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Logistics density, E-commerce and high-quality economic development: An empirical analysis based on provincial panel data in China

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ABSTRACT

Under the background of high-quality development, the e-commerce industry needs to seek more comprehensive development, and the logistics industry should not only maintain higher efficiency, but also meet the requirements of green and low-carbon transportation. This study aims to investigate the link between the logistic density and the proportion of e-commerce transaction scale. There are few studies on how logistics density affects the development of e-commerce quantitatively. In order to solve this gap, this study establishes an impact model of high-quality growth of e-commerce, and based on Solow production model, constructs a calculation method of logistics density, and analyzes the impact mechanism of logistics density on the scale ratio of e-commerce transactions. Using the bidirectional fixed effect model, this paper makes an empirical analysis of the panel data of 31 provinces consisting of 248 observations and autonomous regions in China from 2014 to 2020. The results show that logistic density has a positive and significant impact on the growth of e-commerce, thus promoting the optimization of economic structure. The acceleration of logistics density decreases the expansion of the ecommerce. Finally, there are obvious regional differences between the development of e-commerce and logistics infrastructure in China. Finally, based on the empirical result, this paper puts forward recommendations for government and companies.

1. Introduction

Due to the progress brought about by reforms and opening up, China's economy has risen tremendously in recent decades. The stage of China's economic development has now changed from one of rapid expansion to one of high-quality development. The report of the 20th National Congress of the Communist Party of China stresses the importance of sticking to the theme of promoting high-quality development, boosting the endogenous strength and dependability of the domestic economic cycle, and quickening the development of a modern economic system. The Internet economy has played a vital role in the economic development of China since the twenty-first century (Ding and Zhao, 2021). The China Digital Economy Development Report (2022) indicates that the digital economy's added value in China rose to 45.5 trillion CNY in 2021, representing 39.8% of the nation's GDP (China Academy of Information and Communications Technology, 2022). The development of e-commerce has promoted economic development. However, the Chinese e-commerce market is currently going through a difficult era of development, and many small and medium-sized businesses face a number of challenges. E-commerce related issues that surfaced during the pandemic include excessively high prices increase, concerns about product protection and cyber security, and problems related to the expansion of the logistics industry (Ding and Zhao, 2021). Therefore, it has become vital to identify ways to assist the e-commerce sector in overcoming its developmental barriers and supporting the expansion of small and medium-sized firms' e-commerce activities. Logistics distribution is a vital part of the e-commerce business and cannot be ignored. In effect, the logistics service has become a crucial component in the expansion of the e-commerce industry. To expedite the creation of a new developmental paradigm centered on the domestic economic cycle, China unveiled a directive on March 25, 2022, outlining plans to boost the establishment of a unified domestic market. To

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support high-quality economic development, the proposal calls for the establishment of a national integrated market with a primary focus on the three-dimensional national logistics network. With China's economy entering a new stage of development, it is urgent to look into how the logistics sector and the expansion of the e-commerce market are related to one another. The expansion of the e-commerce economy and providing realistic policy suggestions for China's economy to advance are critical concerns that need to be addressed. Finding ways to utilize the logistics industry's potential in these areas is essential. Seeking solutions new to leverage the logistics industry's potential to boost the high-quality development of the e-commerce economy and offering practical policy recommendations for China's economy's progress are crucial challenges that need to be tackled.

E-commerce and logistics are related in a way that both have an effect on one another. Although the expansion of e-commerce has increased the cost of logistics services, it has also increased their capabilities. As an illustration, study by Cardenas et al. (2017) found that the cost of logistics per plot in rural locations is rather high. This highlights the need for enhancing logistics infrastructure in cross-border e-commerce. According to Li and Miao (2017), China's cross-border e-commerce development is not in line with the expansion of logistics infrastructure, which necessitates the improvement of logistical modes and the establishment of a specialized, effective, and comprehensive logistics service system for cross-border e-commerce. However, the ability of logistical services also has an impact on the growth of the e-commerce industry. Currently, the competition among e-commerce businesses is no longer centered on business model competition but rather, logistical service competition. Guo (2020) claims that the ability to manage logistics distribution speed and cost has emerged as the deciding factor in the competition among e-commerce enterprises. However, China's current logistics infrastructure has some drawbacks, such as insufficient efficiency and poor product delivery, making it impossible to meet the varied needs of the development of e-commerce. Therefore, as suggested by Lee et al. (2010), it is essential for the logistics sector to improve their services by optimizing their outlets, upgrading information systems, and strengthening legislation and regulations. This will enable the strong and quick growth of the e-commerce industry. Furthermore, there is mutual influence and promotion between economic and logistics development (Lean et al., 2014). Economic expansion will increase demand for logistics services, resulting in the development of logistics and a fresh push to economic growth (Li et al., 2018). It is also based on this logic in the new development pattern to construct a unified national market with a logistics and warehousing system as the mainstay to boost the domestic economic cycle and high-quality economic development. Despite the fact that the relationship between the logistics and e-commerce as commonly acknowledged is crucial, studies that investigate this link seems lacking. Out of the studies, many contributions are descriptive and they do not provide meaningful insights about the relationship between logistics and e-commerce (Giuffrida et al., 2017). Thus, there is a need to further explore the link between logistics and e-commerce to get deep insights on this link. Based on this we formulate the following research question:

How the logistics sector and the expansion of the e-commerce market are related to one another?

This article contributes in several ways. This study seeks a coordination mechanism between logistics development, e-commerce development, and high-quality economic development by conducting a theoretical analysis of their relationships. This analysis serves as the theoretical basis and point of reference for comprehensive high-quality development and regional stage development. Second, it has been shown that current research on logistics, e-commerce size, and high-quality economic development mostly focuses on conceptual explanation and qualitative debate. Further, these studies are mostly descriptive, which provide no meaningful insights regarding the above-mentioned relationships. A few academics carry out quantitative evaluations of logistical density and its relationship with the development of e-commerce. As a result, this study selects logistics density as a measuring index, establishes its measurement method based on Solow growth model, identifies its measurement process, and creates a tenable model for the high-quality growth of the e-commerce industry. Parallel to this, the current research puts forth the idea that logistical density influences the size of e-commerce favorably, with the beneficial impact eroding over time. The hypotheses are supported by empirical findings, and the corresponding conclusions are drawn. We find that increasing logistics density drives the development of e-commerce scale, and that the influence is gradually decreasing, implying that the theory is correct. While, there is regional heterogeneity; we found that the positive impact is particularly large in leading e-commerce provinces; while, in underdeveloped areas, the increase of logistics density has a weak influence on the growth of e-commerce. Finally, this study summarizes the findings of the literature and empirical research and makes policy recommendations. We expect that by doing research on the relationship between logistical density and e-commerce development, we will be able to give the government and businesses with practical plans for the high-quality development of China's economy.

This paper is structured as follows. Section 2 provides a literature review. Section 3 presents the theoretical analysis of the relationship between logistics density and development of e-commerce scale and between the growth rates of them based on Solow growth model. Section 4 shows an empirical analysis of the influence of logistics density on e-commerce scale, including variable selection, model construction, empirical result, heterogeneity test, and lagging effect test. Section 5 provides conclusions, policy recommendations, and research limitations. The research steps followed in this study are shown in the following diagram.

2. Literature review

This section reviews and summarizes the literatures on the relationship between logistics industry and e-commerce, logistics industry and high-quality economic development, and E-commerce and high-quality economic development. The literature review conducted is presented through the following diagram in Fig. 1.

2.1. Relationship between logistics industry and E-commerce

2.1.1. E-commerce and logistics industry

While the impact of logistics on business success has been thoroughly studied in a traditional setting, e-commerce has paid relatively less attention to this issue (Ramanathan et al., 2014). Traditionally, logistics services have been designed to promote the smooth flow of information, money, and goods. With data from the events of the last ten years, Rabinovich and Knemeyer (2006) have shown that this linear link has not been disrupted in the context of e-commerce. They assert that the significance of logistics service providers has grown in the online industry. The development of e-commerce has driven the growth of logistics industry, and put forward higher requirements for the timeliness on logistics distribution. Traditional enterprises competition has changed from business model to logistics service as it need to develop an e-commerce platform. In China, the development of logistics industry is an important force for the development of e-commerce. Most of the literature regarding the problems and solutions of e-commerce logistics provide theoretical guidance for activating e-commerce in China. Logistics capability is positively correlated with the performance of e-commerce enterprises (Cho et al., 2008). Teng et al. (2023) found that the growth of logistics has a positive impact on e-commerce and the dynamic relationship between logistics development and e-commerce is moderated by the speed of logistics development in a U-shaped manner. Urban logistics has recently been essential to the triple bottom line of sustainable economic development due to the tremendous changes brought about by novel coronavirus pneumonia and the unprecedented rise of global e-commerce (Villa and Monzon, 2021). The concept of

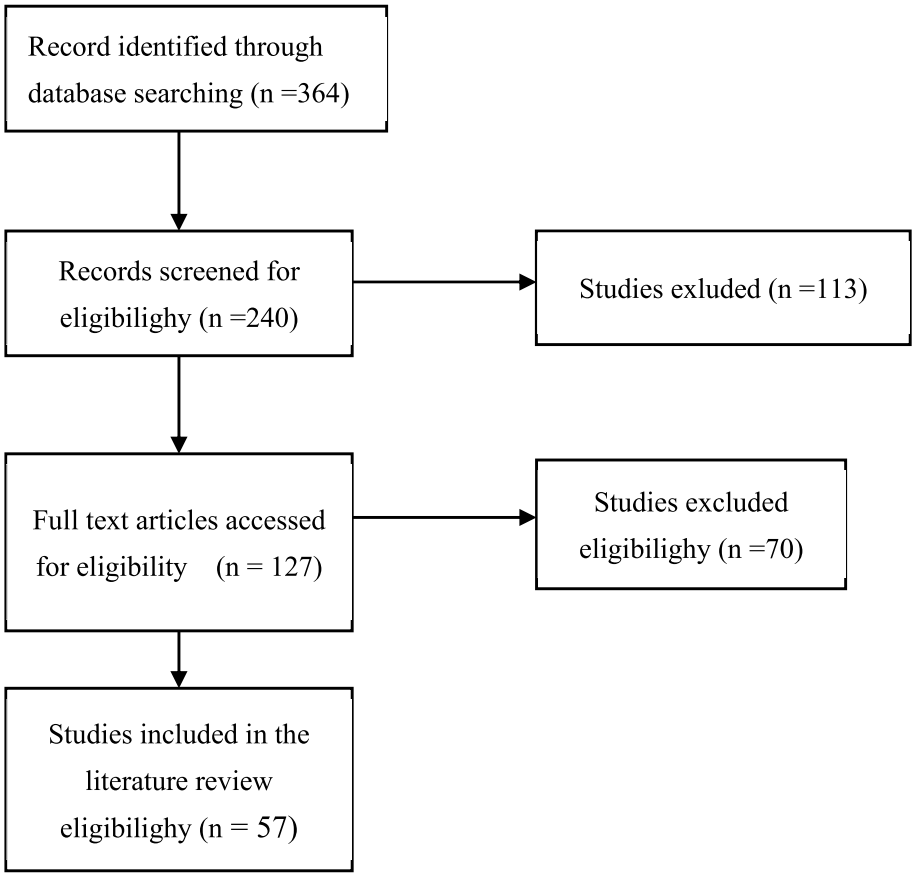

Fig. 1. Flow diagram for the literature review.

"sustainable development" has in some ways displaced previous ecological critiques of development (Kaul et al., 2022). Logistics is a direct link between e-commerce and retail consumers. Some studies have been conducted on the impact of E-commerce development on the logistics business. Logistics service is regarded as one of the most expensive in e-commerce firms (Qin et al., 2020). The various evolution of e-commerce complicates its associated logistics management by examining and exploring the main strategies of the e-commerce logistics business model (Wu and Lin, 2018).

2.1.2. The last one mile of logistics delivery and e-commerce development

The growth of e-commerce business has led to difficulties for the current development of logistics industry. Currently, the logistics efficiency of China is low, and there is a significant gap between the necessary logistical services and the actual logistics services (Lean et al., 2014). Logistics infrastructure is a significant impediment to the growth of e-commerce in China (Teng et al., 2023). Due to the fact that China's logistics sector is still in the early stages of sustainable expansion, it is unable to meet the market's present demand for logistics services. Logistics firms frequently confront issues including delivery failure, reverse logistics, and a consumer-driven economy, all of which put pressure on company expenses. The last mile of logistics delivery is recognized as the most expensive part of the logistics chain due to factors such the large volume of orders and the time constraint for order fulfilment that affect the flow of goods (Prajapati et al., 2023). The last mile is predicted to contribute up to 75% of the total cost of e-commerce logistics due to rising logistics congestions and inadequate planning leading to longer distances to reach the customer locations (Kin et al., 2017). It is estimated to account for 28% of the total transportation cost (Arvidsson, 2013). Even areas with high urbanization and high per capita consumption levels are also facing the most unfavorable conditions in the last mile of logistics distribution (Cardenas et al., 2017). Consumers have increased service expectations in the sector of cross-border e-commerce. Because China's cross-border logistics infrastructure is inadequate, it is required to push e-commerce logistics mode upgrading and to develop a professional, large-scale, and functional logistics service system in cross-border electronic commerce (Li et al., 2017).

2.1.3. The speed and cost of logistics delivery

The competition of e-commerce enterprises lies in how to balance the trade-off between logistics delivery speed and cost. A reasonable location planning of logistics distribution is the key to the efficient operation of the logistics networks (Guo, 2020). Previous studies have carried out logistics performance evaluation for each province, determined geographical and economic indicators, distributed logistics scores using the GIS system, and prioritized indicators using multi-criteria decision analysis tools (Ozceylan et al., 2016). By analyzing the network structure and distribution mode of current e-commerce logistics city distribution, this paper discusses and verifies how to realize the efficiency and cost balance of logistics industry. Some scholars have established logistics network layout model (Liu, 2014; Barenji et al., 2019; Guo, 2020). Or according to the situation of logistics infrastructure in a certain area, the location of logistics facilities and the development of logistics activities are described by using regional data, and the model is estimated, and the key location characteristics affecting the location of logistics facilities are analyzed and revealed (Sakai et al., 2020).

2.2. Relationship between logistics industry and economic development

2.2.1. Logistics investment and economic growth

The coordinated development of logistics industry and the economy

will realize the excavation of great benefit potential of logistics industry. When logistics industry and economy are in a highly coordinated development state, logistics industry will improve economic benefits, reduce operating costs, promote the transformation and upgrading of traditional industries, and promote rapid economic development (Khan et al., 2017). Logistics is indeed the driving force of China's economic growth (Li et al., 2018) and plays a central role in the contemporary economy (Aoyama et al., 2006). Nguyen et al. (2021) showed the positive effect of logistics infrastructure, the on time, up to date delivery, and competitive prices on the growth of Vietnam economy. Hayaloğlu (2015) show that relationship between logistics sector and economic growth varies given the matric in 32 OECD countries. The economic growth of many Asian countries depends on the level of logistics performance of the countries. Investment in logistics infrastructure should be regarded as an investment area that may bring the most benefits, which bring the highest return for the future growth of the countries (Tang and Abosedra, 2019). D'Aleo and Sergi (2017) demonstrate that the global competitiveness index has a favorable impact on GDP and his effect is even more pronounced when logistics performance interacts at the same time. D. Yeo et al. (2020) find the mediating role of international commerce between the logistics performance and economic performance. Further, the sustainable growth of the middle-income countries can be enhanced by improving logistics performance. This synergetic analysis of I4.0 technologies, design postulations for innovations and the underlying sustainability inferences will result in determining the impact of I4.0 at the firm and value chain levels contributing to sustainable development (Ching et al., 2022). Hu et al. (2010) reported that investment in logistics infrastructure Granger cause GDP and the investment in logistics and logistics value added Granger cause each other Considering the huge inequality of regional economic development in China, this paper makes a comparative analysis of regional economic growth in coastal provinces and inland provinces and finds that logistics investment has a significant positive impact on regional economic growth in China (Chu, 2012). According to Li and Chen (2021), the growth of logistics sector has the potential to boost both local economic growth as well the as the economic growth of other areas. Overall, the investment in logistics infrastructure has positive effect on economic growth.

2.2.2. Logistics industry and economic development

Logistics capacity and infrastructure promote economic growth and sectoral value added (Khan et al., 2017). Some scholars have investigated the effect of logistics industry on economic development. By constructing the evaluation index system of urban logistics and economy, Lan et al. (2017) investigate whether there is an interactive relationship between urban logistics and economy, evaluates and tests logistics and economic development level of Beijing, Shanghai, Guangzhou, Chongqing, and Tianjin from 2009 to 2013. These researchers verify the positive relationship between urban economy development and logistics. Another research is based on the method of decision-making trial and evaluation laboratory (DEMATEL), which identifies the influence, attributes of the coordinated development of metropolitan economy and logistics, and reveals the logical relationship among the influence attributes. The DEMATEL-Bayesian network model is used to obtain the key influence attributes and driving paths of coordinated development (Yang et al., 2019).

2.2.3. Logistics industry is important to international trade and investment

Many studies have found that the development of logistics industry will be very important to the trade, so it will directly affect economic development. For instance, better logistics operation will bring higher per capita GDP, better trade opening environment, and greater export opportunities; thus, improving the financial performance of enterprises (Khan et al., 2019). Through an empirical study on the relationship between transportation, logistics, foreign direct investment (FDI), and economic growth in 46 developing countries from 2000 to 2016, Saidi et al. (2020) concluded that transportation and logistics infrastructure contribute to the attractiveness of FDI and sustainable economic growth. Cooperative actions to improve logistics performance of partner countries may have a greater impact on exports of upper-middle income countries than only improving the performance of exporting countries (Celebi, 2019). The environmentally friendly policies and practices adopted in global logistics operations attract foreign investment, which not only improves environmental sustainability but also enhances economic activities in the region with greater export opportunities (Khan and Dong, 2017), the concept of Load capacity factor is important to understand ecological sustainability (Pata and Samour, 2022).

2.2.4. Logistics industry's benefit is heterogeneity in different regions

The development of logistics industry in different regions is heterogeneous. Comparing the coastal and inland regions in China, the contribution of logistics investment to the economic status of underdeveloped inland provinces is greater than that of coastal provinces (Chu, 2012). Low-income economies will be more likely to achieve the highest benefits of their excellent logistics, which will help them to increase their exports. On the contrary, imports of upper-middle-income and high-income economies tend to benefit from better logistics performance than exports (Celebi, 2019).

2.3. Relationship between e-commerce and economic development

The internet revolution has led to the rapid development of e-commerce all over the world. E-commerce allows consumers to shop online easily at any time by using a secure payment system. The internet-led e-commerce industry is changing patterns of global production and consumption. There are two theories on the driving mechanism of the rise of e-commerce: the main driving force of e-commerce growth is within a country or independent of the economic system, which reflects the power of regional economy (Ho et al., 2007). The research shows that in the primary stage of e-commerce, government's supportive policies, effective legal environment and compatible social and cultural infrastructure are powerful promoting factors for the development of e-commerce. With the increasing prevalence of e-commerce, government's supportive policies and socio-cultural infrastructure have promoted e-commerce activities. The rapid development of e-commerce has promoted the economic and social benefits of economic growth and industrial upgrading (Zhu and Thatcher, 2010). E-commerce has significantly promoted the improvement of labor productivity, and then promoted economic development (Vu, K. M. 2013). As a new industry, e-commerce has driven industrial transformation and promoted the development of manufacturing, logistics and service industries. E-commerce has become the driving force of China's economic development (Zhang, et al., 2021). Through the analysis of e-commerce performance, Chen and Zhang further discussed the causality and influence degree of e-commerce performance. IT investment is the most important factor for an enterprise to achieve success, and internet availability has a positive impact on e-commerce transaction volume (Chen and Zhang, 2015). The development of e-commerce has promoted the overall improvement of economy in all aspects. Vietnam is a typical example, Vietnam's fledgling e-commerce will have a greater impact in the future, and more enterprises will benefit from it (Pham et al., 2018). E-commerce has made great progress, making Vietnam one of the fastest growing markets in the world (Le et al., 2012). China's successful experience in e-commerce has had a positive impact on transforming the consumer goods sector of the economy and promoting economic reform. For large enterprises, e-commerce has helped to diversify the end market. For small and medium-sized enterprises, e-commerce promotes functional upgrading and market expansion (Li et al., 2019). China actively develops e-commerce business, and under the promotion of various flows, the influence of e-commerce has spread in all aspects. The adoption of e-commerce has contributed to a significant increase in sales prices, and although its operational requirements have resulted in higher costs,

farmers are nonetheless considered to have benefited from the adoption of e-commerce and total returns have shown an increase (Liu et al., 2021). E-commerce has become a technical catalyst for the changes of industrial structure, employment mode and family economy. Taking Xiaying Village in Central China as an example, it has achieved a leap from traditional agriculture to commercial service and constructed a complete e-commerce-oriented industrial chain (Zhang et al., 2022). Cross-border electronic commerce has a positive impact on China's annual international trade growth (Wang et al., 2017). Although there is great potential for economic development using the internet, it is also necessary to address the possible negative impacts of e-commerce development (Yan et al., 2021). However, through the empirical analysis of Zhejiang Province, there is an inverted "U" relationship between the development of e-commerce and the income gap between urban and rural areas (Li et al., 2021).

2.4. Summary

Many studies discuss and study logistics industry, e-commerce, and economic development. The research on logistics density mainly concentrates on the construction of logistics network; however, reasonable index system for logistics density is lacking. Meanwhile, the research on logistics density's influence on e-commerce and economic development mainly focuses on qualitative discussion. Few scholars conduct quantitative analysis on the influence of logistics density on e-commerce and economic development. Therefore, this study, according to our knowledge is the first one, which determine the measurement index of logistics density and constructs a model of the impact of high-quality development of e-commerce to fill the void in the current research. Given the above discussion, we put forward the following hypotheses:

H1. Logistic density has a positive and significant impact on the protection of e-commerce transactions.

H2. Logistics expansion decreases the growth rate of e-commerce scale development.

3. Method and Theoretical Analysis

Based on the literature reviews, this paper contains the following theoretical models to be tested concerning the impact of logistics density, e-commerce scale, and high-quality economic development.

3.1. Solow growth model introduction

Solow model is a traditional model to study economic growth. Cobb-Douglas production function is the basic basis of Solow model, and its form is

$$Y = F(K, L) = AK^{\alpha}L^{\beta} \tag{1}$$

Where Y means output, K means capital, L means labor, and A means technical level. α and β present the contribution of capital and labor input to output growth, and satisfy the conditions of $0< \alpha, \beta <1$ and $\alpha + \beta = 1$. Cobb-Douglas production function has constant returns to scale for capital and labor. According to Euler's theorem, it can be seen that the sum of the product of the marginal productivity of capital and labor and the input quantity is equal to the output when A is constant.

On the basis of Cobb-Douglas production function, Solow model further introduces the concept of "effective labor". It assumes that technological progress (A_t) is given. On this basis, it analyzes how the distribution of output (Y_t) between consumption and investment affects capital accumulation and growth. Solow model regards savings rate s as an exogenous constant. Solow growth model illustrates how capital, labor and the level of technology affect the output of an economy dynamically (Romer D. 2006). The production function is given by

$$Y_t = F(K_t, A_t L_t) \tag{2}$$

Where t denotes time, Y denotes output, K denotes capital, A denotes the level of technology and L denotes labor. When technology enter multiplicatively with labor it is referred to as labor-augmenting or Harrod-neutral. When technology is multiplied by labor, it is called labor increase or Harold neutrality. It means that when in period t, only $\frac{1}{A_t}$ of labor is needed to complete the production that it takes 1 unit of labor to complete in period 0. According to the nature of constant return to scale of production function. F is a constant returns to scale production function. I.e. $F(cK, cAL) = cF(K, AL)$ for all $c > 0$. We can multiply both sides of formula (2) by $\frac{1}{AL}$, and then we get formula (3)(4).

$$y_t \equiv \frac{Y_t}{A_t L_t} = \frac{F(K_t, A_t L_t)}{A_t L_t} = F\left(\frac{K_t}{A_t L_t}, 1\right) \equiv f(k_t) \tag{3}$$

$$k_t = \frac{K_t}{A_t L_t} \tag{4}$$

where k_t denotes the average amount of capital per unit of effective labor. And y_t denotes the output per unit of effective labor as a function of capital per unit of effective labor.

There are two assumptions about the above Solow model.

(1) $f(k_t)$ satisfies $f(0) = 0, f'(k) > 0, f''(k) < 0$. Where $f'(k)$ represents the marginal product of capital. $f'(k) > 0$ means that the marginal product of capital is positive, but since $f''(k) < 0$, $f'(k)$ tends to decrease as the average amount of capital used per unit of effective labor (k_t) increases.

(2) $f(k_t)$ satisfies the Inada Condition, $\lim_{k\to 0} f'(k) = \infty$, $\lim_{k\to\infty} f'(k) = 0$. Inada Condition ensure that the path of economic growth is convergent.

The production function is shown in Fig. 2.

3.2. Relationship between logistics density and high-quality development of E-commerce scale

Solow model, as a basic theory to understand economic growth, depicts the path of studying economic growth. Labor efficiency is the aggregation of all factors affecting economic growth except labor and capital. On the basis of Solow growth model, the measurement index of logistics density and high-quality economic development is constructed.

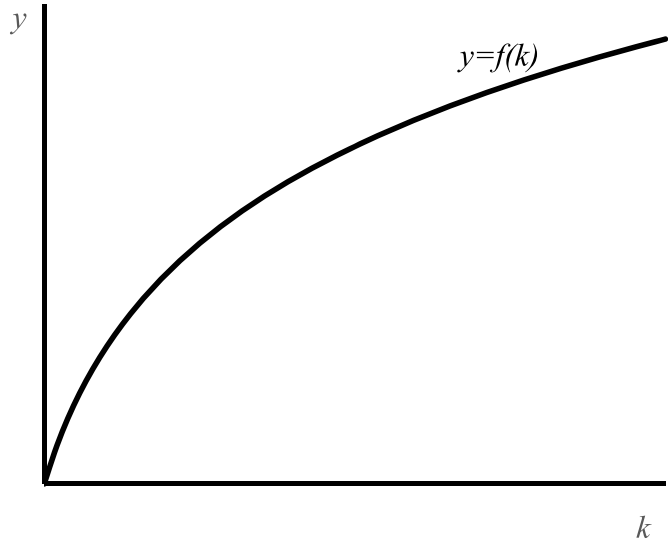

Fig. 2. Production function of Solow growth model.

(1) The proportion of e-commerce transactions $EC_{i,t}$. To measure the scale of E-commerce and the high-quality economic development level, this paper takes the proportion of e-commerce transaction volume to regional GDP (Q) to reflect the influence of e-commerce, a tertiary industry giant, on the industry structure. Therefore, as the definition of y on the left side of formula (3), we defined $EC_{i,t}$ the proportion of e-commerce scale to regional GDP as shown in formula (5). The e-commerce scale mainly includes two aspects: e-commerce sales volume and e-commerce purchase volume. Because there is no statistical index for e-commerce transaction volume at present, we use the average of e-commerce sales volume and e-commerce purchase volume as the e-commerce transaction volume, which is shown in formula (5).

$$y = EC_{i,t} = \frac{(E-commerce\ sales\ volume + E-commerce\ purchase\ volume)/2}{Q} \tag{5}$$

$EC_{i,t}$ represents the proportion of e-commerce transactions at t time of i provinces or autonomous regions, and the molecular part is the arithmetic average of e-commerce sales and e-commerce purchases at t time of i region, which is the e-commerce transaction amount.

(2) LOG_{it} shows logistics density. In this paper, as the definition of k on the right side of formula (3), we can define the index of logistics density LOG_{it} as the average amount of service outlets in logistics industry per unit of effective product of output level and number of employees in logistics industry. It is the ratio between the number of service outlets in logistics industry (N_{it}) and the product of output level with number of employees in logistics industry (Q_{it}*E_{it}). Therefore, formula (6) is used to express the average amount of service outlets in logistics industry per unit of effective product of output level and number of employees in logistics industry LOG_{it}, which means the logistics density in i provinces and autonomous regions at t time.

$$LOG_{i,t} = \frac{N_{i,t}}{Q_{i,t} * E_{i,t}} \tag{6}$$

In China, the development of logistics industry enhances the development of e-commerce, and the logistics capability of a region plays a vital role in the development of e-commerce, showing a positive correlation, which can lead to the following Hypothesis. In this paper, the $LOG_{i,t}$ variable is regarded as the density of logistics industry, that is, the unit effective labor of logistics industry, which is synonymous with kt in formula (4). In this paper, $EC_{i,t}$ is used as a measure of effective output in high-quality economic development, so this paper thinks that LOG and EC conform to the relationship of $EC_{i,t} = f(LOG_{i,t})$.

Hypothesis 1. $EC_{i,t} = f(LOG_{i,t})$ meets the condition in formula (7).

$$EC_{i,t}' = f'\left(LOG_{i,t}\right) > 0 \tag{7}$$

That is, the high-quality development of e-commerce economy i.e. the proportion of e-commerce transactions $EC_{i,t}$ increases when the logistics density LOG_{it} increase, which means that $EC_{i,t}$ has significant positive correlation with LOG_{it}.

3.3. Relationship between the growth rate of logistics density and the growth rate of high-quality development of e-commerce scale

After analyzing the influence of logistics density on the high-quality development of e-commerce economy in 31 provinces and autonomous regions over time, we analyze the influence relationship of growth rate, that is, to discuss the relationship of net value changes of these two variables at different time in the region.

$$l_{i,t} = \frac{\Delta LOG_{i,t}}{LOG_{i,t-1}} = \frac{LOG_{i,t} - LOG_{i,t-1}}{LOG_{i,t-1}} \tag{8}$$

$$ec_{i,t} = \frac{\Delta EC_{i,t}}{EC_{i,t-1}} = \frac{EC_{i,t} - EC_{i,t-1}}{EC_{i,t-1}} \tag{9}$$

In formula (8), $l_{i,t}$ are the change rate of logistics density while in formula (9) $ec_{i,t}$ is the change rate of the proportion of e-commerce transactions.

Then we can rewrite formula (7) to formula (10).

$$ec_{i,t} = g\left(l_{i,t}\right) > 0 \tag{10}$$

China's logistics efficiency is not high, and there is a serious gap between the required logistics services and the actual logistics services. Logistics enterprises often face a series of problems and challenges, such as distribution failure, reverse logistics and consumption-driven economy, which bring pressure on enterprise costs. Therefore, we can further deduce the second hypothesis as follows.

Hypothesis 2. $EC_{i,t} = f(LOG_{i,t})$ satisfies the condition in formula (11) and (12).

$$EC_{i,t}'' = f''\left(LOG_{i,t}\right) < 0 \tag{11}$$

i.e.

$$ec_{i,t}' = g'\left(l_{i,t}\right) < 0 \tag{12}$$

That is, with the increase in the change rate of logistics density, the change rate of the proportion of e-commerce transactions decrease. This means that the positive influence of logistics density LOG_{it} on the growth of the high-quality development of e-commerce economy i.e. the proportion of e-commerce transactions ($EC_{i,t}$) decreases, and the influence function is an increasing convex function.

The relation between logistics density LOG_{it} and the proportion of e-commerce transaction transactions $EC_{i,t}$ can be illustrated by Fig. 3 as follows.

4. Empirical analysis of the influence of logistics density on the scale of E-commerce

4.1. Variable selection and data source

4.1.1. Variable selection

This paper mainly analyzes the influence of logistics density on the high-quality development of e-commerce economy i.e. the proportion of e-commerce transactions in China. Therefore, the proportion of e-commerce transactions (EC) in 31 provinces and autonomous regions in China from 2013 to 2020 is selected as the explained variable; and logistics density, that is, the average amount of service outlets in logistics

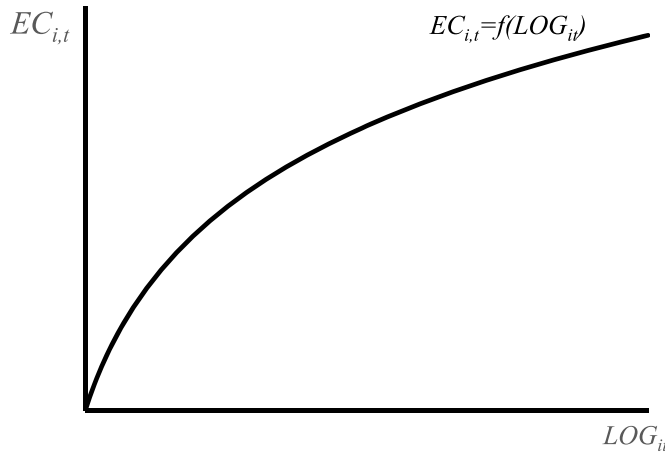

Fig. 3. Function of $EC_{i,t}$ on LOG_{it}.

industry per unit of effective product of output level and number of employees in logistics industry (*LOG*), is the core explanatory variable. Employment level (unemployment rate), urbanization level (urban population rate), scientific research input level (R&D input ratio of enterprises) and human resources level (ratio of college degree or above) are selected as control variables.

Dependent variable: *EC* is the proportion of e-commerce transaction volume in regional GDP. This variable reflects the current scale of e-commerce, and its proportion can effectively reflect the regional economic structure and development level, and it is also an important and intuitive indicator reflecting the high-quality development of regional economy.

Independent variable: *LOG* refers to the level of logistics density, which refers to the per capita output of people engaged in logistics and related industries in each logistics network. This is conducive to the evaluation of logistics output level and operational efficiency in each region. This paper mainly studies the influence of logistics density on the scale and economic structure of E-commerce. Therefore, *LOG* is chosen as the core explanatory variable.

The control variables: *CR* refers to the urbanization rate of each province and city. Based on the proportion of the urban population, urban population growth directly or indirectly provides a continuously expanding market for e-commerce economic growth, is the booster of E-commerce development, and is the environmental basis for the transformation and upgrading of economic structure. *UR* refers to the unemployment rate of each province and city, which reflects the employment situation of the working population in this period and represents the healthy development of the whole economy. The unemployment rate reflects the quality of economic development. Maintaining the unemployment rate at the natural unemployment level will make the E-commerce industry and even the whole macro-economy develop healthily. *RD* represents the proportion of enterprises' investment in scientific research activities to regional GDP, is the core of China's scientific and technological activities and the source of innovation opportunities. It is an important pillar of China's strategy of rejuvenating the country through science and education, and is of great significance to enhance the healthy and rapid development of the national market economy. HR is the structure of human capital, which refers to the proportion of people aged six and above with college education or above. The stock of human capital can promote the high-quality development of economy, not only in terms of technical ability, but also in terms of national influence, and its increase can promote the improvement of total factor productivity.

4.1.2. Data source

The data used in this paper mainly come from China Statistical Yearbook 2013–2021, China Tertiary Industry Statistical Yearbook 2013–2020, and Statistical Bulletin on Postal Industry Development of 31 Provinces and Autonomous Regions in China from 2013 to 2020 (see Table 1).

When calculating the per capita effective output of logistics industry, the number of logistics outlets, the number of employees in logistics industry, and the regional GDP data are needed. The data of logistics outlets comes from the data of postal outlets in China Statistical Yearbook, including the data of postal enterprises and express delivery enterprises that have obtained express delivery business licenses. The data source of logistics employees is the data of transportation, warehousing, and postal employees in China Statistical Yearbook. The regional GDP is also directly obtained from China Statistical Yearbook.

4.2. Model construction

4.2.1. Empirical model setting

This paper mainly studies the influence of logistics density on the proportion of E-commerce transactions. The explanatory variables are introduced into the model, and the influence of employment level, urbanization level, scientific research investment level, and human resources level on high-quality economic development is considered. The control variables are also introduced into the regression model, and a multiple regression model based on panel data of 31 provinces and autonomous regions from 2013 to 2020 is set, as shown in Equation (12).

Table 1
Variable definitions and data sources.

AbbreviationsVariables	Definition	Data source	
EC (y)	Formula(4): the proportion of E-commerce transaction volume to regional GDP	China Statistical Yearbook	China Tertiary Industry Statistical Yearbook
LOG (x)	Formula(5): the average amount of service outlets in logistics industry per unit of effective product of output level and number of employees in logistics industry	China Statistical Yearbook	Statistical Bulletin on Postal Industry Development
CR (z1)	Proportion of urban population to total population	China Statistical Yearbook	
UR (z2)	Unemployment rate	China Statistical Yearbook	
RD (z3)	The proportion of R&D investment of enterprises to GDP	China Statistical Yearbook	
HR (z4)	Proportion of the population aged 6 and above with college degree or above to the total population aged 6 and above	China Statistical Yearbook	

$$y_{i,t} = \alpha x_{i,t} + \beta_1 z1_{i,t} + \beta_2 z2_{i,t} + \beta_3 z3_{i,t} + \beta_4 z4_{i,t} + \gamma_i + \gamma_t + \epsilon_{i,t} \quad (13)$$

In Equation (13), $y_{i,t}$ represent the EC indicators of i provinces and autonomous regions in t years, which is the explained variable. $x_{i,t}$ are logistics density of i provinces and autonomous regions in t years, which are the core explanatory variables of the model. $z1_{i,t}$, $z2_{i,t}$, $z3_{i,t}$, $z4_{i,t}$ are the control variables. $\epsilon_{i,t}$ is a random interference term, and at the same time, the fixed effect of provinces and cities (γ_i) and the fixed effect of years (γ_t) are added.

According to section *3 Method and Theoretical Analysis* and part 4.2 *Model Construction*, the block diagram of the overall procedure is shown in Fig. 4.

4.2.2. Descriptive statistics of variables

The measurement software used in this paper is Stata/SE V16 (Perpetual Academic License Single user, Beijing Uone Info &Tech Co.,Ltd). Descriptive statistics of variables are shown in Table 2.

4.2.3. Correlation analysis of variables

First, before regression analysis, we carried out correlation among all variables. The results of correlation coefficients are shown in Table 3. The explanatory variables are significantly correlated with the explained variables, and all the control variables are significant at a significance level of 1%, which shows that the selection of control variables is effective and can continue to carry out empirical analysis of the model.

Because the correlation coefficient between *z1* and *z4* is 0.846 and 1% significant, we do the multicollinearity test and variance expansion coefficient test again. The multicollinearity test results are shown in Table 4. The VIF value of *LOG* is 1.256, the VIF value of *CR* is 7.096, the

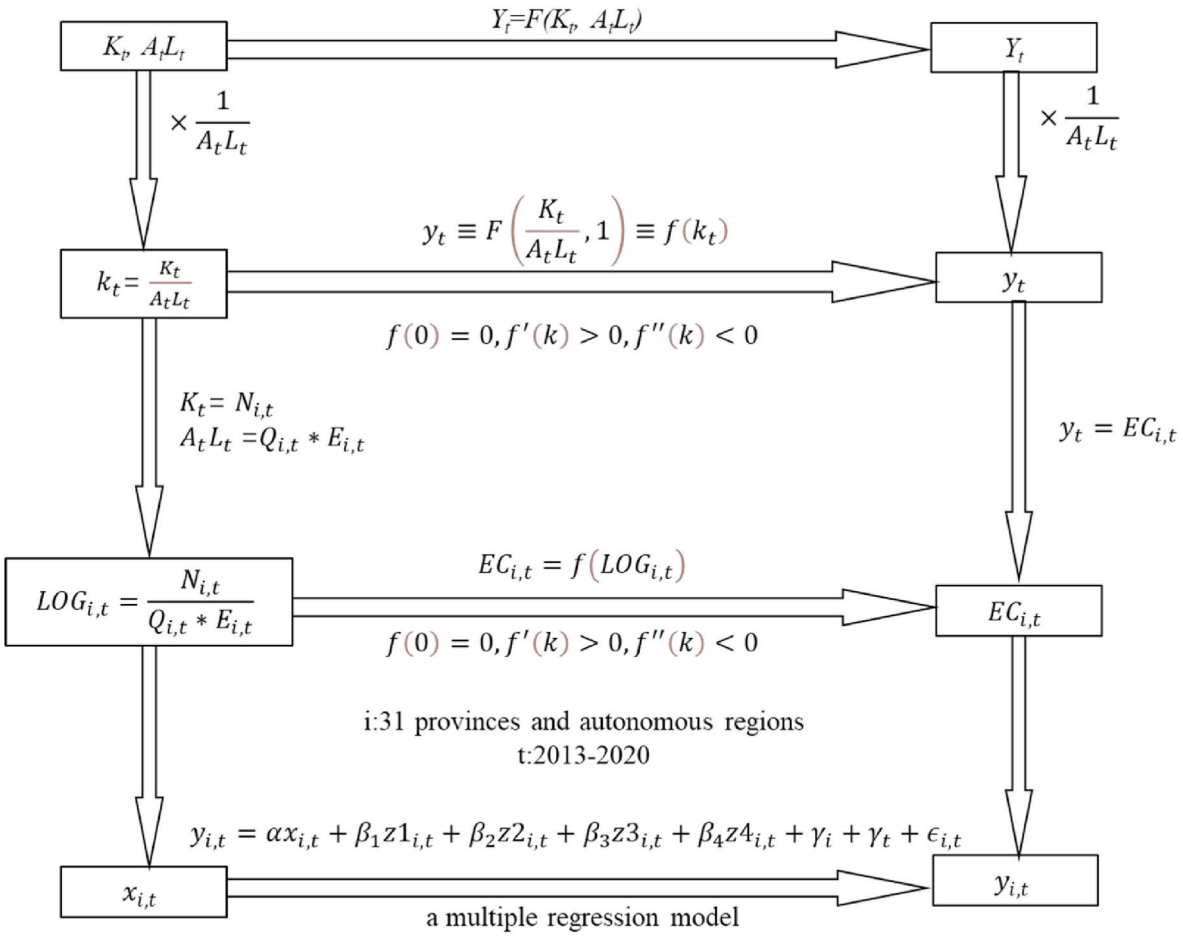

Fig. 4. Flow chart from theoretical model to empirical model.

Table 2
Descriptive statistics of variables.

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Y	248	0.100	0.093	0.013	0.572
X	248	0.041	0.120	0.002	0.946
z1	248	0.595	0.121	0.358	0.885
z2	248	3.195	0.623	1.200	4.200
z3	248	1.073	0.659	0.047	3.242
z4	248	0.145	0.066	0.077	0.382

Data source: 2014–2021 China Statistical Yearbook http://www.stats.gov.cn/tjsj/ndsj/(2014-2021) (accessed on Oct. 2, 2022)

VIF value of *UR* is 1.110, the VIF value of *RD* is 2.054, and the VIF value of *HR* is 4.978. The VIF value of each variable is less than 10. It shows that there is no multicollinearity, and it can be analyzed empirically.

4.3. Empirical results and discussion

4.3.1. Baseline regression results

We choose the two-way fixed effect model of provinces and cities and years to test the influence of logistics density on the proportion of e-

Table 4
Multicollinearity test results.

Variable	VIF	1/VIF
z1	7.096	0.141
z4	4.978	0.201
z3	2.054	0.487
X	1.256	0.796
z2	1.110	0.853
Mean VIF	3.300	

Data source: 2014–2021 China Statistical Yearbook.http://www.stats.gov.cn/tjsj/ndsj/(2014–2021) (accessed on Oct. 2, 2022).

Table 3
Correlation analysis of variables.

Variable	y	x	z1	z2	z3	z4
Y	1.000					
X	−0.152**	1.000				
z1	0.736***	−0.371***	1.000			
z2	−0.270***	−0.154**	−0.053	1.000		
z3	0.313***	−0.348***	0.599***	0.113*	1.000	
z4	0.817***	−0.194***	0.846***	0.195***	0.300***	1.000

*** means $p < 0.01$, ** means $p < 0.05$, * means $p < 0.1$.
Data source: 2014–2021 China Statistical Yearbook.http://www.stats.gov.cn/tjsj/ndsj/(2014–2021) (accessed on Oct. 2, 2022).

Table 5
Baseline regression results.

Variable	(1)	(2)	(3)	(4)	(5)
X	0.038***	0.139***	0.145***	0.169***	0.169***
	(3.80)	(4.06)	(4.11)	(4.49)	(4.48)
z1		−0.011***	−0.010***	−0.012***	−0.012***
		(-3.26)	(-3.15)	(-3.58)	(-3.58)
z2			0.016**	0.017**	0.017**
			(2.17)	(2.60)	(2.64)
z3				0.033**	0.033**
				(2.39)	(2.34)
z4					0.006
					(0.03)
cons	0.057***	0.633***	0.546***	0.640***	0.639***
	(6.77)	(3.68)	(3.34)	(3.83)	(3.71)
Observations	248	248	248	248	248
R-squared	0.348	0.484	0.450	0.519	0.519
Prob (F-statistic)	0.000	0.000	0.000	0.000	0.000

*** means $p < 0.01$, ** means $p < 0.05$, * means $p < 0.1$.: t statistics in ().
Data source: 2014–2021 China Statistical Yearbook. http://www.stats.gov.cn/tjsj/ndsj/(2014-2021) (accessed on Oct. 2, 2022).

commerce scale. The baseline regression results are shown in Table 5.

Firstly, the model is used for benchmark regression to test logistics density on the proportion of e-commerce transactions. In Table 5, column (1) is the regression result without adding any control variables, and column (2) to column (5) are the regression results after introducing control variables in turn. The results in column (1) show that the influence coefficient of logistics density on the proportion of e-commerce transactions is 0.038, and it is significant at the 1% significance level, which preliminarily shows that logistics density has a significant positive impact on the proportion of e-commerce transactions. With the addition of control variables, the coefficients of core explanatory variables are always positive, and all of them have passed the significance test of 1%. After introducing all the control variables, the coefficients of core explanatory variables are 0.169, R^2 is stable at a certain level, and the P value of the model is always 0.000, which confirms Hypothesis 1. Logistics density will have a significant positive impact on the proportion of E-commerce transactions, i.e. $EC_{i,t}$ has significant positive correlation with LOG_{it}.

In terms of control variables, *CR* has a significant negative impact on the scale of E-commerce transactions, while *UR* and *RD* have a significant positive impact on the proportion of E-commerce transactions, and *HR* has no significant impact.

4.3.2. Growth rate regression results

According to Hypothesis 2, the growth rate of logistics density is regressed with the growth rate of the proportion of e-commerce transactions. The results are shown in Table 6.

The model is replaced by explanatory variable (*EC*) and core explanatory variable (*LOG*) with their growth rate data, and the time series become 2014–2020. The results show that there is a significant negative correlation between the above two growth rates, and after adding all the control variables, the explanatory variable coefficient is −0.305, which is significant at 5%. The P value of the model is significant, which can support hypothesis 2 to some extent, that is, with the rapid growth of logistics density ($l_{i,t}$), the growth rate of the proportion of e-commerce transactions ($ec_{i,t}$) slows down.

4.4. Model verification

4.4.1. Heterogeneity test

China has a vast territory, and different regions are affected by geographical location, natural conditions, economic foundation, and other factors. There is a certain heterogeneity between the development of logistics industry and the development of e-commerce industry. The proportion of e-commerce transactions in 31 provinces and cities is weighted and averaged according to the year, and the data in 2020 is taken as the maximum weight 8 and the minimum weight 1 in 2013. The 31 provinces and autonomous regions are divided into two categories. The leading provinces and cities in e-commerce development are Beijing, Shanghai, Guangdong, Tianjin, Shandong, Chongqing, Liaoning, Zhejiang, Inner Mongolia, Hainan, Anhui, Qinghai, Jiangxi, Jiangsu, and Sichuan. Shanxi, Hubei, Guizhou, Gansu, Hebei, Yunnan, Henan,

Table 6
Growth rate regression results.

Variable	(6)	(7)
Δx	−0.313*	−0.305**
	(-2.00)	(-2.04)
z1		−0.034
		(-0.64)
z2		−0.072*
		(-1.73)
z3		0.197
		(0.93)
z4		−4.504*
		(-2.00)
cons	0.516***	2.980
	(6.03)	(1.02)
Observations	217	217
R-squared	0.127	0.149
Prob (F-statistic)	0.007	0.000

*** means $p < 0.01$, ** means $p < 0.05$, * means $p < 0.1$.: t statistics in ().
Data source: 2014–2021 China Statistical Yearbook.http://www.stats.gov.cn/tjsj/ndsj/(2014-2021) (accessed on Oct. 2, 2022).

Table 7
Heterogeneity test results.

Variable	(8)	(9)
X	1.547***	0.006
	(4.05)	(0.39)
z1	−0.016***	0.001
	(-6.60)	(0.57)
z2	0.019	0.003
	(1.56)	(0.47)
z3	0.052***	−0.007
	(4.16)	(-0.38)
z4	0.038	0.100
	(0.12)	(0.70)
cons	0.956***	−0.018
	(5.69)	(-0.23)
Observations	120	128
R-squared	0.671	0.361
Prob*(F-statistic)*	0.000	0.000

*** means $p < 0.01$, ** means $p < 0.05$, * means $p < 0.1$.: t statistics in ().
Data source: 2014–2021 China Statistical Yearbook.
http://www.stats.gov.cn/tjsj/ndsj/(2014-2021) (accessed on Oct. 2, 2022).

Fujian, Guangxi, Ningxia, Shaanxi, Xinjiang, Guizhou, Jilin, and Heilongjiang rank behind in terms of e-commerce scale. The heterogeneity test of the two types of provinces and cities is carried out, and the results are shown in Table 7.

Column (8) is the regression result of the model of the influence of logistics density on the proportion of e-commerce transactions in the leading provinces and cities in e-commerce development. The core explanatory variable coefficient is 1.547, and it has passed the 1% significance test, which confirms that the logistics density has a positive effect on the proportion of e-commerce transactions in such areas. However, in the backward areas of e-commerce development, the logistics density is only 0.006, and there is no significant impact. It shows that the impact of logistics density on the proportion of e-commerce transactions has not been in-depth, and the development degree of logistics density shows a large degree of regional differences, which is closely related to the development of e-commerce.

4.4.2. Lagged effect test

Baseline regression results show that logistics density has a significant immediate positive effect on the scale of e-commerce in various provinces and cities in China. Logistics density plays an important role in infrastructure construction for economic development, which is a long-term basis for stimulating economic growth. In order to verify whether logistics density has a lag effect on the scale of e-commerce in China, the lag term of logistics density is added to the benchmark regression model for testing. Considering the significance of the influence effect and the robustness of the model, the lag term of LOG_{it} is added for regression, and the results are shown in Table 8.

The results show that L. x has a significant effect on y, and the influence coefficient is 0.155, which indicates that LOG_{it} lagging one period still has a significant positive effect on the growth of $EC_{i,t}$. This shows that the logistics industry is the foundation of the rapid development of e-commerce, and the increase of logistics density will still play a significant positive role in the scale of e-commerce in the next year. In order to speed up the development of e-commerce and help high-quality development, the logistics industry should be built for a long time and the logistics density level should be steadily improved.

4.5. Discussion

Logistics services have become a key factor in the growth of e-commerce sector. To promote high-quality economic development, research into the link between the growth of the logistics industry and the e-commerce sector can serve as the theoretical foundation and model for constructing a unified national market in the future. Existing research on logistics density is sparse, and it lacks a unified and standardized measurement index; so, more research is required. Based on the Solow model from macroeconomics, this study proposes the index of constructing logistics density, explores the link between logistics density and e-commerce transaction scale, and conducts an empirical test, which provides a frontier contribution for wider logistics density research, e-commerce application, and high-quality economic development.

Table 8
Lagged effect test results.

Variable	(5)	(10)
X	0.169***	
	(4.48)	
L.x		0.153***
		(5.25)
z1	−0.012***	−0.010***
	(-3.58)	(-3.49)
z2	0.017**	0.014*
	(2.64)	(2.20)
z3	0.033**	0.026**
	(2.34)	(2.66)
z4	0.006	−0.207
	(0.03)	(-1.01)
cons	0.639***	0.567***
	(3.71)	(3.73)
Observations	248	248
R-squared	0.519	0.416
Prob*(F-statistic)*	0.000	0.000

*** means $p < 0.01$, ** means $p < 0.05$, * means $p < 0.1$.: t statistics in ().
Data source: 2014–2021 China Statistical Yearbook. http://www.stats.gov.cn/tjsj/ndsj/(2014-2021) (accessed on Oct. 2, 2022).

4.5.1. Direct effect of logistics density on e-commerce transaction scale

The results show that logistics density has a positive and significant impact on the scale of e-commerce transactions. Further results demonstrate a lag effect. In the era of intelligent logistics, logistics capability is positively correlated with the performance of e-commerce enterprises (Cho et al., 2008). It is the survival strategy of e-commerce enterprises to improve the logistics service level and fully penetrate the sinking market. The different evolution of e-commerce complicates its corresponding logistics management (Wu and Lin, 2018). This inevitably promote logistics enterprises to expand their business outlets, transfer stations and other infrastructure, and open up a wider logistics network. Logistics capacity and infrastructure promote economic growth and sector value-added (Khan et al., 2017). To sum up, we can conclude that logistics density has a significant role in promoting the scale of e-commerce transactions and economic development.

Among control variables, proportion of urban population to total population (CR) has a negative and significant impact on the scale of e-commerce transactions, which may be due to the persistent and significant digital divide between urban and rural populations and between urban population and rural-to-urban migrants. In reality, the digital divide between urban and rural populations in China continues to widen, and within cities, rural-to-urban migrants have more difficult access to ICT than urban permanent residents (Zhu and Chen, 2016) do. Unemployment rate (UR) has a positive and significant impact on the scale of e-commerce transactions. The labor market is faced with some imbalance caused by the economic transformation brought about by technological progress. The difference is that existing studies believe that e-commerce has a positive impact on the labor market by promoting the social integration of people who are excluded from the labor market for subjective reasons (Banescu, C. E. et al., 2022). The proportion of R&D investment of enterprises to GDP (RD) has a significant positive impact on the scale of e-commerce transactions. Zhu et al. (2023) takes e-commerce and R&D as input factors, and finds that e-commerce capital stock and R&D capital stock have a positive and significant impact on output growth.

4.5.2. Influence of logistics density on the growth rate of e-commerce transaction scale

According to the results, due to the increase of logistics density, the growth rate of e-commerce transaction scale decreases. Logistics infrastructure is an obstacle to the development of e-commerce in China (Lean et al., 2014). The difference in scale structure and input efficiency of logistics infrastructure construction elements leads to unbalanced development of e-commerce scale, labor migration, and capital outflow, which reduces the support of logistics industry elements, which may be the reason for the slow growth of logistics density on e-commerce transaction scale. Logistics enterprises are often faced with a series of problems and challenges such as distribution failure, reverse logistics, and consumption-driven economy (Cardenas et al., 2017). China needs to promote the upgrading of e-commerce logistics mode and establish a specialized, large-scale and functional logistics service system in cross-border electronic commerce (Lan et al., 2017).

4.5.3. Heterogeneity analysis of logistics density on e-commerce transaction scale

The results show that the logistics density of the leading provinces

and cities has a more significant impact on the proportion of e-commerce transactions. This is mainly related to the gradient development characteristics of e-commerce in China, and the different evolution of e-commerce makes its corresponding logistics management complicated. In areas where e-commerce industry has developed for a long time, the logistics industry structure and the transportation infrastructure are relatively perfect, the degree of marketization is relatively high, which can better promote the high-quality development of e-commerce and economy. In some areas, the coordination degree between logistics industry and e-commerce industry is still at a low level. This is in line with the studies of Yan et al. (2021) and Zhang et al. (2020). Chu (2012) conducted a comparative analysis of the regional economic growth of coastal provinces and inland provinces, and found that logistics investment synchronized the economic growth of each region. In contrast, Celebi (2019) demonstrate that low-income economies would be more likely to realize the maximum benefits of their excellent logistics.

5. Conclusions and recommendations

5.1. Conclusions

By analyzing the theoretical mechanism and empirical results of logistics density and the proportion of s-commerce transactions, this paper draws the following conclusions by contributing to the literature on the relationship between logistics and e-commerce.

First, logistics density has a positive and significant impact on the proportion of e-commerce transactions, thus promoting the optimization of economic structure. The logistics density has a significant positive impact on the proportion of e-commerce transaction volume at the provincial panel level. With the all-round development of logistics industry, it will drive the rapid development of e-commerce industry. Second, the growth rate of the proportion of e-commerce transactions is slowing down, which is partly due to the expansion of logistics. With the accelerating growth rate of logistics density, the expansion of the proportion of e-commerce transactions slows down, which has a certain degree of influence. It is necessary to pay more attention to the coordinated development of the two industries and solve the problem of low coordination between logistics industry and economy after high-quality development. Third, there are regional differences in the development of e-commerce in China, and the role of logistics density in the proportion of e-commerce transactions is also significantly different. In areas where e-commerce development is relatively leading, the promotion of logistics industry development to e-commerce development is far greater than that in areas where e-commerce development is relatively backward. Finally, there is lag effect, that is, the past logistics density has a positive and significant impact on the current development of e-commerce. This further illustrates the importance of logistics density to the healthy development of e-commerce transactions and even economic structure.

5.2. Recommendations

Through theoretical and empirical analyses, this paper argues that improving logistics density can promote the proportion of e-commerce transactions and effectively promote the transformation and upgrading of macroeconomic structure. Therefore, we should vigorously support the development of logistics industry, intensify the construction of logistics infrastructure, and expand the coverage and depth of logistics services. At the same time, we should solve the problems of redundant construction brought about by the rapid development of logistics. Logistics industry and e-commerce industry should develop effectively to promote the establishment of China's warehousing and logistics system and to help the high-quality economic development. Based on the empirical results, we can propose the following recommendations.

5.2.1. Recommendations for government

Firstly, improve the logistics' infrastructure. The imperfect construction of logistics-related infrastructure leads to the unbalanced and slow development of logistics in China. The national logistics system is huge, so it is necessary to speed up the construction of logistics industry take big cities as the center, carry out radiation drive, strengthen regional cooperation, and build a national logistics network platform. Government should encourage and support logistics companies to establish terminal distribution service stations. The government should give preferential policies such as tax and land use fees to service stations, develops logistics distribution as public infrastructure, and integrates and standardizes terminal distribution.

Secondly, in areas where e-commerce is underdeveloped, in addition to increasing logistics density, measures such as popularizing the internet and helping the poor should be taken to promote the development of E-commerce and logistics. Unified planning and construction of local logistics parks, with various express delivery companies uniting to allocate, classify and distribute resources. In terms of planned land use, rent and taxation, the state will give corresponding preferential treatment, simplify the examination and approval procedures, and encourage and guide express delivery companies to enter.

Thirdly, the government should formulate relevant laws and regulations in logistics industry to protect the consumers, logistics and e-commerce enterprises, thus reducing losses caused by disputes in logistics distribution. The key to fostering the development of logistics is improving our laws and regulations regarding logistics and enhancing the oversight of the logistics sector.

5.2.2. Recommendations for company

Firstly, given the development of logistics enterprises, they should adopt new technologies and new management means to realize the refinement of sorting routes, thus reducing the operation of secondary outlets, improving work efficiency, and avoiding redundant construction. Through cooperation and exchanges between industries, the logistics enterprises should prevent vicious competition and seek common development. Combine with powerful third-party terminal joint distribution companies to standardize end users, logistics enterprises should break the situation of high homogenization, find their development direction and competitive advantage, provide customers with more personalized and personalized services, and enhance the value-added of services.

Secondly, the logistics enterprises should establish the logistics management concept of e-commerce enterprises and establish new business concepts and new strategic advantages to adapt to the rapid development of logistics industry. E-commerce companies must expand their distribution networks, set up more executive centers, adjust vehicle configuration to meet the last mile problem, and cooperate with local distributors. At the same time, these enterprises should actively participate in the competition in the international market, conform to the trend of green logistics, promote the sustainable development of enterprises, and change the current situation that they only pay attention to the market but ignores the operation in the past. The optimal allocation of various resources will continuously improve the economic and social benefits of the e-commerce industry.

Thirdly, logistics and e-commerce enterprises should unite and cooperate to speed up the modernization process and intelligent construction of logistics industry (Sui and Rejeski, 2002).

5.3. Research limitations

This study investigated the link between logistics density, e-commerce, and high-quality economic development. However, due to the particularity of the logistics industry, all the relevant data of logistics-related enterprises in a broad sense are limited, so we selected all the data of postal industry that can be obtained from China Statistical Yearbook, which has certain limitations. As China's e-commerce has a

long history and lacks accurate statistical indicators, it is easy to lead to data loss in obtaining wider time span data. In addition, this study suggests that the heterogeneity analysis in this area can be more in-depth and comprehensive in the future.

CRediT authorship contribution statement

Shaolong Zeng: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Qinyi Fu:** Conceptualization, Methodology, Software, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Funding acquisition. **Fazli Haleem:** Writing – original draft, Writing – review & editing. **Yiyang Han:** Conceptualization, Formal analysis, Writing – review & editing. **Ling Zhou:** Conceptualization, Methodology, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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