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Original Research

Energy Consumption and Growth of China's Logistics Industry: an Empirical Analysis Based on "Growth Drag"

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Abstract

Logistics is China's core industry. However, excessive energy dependence restricts its growth rate and leads to environmental pollution problems. It can help to deal with the above problems by studying the relationship between the growth of the logistics industry and energy consumption. This study firstly constructed a model for calculating the growth drag of energy consumption, and then the empirical analysis was conducted by collecting data. The main results show that the marginal contribution rate of various energy sources (i.e. coal, crude oil, natural gas and clean electricity) to the growth of the logistics industry was -0.052581, -0.011915, 0.257324, and 0.011479, respectively. The growth drag of various energy sources was 0.005252, 0.001184, 0.21806, and 0.001880, respectively. The above results revealed that the consumption of coal and crude oil not only slow down the growth rate of the logistics industry, but also had a negative impact on the industry. Compared with theabove conclusion, while natural gas and clean electricity restricted the growth rate, they had positive impact on the industry. Finally, relevant policy implications were proposed according to the above conclusions.

Keywords: energy consumption, China's logistics industry, growth drag, sustainable growth

Introduction

The logistics industry is the "big artery" of the national economy, and plays an important role in the growth of the national economy [1]. Some studies indicated that there was positive relationship between logistics industry and national (regional) economy [2, 3]. Meanwhile, with the rapid growth of economy and foreign trade, China's logistics industry has experienced rapid growth over the last 30 years (see Fig. 1).

Fig. 1 shows that China's logistics industry has sustained growth for nearly 30 years, and has experienced rapid growth after 2010. The rapid growth of the logistics industry has made a significant contribution to China's economy, but it also has consumed more energy. Fig. 1 displays the energy consumption situation of China's logistics industry from 1990 through 2017. The figure shows that coal consumption continued to decline, and crude oil consumption underwent an inverted U-shaped process. The Chinese government and people paid more attention to environmental issues with the growth of the economy and the improvement of quality of life [4, 5], therefore the consumption of some fossil fuels (especially crude oil products and coal)

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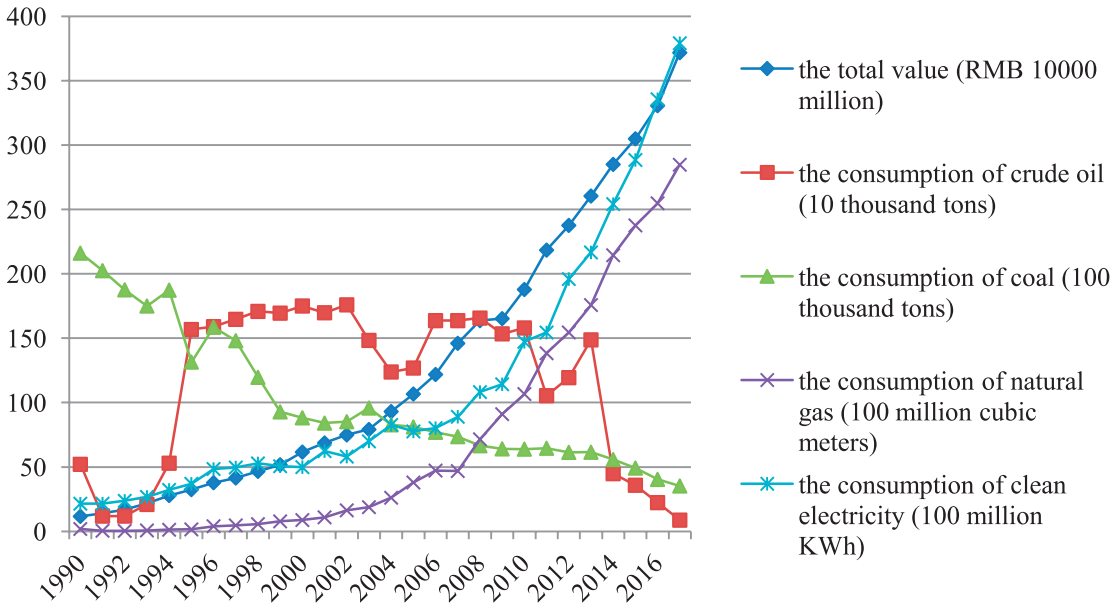

Fig. 1. The total value, consumption of crude oil, coal, natural gas, clean electricity of China's logistics industry from 1990 to 2017.
Notes: 1. Resource: the data of total value come from China Statistical Yearbook (1990-2017); the data of consumption of crude oil, coal, natural gas and clean electricity come from China Statistical Yearbook (1990-2017) and China Energy Statistical Yearbook (1990-2017).
2. There were very few details on solar power generation, so this study did not include data on solar power generation.

gradually decreased. Furthermore, the logistics industry (energy-intensive industry) used more clean energy rather than fossil fuels. The consumption of natural gas and clean electricity[1] thus continued to increase steadily (see Fig. 1). Some scholars noted that China's logistics industry has gradually become a major energy user (e.g. [6]). However, excessive energy consumption in the logistics industry has brought environmental pollution problems. Although the proportion of clean energy consumption in the logistics industry has been gradually increasing, the proportion of petrochemical energy consumption is still large. Based on China's energy structure, the logistics industry has become the main contributor of carbon emissions [7]. As one of the parties to the Paris Agreement, China promised to peak its carbon emissions by 2030 and increase the proportion of non-fossil energy in primary energy consumption to 20%. Therefore, study on energy consumption in China's logistics industry is crucial to achieving the above goals.

On the other hand, energy consumption will restrict economic and industrial growth (i.e. the growth drag of energy consumption), in particular, dependence on non-renewable energy will further impede economic and industrial growth (e.g. [8-10]). The logistics is not only the core industry of China's economy [11], but also a high-energy-consuming industry. Despite its huge role in promoting the economy and resolving employment, its external diseconomy (such as pollutant emissions) is also very obvious because of its excessive dependence on energy consumption [12]. This situation leads to the dilemma between the twin goals of decreasing energy consumption and promoting economic growth in logistics [6]. Therefore, the study on the relationship between the growth of the logistics industry and energy consumption is very necessary to reduce energy consumption and promote the growth of the logistics industry. The relevant studies are nonetheless lacking now, which is the main motivation and innovation for this study.

The remainder of this article is organized as follows. Section 2 reviews the related literatures. Section 3 constructs the model that is used to calculate the values of growth drag. In section 4, the empirical analysis is carried out. Section 5 concludes the article and proposes some policy implications.

Literature Review

Numerous sources studied issues relating to economic growth and energy consumption. A literature review relevant to the energy consumption of logistics industry in terms of the thrust of this article was conducted. The contents of the literature can be divided into categories that follow.

(i) The methodology and empirical studies of energy consumption in logistics industry. These studies included the methods for analyzing the decomposition of energy consumption, the evaluation method of energy efficiency in logistics and the models of evaluation of energy consumption, and so on. Dai and Gao (2016) employed the logarithmic mean Divisia index (LMDI)

[1] The clean electricity includes Hydropower, wind power and nuclear power.

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approach to analyze the key factors driving chronicle changes in China's logistics energy consumption [11]. Improving energy efficiency in logistics is crucial to environmental sustainability and can be achieved through increased capacity utilization, thus Wehner (2018) took an interactive approach to increase capacity utilization [13]. In addition, the evaluation of energy consumption in various aspects of logistics is very important, such as the evaluation of energy consumption of container terminal logistics system [14] and the logistics warehouse systems [15], and so on.

(ii) The related researches of "green logistics" and "low-carbon logistics". Such studies included the relationship between economic growth and energy consumption in logistics industry, how to reduce the energy consumption in logistics industry, and issues of usage of new energy in logistics industry, and so on. The relationship between economic growth, logistics, and energy consumption has become an issue of scholars concerned. Zaman and Shamsuddin (2016) examined the impact of logistics performance indices on national scale economic indicators (namely energy, environment, and economic health) [16]. Liu et al. (2020) conducted a study on how urbanization driven decoupled economic growth from China's logistics energy consumption [6]. Reducing the energy consumption in logistics industry is another important aspect of existing studies. McKinnon (2012) assessed logistics' share of global energy consumption and greenhouse gas emissions, and analyzed numerous ways that can reduce the energy consumption and related emissions [17]. Gorcun (2017) studied the reduction of energy consumption in urban logistics process from the perspective of cost and traffic flow rate [18]. Von der Gracht and Darkow (2016) discussed energy-constrained and low-carbon issues in the transport and logistics industries [19]. Several scholars researched the low-carbon of a link of logistics (such as warehouse) [20] and the use of new energy (e.g. the offshore wind energy) in logistics industry [21]. In addition, several researchers explored related energy consumption issues in reverse logistics [22, 23].

It is worth noting that new analysis tools (software) and techniques are increasingly being applied to the research of energy consumption. These applications may provide new ideas for the study of energy consumption in the logistics industry. For instance, how to analyze the advantages and disadvantages of new energy (such as solar energy) has always attracted attention. The application of new analysis tools (e.g. Advanced SPECA Modelling Tool, T*SOL Software induction methods, hypothetic-deduction methods etc.) is effectively solving above issue [24-26]. In addition, some new technologies are used to solve problems of energy consumption (such as technology of green envelop, driving technologies) [27, 28].

To sum up, the existing studies mainly involved energy consumption measurement methodologies, strategies for minimizing energy consumption in the logistics industry and the application of some new tools and technologies. Nonetheless, few studies discussed the growth drag of energy consumption in the logistics industry. So the aim of this article is to deal with this issue, and then try to discuss the sustainable growth of the logistics industry and environmental protection etc.

Model Construction

The growth drag of energy consumption refers to decrease the speed of growth of logistics industry due to energy constraints. Rome (2001) established a model for calculating the growth drag of economic growth, including natural resources and land constraints [29]. The model takes the form of the Cobb-Douglas production function, the specific model is defined with the following:

$$Y(t) = K(t)^{\alpha} R(t)^{\beta} T(t)^{\gamma} [A(t)L(t)]^{1-\alpha-\beta-\gamma}$$
$$\alpha > 0, \beta > 0, \gamma > 0, \alpha + \beta + \gamma < 1 \quad (1)$$

...where Y, K, L, A, R, T represents output, capital, labor, knowledge, natural resource and land resource, respectively, and α, β, γ indicates the elasticity of capital, natural resource and labor, respectively.

The model including various energy resources based on model (1) is tried to be established:

$$Y(t) = K(t)^{\alpha} E(t)^{\beta} [A(t)L(t)]^{\gamma}$$
$$\alpha > 0, \beta > 0, \gamma > 0 \quad (2)$$

...where E represents the level of energy consumption, and the meaning of K, A, L is the same as model (1); α, β, γ indicates the elasticity of capital, energy resource and labor, respectively.

By taking natural logarithm of both sides of formula (2), following formula can be gained:

$$\ln Y(t) = \alpha \ln K(t) + \beta \ln E(t) + \gamma[\ln A(t) + \ln L(t)] \quad (3)$$

Taking the derivative of both sides of formula (3), then using the derivative of the logarithm of the variable with respect to time as the growth rate to obtain the following equation:

$$g_Y(t) = \alpha g_K(t) + \beta g_E(t) + \gamma[g_A(t) + g_L(t)] \quad (4)$$

...where $g_Y(t)$, $g_K(t)$, $g_E(t)$, $g_A(t)$, $g_L(t)$, represents the growth rate of Y, K, E, A, L, respectively.

Let the growth rate of A, L, E is Δa, Δl, $-\Delta e$, respectively, the equation (4) can be written as follows:

$$g_Y(t) = \alpha g_K(t) - \beta \Delta e + \gamma(\Delta a + \Delta l) \quad (5)$$

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The growth rate of output is equal to the growth rate of capital (i.e. $g_Y(t) = g_K(t)$) under the balanced growth path, thus the formula (5) can be written as follows:

$$g_Y(t) = \frac{\gamma(\Delta a + \Delta l) - \beta\Delta e}{1-\alpha} \tag{6}$$

Lucas (1988) believed that the growth rate of output per capita can better reflect the level of economic growth [30], so the average output growth rate of labor per unit can be calculated, as follows:

$$g_{Y/L}(t) = g_Y(t) - \Delta l = \frac{\gamma(\Delta a + \Delta l) - \beta\Delta e}{1-\alpha} - \Delta l = \frac{\gamma\Delta a + \gamma\Delta l + \alpha\Delta l - \beta\Delta e - \Delta l}{1-\alpha} \tag{7}$$

Next step, the average output growth rate per unit of labor on the balanced growth path can be calculated, provided that the average energy consumption per unit of labor remains unchanged, as follows:

$$\tilde{g}_{Y/L}(t) = \frac{\gamma\Delta a + \gamma\Delta l + \alpha\Delta l + \beta\Delta l - \Delta l}{1-\alpha} \tag{8}$$

Then, the growth drag of energy consumption is equal to the difference between formula (8) and formula (7):

$$\tilde{g}_{Y/L}(t) - g_{Y/L}(t) = \frac{\gamma\Delta a + \gamma\Delta l + \alpha\Delta l + \beta\Delta l - \Delta l}{1-\alpha} - \frac{\gamma\Delta a + \gamma\Delta l + \alpha\Delta l - \beta\Delta e - \Delta l}{1-\alpha} = \frac{\beta(\Delta e + \Delta l)}{1-\alpha} \tag{9}$$

The formula (9) shows that the growth drag of energy consumption in logistics industry is positively correlated with the elasticity of energy resource (β), the growth rate of labor and energy consumption (Δl and Δe) and elasticity of capital (α). That is, the energy consumption of logistics industry increase, meanwhile, the growth of logistics industry will be limited (i.e. the growth drag of energy consumption will increase.). Hence, the study on the growth drag of energy consumption is very important to the growth of logistics industry. In order to show above construction process more clearly, the flowchart was provided as following.

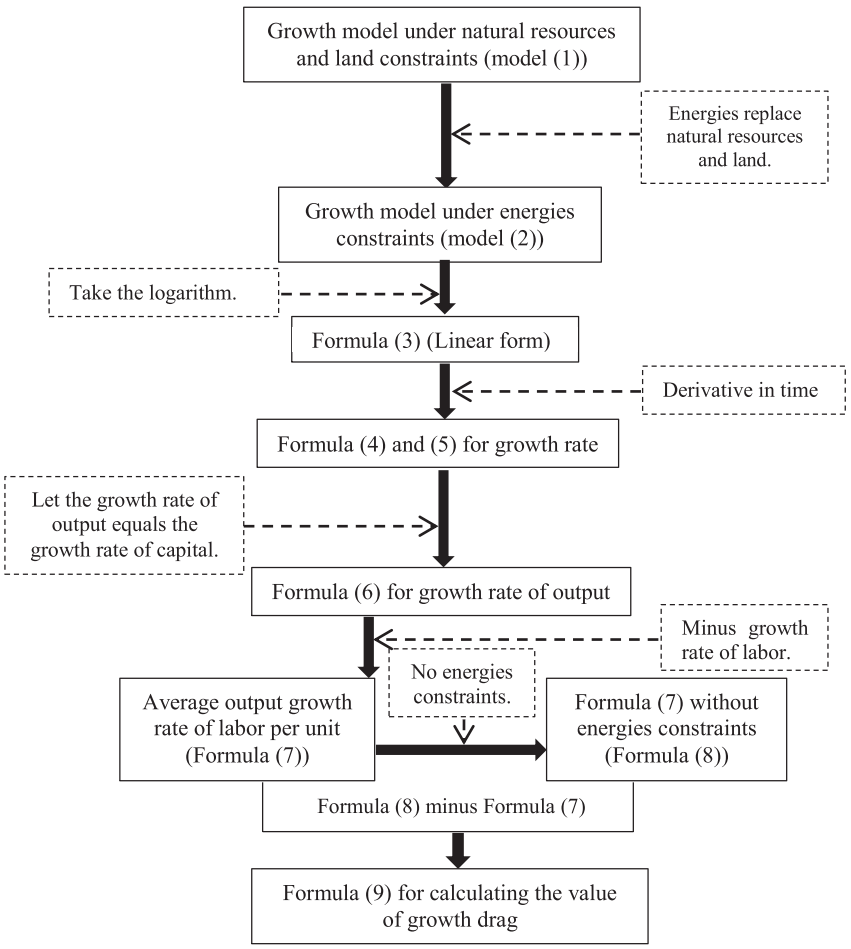

Fig. 2. The flowchart of the construction process of formula of growth drag.

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Table 1. Descriptive statistics.

Variables	N	Minimum	Maximum	Mean	Standard deviation
Y (RMB 100 million)	28	1167.2	37172.6	12785.85	10764.06
K (RMB 100 million)	28	348.41	61449.9	16582.23	18179.53
L (10 thousand)	28	612.7	921	747.8179	112.1124
CO (10 thousand tons)	28	353	2160.9	1017.817	526.0596
O (10 thousand tons)	28	8.76	175.94	113.5771	62.26448
NG (100 million cubic meters)	28	0.4	284.71	70.40607	89.40947
CE (100 million KWh)	28	21.53898	379.084	111.725	99.42455

Empirical Analysis

Variables and Data Source

The variables of empirical analysis included the total value of logistics industry (*Y*), capital (*K*), energy resources (coal (CO), crude oil (*O*), natural gas (*NG*), hydropower, wind power and nuclear power (*CE*) [31]) consumption (*E*) and labor (*L*). It should be pointed out that capital (*K*) was replaced by fixed assets investment (e.g. [32-34]), and the consumption of clean electricity indicated total consumption of hydropower, wind power and nuclear power. The data of total value of logistics industry and fixed assets investment were collected from China Statistical Yearbook (1990-2017), and the data were converted to constant price in 1990 (1990 = 100) in order to eliminate the impact of inflation [35-37]; the data of labor were collected from China Statistical Yearbook and China Labor Statistical Yearbook (1990-2017); the data of clean electricity were calculated according to the data obtained from China Statistical Yearbook and China Energy Statistical Yearbook (1990-2017). The descriptive statistics of all variables are reported in Table 1.

Unit Root Test

Regression of non-stationary time series may lead to false results [38]. Thus, the unit root test for all variables should be run. Meanwhile, the influence of heteroscedasticity can be eliminated by taking the logarithm for all variables (e.g., [39-41]). Augmented Dicky-Fuller (ADF) and Phillips-Perron (PP) test for the unit root test were used (e.g., [42-44]). The article employed three models (the model that has individual intercept and trend, the model has individual intercept and the model with no individual intercept and trend) according to a general test order [38]. The results were reported in Table 2.

The ADF and PP test assume an individual unit root process [45]. Table 2 shows that the null hypothesis should be accepted, i.e. all variables were non-stationary. Then the unit root test for the first-order difference of all variables was run, and the results were listed in Table 3.

Table 3 shows that the null hypothesis was rejected at least at the level of significance 10% except very few results, therefore the first-order difference of all variables were basically stationary, i.e. they were integrated of order one (I(1)). The cointegration test will be carried out because the variables were integrated of the same order. This study used Johansen's multivariate maximum likelihood procedure [46, 47] to conduct

Table 2. The results of unit root test.

	lnY		lnK		lnL		lnCO	
	t-Statistic (Adj.t-Statistic)	Prob.	t-Statistic (Adj.t-Statistic)	Prob.	t-Statistic (Adj.t-Statistic)	Prob.	t-Statistic (Adj.t-Statistic)	Prob.
ADF[1]	-0.4269	0.9810	-3.2291	0.1017	-0.6937	0.9634	-2.0964	0.5237
ADF[2]	-3.1762	0.0327	-4.6453	0.0010	-1.2911	0.6187	-0.3617	0.9024
ADF[3]	2.6825	0.9972	3.4191	0.9996	-0.2071	0.6023	-3.1931	0.0025
PP[1]	-0.1886	0.9899	-3.2218	0.1066	-0.6937	0.9634	-2.4301	0.3572
PP[2]	-4.4101	0.0018	-4.1839	0.0031	-1.4047	0.5650	-0.2710	0.9170
PP[3]	10.3148	1.0000	2.2378	0.9922	-0.1913	0.6080	-3.6793	0.0007

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Table 2. Continued.

	lnO		lnNG		lnCE	
	t-Statistic (Adj.t-Statistic)	Prob.	t-Statistic (Adj.t-Statistic)	Prob.	t-Statistic (Adj.t-Statistic)	Prob.
ADF[1]	-0.1118	0.9918	-1.4555	0.8178	-1.4613	0.8179
ADF[2]	-0.4811	0.8803	-3.9740	0.0056	0.6295	0.9878
ADF[3]	-0.7255	0.3929	2.4968	0.9957	5.8344	1.0000
PP[1]	-0.1118	0.9918	-3.8083	0.0318	-1.5183	0.7978
PP[2]	-0.9818	0.7450	-0.2205	0.9244	0.8625	0.9933
PP[3]	-0.7127	0.3985	2.3017	0.9932	6.5625	1.0000

Notes: [1]The unit root test with the model that includes individual intercept and trend.
[2]The unit root test with the model that includes individual intercept.
[3]The unit root test with the model that does not include individual and trend.

Table 3. The results of unit root test of first-order difference variables.

	D (lnY)		D (lnK)		D (lnL)		D (lnCO)	
	t-Statistic (Adj.t-Statistic)	Prob.	t-Statistic (Adj.t-Statistic)	Prob.	t-Statistic (Adj.t-Statistic)	Prob.	t-Statistic (Adj.t-Statistic)	Prob.
ADF[3]	-4.0500	0.0214	-3.6884	0.0488	-5.0096	0.0023	-5.8852	0.0003
ADF[2]	-3.5604	0.0142	-2.5294	0.1204	-4.3570	0.0022	-6.0069	0.0000
ADF[1]	-1.6689	0.0936	-2.1378	0.0336	-4.4369	0.0001	-4.3827	0.0001
PP[3]	-4.6792	0.0049	-3.6218	0.0464	-5.0096	0.0023	-5.8873	0.0003
PP[2]	-3.5680	0.0139	-2.3155	0.1748	-4.3521	0.0022	-6.0093	0.0000
PP[1]	-1.6408	0.0969	-1.8388	0.0636	-4.4328	0.0001	-4.4223	0.0001
			D (lnO)		D (lnNG)		D (lnCE)	
			t-Statistic (Adj.t-Statistic)	Prob.	t-Statistic (Adj.t-Statistic)	Prob.	t-Statistic (Adj.t-Statistic)	Prob.
ADF[3]			-5.7963	0.0004	-8.8175	0.0000	-6.0748	0.0002
ADF[2]			-2.7040	0.0852	-7.3590	0.0000	-6.0745	0.0000
ADF[1]			-1.6768	0.0878	-1.2320	0.1938	-1.1826	0.2100
PP[3]			-6.1041	0.0002	-21.6678	0.0000	-6.0164	0.0002
PP[2]			-4.0650	0.0043	-7.6439	0.0000	-6.0144	0.0000
PP[1]			-4.1422	0.0002	-4.4115	0.0001	-2.8131	0.0068

Notes: *D*(●) means the first-order difference of variables.
[1]The unit root test with the model that includes individual intercept and trend.
[2]The unit root test with the model that includes individual intercept.
[3]The unit root test with the model that does not include individual and trend.

the test, since the Johansen approach was shown to be superior to Engle and Granger's residual-based approach. Among other things, the Johansen approach is capable of detecting multiple cointegrating relationships [44]. Due to the obvious substitutability between energy sources, the regression analysis for each energy resource was run separately to avoid multicollinearity, namely there are four regression models[2] in the analysis.

2 model (1) consists of ln*Y*, ln*K*, ln*L*, lnCO; model (2) consists of ln*Y*, ln*K*, ln*L*, lnO; model (3) consists of ln*Y*, ln*K*, ln*L*, ln*NG*; model (4) consists of ln*Y*, ln*K*, ln*L*, ln*CL*.

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Table 4. VAR lag order selection.

	Lag	LogL	LR	FPE	AIC	SC	HQ
model(1)	1	184.9954	12.57851	4.34e-11*	-12.51818*	-11.75028*	-12.28984*
model(2)	1	155.8024	16.87874	2.53e-10*	-10.75403*	-9.979815*	-10.53108*
model(3)	1	174.8701	12.11303	3.59e-11*	-12.70961*	-11.92953*	-12.49325*
model(4)	1	189.9091	24.37007	3.01e-11*	-12.88216*	-12.11426*	-12.65382*

Notes: *indicates lag order selected by the criterion; LR: sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion.

Cointegration Test

Firstly, the unrestricted vector autoregressive (VAR) models were established to examine the VAR lag intervals and perform the Johansen test.

The lag periods of 1 for four models were chosen in terms of the criteria of LogL, LR, FPE, AIC, SC, HQ standard in Table 4.

Next step, the trace statistic was used to estimate the number of cointegration relationships [47]. The results were shown in Table 5.

As shown in Table 5, there were at the most four cointegration relationships in model (1), three cointegration relationships in model (2), three cointegration relationships in model (3) and two cointegration relationships in model (4), respectively.

Regression Analysis and Results

In order to analyze the specific relationships between total value and energy consumption, and further calculate the value of growth drag, the regression for model (1), model (2), model (3) and model (4) must be performed. To avoid the issues of serial correlation and heteroscedasticity, the Cochrane-Orcutt regression was employed to regress above models [e.g. 49-51], and the results were presented in Table 6.

As shown in Table 6, the values of adjusted R^2 and F-statistic indicate that all four models were acceptable. The Durbin-Watson test of all models show that the residuals were uncorrelated since the values were approximately very close to 2. The results of the t-test show that each energy had significant impact on the growth of the logistics industry. The consumption of natural gas and clean electricity played a positive role in the growth of China's logistics industry from 1990 to 2017, while the consumption of coal and crude oil played a negative role. Furthermore, the conclusion that the marginal contribution rate of natural gas was greater than clean electricity can be got. The above results were related to China's energy policy. In order to reduce the emission of pollutants, the Chinese government has been reducing the use of high-emission fossil energy (e.g. coal and crude oil) in various industries and encouraging the use of low-emission clean energy (such as clean electricity).

The values of elasticity of capital (α) and energy (β) from the results of above regression analysis were obtained. The values of labor's growth rate and energy's growth rate must be got in terms of the calculation

Table 5. Johansen cointegration test results.

model (1)	Trace Statistic			
	r = 0	r <= 1	r <= 2	r <= 3
L = 1	82.01183***	38.23741***	15.066*	3.436988*
10% CV	44.49359	27.06695	13.42878	2.705545
5% CV	47.85613	29.79707	15.49471	3.841466
1% CV	54.6815	35.45817	19.93711	6.634897
model (2)	Trace Statistic			
	r = 0	r <= 1	r <= 2	r <= 3
L = 1	77.43389***	39.33812***	14.30988*	2.606302
10% CV	44.49359	27.06695	13.42878	2.705545
5% CV	47.85613	29.79707	15.49471	3.841466
1% CV	54.6815	35.45817	19.93711	6.634897

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Table 5. continued.

model (3)	Trace Statistic			
	r = 0	r <= 1	r <= 2	r <= 3
L = 1	80.20288**	38.75189**	11.97103	3.888418**
10% CV	44.49359	27.06695	13.42878	2.705545
5% CV	47.85613	29.79707	15.49471	3.841466
1% CV	54.6815	35.45817	19.93711	6.634897
model (4)	Trace Statistic			
	r = 0	r <= 1	r <= 2	r <= 3
L = 1	78.14751***	32.11077**	11.01142	0.684894
10% CV	44.49359	27.06695	13.42878	2.705545
5% CV	47.85613	29.79707	15.49471	3.841466
1% CV	54.6815	35.45817	19.93711	6.634897

Notes: the composition of model(1), model(2), model(3) and model(4) are the same as Table 3. *r* and L indicates the number of cointegration and the lag interval. CV means Significance level. ***,**,*represents 1%, 5% and 10% level of significance.

formula of growth drag. The value of growth rate of labor can be calculated firstly in terms of formula

$$gr_L = \left(\frac{I_1}{I_0}\right)^{\frac{1}{t}} - 1$$

...where, I_0 and I_1 represents the number of employees in the logistics industry in 1990 and 2017, respectively; t means the number of period of growth. The growth rate of labor is -0.2175% from 1990 to 2017 in terms of the above formula. We can calculate the values of growth rate of consumption of coal, crude oil, natural gas and clean electricity according to the same formula, and the value is -6.4902%, -6.3903%, 2.0387% and 11.2073%, respectively. Then the values of growth drag of energy consumption were calculated according to formula (9). The results were represented in Table 7.

As the Table 7 shows, the value of growth drag of coal, crude oil, natural gas and clean electricity was 0.005252, 0.001184, 0.21806 and 0.001880, respectively. The findings show that different energy resource had different degree of restriction on the growth of China's logistics industry. The growth of China's logistics industry decreased by an average of 0.5252%, 0.1184%, 21.806% and 0.1880% restricted by the consumption of coal, crude oil, natural gas and clean energy. The related views and possible reasons were shown as follows.

Table 6. Results of regression of model (1) to model (4).

Variables	model(1)	model(2)	model(3)	model(4)
lnK	0.328386** (2.125087)	0.334994** (2.332681)	0.761997*** (3.585851)	0.329221* (1.935512)
lnL	0.042135 (0.382132)	0.039021 (0.415803)	0.024504 (0.157910)	0.02905 (0.316892)
lnCO	-0.052581** (-2.61448)			
lnO		-0.011915* (-1.90679)		
lnNG			0.257324*** (7.402331)	
lnCE				0.011479*** (3.89868)
Adj.R^2	0.998755	0.998655	0.985628	0.998578
F-statistic (Prob.)	3609.769 (0.0000)	3342.825 (0.0000)	3240.130 (0.0000)	3161.893 (0.0000)
Durbin-Watson stat	2.41221	2.362973	2.313277	2.366084

Notes: The values in the brackets under the coefficients are the values of *t* statistics. ***, **, *represents 1%, 5% and 10% level of significance.

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Table 7. The values of growth drag of energy consumption.

	Coal	Crude oil	Natural gas	Clean energy
α	0.328386	0.334994	0.761997	0.329221
β	-0.05258	-0.011915	0.257324	0.011479
Δe	-0.064902	-0.063903	0.20387	0.112073
Δl	-0.002175			
D.E.	0.005252	0.001184	0.21806	0.001880

Notes: α, β, Δe, Δl and *D.E.* means the elasticity of capital, the elasticity of energy resource, the growth rate of energy consumption, the growth rate of labor and the growth drag.

Firstly, natural gas had the greatest restriction on the growth of China's logistics industry. The growth of natural gas consumption in China's logistics industry was very rapid from 1990 to 2017. The consumption of natural gas in 1990 was 190 million cubic meters, and it was 28470 million cubic meters in 2017, i.e. the consumption in 2017 increased by about 131 times compared with 1990. There were two main reasons for the above increase: one reason was that the Chinese governments encouraged the use of clean energy including natural gas in order to reduce the emission of pollutants; the second reason was that the technologies of coal-to-gas and oil-to-gas switching were easy to use in logistics equipment. These factors led to China's logistics industry relied heavily on the consumption of natural gas. In additional, China's natural gas has been in short supply. According to data from the second China Natural Gas International Summit held in Beijing on November 9, 2020, China's natural gas demand gap in 2020 is at least 80 billion cubic meters. Thus, natural gas has the greatest drag to the growth of the logistics industry.

Secondly, coal has always been the primary energy source for China's economic growth. Therefore, in the early days, many logistics equipment directly or indirectly used coal as power. With the changes in China's energy policy, coal consumption in the logistics industry has gradually decreased. However, according to the 2018 China Statistical Yearbook, coal consumption in the logistics industry in 2017 was 3.53 million tons. There are two reasons for the high coal consumption: one is that it is difficult to massively replace coal-powered logistics equipment in the short term; the other is that from the perspective of energy consumption structure, coal is still the main energy source for the Chinese economy. Thus the value of growth drag of coal consumption in the logistics industry ranked second.

Thirdly, the value of growth drag of clean electricity was in the third place. Although the consumption of clean electricity such as hydropower wind power and nuclear power also increased significantly, due to technical reasons, the number of electricity-consuming logistics equipment was relatively small compared to natural gas. Therefore, the value of growth drag of consumption of clean electricity was relatively small.

Finally, with the changes in China's energy policy and gradual usage of new energy equipment, crude oil consumption in the logistics industry has been decreasing, that is, the logistics industry's dependence on crude oil consumption kept declining, so the value of its growth drag was smallest.

Conclusion and Policy Implications

This study constructed the model that was used to calculate the value of growth drag of energy consumption in China's logistics industry based on Romer's model of growth drag. By collecting the data of total value, fixed assets investment, labor, the consumption of coal, crude oil, natural gas, clean electricity in China's logistics industry from 1990 to 2017, the specific value of growth drag of various energy resources consumption was calculated. The main results can be divided into two aspects, namely, the marginal contribution rate of each energy source to the growth of the logistics industry (as shown in Table 6) and its growth drag (see Table 7). The values of the contribution margin rate indicated that coal and crude oil have a negative impact on the growth of the logistics industry, while natural gas and clean electricity were the opposite. The values of growth drag indicated that the consumption of natural gas had the greatest restriction on the growth of China's logistics industry, followed by the consumption of coal, clean energy and crude oil.

Compared with the present studies, the differences of this article are mainly reflected in the following aspects: (i) the present literatures mainly studied the overall energy consumption of the logistics industry (e.g., [11], [13, 14] etc.). However, this article analyzed the growth drag of different energies (namely coal, crude oil, natural gas, hydropower, wind power and nuclear power), which is beneficial to analyze the impact of energy structure on China's logistics industry. (ii) Unlike some existing literature that simply analyze the reduction of energy consumption in the logistics industry (such as [6], [18] etc.), the conclusions of this

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article are conducive to discussing policies to maintain the sustainable growth of the logistics industry and deal with the environment issues.

Based on above discussion, the significance of this study is reflected in the following aspects. Firstly, it helps to improve the energy consumption structure of China's logistics, that is, to reduce petrochemical energy consumption and appropriately increase clean energy consumption. This will help China achieve the targets of energy saving and emission reduction by 2030. Secondly, the results of Table 6 shows that consumption of coal and crude oil has played a negative role in the growth of China's logistics industry. The government should introduce corresponding policies to encourage enterprises to actively respond to the energy dilemma in the logistics industry.

The logistics industry is high-energy-consumption industry. To promote sustainable growth in logistics industry and deal with the issues of environmental pollution, the China's government should introduce policies to encourage related enterprises and institutions to solve the issues of energy consumption. Specifically, the following aspects may be involved. One is to encourage logistics enterprises to adopt various methods to reduce energy consumption. In order to reduce the overall energy consumption of the logistics industry, relevant enterprises should adopt energy-saving and environmentally friendly technologies and equipment, and improve the organization and network level of logistics operations. The second is to adjust the energy consumption structure. In addition to continuing to reduce the consumption of coal and crude oil, the government should encourage logistics companies to increase the consumption of clean and renewable energy and reduce the consumption of non-renewable clean energy (especially natural gas). The third is to encourage related institutions to strengthen the research and development of clean energy and renewable energy logistics equipment, and subsidize the enterprises that use the equipment.

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Conflict of Interest

The authors declare no conflict of interest.

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