

Research on the Impact of Data Factor Marketization Allocation on Agricultural Total Factor Productivity

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Abstract

In the era of digital economy deeply enabling the real economy, the market-oriented allocation of data elements has become the key path to promote the improvement of agricultural total factor productivity. This paper selects the panel data of 30 provinces in China from 2010 to 2024 as the research data, introduces the two-way fixed effect model for benchmark regression, and explores the impact of data factor marketization on agricultural total factor productivity, and supports the results through robustness test and time heterogeneity test. At the same time, this paper empirically analyzes the regulatory effect of digital talent aggregation, measures the impact of digital talent aggregation on agricultural total factor productivity, and tests the regional heterogeneity. Finally, the empirical test results are summarized.

Keywords

Market-oriented Allocation of Data Elements; Agricultural Total Factor Productivity; Digital Talent Gathering.

1. Introduction

Agricultural total factor productivity is the core indicator to measure the level of high-quality agricultural development, and its sustained growth is of key significance for ensuring food security and promoting agricultural modernization[1]. However, as the marginal contribution of traditional factors of production to agricultural output tends to decline, the growth momentum of China's agricultural total factor productivity is facing transformation pressure. In this context, data, as a new type of production factor, is considered to be an important breakthrough to break through the constraints of traditional factors and activate agricultural production potential because of its unique attributes such as non competitiveness, low marginal cost and strong permeability. However, whether the data elements can be effectively transformed into the growth momentum of agricultural total factor productivity through market-oriented allocation is still lack of sufficient theoretical interpretation and empirical verification.

In recent years, the national level has intensively issued a series of policy documents around the marketization of data elements and the transformation of agricultural digitization. In 2024, the Ministry of agriculture and rural areas issued the national action plan for smart agriculture (2024-2028), which clearly proposed to promote the digital transformation of the entire agricultural industry chain. At the same time, the State Council stressed the need to accelerate the improvement of the digital level of agricultural production, rural life and rural governance in the deployment of work related to the construction of digital villages. These policy signals show that the strategic position of data elements in agricultural and rural modernization has been highly valued, but the actual effect of policy promotion and whether the market-oriented

allocation of data elements can effectively improve agricultural production efficiency still need empirical research to provide scientific basis.

Existing studies have shown that the marketization of data elements has a direct impact on agricultural total factor productivity. By clarifying data property rights, reducing transaction costs, and promoting the cross regional circulation of data resources, the marketization of data elements enables decentralized agricultural production entities to obtain key information such as market supply and demand, meteorological disasters, and soil moisture at a low cost, so as to alleviate the long-standing information asymmetry in agricultural production and improve the efficiency of factor allocation and the accuracy of resource utilization.

To sum up, the existing research has formed rich achievements around the market-oriented allocation of data elements, agricultural total factor productivity and the correlation between the two. However, this research field is still in a new and developing category, and there is still a lack of sufficient empirical data and verification support on the mechanism of data factor marketization allocation on agricultural total factor productivity. This paper constructs a multi-dimensional evaluation system to quantify the level of data factor marketization allocation and agricultural total factor productivity. At the same time, through in-depth analysis of the regulatory effect of digital talent accumulation on agricultural total factor productivity, this paper discusses the promotion effect of data factor marketization allocation on agricultural total factor productivity, aiming to put forward suggestions for data factor marketization allocation to enable agricultural total factor productivity.

2. Literature Review

Academic circles have carried out multi-dimensional research around agricultural total factors and data elements, and formed rich achievements. Specifically, there are three categories: first, special research on market-oriented allocation of data elements; Second, the independent discussion of agricultural total factor productivity; Third, a comprehensive study on the correlation between the market-oriented allocation of data elements and agricultural total factor productivity.

In the special research on the market-oriented allocation of data elements, the market-oriented allocation of data elements is of key significance to realize the efficient allocation and sharing of data elements, release the potential of elements and maximize value, and enable high-quality economic and social development [2]. From the perspective of economic impact, the marketization of data elements is the core path to activate the potential of data as a "new" economic element. Taking the manufacturing industry as the empirical field, the improvement of its marketization level significantly drives the growth of total factor productivity (GTFP) of the manufacturing industry through the triple path of technical efficiency improvement, innovation ability cultivation and human capital accumulation, while enabling the green transformation of the manufacturing industry by relying on mechanisms such as data insight, process optimization and green technology innovation [3]; Research shows that the level of market-oriented allocation of data elements is significantly and positively driven by six core factors: human resource endowment, innovation ability, economic development level, advanced industrial structure, data trading platform construction and policy support [4]. Among them, data transaction is the key link, and its system innovation and standardized operation directly determine the circulation efficiency and value realization degree of data elements[5].

In the independent discussion on agricultural total factor productivity, from the perspective of high-quality development, the growth of agricultural total factor productivity (TFP) is the core indicator to measure agricultural modernization[6]. The impact mechanism shows multidimensional characteristics: the level of economic development has a significant positive

driving effect on agricultural total factor productivity[7], and the correlation between individual agricultural socialized services and agricultural total factor productivity is differentiated, with the highest correlation between means of production services and social public services [8]. Studies in the eastern region show that rural population aging has a significant positive impact on agricultural total factor productivity and agricultural technology progress[9].

In the comprehensive research on the correlation between the marketization of data elements and agricultural total factor productivity, from the perspective of digital service management, the coupling effect of data-driven decision-making, precision service supply and industrial chain synergy mechanism plays a core enabling effect on the improvement of agricultural total factor productivity[10]. Taking the digitalization of agriculture and rural areas as the research starting point, its significant positive role in promoting agricultural total factor productivity is mainly achieved by improving agricultural technical efficiency [11]. The empirical study based on the panel data of nine prefecture level cities in Fujian Province from 2011 to 2021 shows that digital Inclusive Finance has a significant positive impact on the agricultural total factor productivity of the province[6]. The empirical study based on the provincial panel data of the Yellow River Basin from 2012 to 2021 shows that the total index of digital Inclusive Finance and its coverage, depth of use, and digitization degree sub dimension index have a significant positive impact on the agricultural green total factor productivity (GTFP) and its technological progress and technical efficiency dimensions of the basin[12]; Based on the county panel data of 26 mountainous counties in Zhejiang Province from 2014 to 2021, the empirical study shows that there are significant differences in the impact of various dimensions of digital Inclusive Finance on agricultural total factor productivity: the promotion effect of the depth of use is the most significant, followed by the breadth of coverage, and the impact of the degree of digitization is relatively weak[13].

To sum up, the existing literature explores the path and impact mechanism of agricultural total factor productivity from the dimensions of digital economy, digital service management, and digital Inclusive Finance, and has formed rich achievements. However, this research field still belongs to the emerging and developing category. The existing research focuses on the driving effect of digital economy on agricultural development, while the research on the impact of the market-oriented allocation of data elements is not sufficient, lacking sufficient empirical data and verification support, and needs to be further explored and verified. This paper constructs a multi-dimensional evaluation system to quantify the level of data elements, and uses the benchmark regression model to analyze the specific effect of market-oriented allocation of data elements on agricultural total factor productivity. At the same time, combined with robustness test and time heterogeneity analysis, it enhances the credibility of the conclusion; In depth analysis of the regulatory effect of digital talent accumulation on agricultural total factor productivity, and through the analysis of regional heterogeneity, this paper discusses the promotion effect and influencing factors of data factor marketization allocation on agricultural total factor productivity, so as to help the development of agricultural modernization and digitization.

3. Mechanism of Action and Research Hypothesis

3.1. Direct Impact of Marketization of Data Elements on Agricultural Total Factor Productivity

In the era of digital economy, data has become a key factor of production, and its market-oriented allocation level is directly related to the effective circulation of factors, thus affecting the growth of total factor productivity. Agricultural production is deeply affected by multiple uncertain factors such as natural conditions and market fluctuations. Information asymmetry

is the key bottleneck restricting the improvement of efficiency. The marketization of data elements has broken the long-standing information barriers in the agricultural field. The market-oriented allocation of data elements enables high-quality agricultural data to flow efficiently to the field of agricultural production and management through the trading platform. In addition, the deep integration of data elements and traditional agricultural elements, through the aggregation and analysis of massive agricultural production data, can achieve precision seeding, variable rate fertilization, intelligent irrigation, and greatly improve the marginal output of resources. Through the "Data-Driven" agricultural model, optimizing the production process and improving the efficiency of factor combination directly promoted the leap of agricultural total factor productivity (Qian Li et al., 2025)[14]. Therefore, the improvement of the level of market-oriented allocation of data elements can inject new development momentum into agriculture and promote its transformation from traditional resource dependent to innovation driven. Based on the above analysis, this paper proposes the following research hypotheses:

H1: The marketization of data elements has a significant positive role in promoting agricultural total factor productivity.

3.2. Promotion Effect of Market-oriented Allocation of Data Elements on Agricultural Total Factor Productivity

The market-oriented allocation of data elements aims to realize the efficient circulation and value release of data resources through the market mechanism, thereby enabling the improvement of agricultural production efficiency[15]. This process is highly dependent on digital talents with digital skills. The improvement of data factor market has improved the development level of regional digital economy, enhanced the siphon effect of regions on digital talents, and promoted the aggregation of digital talents to regions with developed data factor market. From the perspective of regional development, the accumulation of digital talents is often closely related to the level of regional economic development and digital infrastructure. Due to the sufficient reserve of digital talents in the eastern region, the marketization of data factors plays a more significant role in promoting agricultural total factor productivity; Due to the shortage of digital talents in the central and western regions, it may be difficult to fully release the efficiency of market-oriented allocation[14]. Therefore, the accumulation of digital talents is not only an important condition for the market-oriented allocation of data elements to play a role, but also may further strengthen its positive impact. In the field of agriculture, on the one hand, high-level rural human capital can activate the endogenous driving force of rural development, promote the innovation efficiency in rural areas, and promote the diversified development of industrial structure, so as to broaden the development channels of digital economy and enhance the enabling effect of digital economy on agricultural total factor productivity[16]. On the other hand, the improvement of digital talent aggregation level is conducive to knowledge spillover effect, guiding the rapid flow of various resource elements between urban and rural areas, helping the high-quality development of digital economy in rural areas, and further improving agricultural total factor productivity. Based on this, this paper puts forward the following assumptions:

H2: Digital talent aggregation positively regulates the impact of data factor marketization on agricultural total factor productivity. The higher the level of digital talent aggregation, the stronger the promotion of data factor marketization on agricultural total factor productivity.

4. Research Design

4.1. Samples and Data Sources

In this paper, the panel data of 30 provinces in China from 2010 to 2024 (excluding Hong Kong, Macao, Taiwan and Tibet) are selected as the research samples, and a total of 450 observations are obtained. The research data are mainly from China Statistical Yearbook, China Rural Statistical Yearbook, China digital economy development report and the statistical yearbooks of various provinces. For the missing values in the data set, linear interpolation method is used to supplement and improve. The descriptive statistics of variables are shown in Table 1:

Table 1. Descriptive statistics

VarName	Obs	Mean	SD	Min	Median	Max
Marketization configuration of data elements	450	0.1176	0.121	0.00	0.08	0.71
Agricultural total factor productivity	450	0.4697	0.206	0.11	0.43	1.00
Digital talent aggregation level	450	0.0501	0.137	0.00	0.01	1.70
Infrastructure construction	450	98.9151	1.261	92.60	99.30	100.00
Level of financial support for agriculture	450	0.1129	0.034	0.04	0.11	0.20
Urbanization rate	450	60.3718	12.308	33.81	59.38	89.85
Per capita GDP yuan	450	6.30e+04	34136.16	753.54	54683.00	228167.00

4.2. Variable Selection

4.2.1. Explained Variable

Agricultural total factor productivity (y). Referring to the practice of Xinyuan et al. (2025), this paper uses Malmquist index method in data envelopment analysis (DEA) method to measure agricultural total factor productivity[17]. Referring to existing studies, the total sown area of crops (1000 hectares), the total power of agricultural machinery (10000 kilowatts), the effective irrigation area (1000 hectares), the net amount of agricultural chemical fertilizer (10000 tons), and the total amount of agricultural water (100 million cubic meters) are selected as input indicators, and the total output value of agriculture, forestry, animal husbandry and fishery (100 million yuan) is selected as output indicators. Through calculation, the agricultural total factor productivity index of each province is obtained.

4.2.2. Core Explanatory Variables

Table 2. Comprehensive evaluation system for market-oriented allocation of data elements

Primary indicator	Secondary index	Indicator attribute
Vitality of marketization subject	Software business income	+
	Number of employed persons in urban units of information transmission, software and information technology services	+
Market scale	Total telecom business	+
	Number of Internet broadband access ports	+
Market environment	Capacity of mobile telephone exchange	+

Data element marketization configuration (DIG). Drawing on the research ideas of wangjiaming et al. (2023), this paper constructs a comprehensive evaluation index system of data element marketization allocation from the three dimensions of data element marketization subject vitality, marketization scale and marketization environment[18], and uses entropy method to measure the comprehensive index of data element marketization allocation. The index can

comprehensively reflect the development level of data element market and the efficiency of data resource allocation in various regions.

4.2.3. Control Variables

Infrastructure construction (TV) is measured by the comprehensive population coverage rate of TV programs (%), reflecting the level of regional information infrastructure construction; Financial support for agriculture is measured by the ratio of local fiscal expenditure on agriculture, forestry and water affairs (100 million yuan) to local general public budget expenditure; The urbanization rate (urban) is measured by the proportion of urban population in the total population of the region at the end of the year; The per capita GDP (money) is expressed by the regional population/Gross Regional Product at the end of the year.

4.3. Model Construction

In order to test hypothesis 1, this paper constructs ordinary least squares (OLS) model, individual fixed effect model and time fixed effect model to estimate.

$$Y_{it} = \alpha_0 + \alpha_1 \text{Digit}_{it} + \beta_1 \text{TV}_{it} + \beta_2 \text{Finance}_{it} + \beta_3 \text{Urban}_{it} + \beta_4 \text{Money}_{it} + \delta_t + \mu_i + \varepsilon_{it}$$

Among them, subscripts *i* and *t* represent provinces and years, respectively; *Y_{it}* is the agricultural total factor productivity; *Digit* is the core explanatory variable, market-oriented allocation of data factors; *TV_{it}*, *Finance_{it}*, and *People_{it}* are control variables; *μ_i* is the provincial fixed effect, controlling for region-specific heterogeneity that does not vary over time; *δ_t* is the year fixed effect, controlling for macro shocks that change over time; *ε_{it}* is the random error term. *α₁* is the estimated coefficient, indicating the impact effect of market-oriented allocation of data factors on agricultural total factor productivity. If *α₁* is significantly positive, research hypothesis 1 holds.

5. Empirical Analysis

5.1. Benchmark Regression Analysis

Table 3. Basic regression results

	(1)	(2)	(3)	(4)	(5)
	OLS no control	Individual Fe	Bi directional fixed effect Fe	PCSE	FGLS
Marketization configuration of data elements	1.2384*** (0.1866)	0.4443* (0.2484)	0.3468* (0.2000)	0.1271*** (0.0336)	0.1582*** (0.0387)
Infrastructure construction		0.0239* (0.0131)	0.0255* (0.0139)	-0.0372** (0.0175)	-0.0144** (0.0062)
Level of financial support for agriculture		-1.6931*** (0.4537)	-1.1812** (0.5230)	-2.5344*** (0.2569)	-2.5363*** (0.1781)
Urbanization rate		0.0154*** (0.0033)	0.0079 (0.0079)	-0.0001 (0.0011)	-0.0026*** (0.0007)
Per capita GDP		0.0074 (0.0284)	-0.0074 (0.0172)	0.0277 (0.0325)	0.0735*** (0.0205)
<i>N</i>	450	450	450	450	450
R-sq		0.7646	0.8093	0.5587	
Adj. R-sq		0.7619	0.8009		

Note: in brackets are cluster robust standard errors, and PCSE and FGLS models have controlled the time fixed effect; * *p*<0.10, ** *p*<0.05, *** *p*<0.01

Column (1) has no control variable; Column (2) control individual fixed effect; Column (3) two way fixed effect model; Column (4) PCSE; Column (5) FGLS**p*< 0.10, ***p*< 0.05, ****p*< 0.01

In order to test the effect of data factor marketization allocation on agricultural total factor productivity, this paper uses panel regression model for benchmark analysis. Before setting the model, the multicollinearity test is carried out to ensure the reliability of the estimation results. The test results show that the variance expansion factor (VIF) of each variable in the model is less than 3, indicating that there is no serious multicollinearity interference, which lays the foundation for subsequent regression analysis. In order to further explore the specific mechanism of the market-oriented allocation of data elements on agricultural total factor productivity, the panel regression model was used for benchmark regression analysis. The regression results are shown in Table 3.

Column (1) of Table 2 shows the mixed OLS regression without control variables. The regression coefficient of data element marketization allocation level is 1.2384, which is significantly positive at the 1% level, indicating that the improvement of data element marketization allocation level has a significant positive impact on agricultural total factor productivity. Specifically, the agricultural total factor productivity index is expected to increase by 1.2384 units for each unit of data element marketization allocation level. Column (2) introduces the individual fixed effect, and the coefficient of data elements is 0.4443, which is significant at the 10% level, indicating that after controlling the inherent characteristics of each province that do not change with time, the promoting role of market-oriented allocation of data elements still exists. Column (3) after controlling the two-way fixed effect, the data element coefficient is 0.3468, which is also significantly positive at the 10% level, further strengthening the reliability of the core conclusion. Moreover, even after the introduction of control variables in columns (2) and (3), the regression coefficient of data elements is still positive, which further confirms the positive role of market-oriented allocation of data elements in promoting agricultural total factor productivity. In the robustness test of column (4) PCSE and column (5) FGLS, the data element coefficients were 0.1271 and 0.1582 respectively, which were significantly positive at the 1% level, and the core conclusion was robust. Hypothesis 1 was verified.

5.2. Robustness Test

In order to ensure the reliability of the benchmark regression results, this paper tested the robustness from three aspects: eliminating the epidemic year, changing the estimation method and dealing with extreme values. In order to eliminate the accidental factors of the results, four robustness test measures were further implemented: (1) eliminate the samples in the epidemic year. Considering that the new crown epidemic in 2020-2022 may have an abnormal impact on agricultural production and factor market, this paper re-estimated the regression after eliminating the samples in 2020-2022. (2) Random effect model was used. In this paper, the random effect model is used for estimation to deal with the possible errors caused by the setting form of individual effects. (3) Tail reduction 1%. In order to eliminate the potential impact of extreme values on the regression results, this paper conducted 1% tailing treatment on all continuous variables before regression. (4) 5% tail reduction treatment. The continuous variables were further treated with 5% tailing to test the sensitivity of the conclusion to different tailing degrees.

The robustness test results showed that column (1) after excluding the epidemic samples, the regression coefficient of market-oriented allocation of data elements was 0.440, which was significantly positive at the 1% level; Column (2) in the random effect model, the data element coefficient is 0.480, which is also significantly positive at the 1% level; Column (3) after tailing 1%, the data element coefficient is 0.354, which is significantly positive at the 1% level; After column (4) is tailed by 5%, the data element coefficient is 0.244, which is significantly positive at the 5% level. The above results are basically consistent with the benchmark regression model in the direction of coefficient and significance level, and the significance is reduced from

1% to 5% after tailing 5%, but it is still statistically significant. It shows that the market-oriented allocation of data factors can have a positive impact on agricultural total factor productivity, and the conclusion that the market-oriented allocation of data factors can promote agricultural total factor productivity is robust.

Table 4. Robustness test results

	(1)	(2)	(3)	(4)
	Eliminate epidemic Fe	Random effect	Shrink tail 1%	Tailing 5%
Marketization configuration of data elements	0.440*** (0.074)	0.480*** (0.079)	0.354*** (0.082)	0.244** (0.109)
Infrastructure construction	0.020*** (0.007)	0.025*** (0.007)	0.016** (0.007)	0.005 (0.007)
Level of financial support for agriculture	-1.612*** (0.324)	-0.785** (0.325)	-1.460*** (0.332)	-0.907*** (0.337)
Urbanization rate	0.015*** (0.001)	0.010*** (0.001)	0.012*** (0.002)	0.010*** (0.002)
Per capita GDP	0.007 (0.014)	0.032** (0.016)	0.076*** (0.028)	0.135*** (0.031)
<i>N</i>	360	360	360	360

Standard errors in parentheses

Note: 1 Eliminate the epidemic samples from 2020 to 2022; 2. the clustering robust standard is in brackets, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; 3. tailing treatment for all continuous variables (1% and 5%).

5.3. Time Heterogeneity Analysis

Table 5. Time heterogeneity: grouped regression before and after 2015

	(1)	(2)	(3)
	Full sample	2015 and before	2016 and beyond
Marketization configuration of data elements	0.4443* (0.2484)	0.4242 (0.3936)	0.2682* (0.1428)
Infrastructure construction	0.0239* (0.0131)	-0.0006 (0.0091)	0.0136 (0.0106)
Level of financial support for agriculture	-1.6931*** (0.4537)	0.1380 (0.4954)	-1.3274*** (0.4771)
Urbanization rate	0.0154*** (0.0033)	0.0135*** (0.0029)	0.0180*** (0.0051)
Per capita GDP	0.0074 (0.0284)	0.0087 (0.0090)	0.1429** (0.0628)
<i>N</i>	450	180	270
Within R-sq	0.7646	0.6404	0.7653

Note: in brackets are robust standard errors of provincial clustering; All models controlled for individual fixed effects; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The action plan for promoting big data issued by the State Council in 2015 and the big data industry development plan (2016-2020) issued by the Ministry of industry and information technology in 2016 both proposed to realize online and offline transactions of data elements

through the construction of data trading platform, promote the integration of data element resources, and then realize their rational allocation. Between 2015 and 2017, there were a large number of big data trading platforms in China [15], and the process of data element marketization configuration entered an accelerated period. Therefore, this paper divided the whole sample into two periods, 2015 and before, 2016 and after, and tested the time heterogeneity of the impact of data element Marketization configuration on agricultural total factor productivity.

In column (1) of Table 5, the coefficient of market-oriented allocation of data elements is 0.4443, which is significantly positive at the 10% level, which is consistent with the conclusion of benchmark regression. Column (2) in the subsample of 2015 and before, the data element coefficient was 0.4242, which failed the significance test; Column (3) in the subsample of 2016 and later, the data element coefficient is 0.2682, which is significantly positive at the 10% level. This shows that the promotion effect of data elements on agricultural total factor productivity has not yet appeared before 2015, but has begun to play a significant positive effect after 2016. In addition, within R^2 of the whole sample is 0.7646, 0.6404 in 2015 and before, 0.7653 in 2016 and after, and the explanatory power of the later model is stronger. To sum up, the role of market-oriented allocation of data elements in promoting agricultural total factor productivity has gradually emerged over time.

5.4. Regulation Effect Analysis

5.4.1. Regulation Effect

The results of the moderation effects are shown in Table 6.

Table 6. Regulatory effect results

	(1)	(2)	(3)	(4)
	Control variables only	Join the main effect	Add interactive item	Bidirectional fixation effect
Infrastructure construction	0.015 (1.164)	0.024* (1.850)	0.023* (1.785)	0.024* (1.701)
Level of financial support for agriculture	-1.767*** (-4.018)	-1.670*** (-3.732)	-1.723*** (-3.908)	-1.333** (-2.616)
Urbanization rate	0.018*** (6.398)	0.016*** (4.774)	0.016*** (4.804)	0.008 (1.100)
Per capita GDP	0.035 (0.612)	0.007 (0.259)	0.006 (0.234)	-0.008 (-0.487)
Marketization of data elements		0.351 (1.360)	0.331 (1.272)	0.277 (1.333)
Digital Talent Gathering		0.088** (2.452)	-0.045 (-0.455)	-0.272*** (-2.843)
Interactive items			0.329 (1.519)	0.641** (2.588)
Cons	-2.312** (-2.132)	-2.731** (-2.354)	-2.662** (-2.320)	-2.184 (-1.549)
<i>N</i>	450	450	450	450
<i>R</i> ²	0.739	0.769	0.771	0.816

Column (1) of table 6 shows the individual fixed effect model with only control variables. Column (2) on the basis of column (1), the market-oriented allocation of data elements after centralization and the main effect of digital talent accumulation are added. Among them, the

coefficient of C digital talent aggregation is 0.088, which is significantly positive at the 5% level, indicating that digital talent aggregation has an independent role in promoting agricultural total factor productivity. Column (3) further introduces the interactive term of the two, and the coefficient of the interactive term is 0.329. At this time, the coefficients of the market-oriented allocation of c u data elements and the accumulation of c u digital talents are 0.331 and -0.045, respectively, which do not reach a significant level. Column (4) after controlling the two-way fixed effect, the coefficient of c u interaction term is 0.641, which is significantly positive at the 5% level, indicating that after controlling the inherent characteristics and common time trend of provinces at the same time, digital talent accumulation plays a positive regulatory role in the relationship between data factor Marketization and agricultural total factor productivity. Specifically, the higher the level of digital talent accumulation, the stronger the effect of data factor marketization on agricultural total factor productivity. At the same time, in column (4), the main effect coefficient of c_digital talent accumulation is -0.272, which is significantly negative at the 1% level, and the main effect of c_data element marketization allocation is 0.277, but not significant, which indicates that when the data element allocation level is low, simply increasing digital talent may lead to resource crowding out or inefficient allocation, while the positive significance of the interaction term indicates that there is a complementary mechanism between the two, and the effect of data elements needs to be based on a certain level of talent accumulation. In terms of the goodness of fit of the model, the R² of column (1) was 0.739, column (2) increased to 0.769, column (3) was 0.771, and column (4) further increased to 0.816, indicating that the explanatory power of the model on agricultural total factor productivity was significantly enhanced after adding interactive terms and controlling the two-way fixed effect. To sum up, the interactive term between the market-oriented allocation of data elements and the accumulation of digital talents is significantly positive under the two-way fixed effect, and hypothesis 2 is verified.

5.4.2. Regional Heterogeneity

The results of the regional heterogeneity test are presented in Table 7.

Table 7. Regional heterogeneity

	(1)	(2)	(3)	(4)
	Full sample	Eastern Region	Central region	Western Region
Marketization of data elements	0.2767 (0.2077)	0.1167 (0.2036)	0.2694 (0.2551)	-0.3409 (0.5916)
Digital Talent Gathering	-0.2718*** (0.0956)	-0.4382** (0.1697)	-0.0039 (0.0902)	0.0298 (0.6095)
Interactive items	0.6414** (0.2478)	0.9346** (0.4163)	-0.7061 (1.3892)	-0.9718 (3.9663)
N	450	165	120	165
Within R-sq	0.8162	0.8352	0.9392	0.8584

In column (1) of table 7, the coefficient of C' interaction term is 0.6414, which is significantly positive at the 5% level, which is consistent with the conclusion of regulatory effect. Column (2) in the sub sample of the eastern region, the coefficient of the C Φ interaction term is 0.9346, which is also significantly positive at the 5% level, and the absolute value of the coefficient is greater than that of the whole sample, indicating that the positive regulatory effect of digital talent aggregation in the Eastern region is more prominent. In the subsample of column (3) in the middle region, the coefficient of C' interaction term was -0.7061, and in the subsample of column (4) in the west region, the coefficient of C' interaction term was -0.9718, which failed the significance test. From the goodness of fit of the model, the within R² of the eastern, central

and Western sub samples were 0.8352, 0.9392 and 0.8584 respectively, which were higher than 0.8162 of the whole sample, and the explanatory power of the sub regional model was strong. In conclusion, the positive regulatory effect of digital talent aggregation has significant regional heterogeneity, and this effect is only established in the eastern region, but not significant in the central and western regions.

6. Conclusion

Based on the provincial panel data from 2010 to 2024, this paper constructs a variety of econometric models to investigate the impact of data factor marketization on agricultural total factor productivity. The results show that: first, the market-oriented allocation of data factors can significantly promote agricultural total factor productivity, which is still true after the robustness test. Second, the promoting effect of market-oriented allocation of data elements on agricultural total factor productivity gradually appears over time. Third, the improvement of digital talent aggregation level can further deepen the enabling effect of data factor marketization allocation on agricultural total factor productivity. The level of digital talent aggregation is related to regional economic development. The enabling effect of digital talent aggregation is more obvious in the eastern region with a higher level of economic development.

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