	0.287*** (0.00789)
roa	-1.002* (0.588)	0.163*** (0.0549)
lp	0.00340 (0.00383)	0.00640** (0.00292)
ec	0.000255 (0.00187)	0.00144*** (0.000411)
pfa	6.901*** (0.142)	-0.365*** (0.117)
age	-0.00467 (0.00551)	0.00905*** (0.00115)
eo	-0.145** (0.0741)	0.0272* (0.0143)
Constant	1.654*** (0.394)	-0.649*** (0.0643)
Observations	11,024	11,024
R-squared	0.814	0.544

Table 5. Heterogeneity analysis

Variables	(1) *tfp*	(2) *tfp*	(3) *tfp*
Dige	0.00570** (0.00272)	0.0657*** (0.0187)	0.000899 (0.0159)
size	0.273*** (0.00922)	0.281*** (0.0212)	0.269*** (0.0282)
roa	0.344** (0.151)	0.0584** (0.0256)	0.275*** (0.0556)
lp	0.0116** (0.00562)	0.00271*** (0.000444)	0.209*** (0.0323)
ec	0.00122*** (0.000457)	0.00130 (0.00132)	0.00269** (0.00121)
pfa	-2.164*** (0.0730)	0.0224*** (0.00683)	-1.203*** (0.171)
age	0.00643*** (0.00138)	0.0128*** (0.00325)	0.00641* (0.00365)
eo	0.0544*** (0.0179)	0.143*** (0.0404)	0.220*** (0.0417)
Constant	0.0519 (0.0758)	-0.733*** (0.169)	-0.685*** (0.217)
Observations	7,464	2,014	1,539
R-squared	0.637	0.669	0.775

5. Conclusions

This paper analyzes the impact of urban digital economy level on TFP of manufacturing enterprises based on panel data of manufacturing companies listed in Shanghai and Shenzhen from 2011 to 2019. Firstly, a benchmark regression model is set and regression analysis is conducted on the sample, and it is found that the development of digital economy positively promotes the TFP of enterprises during the sample period. Secondly, this paper conducts robustness tests by replacing the explanatory variables and core explanatory variables separately, and the test results show that the baseline regression results are robust, and the higher the level of digital economy development is, the higher the TFP of manufacturing enterprises in the region. This paper uses the mediating effect model to test the impact mechanism, using technological innovation as the mediating variable, and the results show that the development of urban digital economy stimulates enterprise innovation and thus improves the TFP of enterprises. Finally, heterogeneity analysis is conducted in

this paper. The main sample is divided into the eastern region sample, the central region sample and the western region sample, and the regression analysis is done for each of the above three sub-samples. The results found that the level of urban digital economy development has the strongest contribution to enterprise TFP in the central region and the weakest in the western region. Based on the above findings, the following suggestions are made: first, vigorously develop the digital economy and promote the digital transformation of enterprises. At present, from a worldwide perspective, the development of the digital economy is still the general trend, and the digital economy is still the main driving force of future economic development. Second, we should focus on the coordinated development of the digital economy region. It is necessary to make different development policies in different regions according to local conditions, so as to effectively stimulate the coordinated development of digital economy in various regions and narrow the regional development gap. Third, increase R&D investment and promote technological innovation. The impact mechanism test in the previous section shows that the digital economy enhances productivity by stimulating innovation. Enterprises increase R&D funding and strengthen cooperation with research institutes, which can promote technological innovation and increase productivity.

References

[1] Negroponte, N., Harrington, R., McKay, S. R., and Christian, W. (1997). Being digital. Computers in Physics, 11(3), 261-262.

[2] Yu, J., Meng, Q., Zhang, Y., Zhang, X., and Chen, F. (2017). Digital innovation: Exploration and enlightenment of the new perspective of innovation research. Studies in Science of Science, 35(07), 1103-1111. (in Chinese)

[3] Gruber, H., Hätönen, J., and Koutroumpis, P. (2014). Broadband access in the EU: An assessment of future economic benefits. Telecommunications Policy, 38(11), 1046-1058.

[4] Xie, X., Shen, Y., Zhang, H., and Guo, F. (2018). Can Digital Finance Promote Entrepreneurship? —— Evidence from China. China Economic Quarterly, 17(04), 1557-1580. (in Chinese)

[5] Wen, J., Yan, Z., and Cheng, Y. (2020). Research on the Effect of Digital Economy on Upgrading Innovation Capacity—— Based on Provincial-Level Panel Data. Reform of Economic System(03), 31-38. (in Chinese)

[6] Cardona, M., Kretschmer, T., & Strobel, T. (2013). ICT and Productivity: Conclusions from the Empirical Literature. Information Economics and policy, 25(3), 109-125.

[7] He, X., Liang, Q., and Wang, S. (2019). Information Technology, Workforce Structure, and Firm Productivity: Solving the "IT Productivity Paradox" Puzzle. Journal of Management World, 35(09), 65-80. (in Chinese)

[8] Qin, J., Zhao, J., and Wang, W. (2022). Mediating Effect of Digital Economy on Industrial Structure Upgrading and Empirical Evidence. Statistics & Decision, 38(11), 99-103. (in Chinese)

[9] Wei, Z., Li, Y., and Wu, K. (2021). Can Digital Economy Promote High-quality Development of Manufacturing Industry? —— Empirical analysis based on inter-provincial panel data. Wuhan Finance(03), 37-45. (in Chinese)

[10] Zhao, T., Zhang, Z., and Liang, S. 2020. “Digital Economy, Entrepreneurship, and High-Quality Economic Development: Empirical Evidence from Urban China.” Journal of Management World 36 no. 10:65–76. (in Chinese)

[11] Du, C., Zhang, Y. (2021). Research on the Influence Mechanism of Digital Economy Development on Enterprise Productivity Growth. Securities Market Herald (02), 41-51. (in Chinese)

[12] Yu, S., Xu, H., and Kong, L. 2022. “The Impact of the Level of the Digital Economy on the Efficiency of Resource Allocation in China’s Manufacturing Industry.” Finance and Trade Research. (in Chinese)