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Analysis of dynamic relationship between agricultural products circulation service industry and circulation efficiency in less developed regions: based on data from Western China

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The market circulation system for agricultural products in less-developed regions lags behind; it fails to meet the requirements for efficient circulation. Therefore, it is crucial to explore the dynamic relationship between the Agricultural Products Circulation (APC) service industry and circulation efficiency. Using panel data from 29 regions in China, the entropy method measured the Development Level (DL) of the APC service industry, while the non-oriented super-efficiency Slacks-Based Measure (SBM) model was employed to assess the APC efficiency. A Panel Vector Autoregressive (PVAR) model was built for estimation. The impulse response function and variance decomposition were utilized to analyze the differences in the DL of the APC service industry, circulation efficiency, and their interaction mechanism across the Western, Central, and Eastern regions of China. The findings indicate that the DL of the APC service industry and APC efficiency in the less-developed regions of the West have a positive driving effect on each other. However, the magnitude of this effect was asymmetric and transient. The APC service industry's DL and APC efficiency are more dependent on their inertia, and no efficient two-way feedback mechanism has been formed. This study provides a reference for the construction and sustainable development of modernized APC systems in less-developed regions.

KEYWORDS

agricultural circulation service industry, circulation efficiency, interaction mechanism, smallholder farmers, Western China

1 Introduction

Promoting the development of less-developed regions is an effective way to achieve coordinated regional development. However, the establishment of a market circulation system for agricultural products in these regions lags behind, hindering the efficient circulation of agricultural products (Park and Lee, 2016). Smallholder farmers face natural disadvantages in accessing markets. Agricultural production services are pivotal in linking them to modern agriculture and technological advancements in farming can increase agricultural income (Khan et al., 2022). Moreover, agricultural digital transformation broadens sales channels to improve circulation efficiency (Zhang and Fan, 2023). Blockchain technology can help identify

and trace losses and contamination in the circulation of agricultural products to ensure food safety (Sharma et al., 2023). Attention to the cold chain logistics of agricultural products has been increasing. Cold chain logistics can reduce the loss of agricultural products in the process of circulation to ensure a degree of freshness (Jin, 2019). Smallholder farmers often face economic barriers to the application of advanced agricultural technologies (Dhillon and Qianna, 2023). Currently, the modernization of the Agricultural Products Circulation (APC) system in the less-developed regions of western China is evolving. Given the case of uneven development, conducting a comparative study of the differences in the APC service industry, circulation efficiency, and their interaction mechanisms among the Western, Central, and Eastern regions of China is significant for promoting the modernization of the APC system in these regions.

In the less-developed regions of Western China, smallholder farmers face inherent challenges in accessing markets. This highlights the crucial role of agricultural production services in bridging small-scale agriculture with modern practices. The APC service industry is an offshoot of agricultural production services, crucial in agricultural development. It encompasses various activities within the agricultural products wholesale market, including procurement, origin processing, storage, transportation, loading and unloading, packaging, distribution, and information management. This comprehensive service system extends to ancillary services such as agricultural product information, finance, business, and technology support. It forms an integral part of the modern agricultural landscape (Hong and Hong, 2007). Studies have found that clusters can promote the development of the APC service industry (Razminiene et al., 2021). For a significant duration, APC has provided a linkage between production and marketing, facilitating the transformation of agricultural value. Furthermore, it guides the production decisions of operation subjects. A key objective of agricultural modernization is to establish a high-quality APC system. Currently, the increasing consumer demand necessitates enhanced operational efficiency within APC systems. This underscores the need to promote the construction of high-quality modern APC systems.

2 Literature review

Effective and sustainable agricultural circulation systems are essential for future social development (Preiss et al., 2022), a concept evolving alongside urbanization and the development of modern logistics (Griffith and Watson, 2016). Sustainable agriculture prioritizes increasing farmers' income (Xu et al., 2021); which is positively and significantly affected by Social capital and smallholder participation in markets (Arsal et al., 2020; Mkuna and Edilegnaw, 2022). Owing to the low elasticity of demand for agricultural products, fluctuations in supply can have a relatively large impact on farmers' incomes (Eckstein and Syrquin, 1971). Circulatory development promotes rural economic growth and is crucial for alleviating rural poverty (He, 2012; Zheng, 2020). Circulation development has led to a gradual reduction in farmers' transaction costs, subsequently improving their income levels (Voors and D'Haese, 2010; Ojango et al., 2018). Farmers' consumption is closely tied to their income. As rural incomes rise, so does rural consumption, potentially expanding the rural consumer market (Xia and Zhang, 2010). The effective circulation of agricultural products should bring stable income and competitive advantage to farmers (Tošović-Stevanović et al., 2020). While the current level of APC in China cannot meet the needs of modern socio-economic development and agricultural modernization (Xia, 2019), concerns about "difficult selling and expensive purchasing" arise in the APC process (Zou, 2019). The APC service industry significantly contributes to agricultural development and farmers' income. It is an integral component of the modernized construction of APC (Liu and Zeng, 2022). Modernization and commercialization of agriculture are pivotal in the development of the APC service industry (Guo, 2015). Oil is an important strategic resource; international oil prices can also impact the APC service industry and circulation costs are closely linked to oil prices (Vochozka et al., 2020a,b). The APC service industry can increase its speed and reduce the cost of circulation (He and Jia, 2013). This digital transformation and reduction in distribution links can improve the Efficiency of APC (Raimbekov et al., 2023; Zhou and Chen, 2023). Some researchers have developed a fuzzy comprehensive evaluation model to measure the level of the APC service industry (Peng and Wang, 2022). Concerning circulation efficiency measurement, different scholars have used the Analytical Hierarchy Process (AHP), Data Envelopment Analysis (DEA), a super-efficiency model with undesirable outputs, and other methods to conduct their research (Su et al., 2019; Tošović-Stevanović et al., 2020; Guo and Li, 2022). Some scholars have conducted related research on the industry linkage effect of the APC service industry (Kim et al., 2021), the interactive development of logistics information services (Wang et al., 2019), and the dynamic relationship between influencing factors and APC efficiency (Wang et al., 2022; Liu, 2023).

Overall, previous studies have primarily focused on the pre-production and production processes of agriculture. Furthermore, little attention has been given to the post-production process. Studies on the APC service industry, which primarily analyze the impact of the APC Service Industry on the increase in farmers' income and production efficiency are lacking. Few studies exist on the interaction mechanism between the APC service industry and circulation efficiency, while studies on the western region in the context of regional practices remain scarce. Therefore, this study's innovation lies in the empirical analysis of the inner mechanism path of interaction between the APC service industry and circulation efficiency, comparing the differences in the Development Level (DL) of the APC service industry, circulation efficiency, and its interaction mechanism between the western region and the central and eastern regions, and providing a reference basis for the construction and sustainable development of modernization of the APC system in the Western region.

3 Theoretical mechanism analysis

3.1 Influencing mechanism of agricultural products circulation service industry on circulation efficiency

Refinement of the professional division of labor: The deepening of input factors in the APC service industry brings about a refined professional division of labor in circulation, improves the proficiency

and labor skills of labor in the process of APC, promotes the development of agricultural product marketing services, logistics services, agricultural information services, and rural financial services, and can have a positive effect on the efficiency of APC. The level of development of the APC service industry, namely, the degree of refinement of the professional division of labor in APC, determines the size of the APC capacity.

Optimization of resource allocation: The development of the APC service industry can promote industrial restructuring, optimize the resource allocation of the circulation process, expand the scope of transactions and innovative transaction methods through efficient circulation services, optimize the intermediate links of circulation, and reduce the cost of circulation, thus improving the circulation efficiency of agricultural products.

Scale operation effect: The rural basic economic system of household contract responsibility system determines that the scale of agricultural operation will not be too large, and through the specialized and market-oriented APC services, the organization of APC is enhanced, and information platforms and other facilities are provided for the communication and searching activities of each main circulation body (Jiang et al., 2017), which alleviates the disconnection and loss of production and marketing caused by information asymmetry and reduces circulation costs, thus enhancing the circulation efficiency of agricultural products.

> *H1*: The development of the agricultural products circulation service industry can improve the circulation efficiency.

3.2 Influencing mechanism of circulation efficiency on the agricultural products circulation service industry

Enhance the attractiveness to capital: The level of circulation efficiency constrains the development of products. The improvement of circulation efficiency can bring revenue growth, thus attracting more capital to enter the circulation industry, increasing the demand for APC services, further promoting the level of APC division of labor, and thus promoting the development of the APC service industry. Moreover, the improvement of circulation efficiency can promote the development of the APC service industry and determines the sustainability of the development and the support for the modernization of the APC system.

Increase the development quality of the APC service industry: In the past, the circulation of agricultural products primarily concentrated on the "quantity" guarantee but overlooked the "quality" requirements, which caused structural contradictions in the circulation of agricultural products, with a supply exceeding the demand for low-quality agricultural products and a large number of unsold products, while there is a large supply of high-quality agricultural products. The improvement of agricultural products' circulation efficiency can increase the quality of agricultural products and improve their value of agricultural products as the quality of agricultural products is directly proportional to people's demand (Nakajima, 2022), and the increase in demand can improve farmers' income and also broaden the scope of the market, which can improve the development quality of APC service industry and play a role in promoting the modernization of APC system.

> *H2*: Improvement of circulation efficiency can promote the development of the agricultural products circulation service industry.

4 Methodology and date

4.1 Variable description

4.1.1 Dvelopment level of agricultural products circulation service industry (lnS)

The APC service industry is a subdivision of the agricultural production service industry. Furthermore, the APC service industry defined in this study includes the wholesale and retail industry, transportation and storage industry, information service industry, and financial service industry, which serve the circulation of agricultural products. According to the connotation characteristics of the development of the APC service industry, the evaluation system of the development of the APC service industry in China is constructed, and the weight of each level is determined using the entropy method, and the specific index system is constructed as depicted in Table 1.

From the calculation findings in Table 2, it is evident that the average DL of the APC service industry in each region is

TABLE 1 Evaluation index system for the development of agricultural products circulation service industry in China.

Criterion layer	Index layer	Explain the index	Weight	
Agricultural products sales service	Market quantity of agricultural products	Market quantity of various agricultural products	0.29	0.57
	Market stalls of agricultural products	Number of stalls that have not operated for a year	0.28	
Agricultural logistics service	The density of the road network	Total mileage of waterways, railroads, and roads per 100 square kilometers	0.14	0.14
Agricultural information service	Internet broadband access users	Number of users with Internet access	0.20	0.20
Rural financial service	Number of rural financial institution outlets	The average number of financial institution outlets per 10,000 people in rural areas	0.09	0.09

TABLE 2 Development level of agricultural products circulation service industry in various regions.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Western average	0.118	0.125	0.135	0.144	0.154	0.176	0.196	0.197	0.208	0.219
Center average	0.164	0.175	0.187	0.197	0.203	0.228	0.255	0.262	0.269	0.281
Eastern average	0.358	0.375	0.401	0.405	0.413	0.438	0.451	0.460	0.466	0.472
Average of each region	0.214	0.225	0.241	0.249	0.257	0.281	0.300	0.306	0.314	0.324

increasing progressively in the long term, among which, the average DL of the Western region is the lowest, not yet exceeding 0.2, compared with other regions. The competitive capacity is not enough and needs to be further optimized and improved. The DL of the APC service industry in the Central region is not high and does not reach the national average, which indicates that the APC service industry in the Central region is relatively lagging behind. The DL of the APC service industry in the Eastern region is relatively high, and the gap with the Western region is above 0.2, which indicates that the development of the APC service industry in the Eastern region is effective, and the APC service industry has a tremendous competitive advantage.

4.1.2 Agricultural products circulation efficiency (lnE)

Proposed a data envelopment analysis model to measure the efficiency values of multiple input and output indexes in a measurement of decision-making unit (Charnes et al., 1978), and there are various methods to measure APC efficiency, and they are continuously developed and optimized. This study uses the non-oriented super-efficient Slacks-based measure (SBM) model to construct and measure the APC efficiency in 29 provinces, municipalities, and autonomous regions in China. In reality, the variation of input and output indexes of decision-making units is usually not in the same proportion, and the traditional efficiency model follows the assumption that input and output indexes change in the same proportion, which will lead to bias in the measurement results, and there is no way to determine who is more efficient among multiple effective decision-making units, while the super-efficient SBM model lose the assumption that input and output indexes change in the same proportion, and multiple optimal decision making units with efficiency greater than one can be compared, taking maximum slack into account while calculating the efficiency (Tone, 2001).

The Equations 1–3 is from Tone (2001).

$$\min \rho_E = \frac{1+\frac{1}{m}\sum_{k=1}^{m}\frac{s_k^-}{x_{ki}^t}}{1-\frac{1}{q}\sum_{r=1}^{q}\frac{s_r^+}{y_{ri}^t}} \quad (1)$$

$$s.t. \sum_{j=1,j\neq k}^{n} x_{kj}\lambda_j - s_k^- = x_{ki} \quad (2)$$

$$\sum_{j=1,j\neq k}^{n} y_{rj}\lambda_j + s_r^+ = y_{ri} \quad (3)$$

Among them, ρ_E is the evaluation index of APC efficiency; x_{ki} and y_{ri} are the input and output vectors of the decision-making unit, x_{ki}^t and y_{ri}^t are the elements of the input and output vectors, respectively; λ is the column vector; s_k^- and s_r^+ denote the input and output slack variables. When H1 of the decision-making unit is measured, it denotes that the best efficiency is achieved, and when $\rho_E \geq 1$ of the decision-making unit is measured, it denotes that the best efficiency is achieved, and when $0 \leq \rho_E < 1$ of the decision making unit is measured, it denotes that the best efficiency is not achieved and needs further improvement.

Since technical factors cannot be measured, the capital input, labor input, and logistics infrastructure of the APC industry were used as input indexes, and the scale of APC and circulation efficiency were used as output indexes. As for the input indexes, the capital input and labor input of the APC industry was replaced by the total social fixed asset investment in the transportation, post and telecommunications and wholesale and retail industries, and the total number of employees in the wholesale and retail, transportation, storage, and postal industries multiplied by the product of the final consumption rate. The proportion of household consumption to final consumption is approximated by the product of the Engel coefficient instead, and logistics infrastructure inputs are measured by road network density. As for output indexes, the scale of agricultural circulation is approximated by the product of final consumption rate, the proportion of household consumption to final consumption, and Engel's coefficient multiplied by the total output value of transportation, post and telecommunications, and wholesale and retail industries in the circulation industry to measure the said total output value of agricultural circulation, and the efficiency of the agricultural circulation is measured by the sales per unit of circulation subject.

The APC efficiency (lnE) of each region from 2010 to 2019 is measured, and Table 3 depicts the findings. The findings indicate that the mean value of APC efficiency in the Western region is lower contrasted to that in the east and higher contrasted to that in the Central region, and the mean value of APC efficiency in the Western region is lower contrasted to the national mean value, and there are

TABLE 3 Agricultural circulation efficiency by region, 2010–2019.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Western average	0.657	0.635	0.596	0.554	0.574	0.681	0.660	0.621	0.581	0.620
Central average	0.467	0.423	0.384	0.357	0.407	0.495	0.500	0.532	0.544	0.521
Eastern average	0.854	0.858	0.828	0.870	0.873	0.875	0.892	0.936	0.898	0.855
Average of each region	0.672	0.653	0.618	0.609	0.631	0.696	0.696	0.705	0.680	0.674

fluctuations in the mean value of circulation efficiency, which indicates that the construction of APC system in the Western region is not yet complete, and it is still in the development stage and lacks development momentum. Moreover, the mean value of APC efficiency in the Eastern region is higher, and the circulation of agricultural products is relatively efficient, indicating that the Eastern region has certain competitive advantages in the modernization of APC and the development of APC system is relatively mature and at the forefront of development.

4.1.3 Controlled variables

With the research, this study selects the level of agricultural economic development (lnA) as a control variable, denoted by the ratio of gross agricultural product to rural population; differences in the level of agricultural economic development in each region can affect the endogenous variables differently.

4.2 Model building

To investigate the dynamic relationship between the agricultural circulation service industry and the agricultural circulation efficiency in each region, the study constructs a Panel Vector Autoregressive (PVAR) model to analyze and study. The PVAR model allows all variables to be endogenous and demonstrates the dynamic impact of multiple variables, which not only can take into account the distinction of each individual but also can solve the problem of variable endogeneity by the addition of the variable lag term, and by orthogonalizing the impulse response, it is possible to decompose the effect of the impact variable on the explained variable (Abrigo and Love, 2016). The Equation 4 is from Abrigo and Love (2016).

$$y_{i,t} = \beta_0 + \sum_{j=1}^{p} \beta_j y_{i,t-j} + B_i x_i + \delta_i + \theta_t + u_{i,t} \quad (4)$$

Among them, β is the estimated parameter matrix, t denotes time, i denotes different regions, $y_{i,t}$ is the explained variable, x_i is the control variable, δ_i is the individual effect of the model associated with the explanatory variables, θ_t is the time effect of the model, $u_{i,t}$ is the random error term of the model that obeys an expectation of 0, and the individual effects can be eliminated by Helmert transformation (Arellano and Bover, 1995). The PVAR model is used to study the dynamic relationship between the DL of the APC services industry (lnS) and the APC efficiency (lnE).

4.3 Data sources

Since some key indicators of the Data is only available through 2019, On the basis of consideration of data continuity and availability, the panel data of 29 provinces, municipalities, and autonomous regions (excluding Hainan, Tibet and Hong Kong, Macao, and Taiwan) from 2010 to 2019 are selected for the study, and the missing data are completed by mean interpolation. The data are obtained from the China Stock Market Accounting Research Database, the China Statistical Yearbook, and the Statistical Yearbook of China Commodity Exchange Market for the relevant years.

5 Empirical analysis and discussion

5.1 Correlation test and optimal order determination

Before using the PVAR model for estimation, to solve the problem of spurious regression and ensure that the estimation results are not biased, it is necessary to verify the smoothness of the panel data of each region by unit root test to ensure that the data meet the requirements of the model, and various unit root tests such as Levin-Lin-Chu (LLC) test, Augmented Dickey Fuller (ADF)-Fisher test, and Im-Pesaran-Shin (IPS) test are selected in this study to ensure accurate results. After the test, the original series of the variables related to the panel data of each region did not pass all the smoothness tests, but all of them were smooth after the first-order difference, and Table 4 depicts the findings. Moreover, this indicates that lnS and lnE of each region are all first-order single integers with smoothness, and on this basis, the long-term equilibrium relationship of each variable is further examined by the cointegration test, and according to the results of the Kao test (Kao, 1999), it indicates that there is a long-term equilibrium cointegration relationship among the series of western, central and eastern regions, and the model can be constructed. The PVAR model is constructed, and the model's optimal lag order is selected by applying Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and Hannan-Quinn Information Criterion (HQIC) criteria to make judgments, and finally determines the first lag order as the PVAR model's optimal lag order for each region.

The Granger causality between the endogenous variables was tested, and the findings are depicted in Table 5. The findings indicate that the Granger causality tests in the western, central, and eastern regions reject the original hypothesis, and the DL of the APC service

TABLE 4 Unit root test.

	Variables	LLC test		ADF test		IPS test	
		Statistics	*p*-value	Statistics	*p*-value	Statistics	*p*-value
Western	D.lnS	−11.262	0.000	1.796	0.036	−3.651	0.000
	D.lnE	−7.131	0.000	1.502	0.067	−1.256	0.105
	D.lnA	−6.765	0.000	−2.545	0.005	−2.033	0.021
Central	D.lnS	−8.321	0.000	−5.550	0.000	−9.019	0.000
	D.lnE	−6.411	0.000	3.403	0.000	−2.211	0.014
	D.lnA	−2.970	0.002	4.206	0.000	−1.996	0.023
Eastern	D.lnS	−7.615	0.000	−1.950	0.026	−4.714	0.000
	D.lnE	−7.608	0.000	−3.722	0.000	−10.678	0.000
	D.lnA	−4.562	0.000	3.019	0.001	−1.879	0.030

TABLE 5 Granger causality test.

Region	H0: the former is not the granger reason for the latter	Chi-square	*p*-value	Result
Western	lnS-lnE	4.613	0.032	0.032
	lnE-lnS	11.49	0.001	0.001
Central	lnS-lnE	8.893	0.003	0.003
	lnE-lnS	3.865	0.049	0.049
Eastern	lnS-lnE	4.42	0.036	0.036
	lnE-lnS	4.413	0.036	0.036

industry (lnS) and the APC efficiency (lnE) are both mutually Granger causality. The development of the APC service industry will bring about a specialized division of labor, and the wholesale and retail, transportation and storage, financial services, and information services brought by the APC service industry will penetrate into the whole APC system, thus affecting the circulation efficiency and cost of agricultural products. The improvement of APC efficiency will act on the APC system to promote the optimization and improvement of the system, and then the demand of the APC service industry will be expanded, and finally, the development of the APC service industry will be influenced.

5.2 Correlation test and optimal order determination

5.2.1 PVAR model estimated results

Based on the smooth and cointegrated model variables, the PVAR model of each region's panel data is constructed by selecting the first lag order as the optimal lag order, and the model estimated findings are depicted in Table 6. From the findings, the coefficient of action between the DL of APC service industry (lnS) and APC efficiency (lnE) is positive, indicating a positive interaction, except for the central region, where the coefficient of action between the DL of APC service industry (lnS) and APC efficiency (lnE) is negative and has a negative effect. The coefficient of action of each region's agricultural circulation efficiency (lnE) on the DL of the APC service industry (lnS) is smaller compared with the coefficient of action of the DL of the APC service industry (lnS) on the APC efficiency (lnE), and the degree of their mutual action is asymmetrical.

It should be noted that the PVAR model for each region in this study is estimated by treating the endogenous variables with a one-period lag, which may cause the estimated parameters to be insignificant due to the collinearity problem, but this will not affect the conclusion of the analysis. The PVAR model is concerned with predictive analysis without paying much attention to the coefficients of the variables, and the variables are further investigated by constructing impulse response functions.

5.2.2 Impulse response analysis

Impulse response analysis refers to the feedback of the response of variables in the PVAR model to an endogenous variable after a standard deviation impact in the current and distant periods. In this study, the impulse response function is orthogonalized to analyze, more specifically, the dynamic relationship between the impact and response of each endogenous variable, and the number of response periods is selected to be 10. After 200 Monte Carlo simulations, the impulse response diagrams of each region are finally obtained, Figures 1–3 with the 95% confidence interval positions marked by the upper and lower curves. The diagram shows the impact response of APC efficiency (lnE) to itself, the impact response of APC service industry level (lnS) to APC efficiency (lnE), the impact response of APC efficiency (lnE) to APC service level (lnS) and the impact response of APC service level (lnS) to itself, respectively.

According to Figure 1, it can be seen that the APC service industry in the Western region has a positive impact on APC efficiency, and the development of the APC service industry can improve APC efficiency. The response value of APC efficiency (lnE) is negative after a standard deviation impact on the DL of the APC service industry (lnS), and then it is positive and peaks around the first period, and the response value decreases over time and gradually tends to zero in the third period. Moreover, compared with the Eastern region, the promotion effect is weak, indicating that in the Western region, the development of the APC service industry is insufficient, and the level of the agricultural economy is relatively backward. The promotion effect of

TABLE 6 Estimated results of the PVAR model.

Region		Western		Central		Eastern	
	Variables	Coef.	*Z*-value	Coef.	*Z*-value	Coef.	*Z*-value
lnS	lnS(−1)	−0.083	−0.45	−0.082	−0.6	0.349*	1.89
	lnE(−1)	0.016***	3.39	0.041**	1.97	0.051**	2.1
lnE	lnS(−1)	5.584**	2.15	−4.648***	−2.98	2.056**	2.1
	lnE(−1)	0.138	1.38	0.2735**	1.22	0.020	0.09

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

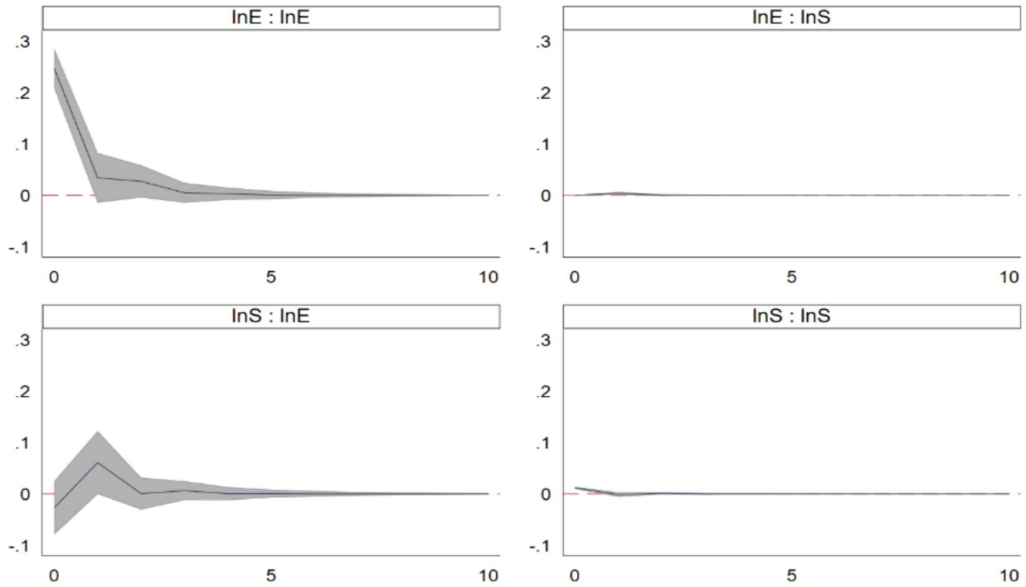

FIGURE 1
Impulse response function of PVAR model for the western region.

the APC service industry on APC efficiency is not strong and there is a temporary effect, which cannot promote APC efficiency continuously and effectively. APC efficiency has a weak positive influence on the APC service industry, and the improvement of circulation efficiency can promote the development of the APC service industry. However, the increase in circulation efficiency can promote the development of the APC service industry. The improvement of distribution efficiency can promote the development of the APC service industry. Nevertheless, the promotion is limited compared to the central and Eastern regions. The response of APC efficiency (lnE) to a standard deviation impact is positive and reaches a peak around the first period, and then decreases and gradually approaches zero. The two-way interaction between the APC service industry and APC efficiency is asymmetric, which is hindered by the level of agricultural economic development and other factors, and no effective interactive development mechanism has been formed in the Western region, which is not conducive to the construction and sustainable development of the modernization of APC system in the Western region.

According to Figure 2, it can be seen that the development of the APC service industry in the Central region hinders the improvement of APC efficiency to a certain extent. The response value of APC efficiency (lnE) is positive in the current period after a standard deviation impact on the DL of the APC service industry (lnS) and then gradually becomes negative and reaches the lowest value around the first period, and over time around the third period the impact response becomes positive and gradually becomes smaller and tends to zero. Moreover, it indicates that the APC efficiency gradually matches with the APC service industry after a period of adjustment and adaptation, and the APC service industry has a positive influence on the APC efficiency; improving the APC efficiency can drive the development of the APC service industry, and the response of the APC efficiency to the DL of the APC service industry is weak after a standard deviation impact and reaches the peak around the first period, and then starts to decline and gradually approaches zero. The Central region has not formed an efficient two-way feedback mechanism either.

According to Figure 3, the development of the APC service industry in the eastern region can increase the APC efficiency, the response of APC efficiency (lnE) is negative in the current period after a standard deviation impact on the DL of the APC service industry (lnS), and becomes positive with time, and reaches the highest peak in the first period, and the overall trend is weakening with time and gradually tends to zero. The enhancement of APC efficiency can promote the development of the APC service industry. After a

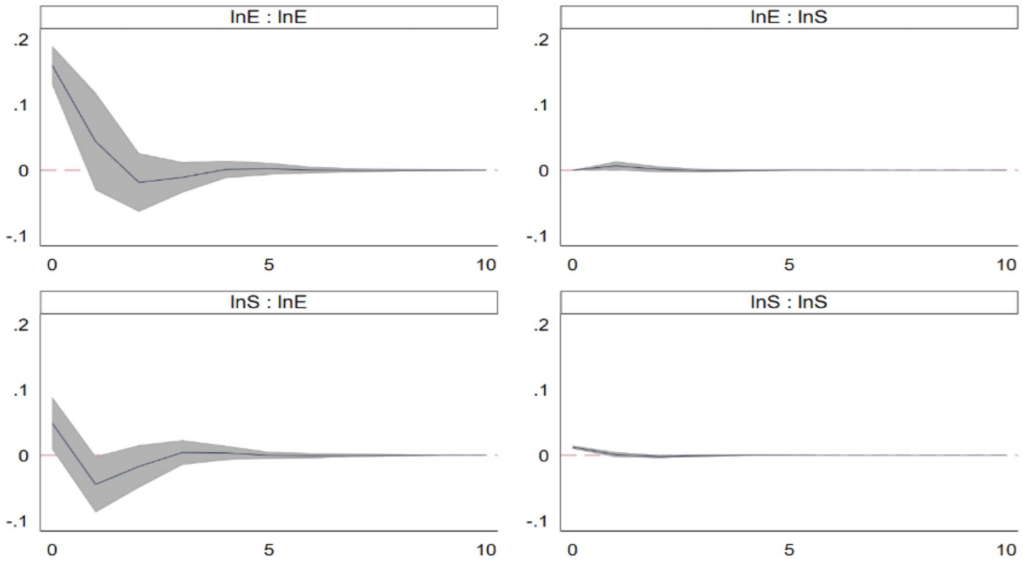

FIGURE 2
Impulse response function of PVAR model for the central region.

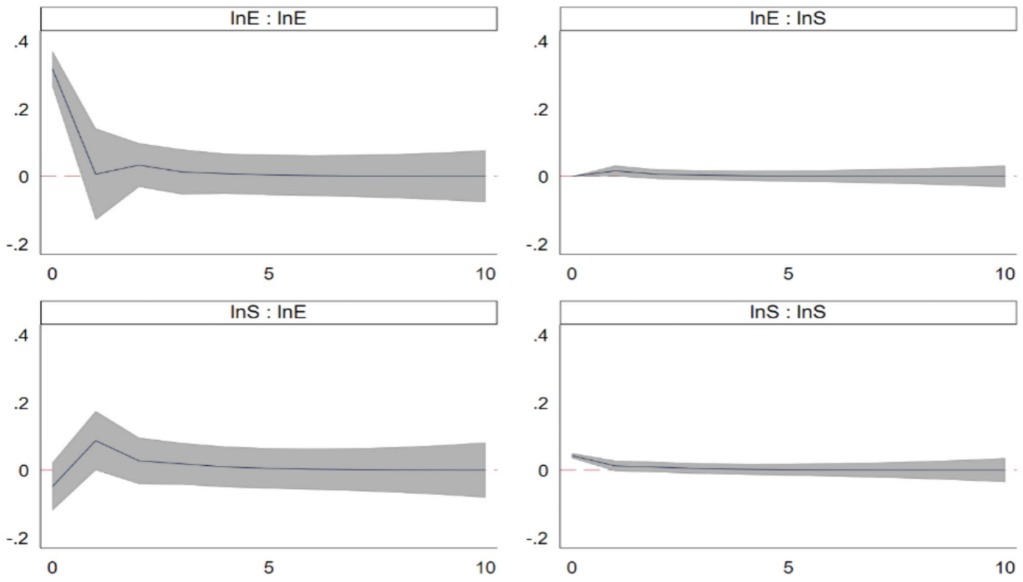

FIGURE 3
Impulse response function of PVAR model for the eastern region.

standard deviation impact on APC efficiency, the response of APC service industry DL is strong and reaches the peak around the first period, and then begins to decline gradually to zero. Furthermore, there is a positive mutual influence between the APC service industry and APC efficiency in the Eastern region. Compared with the Western and Central regions, the APC service industry and APC efficiency have a strong positive effect on each other. However, the degree of mutual effect is asymmetric, indicating that the Eastern region also has not formed an efficient two-way feedback mechanism and needs further to strengthen the modernization of the APC system, optimize the resource allocation, and improve the circulation management level.

5.2.3 Variance decomposition

To further measure the relationship between the DL of APC and circulation efficiency, this study performs variance decomposition of the forecast errors of the variables and obtains the findings as depicted in Table 7. Among them, the variance decomposition results of the 5th and 10th periods are less different, indicating that the fluctuation of each variable tends to be stable up to the 5th period. The interaction between the DL of the APC service industry and circulation efficiency in each region has been increasing over time. However, the DL of the APC service industry and circulation efficiency have stronger explanatory power for their own contribution, indicating that the DL

TABLE 7 Results of variance decomposition.

Variables	s/ period	Western		Central		Eastern	
		lnS	lnE	lnS	lnE	lnS	lnE
lnS	1	1	0	1	0	1	0
lnE	1	0.012	0.988	0.086	0.914	0.023	0.977
lnS	5	0.893	0.107	0.776	0.224	0.868	0.131
lnE	5	0.067	0.933	0.144	0.856	0.097	0.902
lnS	10	0.893	0.107	0.776	0.224	0.868	0.132
lnE	10	0.067	0.933	0.144	0.856	0.098	0.902

of the APC service industry and circulation efficiency in each region rely on their own inertia and do not form an efficient two-way feedback mechanism. The situation is particularly serious in the Western region, and it is urgent to establish an effective interaction mechanism to promote the construction and sustainable development of the modernization of the APC system.

6 Discussion

The DL progress of China's APC service industry remains in the early stages. It corresponds to the findings of other researchers (Jin, 2019; Xu and Yu, 2022), albeit displaying an upward trend. Concurrently, the Efficiency of APC was low (Guo and Li, 2022). This aligns with the findings of other scholars. The dynamic relationship between the APC service industry and circulation efficiency is complex and remains in a state of primary coordination. The APC service industry in the less-developed regions of Western China positively impacts the efficiency of APC. Thus, H1 is verified, which is similar to that of the Eastern region, albeit with heterogeneity. The Western region was stronger than the Central region and weaker than the Eastern region. The Western and Central regions are in the developmental stage of the APC system. Moreover, with the development of the agricultural economy and optimization of the circulation environment, the impact of the APC service industry on circulation efficiency gradually increases. However, the promotion effect is limited to that in the Eastern region. Conversely, the promotion effect of the APC service industry on circulation efficiency requires further improvement. The promotional effect of APC efficiency on the DL of the APC service industry in the Western region is weak and some variations occur from H2. In contrast to the Central and Eastern regions, the impact of APC efficiency (lnE) on the DL of the APC service industry (lnS) in the Western region is the weakest. By studying the dynamic relationship between APC service industry and circulation efficiency in less developed regions, it provides reference for the development of APC in less developed regions.

Furthermore, the digitalization of the APC service industry depends mainly on its existing processes, lacking a robust two-way feedback mechanism to effectively support the development of modernized agricultural circulation systems. Overall, a positive promotion effect exists between the APC service industry and APC efficiency. However, the impact varies across regions, as indicated by the results of model estimation analysis. Not all regions have established an effective two-way feedback mechanism, and the influence is temporary, unable to drive the construction of modernized APC systems. Limited access to data, the timeliness of the study, and the construction of the indicator system were inadequate. In the future, attempts can be made to enrich relevant studies with survey data, such as questionnaires and interviews. This study only explores the dynamic relationship between the APC service industry and circulation efficiency and heterogeneity across regions. Future research will explore the respective influence mechanisms of the APC service industry and circulation efficiency. Additionally, we will expand our research on external driving mechanisms to further promote the circulation of agricultural products. The deep integration of artificial intelligence and traditional APC provides new ideas and solutions for promoting the circulation of agricultural products (Lin et al., 2023).

7 Conclusions and recommendations

This study developed an analytical framework to analyze the dynamic relationship between DL of the APC service industry and circulation efficiency in less-developed regions. This study's findings are as follows.

There is a dynamic relationship between the DL of the APC service industry (lnS) and APC efficiency (lnE) in the less-developed regions of Western China.

The APC service industry and the APC efficiency demonstrate a positive promotional effect on each other. This effect is weakest in the less-developed regions of Western China. No efficient two-way feedback mechanism is observed.

The DL of the APC service industry and improvement in circulation efficiency depends on its inertia, particularly in the less-developed regions of Western China.

To solve the problems of the linkage between the production and marketing of agricultural products in less developed regions, the following countermeasures and recommendations are proposed:

Firstly, mobilize the government functions. Since the APC system itself cannot form an efficient two-way feedback mechanism, it needs to rely on the promotion of government policies and the introduction of a series of preferential policies, focusing on improving the circulation environment of agricultural products in less developed regions and promoting the modernization of the APC system.

Secondly, strengthen the linkage between the circulation service industry and the APC, accelerate the penetration of the APC service industry into the APC system, encourage the outsourcing of APC services, strengthen the professional division of labor, achieve positive interaction, and optimize the APC system.

Thirdly, play the role of talent to promote. The less developed regions needs to strengthen the APC service industry and APC industry talent infrastructure construction, thus improving the competitiveness of the APC service industry and the quality of development.

Fourthly, optimize the industrial structure of the APC service industry. According to the results of the previous study, the level of agricultural products sales service and agricultural information service should be vigorously promoted to achieve the synergistic development of agricultural information service and agricultural products sales service, promote innovation, develop new circulation channels, bring new vitality to the APC system, and simultaneously play a good role in guaranteeing the logistics and financial service of agricultural products.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: https://www.stats.gov.cn/.

Author contributions

XL: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Writing – original draft, Writing – review & editing. TC: Project administration, Supervision, Writing – review & editing. LL: Data curation, Investigation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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