Analysis of the Impact of Digital Economy Development on the Scale of Labor Demand: Empirical Test Based on Listed Companies

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Abstract. The development of digital economy brings opportunities and challenges to Chinese enterprises. This paper incorporates the development of digital economy and the labor demand of enterprises into the same analytical framework, with the help of data from the National Bureau of Statistics, CSMAR database and annual reports of enterprises, and takes 2,160 non-financial listed companies in 31 provincial regions of China (except Hong Kong, Macao and Taiwan) as the research samples in the period of 2013-2022, and utilizes entropy weighting to derive the digital economic development level, and empirically examined the impact of digital economy development on labor demand using a panel data model. It is found that digital economic development has a significant positive impact on the scale of labor demand, and there is a non-linear relationship between the two, i.e., there is a double-threshold effect with the enterprise digital transformation index as the threshold variable; further heterogeneity test finds that the digital economic development has a heterogeneous effect on the labor demand of listed companies in different industries. In this regard, this paper puts forward the relevant policy recommendations for the continuous promotion of labor demand, so that it can not only enrich the content of the research on the development of the digital economy, but also has an important significance for how to solve the employment problem in the era of the digital economy, and then for the realization of maintaining social stability and high-quality development of the economy.

Keywords: digital economy; labor force; demand scale

1 Introduction

With the rapid development and wide application of digital technology, the digital economy is gradually becoming a new driving force for global economic development. The epoch of digital economy has quietly arrived in full force, providing unprecedented strong support for the development of various industries while also bringing great impact. Its double-edged sword effect is most typically seen in its impact on the labor market[1]. Data from the National Bureau of Statistics shows that the number of jobs

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provided by urban units in information transmission, software and information technology service industry grew from 1.86 million in 2010 to 5.29 million in 2022, a growth rate of 184.4%. From the above data, it is clear that it has not only driven rapid economic growth, but also created a large number of job opportunities for China, significantly promoting the prosperity of the job market, but according to McKinsey's prediction, by 2030, at least 118 million people in China will be replaced by artificial intelligence or robots[2]. Labor, as the core and most active factor of production, constitutes the fundamental driving force and decisive factor that drives the continuous development of productive forces[3]. Digital work platforms are reshaping labor markets around the world in unprecedented ways, leading revolutionary changes in employment patterns and labor allocation[4]. The development of the digital economy is profoundly affecting the labor demand of enterprises is a complex issue, which needs for in-depth analysis and research from multiple dimensions. In view of this, this paper will study the development of enterprises in the context of digital economy, identify its impact on the diversity and complexity of labor demand, and put forward relevant policy recommendations by combing and organizing the existing literature.

The possible marginal contributions of this paper lie in the following: first, this article uses the entropy weight method to scientifically evaluate and quantify the level of digital economy development in 31 provincial-level regions across the country. Subsequently, the evaluation results are effectively integrated with the data of listed companies obtained through the CSMAR database, and in-depth empirical tests are conducted to reveal the inherent connection and impact mechanism between digital economy development and enterprises. Second, using a threshold model, it was found that the development of the digital economy has a dual threshold effect on labor demand, with the enterprise digital transformation index as the threshold variable, indicating that this effect has nonlinear characteristics. Third, examine the heterogeneous impact of digital economy development on the scale and structure of labor demand between industries, explore its differential effects on different industries, and reveal the true characteristics of enterprise labor demand under the background of the booming digital economy.

2 Theoretical Analysis and Hypotheses

2.1 The Direct Impact of Digital Economy Development on Labor Demand

The digital economy[5] mainly affects the demand for labor through the positive effects of “job creation” and “job compensation” and the negative effect of “job extrusion”[6]. First, he employment creation effect is reflected in the development process of the digital economy, which has given birth to numerous emerging industries and created a large number of new job opportunities. A large number of emerging industries have emerged, which drive the development of related industrial chains, thus further expanding labor demand. Some scholars have found that, contrary to common concerns, digital applications have instead led to a significant rise in labor demand. Combining the above analysis, this paper proposes Hypothesis 1: from a long-term perspective, the development of the digital economy can significantly promote the expansion of labor demand scale.

2.2 The Nonlinear Impact of Digital Economy Development on Labor Demand

Through the analysis above, reveals that the impact of the digital economy on the demand for labor is generated through the joint action of three effects: employment creation, employment compensation and employment crowding out. Traditional industries, empowered by digital technology, have realized the improvement of production efficiency and product quality, while at the same time giving rise to many new industries and fields. These changes have brought new employment opportunities to the labor market, so the scale of labor demand has increased accordingly with the deepening of digital transformation. Combined with the above analysis, this paper puts forward Hypothesis 2: the impact of the development of the digital economy on labor demand exhibits non-linear characteristics, and its degree of influence is constrained by the threshold effect measured by the digital transformation index.

2.3 Heterogeneity Analysis of Labor Demand in the Development of Digital Economy

Different sectors have different modes of operation and therefore have different needs and skill requirements for labor. Cai Fang (2021)[7] assumed that the society is composed of two sectors, manufacturing and service, so the labor force displaced from one of them is bound to enter the other. Liu Yurong et al. (2016)[8] found that the service sector's ability to absorb employment has a significant stage characteristic, its demand for labor will reach saturation, or even show a downward trend. On the contrary, the labor demand of manufacturing industry may show a rising trend. And there are different views in the academic community on what characteristics of the skill structure of the labor force in the development of digital economy, and some believe that it may lead to unidirectional polarization or bipolarization of employment skills. Combined with the above analysis, this paper puts forward Hypothesis 3: the promotion effect of digital economic development on labor demand varies in the structure of employees in different fields, and the promotion effect on technicians will be more significant.

3 Formula Setting for Calculating the Level of Development of the Digital Economy

Considering the existence of multiple definitions of indicators for measuring digital economic development in the literature, this paper uses the level of digital economic development to use this indicator to accurately measure the level of development of the digital economy in specific regions or fields.t. Adopts eight secondary indicators as shown in Table 1, and specifically corresponds to 18 tertiary indicators.

3.1 Formula Setting for Calculating the Level of Development of the Digital Economy

In order to facilitate the comparison of different indicators, the data need to be standardized. In this study, considering that the selected economic indicators have a positive promoting effect on the development of the institutional system, we identified them as positive indicators and accordingly adopted the calculation method of positive indicators for analysis, so formula (1) is set as:

$$Y_{ij} = \frac{X_{ij} - \min\{X_j\}}{\max\{X_j\} - \min\{X_j\}} \tag{1}$$

Where Y_{ij} is the standardized value, X_{ij} represents the original data of indicator j in province i, where i = 1, 2, ..., 31; j = 1, 2, ..., 18

3.2 Determine the Weight of Indicators

This article uses entropy weighting method to assign weights to the above indicators. The final weight results are shown in Table 1.

Table 1. evaluation system for the development level of digital economy.

first-class targets	second-class targets	third-class targets	Unit	Weight
digital fundamentals	mobile fundamentals	mobile phone penetration rate	department/100 people	0.0159
		capacity of mobile telephone exchange	ten thousand households	0.0267
	fixed infrastructure foundation	internet broadband access port	ten thousand	0.0342
		number of web pages	ten thousand	0.1390
		number of Domain Names	ten thousand	0.0789
digital applications	personal application	number of digital TV users	ten thousand households	0.0303
		proportion of actual cable radio and television users	%	0.0282
	enterprise applications	number of websites per hundred enterprises	each	0.0063
		proportion of enterprises engaged in e-commerce transactions	%	0.0157
digital innovation	innovation investment	full time equivalent R&D personnel of industrial enterprises above designated size	person year	0.0830
		R&D funds for industrial enterprises above designated size	ten thousand yuan	0.0755
	innovation output	proportion of invention patent applications by industrial enterprises above designated size and total number of patent applications	%	0.0124
		technology market transaction volume	ten thousand yuan	0.1133
digital industry	E-commerce development and transformation	software business revenue/GDP	%	0.0837
		E-commerce sales revenue/GDP	%	0.0408
		E-commerce procurement amount/GDP	%	0.0436
	new product benefits transformation	new product development expenses	ten thousand yuan	0.0875
		new product sales revenue	ten thousand yuan	0.0850

Data source: National Bureau of Statistics.

3.3 Calculate the Development Level of the Digital Economy

Based on the weights measured above and equation (2), the level of development of the digital economy can ultimately be determined.

$$dig_{it} = \sum_{j=1}^{18} X_{it} W_j \tag{2}$$

X_{it} denotes the standardized value of indicator j in province i, and W_j denotes the final weight of indicator j measured by entropy weight method, where i=1, 2, ..., 31; j=1, 2, ..., 18.

The data of digital economy measurement indicators mainly come from the National Bureau of Statistics, due to some are missing, in order to successfully complete this study, the vacant data have been supplemented by linear interpolation.

4 Sampling and Study Design

4.1 Sampling and Data Sources

Panel data of 2,160 non-financial listed companies in 31 provincial-level regions in China from 2013 to 2022 are selected as a sample. The data related to the explanatory variables have been explained in detail in the previous chapter. The main data sources include the CSMAR database and corporate annual reports, which provide raw information on the dependent variable and other key control variables. In order to ensure the comprehensiveness and balance of the information obtained, this paper excludes ST, ST* and some listed companies with serious missing data, and further excludes listed companies with data anomalies based on the variable settings.

4.2 Model Setting

Linking theory and practice, the construction of the measurement model is shown in equation (3):

$$\ln labor_{it} = \alpha_0 + \beta dig_{jt} + \gamma Controls_{it} + \mu_j + \lambda_t + \varepsilon_{ijt} \tag{3}$$

Where, i、j、t denotes listed companies, provinces and years respectively, α_0 is the intercept term, $\ln labor_{it}$ denotes the explanatory variable, i.e. the labor demand of listed company i in the t year; β is the regression coefficient of the digital economy on the labor demand of enterprises, dig_{jt} is the core explanatory variable, i.e. the level of the development of listed company i in the digital economy in the t year; $Controls_{it}$ is the control variable, denotes the influence of the development scale of listed company

i on their labor demand; μ_j is the unobservable regional effect of province j ; λ_t is the time effect, ε_{ijt} is the random disturbance term.

4.3 Variable Selection

4.3.1. Explained Variables.

The explanatory variable of this paper is labor demand. Using the total number of employees of listed companies as a specific measurement indicator to evaluate and analyze the relevant situation, and in order to avoid pseudo-regression and eliminate heteroskedasticity, the total number of employees will be logarithmically processed in the following.

4.3.2. Explanatory Variables.

The explanatory variables of this paper, i.e. (dig_{jt}) , have been measured and calculated through various indicators in the previous section.

4.3.3. Control Variables.

Taking into account the impact of the enterprise's economic situation on its labor demand, the following data that can indicate the scale of enterprise development are selected to be controlled: fixed assets (fa) , total assets (ta) , operating income growth rate (rgr) , growth rate of net assets $(groe)$, sales profit growth rate $(gagr)$ and sustainable growth rate (sgr) , and descriptive statistics are obtained through calculations, as shown in Table 2.

Table 2. summary statistics.

	Variables	*N*	*M*ean	*SD*	*Min*	*Max*
Explained Variable	ln *labor*	21600	7.830	1.330	0.690	13.25
Explanatory Variable	*dig*	21600	0.250	0.160	0.020	0.640
Control Variables	*fa*	21600	5.080e+09	2.590e+10	1335	7.330e+11
	ta	21600	2.220e+10	1.000e+11	3.084e+06	2.730e+12
	rgr	21600	0.240	31.96	-2.680	4500
	groe	21600	0.0100	0.810	-113.1	9.160
	gagr	21600	2.760	148.1	-828.4	16055
	sgr	21600	0.0100	0.230	-16.99	8.110
Threshold Variable	*dti*	21600	37.51	10.91	21.38	80.04

5 Empirical Results and Analysis

5.1 The Impact of Digital Economy Development on Labor Demand

Before conducting the benchmark regression analysis, the sample data model is first subjected to the Hausman test, and since the p-value is infinitely close to 0. Based on the results of data analysis, we reject the null hypothesis of using a random effects model and instead choose a fixed effects model for more accurate and appropriate analysis.

Based on the benchmark model (3) constructed in the previous section, Table 3 presents the estimated impact of digital economy development on labor demand, with a regression coefficient of 0.631 for the key explanatory variable - the level of digital economy development, reaching a statistical significance level of 1%. This result indicates a significant positive correlation between digital economy development and labor demand. In other words, the development of the digital economy has had a significant positive impact on labor demand, thus verifying the correctness of Hypothesis 1.

Table 3. the impact of digital economy development on labor demand.

Variables	(1) ln *labor*	(2) ln *labor*	(3) ln *labor*	(4) ln *labor*
dig	0.701***	0.669***	1.163***	0.631***
	(0.097)	(0.105)	(0.055)	(0.097)
_cons	7.655***	7.586***	7.457***	7.595***
	(0.025)	(0.028)	(0.014)	(0.025)
Control Variables	×	√	√	√
Fixed individual effects	√	√	√	√
Fixed time effects	√	√	×	√
Fixed regional effects	√	×	√	√
N	21600	21600	21600	21600
Adj_R^2	0.883	0.885	0.885	0.887

Note: (1)The standard error of clustering robustness is in parentheses.

(2) *, * *, * * represent statistical significance levels at 0.1, 0.05, and 0.01, respectively.

5.2 Robust Test

Here, when evaluating the level of development of the digital economy, digital economy input indicators and digital economy output indicators were used as measurement standards, repeating the previous operation, using the entropy weighting method to assign weights to the asset inputs, labor inputs, technological inputs, digital technologies and tools, electronic and communication equipment manufacturing industry, telecommunication and Internet industry, software and information technology service industry, digitization of traditional industry and digitization of governmental environment 18 indicators are assigned, and bring it into formula (3) for regression. As municipalities

have special administrative status and development advantages, and their statistical data are usually more comprehensive and accurate, this may result in municipalities being overweighted in the sample, which affects the robustness and reliability of the overall research results. Therefore, this paper exclude the samples of Beijing, Shanghai, Tianjin and Chongqing. The results, as shown in Table 4, the benchmark regression conclusion is further supported.

Table 4. robustness test results.

Variables	(1) Replace explanatory variable		(2) Exclude municipalities directly under the central government	
dig	0.500***	0.463***	0.854***	0.837***
	(0.076)	(0.075)	(0.108)	(0.106)
_cons	7.713***	7.644***	7.633***	7.544***
	(0.019)	(0.019)	(0.026)	(0.028)
Control Variables	×	√	×	√
Fixed individual effects	√	√	√	√
Fixed time effects	√	√	√	√
Fixed regional effects	√	√	√	√
N	21600	21600	21600	21600
Adj_R^2	0.883	0.886	0.876	0.882

5.3 The Nonlinear Impact of Digital Economy Development on Labor Demand

The digital transformation index of listed companies is set as a threshold variable to discuss the role of digital economic development on labor demand as the digital transformation of enterprises continues to deepen. In this paper, hypothesis testing is conducted on whether the existence of threshold effects, and the results are shown in Table 5.

Table 5. threshold effect test.

Model	*F − value*	*P − value*	*Bootstrap*	*critical value*		
				1%	5%	10%
Single threshold	108.19***	0.0000	1000	38.1042	30.0276	25.0814
Double threshold	90.69***	0.0000	1000	36.3383	28.1365	23.5572
Triple threshold	42.35	0.2120	1000	97.4192	73.5535	62.5809

In addition, Figure 1 further depicts the correspondence between the $LR-value$ and the thresholds and clearly plots the non-rejection domain of the true thresholds. Where the lowest point of the $LR-value$ corresponds to the true threshold value, it is clear that the single and double thresholds are less than the critical value of 7.35, while the triple threshold did not reach a statistically significant level and did not pass the test. In

summary, there is a double threshold effect in this paper with digital transformation index as the threshold variable.

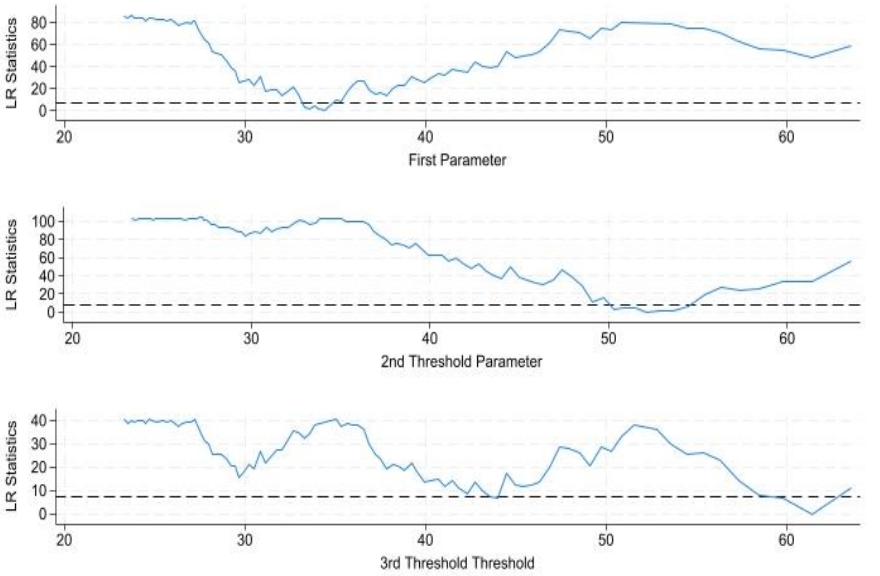

Fig. 1. threshold effect test result chart.

Table 6 shows the results of threshold regression analysis, from which it can be clearly observed that the positive promotion effect of digital economy on labor demand is significant at the 1% level in the three different stages of division. This indicates that with the deepening of enterprise digital transformation, the promotion effect of digital economy development on labor demand is gradually increasing. The regression results confirm that Hypothesis 2 holds.

Table 6. threshold effect regression results.

Variable	*regression coefficient*	*t – value*
$dti < 34.4195$	0.624*** (0.127)	4.93
$34.4195 \le dti < 52.1337$	0.980*** (0.116)	8.47
$dti \ge 52.1337$	1.362*** (0.120)	11.39
_cons	7.519*** (0.029)	259.47
N	21600	
Adj_R^2	0.085	

5.4 The Impact of Digital Economy Development on Labor Demand in Different Industries

Due to differences in the application and acceptance of digital technology among different industries, the impact of digital economy development on their labor demand varies, some industries may be more likely to adopt the changes brought about by digital technology, while others may take a relatively longer time to adapt to the digital economy era. This paper divides the 2,160 non-financial listed companies into two categories: manufacturing and service industries, and empirically analyzes the impact of the level of explanatory variables on different industries. Table 7 shows that the level of digital economy development shows a significant positive correlation on both manufacturing enterprises and service enterprises.

From the perspective of the demand structure for labor skills, the digital economy development presents a facilitating effect on employees of any skill level, but the facilitating effect on technicians is more significant in the manufacturing industry compared to the service industry. The possible source for this phenomenon may be the manufacturing industry is undergoing a profound transformation and upgrading with the introduction of concepts such as Industry 4.0 and Smart Manufacturing. In this process, the application of a large number of new technologies and processes is increasing the demand for technicians. In summary, Hypothesis 3 is established.

Table 7. the impact of digital economy development on labor demand in different industries.

Variables	Manufacturing Industry			Service Industry		
	ln *labor*	Technical staff	Non technical	ln *labor*	Technical staff	Non technical
dig	0.679***	2.576***	0.499***	0.640***	1.114**	0.529***
	(0.111)	(0.310)	(0.123)	(0.168)	(0.453)	(0.178)
_cons	7.648***	5.072***	7.477***	7.488***	4.970***	7.194***
	(0.029)	(0.083)	(0.032)	(0.045)	(0.122)	(0.048)
Control Variables	√	√	√	√	√	√
Fixed individual effects	√	√	√	√	√	√
Fixed time effects	√	√	√	√	√	√
Fixed regional effects	√	√	√	√	√	√
N	13358	13358	13358	8224	8224	8224
Adj_R^2	0.901	0.654	0.882	0.903	0.705	0.900

Note: Regarding the significance test of inter group coefficient differences, the test was conducted on the labor demand of manufacturing and service industries, and the results were not significant, making it impossible to directly compare the coefficient sizes.

6 Conclusions

The arrival of the digital economy has led to profound changes in the way people live and work. At this critical moment, the digitalization of enterprises and the employment of the working population have become particularly prominent. In this context, this paper puts the relative level of digital economy development and enterprise labor demand in a framework to study, which has certain theoretical significance.

The research conclusions mainly include: first, it significantly promotes the scale of labor demand in enterprises. Second, its impact on labor demand is phased, with a dual threshold effect based on the digital transformation index as the threshold variable. That is, as a company's digital transformation deepens, its demand for labor becomes increasingly strong, and the number of positions provided by the company will increase accordingly. Finally, the heterogeneity analysis based on the perspective of segmented industries shows that it significantly promotes the total scale of labor demand in manufacturing and service industries, and any industry has a promoting effect on both technical and non-technical personnel. Therefore, how to achieve a positive interaction between it and expanding enterprise demand, improving employment quality, protecting employees squeezed out of the labor market due to the development of the digital economy, and creating new job positions for employees, is a problem that needs to be emphasized and solved at this stage.

Based on the above analysis, this study suggests that the focus of education and training should be shifted to digital skills to improve the digital literacy of workers. First, support for the digital transformation of enterprises should be strengthened to enhance the prevalence and quality of digital transformation. Formulate and improve relevant standards and specifications for digital transformation, and guide enterprises to carry out transformation in accordance with standard requirements. At the same time, strengthen the publicity and promotion of the standards, and improve enterprises' awareness and implementation of the standards. Second, strengthen labor market adaptation. Strengthen skills training and re-education for the labor market, and improve the digital skills and innovation ability of workers. Through the establishment of special training programs, workers' enthusiasm for learning and innovative ability will be stimulated. Finally, improve the employment service system. Provide workers with accurate employment information and guidance services. Through a combination of online and offline methods, an employment service platform has been set up to promote an effective match between labor supply and demand.

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