Study on the Management of Rural Logistics Efficiency: A Case Study of Liaoning Province

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Abstract. Rural logistics efficiency management and development is essential in promoting the comprehensive construction of agricultural and rural modernization. Utilizing panel data on rural logistics in Liaoning Province from 2017 to 2021, an evaluation system for rural logistics efficiency is established based on input and output dimensions. The evolution of rural logistics efficiency is examined from static and dynamic perspectives using models such as DEA-BCC, and the factors influencing rural logistics efficiency are further analyzed. The research reveals that the overall level of rural logistics efficiency in Liaoning Province is favorable, yet distinct regional disparities and uneven development exist. Enhancing regional development is pivotal to strengthening rural logistics efficiency. Consequently, recommendations are proposed to enhance logistics technology and management innovation, promote regional cooperation, and leverage locational advantages to utilize the "diffusion effect fully."

Keywords: rural logistics management, efficiency measurement, DEA model, Tobit model, influencing factors.

1 INTRODUCTION

Since the implementation of the rural revitalization strategy emphasized by the Twentieth National Congress, it has been explicitly stated that priority should be given to developing agriculture and rural areas, focusing on promoting the revitalization of rural industries [1]. Rural logistics, a pioneering sector transforming rural commodity circulation and promoting rural consumption upgrading, has gradually become vital in rural revitalization. In 2020, the "Implementation Opinions on Further Reducing Logistics Costs" emphasized the need for the logistics industry to shift its focus from "quantity" to "efficiency" and to promote the quality and efficiency of logistics operations. However, in recent years, despite the rapid development of the rural logistics industry in Liaoning Province, its operation mode remains inefficient and environmentally polluting, far from meeting the requirements for the modernization of agriculture and rural areas. Therefore, measuring the efficiency of rural logistics in Liaoning Province and identifying the factors influencing it are significant in promoting comprehensive rural agricultural development and achieving rural revitalization.

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Drawing from definitions of efficiency in manufacturing and other fields, relevant scholars have defined rural logistics efficiency as "the optimized social and economic benefits achieved through the minimal input of logistics resources". In exploring rural logistics efficiency within the literature, it is crucial to differentiate objectives and research domains, as well as acknowledge the varied measurement methodologies employed. Scholars commonly focus on analyzing static efficiency trends using models such as super-efficiency-SBM and BCC, while seeking to mitigate external environmental influences, researchers often employ the three-phase DEA for efficiency analysis[2]. The Malmquist efficiency index is particularly effective for assessing dynamic efficiency trends[3]. Despite the broad spectrum of topics covered in the relevant literature, ranging from water use efficiency[4] to green development efficiency[5], with a focus on regions[6] and enterprises[7], there remains a paucity of studies pertaining specifically to the measurement of rural logistics efficiency.

2 Research Methodology

2.1 Model Assumptions

The DEA-BCC Model. The DEA model serves as an evaluative method for assessing the production efficiency of decision-making units that involve multiple outputs and inputs. In this study, the input-oriented BCC model is selected to evaluate the static logistics efficiency in rural Liaoning Province, as depicted in equation (1):

$$s.t.\begin{cases}\min[\theta-\varepsilon(\hat{e}^T s^- + e^T s^+)]\\ \sum_{j=1}^{n} x_j\,\lambda_j + s^- = \theta x_{j0}\\ \sum_{j=1}^{n} y_j\,\lambda_j - s^+ = y_{j0}\\ \sum_{j=1}^{n}\lambda_j = 1\\ \lambda_j \ge 0, j = 1,\cdots,n\\ s^- \ge 0, s^+ \ge 0\end{cases} \tag{1}$$

where n denotes cities; θ denotes logistics efficiency, x_j and y_j denote inputs and outputs, respectively; and s^+ and $s^-$are output surplus and input deficit.

The Malmquist Index. Given the limitation of the DEA-BCC model in assessing cross-sectional rural logistics efficiency values within a specific timeframe, the Malmquist index is employed for dynamic efficiency measurement. The corresponding model is presented in equation (2):

$$M(y_n^{t+1}, x_n^{t+1}, y_n^t, x_n^t) = \frac{D^t(y_n^t, x_n^t)}{D^{t+1}(y_n^{t+1}, x_n^{t+1})}\left[\sqrt{\left(\frac{D^{t+1}(y_n^t, x_n^t)}{D^t(y_n^t, x_n^t)}\right)\left(\frac{D^{t+1}(y_n^{t+1}, x_n^{t+1})}{D^t(y_n^{t+1}, x_n^{t+1})}\right)}\right] \tag{2}$$

Where M reference set denotes the efficiency value measured by the model, $D^t(y_n^t, x_n^t)$ denotes efficiency value measured for the current decision unit N in period $t+1$, and the other denotations have similar meanings.

Tobit Regression Model. The Tobit regression model is well-suited to scenarios where explanatory variables fall within a restricted range. As the value of the explanatory variable - in this case, comprehensive efficiency - is limited to the range of [0-1], a Tobit panel data regression model is constructed to examine the factors affecting rural logistics efficiency in Liaoning Province. The corresponding model is demonstrated in Equation (3):

$$TE_{it} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3it} + \varepsilon_{it} \tag{3}$$

Where, TE_{it} is the explanatory variable, denoting the combined efficiency value of the i region, t period; X_{it} is the set of explanatory variables; β_0 is the coefficient to be estimated; and ε_{it} is the random perturbation term.

2.2 Indicator Selection and Data Sources

Drawing upon the insights of Zhang Qinghua et al. [8] regarding constructing an evaluation index system for rural logistics efficiency and considering the current state of rural logistics development in Liaoning Province, we establish a comprehensive rural logistics efficiency evaluation index system. This system encompasses five input dimensions, namely capital input, labor input, infrastructure input, information input, and governmental support input, as well as two output dimensions: rural logistics transportation capacity and rural logistics development scale (refer to Table 1). Table 1 provides a detailed overview of the index above system derived from existing research findings and considers the present conditions of the rural logistics industry in Liaoning Province. The selected explanatory variables include regional development level, policy support strength, and infrastructure. Assessing the regional development level allows for a more intuitive understanding of logistics development capability, influencing logistics efficiency. Policy support is an institutional guarantee for logistics development, while infrastructure plays a foundational role that significantly impacts logistics efficiency. Given the transportation industry's significant proportion within the logistics industry, data relating to the transportation industry is utilized as a substitute for logistics industry data.

Table 1. Rural logistics efficiency index system and influencing factors[1]

system level	subsystem level	Specific indicators
Inputs	Capital input	Investment in fixed assets in the transport
	Labor input	Number of employees in the transport
	Infrastructure input	Miles of the transport route network
	Information input	Number of Internet broadband access ports
	Government support input	Expenditure on transport
outputs	Rural logistics capacity	The volume of cargo transported
	Rural logistics scale	Total postal and telecommunication operations
	Rural development level	Rural disposable income per capita
Factors affecting	Policy support	Transport expenditure as a share of fiscal expenditure
	Regional development	Miles of motorways in the country

3 EMPIRICAL ANALYSIS

3.1 Static Efficiency Analysis

Utilizing the DEA-BCC method to assess the static rural logistics efficiency of Liaoning Province from 2017 to 2022, the measurement outcomes are presented in Fig. 1. The average rural logistics efficiency in Liaoning Province exhibits a generally fluctuating upward trajectory, with a notable decline in 2020 followed by a gradual recovery. The sudden drop in 2020 can be primarily attributed to the impact of the Xin Guan epidemic. However, with the subsequent epidemic prevention and control measures and the resurgence of the logistics industry, the overall rural logistics efficiency demonstrated a gradual rebound. From 2017 to 2019, a minor decrease was observed, attributed to China's logistics industry focusing on cost reduction and efficiency enhancement, along with policy adjustments leading to financial strains for a considerable number of logistics enterprises, thereby contributing to the decline in rural logistics efficiency. With the implementation of the “Measures to Accelerate the Construction of Rural Logistics System in Liaoning Province” in 2022, various levels of government will coordinate rural logistics resources, further propelling the efficiency of rural logistics in Liaoning Province.

[1] Source: The statistical information used in this study is sourced from the 2017-2022 China Agricultural Statistical Yearbook, Liaoning Provincial Statistical Yearbook, and other relevant sources.

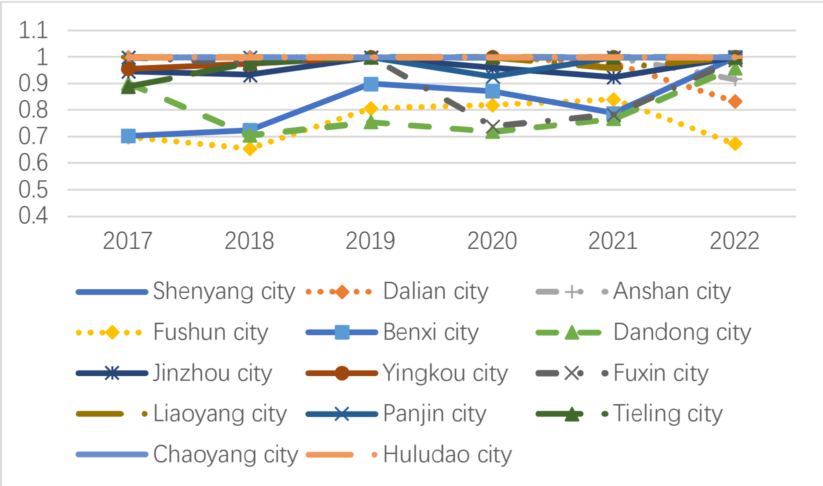

Fig. 1. Development trend of comprehensive efficiency of rural logistics[2]

3.2 Dynamic Efficiency Analysis

The results of total factor productivity for rural logistics in Liaoning Province are presented in Table 2. The level of rural logistics efficiency exhibits a consistent upward trend, with the scale efficiency index demonstrating the smallest mean value. This implies that scale efficiency constitutes a significant obstacle to enhancing rural logistics efficiency. Conversely, the mean value of the technological progress index stands at 1.03, denoting the potential contribution of technological progress to the improvement of total factor productivity.

The decomposition analysis of Malmquist total factor productivity reveals the following: (1) From 2017 to 2022, rural logistics efficiency in Liaoning Province demonstrates an oscillating upward trajectory, with an overall "M" shape pattern. (2) Throughout the examination period, the average annual growth rate of technical progress reaches 2.714%, whereas the average annual growth rate of pure technical efficiency amounts to the lowest value of -0.349%. Moreover, technical efficiency can be further broken down into pure and scale efficiency. It is important to note that pure technical efficiency represents a crucial aspect that exerts the most significant influence, which can be primarily attributed to a decline in management level. These findings highlight the intrinsic role of technological progress in improving rural logistics efficiency in Liaoning Province. However, it is equally essential to continuously enhance the institutional mechanisms of rural logistics to ensure systematic stability and compensate for any deficiencies[9].

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[2] Source: DEPA calculations yielded, EXCEL plotting

Table 2. Decomposition results of Malmquist TFP[3]

Year	Technical efficiency	technological progress	Pure technical efficiency	Scale efficiency	Total factor productivity
2017-2018	0.985	1.035	1.004	0.981	1.020
2018-2019	1.047	0.993	1.007	1.039	1.040
2019-2020	0.966	1.038	1.001	0.965	1.003
2020-2021	1.002	1.134	1.001	1.000	1.137
2021-2022	1.025	1.147	0.990	1.036	1.176
Mean	0.985	1.035	1.004	0.981	1.020

3.3 Analysis of Influencing Factors

Utilizing the Tobit regression model established earlier to investigate the determinants of rural logistics efficiency, as presented in Table 3, it is evident that all three independent variables exhibit statistically significant relationships with rural logistics efficiency. Notably, the regional development level shows a significantly positive association, followed by infrastructure and policy support. This underscores the pivotal role of regional development in enhancing rural logistics efficiency. With increased regional economic growth, more significant investments in the logistics sector can facilitate technological advancements and improve operational efficiency. The correlation coefficient for government support is -0.018, indicating a noteworthy negative correlation. Government assistance in enhancing rural logistics efficiency represents a double-edged sword, as heightened government investments may displace private investments, resulting in reduced fund utilization and excessive government intervention impacting the market-oriented nature of the logistics industry[10]. Location development factors are significantly linked to rural logistics efficiency, especially within regions where logistic activities are concentrated, leading to economies of scale and improved industrial efficiency through specialization and division of labor.

Table 3. Results of Tobit analysis[4]

explanatory variable	regression coefficient	P-value
Level of regional development	0.1889***	0.002
Policy support	-0.0679*	0.082
regional development	0.1987**	0.044

[3] Source: DEPA calculations yielded, EXCEL plotting

[4] Source: Stata calculations yielded, EXCEL plotting

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusion

Utilizing the DEA-BCC model, Malmquist index, and Tobit regression model to assess and analyze rural logistics efficiency and its influencing factors in Liaoning Province during the period from 2017 to 2022, the following conclusions can be drawn:

(1) The overall level of rural logistics efficiency development in Liaoning Province is commendable; however, regional variations are conspicuous, leading to non-uniform development. The disparities between the eastern and western regions of Liaoning Province are primarily attributed to differences in locational advantages and economic development levels. Rural logistics efficiency experienced a significant decline around 2020 following the impact of the COVID-19 pandemic, followed by a subsequent recovery, indicating a positive overall developmental trajectory.

(2) Augmenting the magnitude of regional development represents a pivotal leverage to enhance rural logistics efficiency. Boosting regional economic development attracts higher investments in the logistics industry, expedites technological modernization, and raises the level of rural logistics efficiency. Nonetheless, policymakers should remain wary of its negative effect on rural logistics efficiency due to undue policy support.

4.2 Recommendations

(1) Intensifying innovation across logistics technology, management concepts, and regional collaboration represents a seminal strategy to offset the ‘Matthew effect’ in rural logistics. Augmenting logistics technology innovation, research, and development, bolstering resource utilization, enhancing competition policy enforcement, and mandating the transformation and upgrading of the logistics industry all prove pressing imperatives. Concurrently, improving regional collaboration, promoting transport hub facilities construction and sharing, invigorating advanced logistics technology flows, spurring information exchange between regions, and realizing gradual rural logistics technology convergence and synergistic development are all highly necessary.

(2) Leveraging locational advantages to fully harness the “catfish effect” and “diffusion effect” is imperative. Exploiting the bipolar diffusion effect of Shenyang City and Dalian City to propel the interconnected development of the regional rural logistics industry remains paramount; further investment in the construction of coastal port cities and circulation node cities, coupled with the maximal utilization of their locational advantages, significantly fosters the amplification of rural logistics efficiency.

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