Research on Economic Growth of Exhaustible Resource-based Cities in Heilongjiang Province

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ABSTRACT. *It cannot be denied that resource-based cities in Heilongjiang prov ince still depend on exhaustible resources. Therefore,to explore the economic growth of exhaustible resource-based cities in Heilongjiang Province is necess ary. Initially, from an empirical perspective, the relationship between the dem and for exhaustible resources and economic growth was evaluated. Specificall y,it focuses on explaining the growth paths and growth suggestions for differe nt types of resource-based cities.The influences of exhaustible resources direct ly affect the economic development prospect of Heilongjiang Province. Hence, how to seek for the new mode of industrial transformation and economic dev elopment is the vital to economic development.*

KEYWORDS: *exhaustible resources, economic growth, industrial transformation, granger causality*

1. Introduction

As a resource-based province, Heilongjiang is famous for its two types of exhaustible resources which are coal and petroleum. According to the State Council's National Sustainable Development Plan for Resource-Based Cities issued by the State Council in November 2013, resource-based cities refer to cities that consume resources to achieve economic growth. At the same time, "Planning" pointed out that there are nine prefecture-level cities in Heilongjiang Province, and two county-level cities are listed as resource-based cities. The fourth part of this study focuses on the economic growth of nine resource-based cities in Heilongjiang Province. The nine cities are Mudanjiang, Daqing, Jixi, Heihe, Shuangyashan, Daxinganling, Qitaihe, Hegang and Shuangyashan. All the cities mentioned above are famous for coal or oil, which have all experienced the stage of sufficient resource protection and high level of economic and social development. Nowadays, some cities have gradually exhausted resources, lagging in economic development,

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and deteriorating the ecological environment. Therefore, studying how resource-based cities to break through the bottleneck of exhaustible resource constraints, seek and develop alternative industries and new kinetic energy for economic growth, not only helps resource-based cities adjust their industrial structure, but also helps resource-based cities achieve high-quality economic growth.

2. Description of Econometric Model

As a large resource province, Heilongjiang Province also has good advantages in depleting resources such as coal and oil. Therefore, in the study of the economic growth of resource-based cities in Heilongjiang Province, this study selects Daqing, Jixi, Hegang, Shuangyashan and Qitaihe as the key research objects. And according to the statistical data of the Heilongjiang Province Statistical Yearbook of several years, the main selection is the exhaustible resource consumption in the above regions in different years, that is, local energy consumption; and electricity consumption and the total GDP of each region representing economic growth. Then through the time series analysis to get the relationship between the selected variables. And this research mainly uses Granger causality test in time series and ECM model analysis.

2.1 Sequencenon-stationary and co-integrated analysis

Sequencenon-stationary is a common problem encountered in the research process. Another problem is the co-integration directly related to pseudo regression, that is, the co-integration relationship between non-stationary sequences. For example, the OLS regression of two variables that increase with time has a good goodness-of-fit value, but there is no real correlation. However, there may still be a co-integration relationship between these two variables and the third variable. For example, high economic growth will also promote higher prices of exhaustible resources and consumption demand of exhaustible resources. Simple OLS regression will result in high prices. The conclusion of high consumption of exhaustible resources, but this violates the conventional demand theorem, so it is called pseudo regression.

According to the specification, if both time series x_t and y_t are non-stationary, they could be a linear combination of the form $x_t - \beta y_t$. It can be constructed to form a new stationary series w_t, then the two sequences are co-integrated. Or, if a co-integrated vector $[1, -\beta]$ that generates a stationary sequence exists, there is a co-integrated relationship between the two non-stationary sequences, otherwise there is no co-integrated relationship. The role of the ECM model is to explain the existence of the co-integrated relationship. This model was proposed by Engle and Granger (1987) and improved by Johansen (1988).

The ECM model theory believes that a suitable linear combination of co-integration variables can generate a stationary sequence to correct the short-term

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deviation of the long-term deviation trend between the two variables. Using the ECM model, the co-integrated relationship between sequences can be identified according to the estimated error sequence, and the potential information contained can be found. For the sequence of co-integration relationship of energy econometrics, the ECM model can be further constructed.

2.2 Modeling Mechanism

For the relationship between the energy consumption of exhaustible resources (coal, oil, etc.) and the level of economic growth (GDP), including causality, long-term demand elasticity, and short-term demand elasticity. The modeling mechanism is to test whether the exhaustible resources and economic growth existing Granger causality. Before this, the stability between the two variables needs to be tested. When the sequence is non-stationary, the first-order difference sequence should be used as the data basis. Then, we choose independent variables with relatively high explanatory power in Granger test to test the long-term elasticity between different variables. Finally, in order to obtain a standardized description of the co-integrated relationship between time series, an appropriate ECM model is established. There are several methodological issues with the above steps, including:

Question 1, Granger causality test

Granger causality is not a logical causality in general, but a long-term stable correlation between variables. The main purpose is to analyze and judge whether an unconstrained equation will have a better interpretation effect. Before Granger causality test, non-stationary test is required. In theory, the stationarity test is used to determine the fixed and trend items of the model. After determining the stationary of the time series, or using the first-order difference to eliminate non-stationary, the Granger causality test can be used to analyze the causal relationship between variables. The test usually takes two variables to determine whether the variable x_t is causing a change in y_t.and vice versa.

Unconstrained equation:$y_t = \gamma_0 + \sum_{i=1}^{T} \gamma_{1i} y_{t-i} + \sum_{j=1}^{T} \gamma_{2j} x_{t-j} + \varepsilon_t \quad (0 \le i, j \le 1)$

Constrainedequation:$y_t = \delta_0 + \sum_{i=1}^{T} \delta_{1i} y_{t-i} + \varepsilon_t \sum_{j=1}^{T} \gamma_{2j}\, x_{t-j} = 0$

If the test rejects the null hypothesis (ie $\gamma_{21} = \gamma_{22} = \cdots = \gamma_{2T} = 0$) of the constrained equation, it can be inferred that x_t is the Granger cause of y_t. In addition, Granger causality test results are sensitive to the choice of lag period. Theoretically, the length of the maximum lag period chosen should be greater than or equal to the number of parameters. According to the F value calculated by E views, the null hypothesis cannot be rejected at the 5% significance level, which means that x_t is not the cause of the change in $y_{t.}$

As a result, when the causal relationship between economic growth and consumption of exhaustible resources is determined, a regression equation can be established to estimate the long-term relationship between the two sequences. The

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determination of the dependent variable and independent variable is mainly based on the results of Granger causality test.

Question 2, Co-integrated test and ECM model

The main idea of testing the co-integrated relationship is to try to find a linear combination that can generate a stationary sequence for two non-stationary sequences. If the linear combination does not exist, there is no co-integrated relationship between the variables, no error correction is required.According to the definition of Engle and Granger (1987), if the residual term $\hat{\alpha}$ of the OLS equation contains unit roots, there is a co-integrated relationship between the variable sequences. Estimate the parameters α and β of the regression equation$y_t = \alpha + \beta x_t + u_t$ the corresponding estimators are a and b, respectively, and we can get: $\widehat{u_t} = y_t - a - bx_t$.

In order to test the co-integrated relationship betweeny_t andx_t, the null hypothesis $H_0: \hat{u}_t = \varphi \hat{u}_{t-1} + \varepsilon_t$, $\varphi = 1$ is set. If the residual sequence follows a random walk process, the two variables are co-integrated. Once the co-integrated relationship is established, the ECM model can be used to estimate the short-term relationship between variables. For the first-order variance series, the ECM model is used to correct the impact of external shocks that cause the variables to deviate from the long-term trend.

Assume that the initial OLS regression equation is:

$$y_{t-1} = \alpha_0 + \alpha_1 x_{t-1} + \varepsilon_t \quad (1)$$

Then the definition of the corresponding ECM model is:

$$\Delta y_t = \beta_0 + \beta_1 \Delta x_t + \beta_2 (y_{t-1} - \alpha_1 x_{t-1} - \alpha_0) + \varepsilon_t \quad (2)$$

$\beta_2 (y_{t-1} - \alpha_1 x_{t-1} - \alpha_0)$is the error correction term. Normally,$\beta_2 < 0$. The error correction term is used to describe the degree of the regression of the sequence to the long-term stable trend when the short-term deviation occurs. It can also be interpreted as an adjustment coefficient relative to the system adjustment rate. When there is no co-integrated relationship, the coefficients α_0 and α_1 can directly describe the long-term structural relationship between y_t and x_t.

3. Econometric Model Analysis

3.1 Data description

In this study, the data of the exhaustible resource consumption and economic growth (GDP) of five exhaustible resource-based cities in Heilongjiang Province were used. Among them, the exhaustible resources mainly refer to coal and oil. Therefore, according to "Statistical Yearbook of Heilongjiang Province", this study try to find the corresponding total consumption of coal and oil. This research explores whether there is a Granger two-way causal relationship between the

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consumption of exhaustible resources and economic growth in the exhaustible resource cities which are Daqing, Jixi, Hegang, Shuangyashan and Qitaihe. Similarly, Granger has a two-way causal relationship between exhaustible resource consumption, electricity consumption and economic growth. Among them, the total consumption of exhaustible resources (oil, coal) and economic growth have non-stationary variables with time-varying characteristics. However, after smoothing these variable sequences, at a significant level of 5%, most causality will no longer hold. The situation in Daqing is an exception. The direction of Granger causality between related variables is different, that is, for Daqing, there is a unidirectional causality from power consumption to economic growth.

Most of the data used in this study is the total data of exhaustible resource consumption and economic (income) growth. Granger causality test shows that there is a co-integrated relationship between energy consumption and income level variables. The exhaustible resources include total coal and oil consumption, electricity consumption, and GDP data, all of which are taken from the Heilongjiang Statistical Yearbook in different years.

3.2 Model definition

After using Granger causality test to show that there is a causal relationship between the two variables, it need to select and determine exogenous and endogenous variables. In addition, the impact of oil prices needs to be tested, and relevant variables of exhaustible resources (such as total regional coal energy consumption or total petroleum energy consumption and electricity consumption) are used as explanatory variables to form the following relationship:

$$gdp_t = \beta_0 + \beta_1 resource_t + \beta_1 oilprice_t + \rho_t, \quad (3)$$

β_1 and β_2 represent the long-term elasticity of GDP relative to the total amount of energy consumed by the exhaustible resources and the price. Using the total GDP by region as an explanatory variable, the equation to be tested is as follows:

$$resource_t = \beta_0 + \beta_1 gdp_t + \beta_1 oilprice_t + \rho_t (4)$$

β_1 and β_2 denote the long-term elasticity of the energy consumption of exhaustible resources to GDP and the price of exhaustible resources, respectively. After testing the co-integrated relationship between different variables, an ECM model is established to correct errors. Taking the energy consumption of exhaustible resources, total GDP and oil price by region as explanatory variables, the expression of the error correction term is obtained from equation (3):

$$ecm = e_{t-1} = gdp_{t-1} - \beta_0 - \beta_1 resource_{t-1} - \beta_2 oilprice_{t-1} \quad (5)$$

To build a complete ECM model, it is necessary to rewrite the initial model, equation (3), into a linear dynamic form, and replace the ρ_t with the error correction term in equation (5):

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$$gdp_t = \alpha_0 + \alpha_1 resource_t + \alpha_2 oilprice_t + \alpha_3 gdp_{t-1} + \alpha_4 resource_{t-1} + \alpha_5 oilprice_{t-1} + \vartheta_t \quad (6)$$

Perform differential processing on the model, subtract gdp_{t-1} from both sides of the equation, subtract $\alpha_1 resource_{t-1} + \alpha_2 oilprice_{t-1}$ from the right side of the equation to obtain the following ECM model

$$\Delta gdp_t = b_0 + b_1 \Delta resource_t + b_2 \Delta oilprice_t - b_3 (gdp_{t-1} - \beta_0 - \beta_1 resource_{t-1} - \beta_2 oilprice_{t-1}) + \varepsilon_t \quad (7)$$

Where

$$b_1 = \alpha_1, b_2 = \alpha_2, b_3 = 1 - \alpha_3, a_0 = \alpha_0 - b_3\beta_0 = \alpha_0 - (1-\alpha_3)\beta_0 \beta_1 = (\alpha_4 + \alpha_1)/(1-\alpha_3), \quad \beta_2 = (\alpha_5 + \alpha_2)/(1-\alpha_3)$$

Using the OLS method to estimate equation (7), we get: parameter β_1 is the short-term elasticity of GDP relative to the energy consumption of exhaustible resources, parameter β_2 is the short-term elasticity of GDP relative to oil prices; parameter b_3 represents the short-term deviation Δresourceand Δoilprice (shock) In the case of impact), the system adjusts the rate from the long-term mean (or initial equilibrium level) to the new long-term equilibrium path. When the explanatory variable is the total regional GDP, the ECM model is:

$$\Delta resource_t = b_0 + b_1 \Delta gdp_t + b_2 \Delta oilprice_t - b_3 (resource_{t-1} - \beta_0 - \beta_1 gdp_{t-1} - \beta_2 oilprice_{t-1}) + \varepsilon_t (8)$$

Where

$$b_1 = \alpha_1, b_2 = \alpha_2, b_3 = 1 - \alpha_3, a_0 = \alpha_0 - b_3\beta_0 = \alpha_0 - (1-\alpha_3)\beta_0$$

$$\beta_1 = (\alpha_4 + \alpha_1)/(1-\alpha_3), \quad \beta_2 = (\alpha_5 + \alpha_2)/(1-\alpha_3)$$

Using the OLS method to estimate formula (8), the parameter β_1 is the short-term income elasticity of energy demand, and the parameter β_2 is the short-term price elasticity of energy demand; parameter b_3 indicates that in the case of short-term deviations Δgdp and Δoilprice (shock effects) The rate of adjustment from the initial equilibrium level to the new long-term equilibrium path.

3.3 Regression results and test

3.3.1 Non-stationary test

The time series of economic growth, energy consumption of exhaustible resources, power consumption, and oil prices in five exhaustible resource-based cities in Heilongjiang Province were tested for stability, and the following results were obtained:

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Table 1 non-stationary test

(The t-statistic of the PP test is obtained by the Bartlett kernel test to obtain the NW bandwidth)

	GDP	Total energy consumption of exhaustible resources	Price of oil or coal
Qitaihe	1.78***	-1.57***	No c
Jixi	[-4.16]	-1.97***	No c
Hegang	0.47***	0.47***	0.17***
Shuangyashan	1.53***	-0.96***	
Daqing	-1.29***	-2.19***	with c and t

Note: Given the null hypothesis, the series (except for the price of oil, the estimated model contains intercept terms but no trend terms) contains unit roots, which are tested. The symbols (*) (*not) (*string) indicate acceptance of the null hypothesis at 1%, 5%, and 10% significance levels, respectively.

Excepting the oil price series, based on the regression model with intercept terms and no trend terms, the stationary test is performed on the time series of different variables. The premise of the model assumption is: the initial GDP or energy consumption level of any exhaustible resources in any city is not zero; secondly, no city's income or consumption can grow forever. However, the characteristics of economic activities related to oil prices may be different. Before testing the time series of oil prices, there is still no relevant theoretical basis in this regard. Therefore, for the stability test of oil price series, three regression model assumptions are adopted, including M1, M2 and M3. The results are as follows:

Table 2 Non-stationary test for first-order difference sequences

(The t-statistic of the PP test is obtained by the Bartlett kernel test to obtain the NW bandwidth)

	Δgdp	Δresource	Δoilprice
Qitaihe	[-3.92]	[-4.26]	NO C
Jixi	[-3.71]	[-3.12]	NO C
Hegang	[-3.66]	[-4.13]	[-5.08]
Shuangyashan	[-3.79]	[-4.35]	
Daqing	[-3.67]	[-4.88]	with C

Note: Given the null hypothesis, the series (except for the price of oil, the estimated model contains intercept terms but no trend terms) contains unit roots,

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which are examined. The symbols (*) (**) (***) indicate acceptance of the null hypothesis at 1%, 5%, and 10% significance levels, respectively. The critical values of M (with intercept term and no trend term) are -3.679, -2.968, and -2.623 at the significant levels of 1%, 5%, and 10%, respectively. The square brackets indicate that the null hypothesis is rejected, and the series is stationary. Only when all time series are stationary at the first-order difference level can bidirectional Granger causality tests be performed.

3.3.2 Granger causality test

To carry out Granger test on the causal relationship between the variables of exhaustible resource consumption and GDP by region, the significance of the following two equations needs to be compared, namely, formula (9) and formula (10), formula (11) Formula (12)

$$gdp_t = \beta_1 + \sum_{i=1}^{T} \beta_{2i} gdp_{t-i} + \sum_{j=1}^{T} \beta_{3j} resource_{t-j} + \varepsilon_t, \quad (9)$$

$$gdp_t = \beta_4 + \sum_{i=1}^{T} \beta_{5i} gdp_{t-i} + \varepsilon_t, \quad (10)$$

$$resource_t = \beta_6 + \sum_{i=1}^{T} \beta_{7i} resource_{t-i} + \sum_{j=1}^{T} \beta_{8j} resource_{t-j} + \varepsilon_t, \quad (11)$$

$$resource_t = \beta_9 + \sum_{i=1}^{T} \beta_{10i} gdp_{t-i} + \varepsilon_t. \quad (12)$$

Granger causality tests conducted in two directions between the three sets of variables of GDP and exhaustible resource energy consumption, GDP and regional electricity consumption show that: at a significant level of 5%, there are more than three groups in 5 sample cities None of the variables have a significant relationship.

However, the results of Daqing and Jixi are different. For Daqing, there is a one-way causal relationship from oil energy consumption, electricity consumption to economic growth. Jixi is not the case. The direction of causality is just the opposite. That is, GDP growth is the Granger cause of coal energy consumption and electricity consumption growth. At a significant level of 10%, power consumption growth is the Granger reason for GDP growth in Shuangyashan and Qitaihe; In Hegang, growth is the Granger reason for the increase in energy consumption of exhaustible resources in the region.

From table3 for detailed results. "Yes" and "No" indicate whether there is Granger causality between the two variables. The numbers in parentheses are F-statistics, which are used to test whether Granger causality exists between the corresponding variables in the ranks. The length of a given sample period is 30 years, the degree of freedom is 1, and the null hypothesis is rejected at a significance level below 5%. The corresponding F-statistic critical value is 2.99.

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Table 3 Granger Causality Test Results

	GDP	Resource	Eletricity
Qitaihe			
GDP	n.a	No(0.54)	No(2.34)
Resource	No(0.44)		
Electricity	No(0.94)		
Jixi			
GDP	n.a	No(0.54)	No(0.94)
Resource	No(1.06)		
Electricity	No(3.23)		
Hegang			
GDP	n.a	No(2.89)	No(0.74)
Resource	No(2.84)		
Electricity	No(1.54)		
Shuangyashan			
GDP	n.a	No(0.58)	No(2.72)
Resource	No(0.84)		
Electricity	No(0.58)		
Daqing			
GDP	n.a	yes(0.39)	yes(3.27)
Resource	No(0.89)		
Electricity	No(0.91)		

3.3.3 Long-term OLS equation estimation

At the 5% significance level, the Granger causality test for Daqing and Jixi shows that there is a significant causality between the above variables. Initially, taking Jixi as an example. After Granger causality test, Jixi's economic growth is the Granger reason for its exhaustible resources, namely coal energy consumption and power consumption growth. However, the analysis of the relationship between GDP and electricity consumption, GDP and energy consumption of exhaustible resources shows that neither of these two pairs of relationships can adopt the ECM model. Because there is no co-integrated relationship between GDP and coal energy consumption, there is a co-integrated relationship between GDP and electricity consumption series. In the ECM model, the GDP variable does not have statistical significance (5% significance level). Therefore, the long-term relationship between Jixi’s exhaustible resource coal and economic growth can be estimated directly using OLS:

$$resource_t = -1.45 + 0.59gdp_t + 0.52resource_{t-1} + \varepsilon_t, \quad (13)$$

(0.45) (0.18) (0.15)

The exhaustible resources are used as lag variables to explain the laziness of regional behavior adjustment. In addition, the brackets below the variables in the above formula are the estimated standard deviations of the corresponding coefficients. After testing, all variables are significant at the 5% significance level,

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with a R^2 value of 0.97. The DW statistics are good, with a value of 1.85. It can be concluded that in the long run, for every 1% increase in Jixi GDP, the corresponding energy consumption of exhaustible resources will increase by 0.6%.

In Daqing, electricity consumption and energy consumption of exhaustible oil are Granger reasons for GDP growth. When the OLS method is used to estimate the long-term relationship between electricity consumption in Daqing, exhaustible resources, energy consumption and GDP, the equation

$$gdp_t = \gamma_0 + \gamma_1 electricity_t + \gamma_2 resource_t + \varepsilon_t$$

γ_1 and γ_2 represent the long-term elasticity of electricity consumption and energy consumption of exhaustible oil to economic growth GDP,

The corresponding estimation result is:

$$gdp_t = -0.64 + 1.29 gdp_t - 0.24 resource_{t-1} + \varepsilon_t (14)$$

(0.2) (0.05) (0.11)

R^2 is 0.99, DW test result is too small, the value is 0.33. Due to the need for further autocorrelation, the GDP lag variable, used to describe Daqing's economic growth cycle, is obtained

$$gdp_t = -0.17 + 0.37 electricity_t - 0.11 resource_t + 0.75 gdp_{t-1} + \varepsilon_t (15)$$

(0.09) (0.07) (0.04) (0.07)

All variables except the intercept term are statistically significant at the 5% significance level, with R^2 of 0.99 and DW test of 1.49. Although the estimated results have improved significantly, the ECM model is also used to test whether there is a co-integration relationship among Daqing GDP, electricity consumption, and oil consumption of exhaustible resources. The results of the Johansen co-integrated test indicate that at the 5% significance level, there are two sets of co-integrated relationships between the above variables.

Table 4 Unconstrained co-integrated rank test

(Object sequence: GDP, power consumption and energy consumption level of exhaustible resources)

Noofco-intereating equations	Eigenvalue	Trace statistic	0.05Criticacl value	Probability
None*	0.47	33.94	24.27	0.00
at most I *	0.32	14.76	12.31	0.01
at most 2*	0.09	3.13	4.13	0.09

Note: The rank test indicates that there are two sets of co-integrated relationships at the 5% significance level, and the symbol "*" indicates that the null hypothesis is rejected at the 5% significance level.

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Table 5 Estimation of ECM model

Variable	Δgdp_t is dependent variable			
	Coefficient	Standard error	T-Statistic	Probability
Constant	-0.17	0.01	-1.32	0.32
$\Delta electricity_{t-1}$	0.67	0.14	4.75	0.00
$\Delta resource_{t-1}$	-0.19	0.09	-1.32	0.19
Δgdp_{t-1}	0.70	0.17	4.10	0.00
Error correction term	-0.62	0.25	-2.45	0.02
R^2	0.62	Mean dependent variable		0.07
AdjustedR^2	0.56	S. D. dependent variable		0.03
Standard Error regression	0.02	AIC		-4.56
sum squared of residuals	0.01	SC		-4.32
Log likelihood	73.43	F-statistic		10.39
D.W.	1.615	P-Value		0.000

3.3.4 ECM model and short-term change estimation

ECM tested the existence of the co-integrated relationship. Among them, the error correction term is given by the lag OLS estimation formula (13)(14):

$$ecm = e_t = gdp_{t-1} - \gamma_1 - \gamma_2 electricity_{t-1} - \gamma_3 resource_{t-1} - \gamma_4 gdp_{t-2} \quad (15)$$

Incorporate the error correction term, such as formula (15), and establish the ECM model:

$$\begin{aligned}\Delta gdp_t &= r_1 + r_2 \Delta electricity_t + r_3 \Delta resource_t + r_4 \Delta gdp_{t-1} \\ &- r_5 (gdp_{t-1} - r_1 electricity_{t-1} - r_3 resource_{t-1} - r_4 gdp_{t-2}) + \varepsilon_t\end{aligned} \quad (16)$$

Estimating equation (16), the following conclusion is obtained: the short-term elasticity of GDP to electricity consumptionr_2= 0.67, and the short-term elasticity of GDP to energy consumption of exhaustible resources is relatively small, r_3 = -0.19. In addition, the variable is only meaningful at a significance level of 0.2. r_4=0.70 indicates the flexibility of current income relative to the income of the previous period. The magnitude of the impact of electricity consumption on GDP is similar to the impact of the previous per capita GDP level, r_5=-0.62, which can explain the system adjustment rate, which means that 62% of the effects that cause deviations from long-term relationships are corrected each year. In other words, before the system returns to the long-term relationship trend, the impact of any short-term shock can only be maintained for 1.5 years. The characteristics of the residual sequence are tested. The JB test results show that the residual sequence follows a normal distribution, and the corresponding distribution probability is 39%.

In addition, for the economic cycle, using GDP as the explanatory variable, electricity consumption, and energy consumption of the exhaustible resources as the explanatory variables, they could describe the economic cycle as follow:

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$$gdp_t = -0.81 + 1.11\,electricity_t - 0.06 resource_t + 0.07 cycle^3 + \mu_t \quad (17)$$

(0.05) (0.01) (0.01) (0.01)

Each variable is significant, goodness of fit value is 0.99, DW statistic is 1.86. The results confirm the conclusion based on the ECM model that daqing's electricity consumption is also a key driver of economic growth, which is why the region has also introduced a large amount of wind power in recent years.

3.4 Conclusion and prospect

The results of the Granger causality test shows that "there is an important relationship between the energy consumption of exhaustible resources and economic growth." The relationship between the two is not clear. At the 5% significance level, empirical tests indicate that there is no correlation between Shuangyashan's GDP and energy consumption. The test results of Jixi believe that there is a close relationship between the two variables. When the significant level is increased to 10%, the power consumption of Hegang and Qitaihe has a significant impact on economic growth.

The analysis of the measurement results of Daqing shows that the energy consumption of electricity and exhaustible resources, namely oil, will promote economic growth to a certain extent. Specifically, every 1% increase in electricity consumption will promote GDP growth by 0.5%. At present, Daqing's economic development requires little additional stimulation. There is no correlation between GDP growth and oil energy consumption, which may be due to the policies of emerging industries to stimulate economic growth. The energy consumption of exhaustible oil has a small negative impact on GDP, which is also related to the extensive economic growth of Daqing in the early years.

The conclusion of Jixi's quantitative analysis is as follows: There is a one-way causal relationship between the GDP growth and the energy consumption of exhaustible coal. This conclusion is consistent with the actual development of Jixi. Especially in recent years, rate of economic growth in Jixi has been defined as a resource-based city with recession, and the mining and utilization of coal has gradually been exhausted. At this time, Jixi's economic growth depends on welfare policy tendencies, rather than every 1% increase in economic growth, the energy consumption of exhaustible resources, namely coal, increases by 0.6%. However, the conclusion of this study cannot solve the current policy problems and economic development bottlenecks in Jixi. At present, simply considering the industrial transformation may bring unpredictable social and political impact. However, maintaining current policies also means maintaining low energy efficiency while continuing to burden government budgets and economic growth.

Different exhaustible resource-based cities have different relations between the energy consumption of exhaustible resources and economic growth. This shows that the performance of exhaustible resources on economic growth cannot be completely solved and realized by market forces. The provision of infrastructure, financial

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subsidies, trade policies, climate and even cultural factors may all have important influences. However, these factors are difficult to analyze through econometric methods. It will be more difficult and challenging to establish resource analysis models suitable for different exhaustible resource cities. This has also become one of the issues that can be discussed and elaborated in this study.

4. The economic development of resource-exhausted cities in Heilongjiang Province

4.1 Difficulties in urban development and transformation

Heilongjiang Province, with its rich exhaustible resource reserves, relied on extensive development to achieve rapid economic development in 1940s. However, with the decline in exhaustible resource reserves in recent years, the major resource-based cities in Heilongjiang Province are seeking transformation. For example, Daqing explores the tourism industry with its abundant hot spring resources. With the increase in the consumption of hot springs, the government supports individuals to invest in the construction of large-scale hot spring playgrounds and hot spring gardens. Take hot spring venues such as "Northland Hot Spring" and "Lianhuan Lake" as representative. Al subjects boost development of Daqing's tourism economy, and attract a large number of domestic and foreign tourists, especially a large number of Russian tourists. In the short term, hot spring tourism projects can indeed effectively promote the current economic growth of Daqing City, and also effectively solve employment problems. But in the long run, hot springs, as exhaustible resources, do not possess superior regenerative characteristics. Therefore, although Daqing City has embarked on a transformation, there are still some difficulties in practically solving the way of relying on the exhaustible hot spring resources to promote economic growth.

4.2 Unreasonable urban industrial structure

Resource-based cities, especially declining resource-based cities, often rely on exhaustible resources as their leading industries, such as Daqing's oil and Jixi's coal. In the economic development, it is easy to have a high proportion of the primary industry, but the industrial efficiency declines year by year. The technical content of the secondary industry is relatively low. Therefore, most resource-based cities currently seek industrial transformation. For example, exhaustible resource-based city in Heilongjiang province, they are more dependent on the development of tourism industry during the transformation. . It is not only the theory of industrial structure adjustment, but to find a new industrial development model suitable for the local area.

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4.3 Insufficient technological innovation and effective investment

According to the previous theoretical description, technological innovation can break the dilemma of economic growth under the constraints of exhaustible resources. At present, Heilongjiang Province is also actively responding to the policy requirements of "mass innovation and entrepreneurship", it has established its own incubation center. But there is still a lack of mature technology industry. Hence, the rate of technological progress in Heilongjiang Province is much lower than the rate of exhaustible resource consumption. The long-term will result in an economic recession under exhaustible reserves. How to encourage technological innovation is not only to comply with the background and policy requirements, but also an important way to effectively break the constraints of exhaustible resources.

In this study, the research team conducted on-the-spot investigations. Resource-based cities, especially those that are exhaustible, lack effective investments of high quality. With the stagnation of local economic growth, a large number of enterprises have chosen to leave for better development. As a mature resource-based city, Daqing is also subject to resource constraints. It introduce "Volvo" auto companies, which can not only solve the problem of industrial transformation, but also solve the local employment pressure. In contrast, although the investment environment of other resource-based cities in this study is improved under the adjustment of the local government, there are not many high-quality investments. In the case of exhaustible resource reserves, investment in resource-based cities has also gradually slowed down. So how to improve the business environment and attract more effective foreign investment are the key to resolved the problems in current resource-depleting cities.

5. Policies and suggestions for the economic development

5.1 Strategies for economic transformation of resource-exhausted cities

For resource-based cities, especially those under the constraint of depletion, the economic growth model should be changed in time. In particular, it is important to move away from growth driven by exhaustible resources as soon as possible. The economy of resource-based cities in this study should break through the growth constraint of exhaustible resources and make full use of local characteristic resources. However, Daqing, for example, should be developed and used its unique hot spring resources. Accordingly, each district should adjust measures to boost local economics. At the same time, we should adjust and perfect the industrial structural model of resource-based cities to provide strong support for economic transformation. Meanwhile, green agriculture should be encouraged. Although Heilongjiang province is famous for agricultural province, agriculture is with low added value. Therefore, Heilongjiang province, especially its resource-exhaustible cities, can take green agriculture as a new growth driver, increasing the added value of products, producing and supplying organic or green food. On the other hand, labor-intensive industries are the main power to drive economic growth in

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resource-based cities. This means these cities should be develop more capital-intensive industries. If resource-based cities could complete the upgrading of industrial structure, economic growth mode transformation should be realized.

5.2 The Government should provide a sound business environment

When GDP is no longer the only measure of economic growth, the government should consider a number of factors. Investment can be used as a measure of economic growth, but it is not the only measure factor. The investigations for the resource-based cities are found in many investment still exist the following problems: some housing investment projects is unfinished, some investment habitual delayed, other ones could be caused pollution to the environment. It means the government should not only attract investment, but also identify the rationality and effectiveness of investment. For outstanding investment projects that can promote economic growth and improve people's livelihood, the government should provide preferential investment policies. For foreign investors, it is necessary to give them appropriate humanistic cares.

5.3 Technological innovation can boost economic development

Technological innovation is the main driving force and source of economic growth. Resource-based cities, especially those suffering from declining exhaustible resources, should pay more attention to technological innovation, which should also include the transformation of traditional agriculture. Taking Daqing as an example, agriculture, rural areas and agricultural population are all important factors affecting economic development. Therefore, the reformation of traditional agriculture should introduce new technology, realize agricultural modernization and improve the technical content of agriculture. To realize agricultural modernization should be contains many ways including to invite experts to teach peasants technology, encourage peasants to carry out sideline business, and invest in peasants in a tilted way, such as setting up technical schools and introducing modern rural production organizations. At the same time, attention should be paid to the loss of rural working-age population. At present, most of the rural working-age workers in resource-based cities in Heilongjiang Province choose to move to cities. For example, many peasants work in cities such as Dalian and Beijing to get more income and improve their quality of life. This directly leads to the fact that most of the rural surplus population are old people and children, which not only leaves safety hidden danger, but also causes part of the farmland to be abandoned, hindering the rural economic development. Hence, through the introduction of technological innovation, the government should enable peasants to find new products and technologies suitable for their own development, so as to achieve the goal of getting rich and effectively solve the problem of the loss of rural working-age population.

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6. Conclusion

The economic development of resource-based cities in Heilongjiang province is typical. On one hand, there are resource-based cities dominated by exhaustible resources, such as Daqing and Jixi; on the other hand, there are resource-based cities represented by Heihe and Mudanjiang which are rich in natural resources. Therefore, in the process of economic development, resource-based cities in Heilongjiang should make effective use of exhaustible resources, moderately develop natural resources and develop tourism industry based on regional characteristics. In the process of transformation and development, cities with high natural endowments should pay attention to the development of characteristic agriculture and complete the integration and upgrading of industrial structure. At the same time, we should also pay attention to the common problems of urban economic development, such as "three agriculture" problems, and the way of agricultural modernization. In this way, the limitation of exhaustible resources can be broken and the high quality development of resource-based city economy can be realized.

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