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Article

The impact of industry structure on the value of national logistics costs/gross domestic product: Evidence from China

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Abstract: The proportion of national logistics costs to Gross Domestic Product (NLC/GDP) serve as a valuable indicator for estimating a country's overall macro-level logistics costs. In some developing nations, policies aimed at reducing the NLC/GDP ratio have been elevated to the national agenda. Nevertheless, there is a paucity of research examining the variables that can determine this ratio. The purpose of this paper is to offer a scientific approach for investigating the primary determinants of the NLC/GDP and to advice policy for the reduction of macro-level logistics costs. This paper presents a systematic framework for identifying the essential criteria for lowering the NLC/GDP score and employs co-integration analysis and error correction models to evaluate the impact of industrial structure, logistics commodity value, and logistics supply scale on NLC/GDP using time series data from 1991 to 2022 in China. The findings suggest that the industrial structure is the primary factor influencing logistics demand and a significant determinant of the value of NLC/GDP. Whether assessing long-term or short-term effects, the industrial structure has a substantial impact on NLC/GDP compared to logistics supply scale and logistics commodity value. The research offers two policy implications: firstly, the goals of reducing NLC/GDP and boosting the logistics industry's GDP are inherently incompatible; it is not feasible to simultaneously enhance the logistics industry's GDP and decrease the macro logistics cost. Secondly, if China aims to lower its macro-level logistics costs, it must make corresponding adjustments to its industrial structure.

Keywords: macro-level logistics costs; NLC/GDP; industrial structure; co-integration analysis; error correction mode

1. Introduction

Logistics services involve the movement of commodities from the point of origin to the final destination. Normally, the need for logistics services is primarily driven by the spatial patterns of economic activities and imbalanced distribution of resources. It is organically incorporating fundamental tasks such as transportation, storage, loading and unloading, handling, packing, circulation processing, distribution, recycling, and information processing based on current requirements. Logistics sector may facilitate the flow of production elements and increase a nation's globalisation; hence, it is regarded as an essential aspect for national competitiveness (Arvis et al., 2018). In order to promote competitiveness and support the issuance of national industrial development programmes, a growing number of nations are seeking to improve the logistics efficiency with national policy (Ding, 2024; Putri et al., 2022; Rantasila and Ojala, 2012), especially in some emerging nations. National logistics efficiency can be evaluated in terms of trade-offs between a country's economic output, i.e., gross domestic product (GDP), and its national logistics costs (NLC), that is NLC/GDP (Havenga, 2018). Numerous nations utilise NLC/GDP as a significant measure to indicate a country's macro-level logistics costs and to assess the effectiveness of its logistics policy (Sugeng et al., 2021). How to improve the national competitiveness by efficiently reduce macro-level logistics costs has become a government priority and has been elevated to national strategy.

Under the direction and development of industry policies, China's logistics sector continues to advance. The macro-level logistics costs have decreased in recent years and reached 14.4 % approximately in 2023 from 24% of the year 1991, when national logistics cost records began, and it maintains a continuity historical lower value since 2006. However, the governor and policymaker believe that it is still excessively high and that the difference with industrialised nations (e.g., Japan, the European Union, and the United States, 8 to 9.5 %) remains significant (Pohit et al., 2019). Clearly, this index value does not satisfy the Chinese leadership. The department of the National Development and Reform Commission and the Ministry of Communications of China jointly issued the policy document "Notice of implementation opinions on further reducing logistics costs" (GBF [2020] No. 10) in the year 2020 with the intention of promoting the ongoing reduction of China's macro-level logistics costs. "Notice of the General Office of the State Council on Printing and Distributing the "14th Five-Year Plan" Modern Logistics Development" (GBF [2022] No. 17) was formally published in the year 2022. It is considered a programmatic document to encourage the development of modern logistics at the national level, and policy will guide the construction of a modern logistics system over the time of the "14th Five-Year Plan" and promote high-quality development. And until to the year of 2024, how to effectively reduce the macro-level logistics costs is still one of the major topics of China's Central Economic Work Conference.

As an index of macro-level level logistics costs, numerous variables affect the value of NLC/GDP (Satyendra Nath Chakrabartty, 2022). Simply reducing micro-level logistics rate is not a scientific way to effectively reduce NLC/GDP (Lazrak, 2024), and may even cause adverse effects with more logistics demand caused by lower logistics service rate. Analysis from the perspective of institutional economics, NLC/GDP may exhibit the characteristics of North's second paradox, in which a higher NLC/GDP ratio indicates a greater scale of logistics demands and transactions. Analysis from the demand theory, the logistics service is following the derived demand of the industrial structure of the economy. It is vital to develop a dependable approach for identifying the elements that influence the NLC/GDP ratio, so that effective strategies can be developed to lower it. In order to offer a scientific approach to policymakers for reducing macro-level logistics costs, this paper employs a comprehensive analytical framework that encompasses variables such as industry structure, logistics supply scale, and the value of logistics commodities, along with factors that reflect logistics demand, to investigate the fundamental causes of elevated macro-level logistics costs.

2. Literature review

Transportation development accompanied the evolution of humans. In classical economics framework, commodity transportation conditions (often referring to water transport) were viewed as the sole determinant of market size and the necessary foundation for economic progress (Krugman, 1991; Smith, 1976). In contemporary economics theory, transportation infrastructure has a favourable impact on high-quality regional economic development (Banerjee et al., 2012; Gallen and Winston, 2021; Havenga and Hendrik, 2015; Mart and Puerta, 2017). In the context of regional and trade economics framework, logistics is used to replace transportation—or to co-study with transportation—to investigate the correlation between logistics and the economy, and a macro- and micro-level statistically significant relationship has been established between logistics costs and economic growth (Hausmann et al., 2013; Hayaloğlu, 2015; Portugal-Perez and Wilson, 2012; Zhang, 2020).

At the micro level, logistics costs mostly tie to a company's own logistics activities (Grant et al., 2006). And the objective of logistics is to lower the total costs of ownership of supply chains by enabling trade-offs between cost components of supply chains (Ellram, 2002; Patil et al., 2023). With a lower micro-level logistics cost, the circulation and allocation of production factors can be more efficient (Ding et al., 2023; Han and Zhang, 2015), and less developed regions can more readily benefit from the knowledge spillover of developed regions (Martin and Ottaviano, 1999), thereby achieving common economic development. In practise, it has also been demonstrated that adequate transportation conditions and logistics service efficiency have a high association with urbanisation and the free movement of production factors (Huan et al., 2018; Ran et al., 2022).

There are two alternative techniques for measuring national logistics performance at the macro level (Havenga, 2018). The Logistics Performance Index (LPI) is a technique that focuses primarily on the logistics performance and trade connectivity of nations. The LPI examines the logistics performance of trade nations in six logistics areas, including customs, infrastructure, the ease of scheduling shipments, the quality of logistics services, punctuality, and tracking and tracing. It was first adopted in 2007 and is currently released every two years (Bank, 2014). The LPI is a comprehensive and long-lasting macro-level indicator for the logistics industry (Kinra et al., 2020), and the World Bank has pushed it as an essential transport policy decision making tool from a trade facilitation perspective since its introduction. There is limited guidance for policy formulation and its practical usage as a public policy intervention instrument (Roy and Schoenherr, 2020). The second method is assessing the trade-offs between NLC and a nation's GDP (Rantasila and Ojala, 2015), which is focuses on the macro-efficiency of the logistics industry or operations at the national level. The metrics of percentage comparison with the GDP level, measured with the NLC as a percentage of the GDP, are regarded as a benchmark used to measure and compare the macro-level logistics costs and is an appropriate indicator that can support future national policy planning, measure performance, and pave the way for any corrective actions (Havenga et al., 2022; Pishvaee, 2009). The basic estimation method was first recommended by Heskett et al. (1973), refined and improved by Bowersox and Calantone (1998) and Rodrigues et al. (2005) by use of new input variables including infrastructure variables related to costs and information systems, and is now accepted and used by numerous countries, as observed in World Bank reports. Numerous nations utilise it as a crucial measure of their overall logistics success and to monitor their respective logistics policies. Although some research suggest that the NLC as a percentage of GDP contains simply the added value from one sector to another, it does not represent the total turnover of all economic activity (MacroSys Research and Technology, 2015).

Parallel comparing the ratio of NLC to GDP among nations is difficult because of the lack of a universally acknowledged distinct theoretical framework and data statistical channels, which necessitates the use of a variety of data sources and computation methods. Some developing nations attempt to construct a comparative scientific technique for evaluating the NLC in order to more properly assess the national macro logistics cost and horizontal comparability. Thailand adopted a more complete method based on the CASS model by combining macro-level and micro-level data, and the calculation results indicate that the revised model is more accurate and applicable to Thailand's logistics setting (Banomyong et al., 2022). Indonesia establishes a national logistics cost measuring model by combining the methods and models of the United States, South Korea, and South Africa (Santoso et al.,2021).

Since 2004, China has adopted a very stable and scientific national logistics cost calculation model, therefore the research focus of Chinese scholars differs from that of experts in other developing nations. In order to give a guideline for the Chinese governor and policymakers to issue scientific policies or techniques to reduce the index of NLC/GDP, a number of scholars have attempted to statistically examine the elements impacting the index from a variety of vantage points. Fan (2014) demonstrated that the proportion of primary industry to GDP is positively correlated with the NLC/GDP, whereas secondary and tertiary industries, as well as the development of science and technology, have a negative impact, and the level of economic development and degree of marketization have no significant relationship with this index. The mechanism of this index was explained by Zhang and Han (2018) from a micro perspective, and they divided it into the unit GDP logistics turnover (i.e., social logistics demand) and the unit logistics turnover rate (i.e., the micro logistics rate)—that is, the ratio of NLC/GDP is jointly determined by the macro social logistics demand and the micro logistics rate. Fan and Jin (2023) got the same conclusion with Zhang and Han with a two-stage research method. Pan (2024) shows the mechanism that the micro transportation rate and the value the logistics goods have a strong correlation with the NLC/GDP. The outcomes of these studies are plausible, but one-sided; no clear and effective measures to reduce NLC/GDP are proposed, the selection and computation of explanatory factors are limited due to the absence of a connotation framework analysis of the NLC/GDP. This study creates an analytical framework to explain the connotations and mechanisms of the NLC/ GDP from the standpoint of supply and demand equilibrium under macroeconomic perspective, and then regresses the relevant variables using co-integration analysis and an error correction model to demonstrate the variables' association.

3. Methodology

3.1. Theoretical mechanism and research hypothesis

The economy employs the production factors of all types of businesses to produce the whole output of an economy, i.e., the GDP, which includes the national logistics costs, as seen in **Figure 1**. The enterprises can be split into three categories based on their respective economic functions: logistics supply enterprises, logistics demand enterprises, and non-logistics enterprises. Non-logistical firms do not generate any logistics demand behaviour, nor do they offer logistics services. Logistics demand firms generate a demand for logistics, which can be met in one of two ways: either a portion or all of the logistics demand is met internally, or a portion or all of the enterprise's logistical needs are outsourced to external logistics providers. The national logistics costs are addressed and defined from the perspective of the logistics demand side as opposed to the logistics supply side; that is, the national logistics costs reflect the economic value that the logistics demand side must or should pay for the usage of logistical services. This economic value is comprised of two components: the expenditure for purchasing logistics service based on a specified service rate paid by the requester, and the internal management costs of purchasing logistics service. Logistics demand is a prerequisite for the production of logistics services, and logistics demand is the principal determinant of logistics supply. Among economic considerations, industrial structure is regarded as the most influential on a country's logistics needs (Alises and Vassallo, 2014; Feng et al., 2012; Wang and Duan, 2024). These two elements have a strong association in China, a country with a vast geographical area and pronounced regional economic inequalities (Song et al., 2014; Xiao et al., 2022). From a supply-side perspective, the total national logistics costs can be viewed as the sum of individual logistics service behaviour costs, $\sum_{i=1}^{n}(\text{Costs of the } i^{th} \text{ logistics service})$, and can be expressed in equation as $\text{NLC} = \sum_{i=1}^{n} lc_i = \sum_{i=1}^{n}(ls_i \times lr_i)$, where NLC is the total national logistics costs, lc_i is the cost of the specific ith logistics service, ls_i is the scale of the specific *ith* logistics service, and lr_i is the rate of the specific *ith* logistics service, and *n* is the number of logistics transactions.

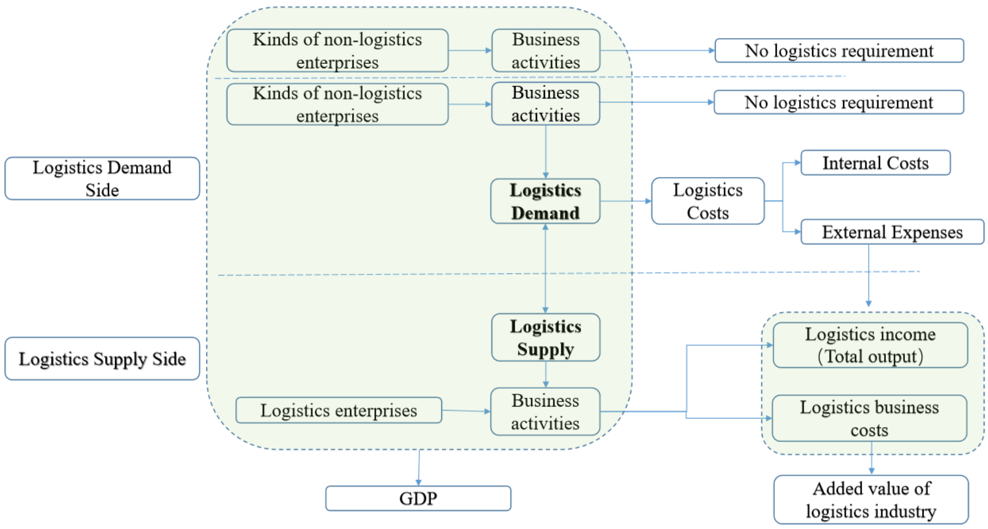

Figure 1. Industrial structure of logistics demand and supply.

According to the market mechanism, the pricing for logistics services is essentially decided by the link between supply and demand: the logistics provider offers logistical services at a particular price level. As indicated in **Figure 2**, logistics transactions take place between the sides of demand and supply, and the micro logistics service rate can be considered a "marginal cost" for the demander in the purchase decision, and it is the only condition that determines whether a particular logistics activity will be conducted or not. A specific logistics service behaviour is executed based on whether or not the cargo can bear the cost of logistics behaviour. Any expenditure or cost for every specific logistics activity is determined by the market equilibrium mechanism, with the specific logistics activity agreed upon by both demand and supply sides.

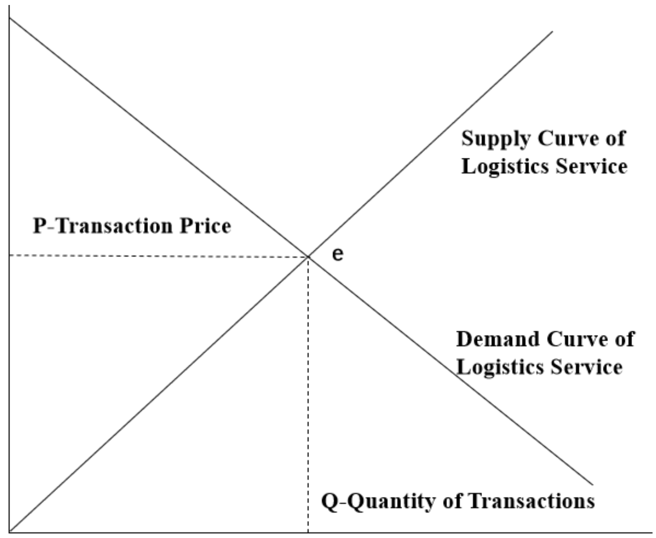

Figure 2. Logistics service rate determination mechanism.

Based on the market equilibrium mechanism described previously, the industrial structure is the primary driver of the logistics supply, and the specific "marginal cost" of the logistics service activity is influenced by the scale of the supply and the value of the logistics commodity, excluding the logistics demand factor. All three components are endogenous, and they have mutual impact on one another. In accordance with the general principle of economics, as the commodity price rises, the price sensitivity of logistics activities will gradually decrease. However, this does not imply that the NLC/GDP ratio will decrease proportionally, as more logistics demand (longer distance logistics service or logistics transaction times) may be generated with a lower logistics service rate. To clarify the influence mechanism of the components on NLC/GDP, the study provides the following hypothesis based on the logistics market supply and demand equilibrium mechanism:

Hypothesis 1: The scale of social logistics demand has a positive impact on the NLC/GDP. The demand is the foundation of logistics service; the greater the social logistics demand coefficient (Logistics turnover per GDP) will generate the greater the scope of logistics operations and the higher micro logistics price, and produce greater macro-level logistics costs. Changes in industrial structure will alter the logistics demand coefficient, as industrial structure is assumed to be the most influential factor in determining the size of societal logistics demand.

Hypothesis 2: The value of logistics commodity per unit weight has a negative impact on the NLC/GDP. The value of the logistics commodity is seen as a factor influencing the magnitude of logistics demand; as the value of logistics commodity increased, price elasticity for logistics demand decreased. According to the ad valorem technique and principle of marginal effect, the market's readiness to accept logistics services at the same price as before increases as the value of the logistical commodity increases. In the meantime, the increased value of logistics commodities generates a larger GDP, and the micro logistics rate decreases in proportion to the rising value of logistics commodities.

Hypothesis 3: The logistics supply scale has a positive impact on the NLC/GDP. The objective of the logistics supply scale is to meet logistical demand; greater logistics supply equals a larger logistics market and higher national logistics expenses. It is considered that there is a substantial correlation between the logistics supply scale and the logistical service rate. The greater supply size results in a decrease in the micro logistical service rate and an increase in the scale of logistics transactions.

3.2. Empirical model construction and data selection

This study used Equation (1) to investigate the relationship between industrial structure, logistics commodity value, and logistics supply size and China's macro-level logistics costs, as proposed by Zhang and Han (2018). To make the regression equation efficient, consistent, and intelligible, the natural logs of all variables are used to smooth the data.

$$\ln R_t = \alpha + \sum_{i=1,2,3} \beta_{t-i} \ln R_{t-i} + \beta_2 \ln S_t + \beta_3 \ln V_t + \beta_4 \ln P_t + \varepsilon \quad (1)$$

where, R is the macro logistics cost, calculated by the NLC/ GDP, R_{t-i} is the i-th lag term of R, S is the industrial structure, V is the value of logistics goods, and P is the scale of logistics supply. According to the characteristics of logistics demand and the statistical rules of China's Logistics Yearbook, agriculture, industry, and trade (wholesale and retail) are the primary sources of logistics demand. The industrial structure is thus expressed as a percentage of China's total GDP for agriculture, industry, wholesale, and retail commerce. This study employs the commodity price per tonne as a proxy for the logistics commodity's value, which is determined by dividing the entire value of social logistics goods by freight volume. The logistics supply scale is shown by the number of logistics companies, trucks, and facilities in the entire community. Following the concept of Zhang and He (2019), this paper uses the total number of logistics professionals as a surrogate for the logistics supply scale.

The data for the total NLC from 1991 to 2022 is derived from the China Logistics Yearbook; and the following data is derived from China Statistical Yearbook: GDP for agriculture, industry, and trade (wholesale and retail); freight volume for various modes of transportation; and China's national GDP. Based on the availability of data, the number of people employed in the logistics industry has been replaced with the number of people engaged in the transportation, storage, and postal industry (derived from the China Statistical Yearbook). The statistical results of log data are presented in **Table 1**.

Table 1. Summary of descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
ln *R*	32	−1.729	0.14	−1.933	−1.446
ln *S*	32	−0.526	0.114	−0.728	−0.362
ln *V*	32	6.956	0.641	5.725	7.667
ln *P*	32	6.452	0.208	6.037	6.759

3.3. Method

The single-equation OLS approach has been frequently utilised in regression analysis for time series data to identify causality and correlation between variables. A fundamental assumption of the OLS technique is that variables are stationary; however, in empirical investigations, the majority of economic variables are non-stationary, and the use of the OLS method with non-stationary variables may lead to the conclusion of pseudo-correlation. Despite the fact that time series data are non-stationary, there are circumstances in which their linear combination is stationary, and the equilibrium relationship between them over the long run is the subject of study. The method of co-integration analysis and the error correction model proposed by Engle and Granger (1987) have provided a new solution to the problem of pseudo-regression for non-stationary variables, which use Wald statistics to test the significance or joint significance of relevant variables of the regression equation and to determine the short- and long-term causality and correlation of variables. Since the 1990s, co-integration test technology has gradually developed and improved, providing convenient and effective analysis tools for analysis of multi-variable model systems and effectively overcoming various challenges faced by traditional econometric analysis technology in the analysis of non-stationary economic time series (Juselius, 1990; Kitamura, 1998). Co-integration analysis and an error-correction model served as the fundamental analytical tools for this paper.

4. Empirical analysis and results

4.1. ADF test of variables

To avoid the distortion of non-stationary time series regression, we conducted an ADF test with the co-integration theory and the method suggested by Engle and Granger (1987) on the aforementioned variables. **Table 2** provides the results.

Table 2. Unit root test of ln *R*, ln *S*, ln *V*, and ln *P*.

Variable	Number of difference	(C T K)	DW value	ADF test	1% Test critical values	5% Test critical values	*P* values	The results of ADF test
ln *R*	1	(C 0 1)	1.95	3.34	3.70	2.98	0.0227	I (1)
ln *S*	1	(C 0 0)	2.00	3.80	3.70	2.97	0.0077	I (1)
ln *V*	1	(C T 0)	1.83	3.80	4.32	3.58	0.0037	I (1)
ln *P*	1	(0 0 1)	1.95	3.04	2.65	1.95	0.0038	I (1)

Note: (C, T, K) represent the type of equation containing constant term, trend, and lag period. The lag order is selected according to the principle of minimum AIC and SIC.

The results of the unit root test indicate that ln *R*, ln *S*, ln *V*, and ln *P* are non-stationary sequences, which satisfy first-order differential stability and belong to first-order single positive I (1) and meet the conditions of the co-integration test. The co-integration relationship between ln *R* and other explanatory variables tested before regression between ln *R*, ln *S*, ln *V*, and ln *P*.

4.2. Co-integration test

The co-integration relationship was examined using the Johansen approach. The structure of a long-term equilibrium relationship is decided by whether the co-integration equation includes the intercept and deterministic trend. Considering that the observation series of all variables exhibit a time trend, the co-integration term was designed to incorporate both the intercept and the time trend. **Table 3** displays the Johansen test results. The results of the trace and maximum eigenvalue tests indicated, at a significance level of 5%, that the null hypothesis of no co-integration relationship was rejected and the null hypothesis of at most one co-integration relationship was accepted, indicating that there was a long-term correlation between ln *R* and ln *S*, ln *V*, and ln *P*, which was amenable to regression analysis.

Table 3. Johansen co-integration test results.

Hypothesized Number of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.6205	53.5363	47.8561	0.0133	27.1297	27.5843	0.0571
At most 1	0.4468	26.4066	29.7971	0.1170	16.5752	21.1316	0.1930
At most 2	0.2657	9.8314	15.4947	0.2939	8.6468	14.265	0.3167
At most 3	0.0414	1.1846	3.8414	0.2764	1.1847	3.8415	0.2764

Note: The critical value is the Mackinnon value, * means significant at the 5% confidence level.

On the basis of the co-integration relationship between the variables, OLS regression was conducted on ln *R* with ln *S*, ln *V*, and ln *P*, obtaining the following equation:

$$\ln R = -0.8029 + 0.8236 \ln S + 0.0027 \ln P - 0.07 \ln V \quad (2)$$

$$(-2.5691^{***}) \quad (5.6713^{***}) \quad (0.0520) \quad (-3.7088^{**})$$

In general, the fit of the regression equation was satisfactory. ln *S* passed the significance test at the 1% level, whereas ln *V* passed the test at the 5% level; the *R*-squared value was 0.9735. However, the Durbin–Watson value was only 0.5829, indicating that the regression equation had positive autocorrelation, and the test confirmed that the regression equation has autocorrelation of the first order. On this basis, as in Equation (1), the lag variables were considered for input into the regression, the lag order of ln *R* was chosen based on the AIC criterion, and the regression was repeated. The majority of regression models failed one or more residual normality, autocorrelation, and heteroscedasticity tests, posing significant challenges for this particular regression. After multiple tests gradually eliminating lag terms, the following regression models were constructed:

$$\ln R = -0.5773 + 0.5159 \ln S + 0.0224 \ln V - 0.0009 \ln P + 0.83 \ln R(-1) - 0.4299 \ln R(-2) + 0.0272 \ln R(-3) \quad (3)$$

$$(-1.8750^{**})(2.9487^{***})(-1.3629^{*})(0.0242)(4.5804^{***})(-1.6497^{*})\ (-0.1679)$$

Residual normality, autocorrelation, and heteroscedasticity tests were passed by the regression. The results of co-integration Equation (3) reveal that, in the long run, industrial structure and logistics supply scale are significantly positively correlated with the macro-level logistics costs, and that the influence coefficient of industrial structure on macro logistics cost reaches 0.5159—that is, for every 1% change in the industrial structure, there will be a 0.52% change in the macro-level logistics costs. However, the impact coefficient of logistics supply scale, which impacts on the macro-level logistics costs is only 0.0009; that is, the scale of logistics supply hardly affects the value of NLC/GDP, totally encounters the nature of a fully buyer's market within the logistics sector and the resultant demands of the logistics industry. Moreover, the value of the logistics commodity is negatively correlated with the macro-level logistics costs, and the effect coefficient is 0.0224; that is, when the value of the logistics commodity varies by 1%, the macro logistics cost changes by 0.02% in the opposite way.

4.3. Error correction model

According to the theory and relevant experiments in this study, lnR and lnS, lnV, and lnP are in long-term equilibrium; to validate the short-term effect between variables, the following error correction model was developed:

$$\Delta \ln R_t = \sum_{i=1,2} [\, a_i \Delta \ln S_{t-i} + b_i \ln V_{t-i} + c_i \ln P_{t-i}] + \lambda_i ECM_{t-1} + \varepsilon \quad (4)$$

The best lag time was determined to be based on the AIC and SC criteria, and the error correction model's regression result is given by:

$$\Delta \ln R_t = 0.0157 + 0.0480 \Delta \ln R_{t-1} + 1.1897 \Delta \ln S_{t-1} - 0.1424 * \Delta \ln V_{t-1} + 0.0124 * \Delta \ln P_{t-1} - 0.1257_i * ECM_{t-1} \quad (5)$$

$R^2 = 0.5075$ F-statistic = 4.53.

The coefficients of △ln *S* and △ln *P* are positive, whereas the coefficient of △ln *V* is negative. The sign of the variable coefficient is consistent with that of the long-term equilibrium equation. Industrial structure and logistics supply size have a favourable effect on China's macro-level logistics costs in the medium term, however logistics goods value has a negative effect. Industrial structure has a major impact on macro-level logistics costs, which will increase by 1.19% for each percentage point of industrial structure growth. In addition, the coefficient of the logistics supply scale as a factor influencing the logistics rate is 0.0124, suggesting that when the logistics scale changes by 1%, the macro-level logistics cost increases by only 0.01%. The coefficient of ECM_{t-1} is 0.1257, which indicates that the unbalanced mistake of the previous year is corrected in reverse by the ln *R* of the current year by 12.57%.

4.4. Granger causality test

The findings of the co-integration test merely indicate that there is a long-term stable equilibrium correlation between ln *R* and ln *S*, ln *V*, and ln *P*, but further investigation is required to determine whether this equilibrium link is causal. The Granger test was performed to verify the causal relationship between the time series variables to support the inquiry described above. The results of the Granger test for each variable are showed in **Table 4**. Ln *S*, ln *V*, and ln *P* do not Granger cause each other at the 5% significance level, but they are all Granger causes of ln *R*. Meanwhile, at a significance level of 5%, ln *R* was not the Granger cause of ln *S*, ln *V*, and ln *P*. The results indicate that industrial structure, logistics commodity value, and logistics supply size influence macro-level logistics costs, but there is no association between them. In the meanwhile, macro-level logistics costs have no effect on industrial structure, logistics product value, or logistics supply size.

Table 4. Granger test of ln *R*, ln *S*, ln *V*, and ln *P*.

Null content:	Obs	*F*-Statistic	Prob.
ln *V* does not Granger Cause ln *S*	32	2.3233	0.1403
ln *S* does not Granger Cause ln *V*		0.5604	0.5852
ln *P* does not Granger Cause ln *S*	32	3.7061	0.0558
ln *S* does not Granger Cause ln *P*		0.3263	0.7278
ln *R* does not Granger Cause ln *S*	32	0.4783	0.6312
ln *S* does not Granger Cause ln *R*		8.0136	0.0062
ln *P* does not Granger Cause ln *V*	32	0.3340	0.7225
ln *V* does not Granger Cause ln *P*		0.5775	0.5761
ln *R* does not Granger Cause ln *V*	32	3.2316	0.0754
ln *V* does not Granger Cause ln *R*		4.2381	0.0405
ln *R* does not Granger Cause ln *P*	32	0.2889	0.7542
ln *P* does not Granger Cause ln *R*		6.3457	0.0132

5. Conclusions and recommendations

Main conclusion

The logistics industry and its operations are entrusted with significant duties within the economic system. In recent years, reducing the (macro-level and micro-level) logisticical costs of the real economy has been a priority for the governments of China and other emerging nations, and all levels of government have issued industrial development strategies in response. However, the policy documents are comprised solely of ideas and actions from the perspective of the logistics supply side, and experience has shown that these measures and proposals cannot lower macro-level logistics costs in an effective and scientific manner. In this paper, a comprehensive framework for analysing macro-level logistics costs is developed from the perspective of supply-demand equilibrium. The research framework includes factors such as the industrial structure at the demand level, the value of logistics commodities, and the scale of logistics supply at the supply level. Analyze the meanings and confirm that the industrial structure is the most significant factor determining NLC/GDP. Tests demonstrated that the industrial structure is a significant factor influencing macro-level logistics costs in China on both the short and long term. When the industrial structure changes by 1% over the long term, the macro logistics cost changes by 0.52% in the same direction, whereas it changes by 1.19% in the same direction over the short term. This conclusion is consistent with economic principles, and the adjustment of short-term industrial structure drives the increase in macro-level logistics costs, resulting in the periodic increase of those costs in the short term, whereas in the long term, with the expansion of the supply scale, the costs will gradually decline to the equilibrium point.

There are two main policy implications of our result. The first one is to minimise NLC/GDP, more focus should be placed on adjusting the industrial structure of the economy. From the perspective of the supply and demand mechanism, when the level of economic development has reached a certain stage and the industrial structure is relatively stable, it is not sufficient to simply reduce the logistics rate on the supply side to reduce the social logistics cost, as this may result in an increase in logistics demand. For a particular logistics activity, a lower service rate can cut logistics costs, but for the logistics industry as a whole, a lower micro-level service rate leads to greater scale. According to the supply-demand equilibrium mechanism, if demand is reduced, both the micro logistics rate and logistical service scale will decrease. Given a fall in logistical demand and rate, the cost of social logistics will surely decrease. The second is that the logistics sector's aim of GDP does not consistent with the decrease of the macro-level logistics costs. A higher GDP shows a better economic contribution to the industry when considering only the growth of the logistics sector. According to the production accounting approach, an industry with a larger GDP is likely to be very profitable and pay its employees greater wages. If we look at the logistics sector's GDP from the perspective of the entire economic operation system, a higher GDP in this sector translates into a higher total income for the sector, which in turn forces the demand side to increase the price of logistics. As a result, the ratio of national logistics costs to GDP is intended to stay high. As a result, it is imperative to reevaluate GDP as an economic indicator for the logistics sector. Under the current industry structure and scale of supply, the GDP of the logistics sector is more accurately reflected in the size of its economic activities, so the local government shouldn't set an industry target GDP.

Limitation of this study is the specific consideration of economies of China and the analysis with limited linear data; thereby it is required to replicate and study these results with the similar other countries or provincial panel data. This study also needs to be evaluated the impact effect of micro-level logistics service rates and logistics market elasticity. The outcome has displayed some solutions that link to achieving lower NLC/GDP. Future research study will focus on to stablish an analytical framework for NLC/GDP with consideration of micro-level logistics rates and logistics market price elasticity, and compare the results with the panel data of different countries or Chinese provincial panel data.

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