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# Natural Resource Curse, Total Factor Productivity and Regional Disparity in China: Based on Dynamic Panel Data Model Analysis

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**ABSTRACT**

There has been the long debate over the relation between natural resource abundance and economic growth. Since the hypothesis of "natural resource curse" advanced by Gelb (1988) and Auty (1994), many scholars have concentrated on the topic, but no agreement has yet been achieved. This paper makes use of panel datasets of China's 30 provinces from 1998 to 2009, and GMM method of dynamic panel data model, to calculate the Malmquist index of total factor productivity (TFP), test the natural resource curse hypothesis, and estimate the natural resource consumption equation. Firstly, the TFP index shows that China's high economic growth is less efficient, and interior provinces have large disparities. Moreover, estimation results of capital and labor equations show that, for the whole country, the natural resource sector's investment and employment promote GDP growth, so no natural resource curse exists in China. But integral three regions show different situation. The eastern region has been constrained by the resource curse effect since 2007, although the middle and west are not troubled by this due to their lower resource consumption. In addition, the natural resource consumption equation indicates that TFP has significantly negative impact on natural resource consumption for the whole country. The three regions' TFP are all negatively correlated with resource consumption, owing to fast technological progress in resource exploitation and utilization during these years. Based on these findings, the paper reckons that if TFP rise can reduce natural resource consumption remarkably, the country or the region can eliminate the resource curse effect; or else, it has to suffer negative impact of excessive resource reliance. Finally, it makes some policy recommendations.

**Key words:** natural resource curse, total factor productivity (TFP), regional disparity, dynamic panel data model

**JEL Classification:** O13, O47, Q32

# Natural Resource Curse, Total Factor Productivity and Regional Disparity in China: Based on Dynamic Panel Data Model Analysis

## 1. INTRODUCTION

The “natural resource curse” hypothesis is a controversial and important topic in the field of development economics. It appears that the hypothesis is tenable in many cases, since many countries abundant in natural resources are economically backward, whereas many countries with scarce resources tend to grow faster, like many newly industrialized countries of Asia. However, scholars hold different points of view towards the relationship between natural resources and economic growth. Starting from Sachs and Warner’s initial studies (1995, 1999 and 2001), many papers followed the analytical framework, investigated different countries’ cases, but derived disparate conclusions. Some of them, in agreement with Sachs and Warner’s argument, believe that natural resources are curse for most countries, because natural wealth can be wasted and lead to destructive behaviors like “rent-seeking” activities, and crowding-out effect on manufacturing, education, and other factors considered to be important for economic growth, introduced by the “Dutch disease” model (Corden and Neary, 1982). But is this the general rule? Isn’t it true that many of the present-day richest countries (such as the United States, Canada, Australia, and the Scandinavian countries) became rich and technologically developed precisely through a judicious use of their natural resource wealth (Lederman and Maloney, 2007)? Another body of literature has questioned the validity of the resource curse hypothesis on several grounds. As demonstrated by Ding and Field (2005), Stijns (2005 and 2006), and Brunnschweiler (2006), there is a long literature that questions the detrimental impacts of natural resources, and these scholars, along with Blomström and Kokko (2007), stress the numerous successful stories among advanced and emerging resource-abundant countries. This has given rise to a line of research investigating the drivers of differential performance, including endogenous technological progress, poor policy, or institutions. Taking Sachs and Warner’s dataset and estimating approach as given, is there any other explanation for the observed relationship besides the low productivity growth story? We confirm Lederman and Maloney’s (2002) finding that Sachs and Warner’s results are not robust when unobserved heterogeneity is controlled for in a panel data context. Moreover, they demonstrated that the results are not robust to measures of resource abundance, small changes in samples, or estimating techniques.

Why are there distinct arguments on the natural resource curse hypothesis? Based on a review of related literature, at least two reasons can be discovered. First, methodologies and datasets chosen in regression analysis are quite different. When using Sachs and Warner's data, even after dealing with some potential statistical pitfalls, the resource curse continues to exist in the cross-section.[1] Indeed, most cross-section data used to test the resource curse hypothesis can derive resource curse, as seen in many papers. However, if cross-section data is replaced by panel data, which better reflects dynamic characteristics of natural resources and economic growth, the results may be reversed. This has been verified in research conducted by Lederman and Maloney (2002). Even the conclusion that, on average, resource-abundant countries grow more slowly has come under assault. For instance, Doppelhofer, Miller and Sala-i-Martin (2000), applying a Bayesian approach into their study, found that mining production as a share of GDP was among the four extremely robust variables positively affecting growth, a finding broadly confirmed by Davis (1995). The other reason for viewpoints between contradictions lies in disagreement about the sources of the natural resource curse. Most papers pay more attention to the impact of natural resources on other transmission variables,[2] in turn concluding these as curse sources (Sonin, 2003; Aslaksen, 2010; Arezki and Ploeg, 2010). But this seems unreasonable. If one country does not have a negative relationship between natural resources and economic growth, resources must have impact on other variables, but this cannot be easily considered as a source of resource curse. We have observed some countries abundant in resources grow quickly in past years, even if a resource curse effect exists. Thus the cause of resource curse is not natural resources per se but its real effect in the economic system. That is, how natural resources interact with economic variables may contribute to the existence of a resource curse.

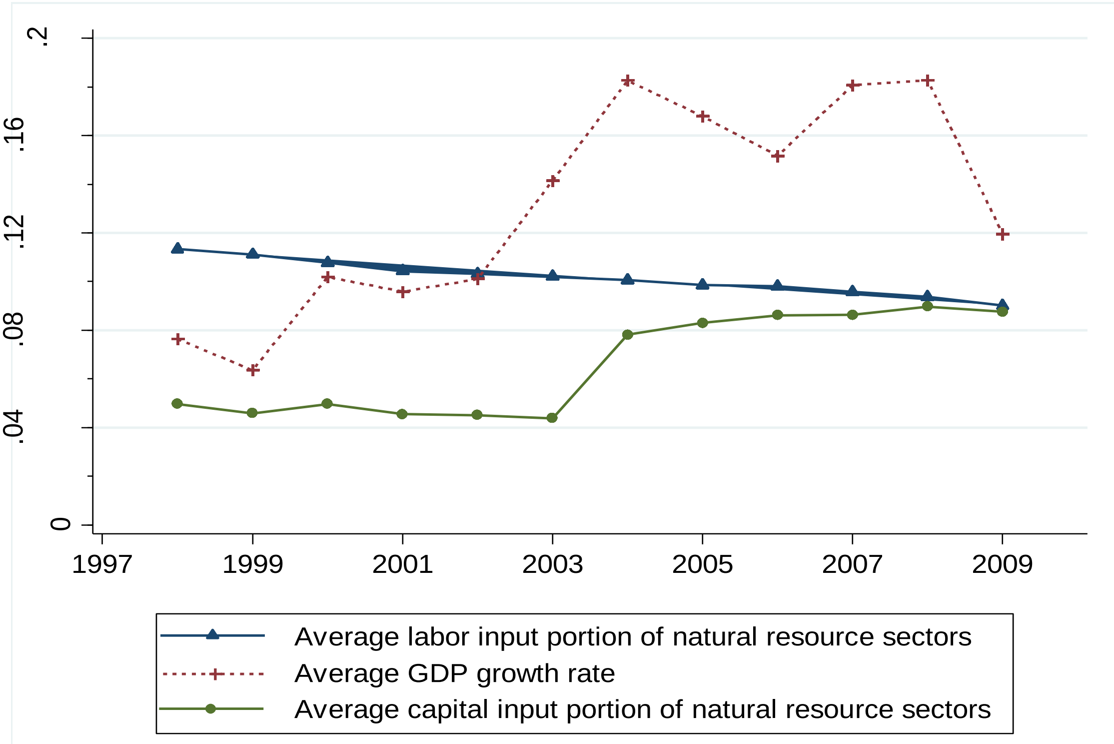
Whether the natural resource curse hypothesis can be applied in a country to analyze its regional economic disparities has valuable academic significance. These differences are not defined only by growth rate but are also denoted by growth productivity, since optimal economic performance requires maximum outputs with minimum inputs. As important inputs, maybe intermediate or final inputs during growth, natural resources are objectively minimized to achieve a higher growth rate according to the principles of cost minimization or profit maximization. Therefore, they must be affected by economic growth productivity, and produce the diverse phenomena of the resource curse. Economic growth productivity is an important

[1] The conclusion is based on the estimation results of Manzano and Rigobón (2007). Resource Curse or Debt Overhang? in: Lederman, D. and W.F. Maloney, 2007, Natural Resources: Neither Curse Nor Destiny. Stanford University Press and the World Bank, 41-71.

[2] Until now, transmission variables used in literatures contain investment, manufacturing, education, R&D, openness and institution.

concept in the field of macroeconomics, and can be evaluated by the index of total factor productivity (called TFP for short). TFP is sometimes called "multi-factor productivity" and measures contributions of technological progress to economic growth. It is a good index to reflect the quality of economic growth and level of technological progress. In classical theories, using output growth, factor shares, capital stock growth and labor force growth, TFP can be estimated by the linear Solow growth model. But this method always brings many errors of estimation, so this paper introduces a new method, the Malmquist productivity index, to accurately calculate China's and its regions' TFP. Based on these facts, this paper tries to explore the natural resource curse hypothesis empirically using China's provincial panel dataset, since the economies of the country and its inner regions are still growing no matter whether or not the natural resource curse exists in different places. We want to learn what accounts for the outcomes of the resource curse on earth. Is there any other appropriate explanation of natural resources' effect on economic growth?

**Figure-1: Time Trend of Average GDP Growth Rate and Average Portions of Natural Resource Sectors' Investment and Employment in China (1998-2009)**

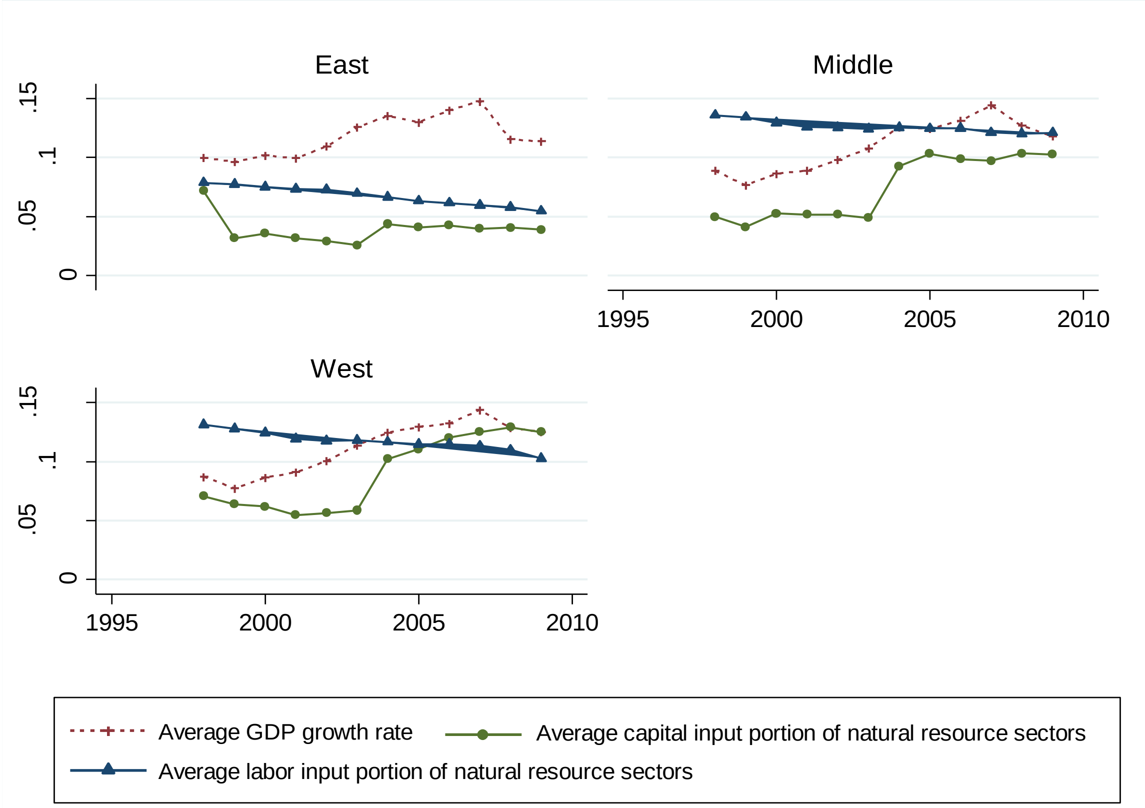



Source: Author's Calculations Based on China Statistical Yearbook.

Figure 1 gives us a preliminary observation on the change of China's economic growth and natural resource sectors during 1998 to 2009. In the past 12 years, China has experienced rapid economic growth with an average growth rate about 13.05% every year. Under the natural resource curse hypothesis, if a country is abundant in resources, it is expected that to achieve a high growth rate, natural resource sectors' contributions should become less year by year. To describe natural resources accurately, we use the average proportion of natural resource sectors' investment to total investment in fixed assets, and the average proportion of natural resource sectors' staff and workers to total staff and workers as the measure of natural resource abundance. Natural resource sectors contain agriculture, forestry, animal husbandry, fishery and mining (including coal, oil, natural gas, metal and nonmetal mining). According to Figure 1, it appears that number of staff and work in resource sectors shows a slight decrease, which seems to support the natural resource curse hypothesis, but investment in resource sectors has the same trend as GDP growth and gradually increases from 1998 to 2009. Hence, it is uncertain whether the natural resource curse exists in China, judging from intuitive observations, and precise statistical and econometric analysis is needed.

Although China's economy grew quickly in the past 12 years, disparities between interior regions are becoming very large. For example, GDP per capita of Tibet was 1524.58 Yuan in 2006 which is smaller than that of Shanghai, which was 2596.24 Yuan in 1981. And GDP per capita of Shanghai in 2006 is 10036.50 Yuan, 6.6 times that of Tibet. Furthermore, natural resources are located unevenly in the country, and show a decreasing trend from the east region to the west region. Regional resources may show diverse characteristics in the curse hypothesis. In the paper, we group China's 30 provinces (mainland provinces excluded Tibet due to data availability) into three integral regions: east, middle and west, and try to discover their homologies and differences for the natural resource curse. Here, the east region contains 11 samples (Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan), the middle region contains 8 samples (Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan), and the west region contains 11 samples excluded Tibet (Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang).

**Figure-2: Time Trend of Average GDP Growth Rate and Average Portions of Natural Resource Sectors' Investment and Employment in China's Integral Regions (1998-2009)**




Source: Author's Calculations Based on China Statistical Yearbook.

Figure 2 is drawn to describe disparities between the three regions intuitively, and it indicates that east China is growing faster on average than middle and west China from 1998 to 2009, but the ratios of investment and employment in natural resource sectors look smaller than the other two regions. According to comparison of the small graphs, the east region's investment and employment in resource sectors decreased against the trend of GDP growth rate, whereas natural resource sectors in the middle and west expanded, in line with the growth of GDP, which seems not to support the natural resource curse theory for integral regions. But we cannot make conclusions only based on simple appearances. For reliable economic analysis, detailed econometric analysis is conducted on these different regions in the following text.

In addition, China's high economic growth is accompanied by low growth quality, denoted by TFP growth rate of approximately -0.46% every year. That is a downward trend in productivity, which shows that, to achieve a high growth rate, China has to input more factors including capital, labor, resources and others, since the transformation efficiency (mainly technological efficiency) from inputs to outputs is decreasing. Therefore, in transforming different inputs, what effect does total factor productivity have on natural resources? If there is some relation between TFP and natural resources, does TFP have impact on economic growth through natural resources? Can TFP influence the natural resource curse effect? This is explored in the following text. Moreover, I also check it from the perspective of the country and different regions. Therefore, the purpose of this paper is not only to test whether the natural resource curse hypothesis holds in China, but also to reveal further causes of the hypothesis, and discover internal mechanisms among natural resources, growth rate and growth productivity. Based on this, it provides a rational explanation for China's large regional disparities, and makes corresponding recommendations for China's natural resource policies and regional development polices.

The next section introduces the paper's analytical framework including basic models, TFP measurement method, variables and data sources used in the estimation. Section 3 concerns econometric methods and data issues. In the paper, GMM estimation of dynamic panel data model is used in order to derive validity estimators. It explains why we use this method and its estimation procedures. Moreover, it introduces a nonparametric linear programming technique, and then derives TFP and its decomposition indices of China and its provinces. It also gives summary statistics and a correlation matrix of variables used in the econometric analysis. Section 4 contains empirical results and implications. It gives estimation results of the natural resource curse hypothesis test and natural resource consumption equation test from different perspectives. Also, it explains the hypothesis from the viewpoint of TFP, and then derives some important implications. Section 5 concludes the paper and puts forward policy recommendations.

## 2. ANALYTICAL FRAMEWORK

### *2.1 Model*

#### *2.1.1 Test of Natural Resource Curse Hypothesis*

Based on classical economic growth theory, we make use of Cobb-Douglas production function containing capital and labor input, to reflect relations among technology development, factor inputs and economic growth. Taking every province of China i as one unit and adding time-series t, the production function is set as

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{\beta} \tag{1}$$

$Y_{it}$ is gross output for province i at year t which can be represented by GDP. $A_{it}$ is technology level. $K_{it}$ and $L_{it}$ are capital input and labor input respectively. α and β are coefficients of capital elasticity and labor elasticity respectively. Taking logarithms of both sides of Eq. (1) yields

$$\ln Y_{it} = \ln A_{it} + \alpha \ln K_{it} + \beta \ln L_{it} \tag{2}$$

Taking the derivative of Eq. (2) with respect to t yields

$$\frac{d \ln Y_{it}}{dt} = \frac{d \ln A_{it}}{dt} + \alpha \frac{d \ln K_{it}}{dt} + \beta \frac{d \ln L_{it}}{dt} \tag{3}$$

That is

$$\frac{\dot{Y}_{it}}{Y_{it}} = \frac{\dot{A}_{it}}{A_{it}} + \alpha \frac{\dot{K}_{it}}{K_{it}} + \beta \frac{\dot{L}_{it}}{L_{it}} \tag{4}$$

Each term of Eq. (4) stands for the growth rate of the corresponding variable. We can transform it into

$$y_{it} = g_{Y_{it}} = g_{A_{it}} + \alpha g_{K_{it}} + \beta g_{L_{it}} \tag{5}$$

In the equation, $y_{it}$ , $g_{A_{it}}$ , $g_{K_{it}}$ and $g_{L_{it}}$ are respectively growth rate for GDP, technology, capital input and labor input. From this equation, we can conclude that economic growth is mainly contributed by capital growth, labor growth and technological progress.

To test the natural resource curse hypothesis, we plan to introduce panel data model in order to increase the number of samples and investigate the dynamic characteristics of natural resource use during each period of time. According to the classical “Dutch disease” model of Corden and Neary (1982),[3] to explore the relationship between economic growth and natural resource use, we have panel regression model like

$$\begin{gathered} y_{it} = \theta Natr_{it} + \theta' Manu_{it} + \lambda Z_{it} + \varepsilon_{it} \\ \varepsilon_{it} = \mu_i + e_{it} \end{gathered} \tag{6}$$

In the equation, i is the cross section unit for each province, and t is the time unit of a year. The left side term, $y_{it}$, is the economic growth rate. The right side term, $Natr_{it}$, is the input level of natural resource sectors, and $Manu_{it}$ is the input level of the manufacturing sector. $Z_{it}$ is a set

[3] The model is described in detail by Corden, W.M. and J.P. Neary (1982). Booming Sector and De-industrialization in a Small Open Economy. *The Economic Journal*, 92, 825-848.

of control variables including other factors affecting economic growth, and $\varepsilon_{it}$ is idiosyncratic errors, which consist of $\mu_i$, a regional specific component, and $e_{it}$, a remainder component. It is usually assumed that all explanatory variables are independent of all $\varepsilon_{it}$.

Because there are many types of natural resources in real economic systems, it is difficult to reflect all of them using several variables. Thus, here we use input levels of the sectors of agriculture, forestry, animal husbandry, fishery and mining to represent natural resource abundance. For these sectors, input quantities totally depend on natural resources availability, so their input levels can reflect region's natural resource abundance well.

However, it is notable that Model (6) neglects dynamic characteristics of economic growth which take time into consideration, since the growth of last year has a significant impact on next year's growth. Therefore, a first order lagged term of growth should be included in the panel regression, thus the model is

$$\begin{gathered} y_{it} = \eta y_{i.t-1} + \sum_{k=1}^{k} \theta_k x_{kit} + \lambda Z_{it} + \varepsilon_{it} \\ \varepsilon_{it} = \mu_i + e_{it} \end{gathered} \tag{7}$$

Eq. (7) is actually a dynamic panel data model with first order lagged term $y_{i,t-1}$, and if $|\eta| < 1$, it is stationary. $x_{it}$ is the set of explanatory variables which contribute most to growth rate. Here, $Z_{it}$ is the set of control variables. According to the implications of Eq. (5), explanatory variables mainly consist of capital input, labor input and technological progress. If they are included in the model, estimation results can correctly reflect the effect of natural resources on economic growth. Moreover, based on Eq. (6), to study the impact of natural resources on growth, capital and labor input of both sectors of natural resources and manufacturing should also be included in the model.

Following classical economic growth theory, factor inputs of explanatory variables can be divided into capital part and labor part which consist of all inputs into growth. Therefore, we can fully study the factor transfer effect in "Dutch disease" model. Furthermore, because capital and labor are highly correlated, if they appear in the same equation simultaneously, there will be a collinearity problem. In order to overcome this problem, based on the principles of Eqs. (6) and (7), capital factor and labor factor are estimated in different equations, and the final econometric models are set as

$$\begin{gathered} y_{it} = \eta y_{i,t-1} + \theta_1 KNatr_{it} + \theta_2 KManu_{it} + \theta_3 KEdu_{it} + \theta_4 KRd_{it} + \lambda Z_{it} + \varepsilon_{it} \\ \varepsilon_{it} = \mu_i + e_{it} \end{gathered} \tag{8}$$

$$y_{it} = \eta' y_{i,t-1} + \theta_1' LNatr_{it} + \theta_2' LManu_{it} + \theta_3' LEdu_{it} + \theta_4' LRd_{it} + \lambda Z_{it} + \varepsilon_{it}$$
$$\varepsilon_{it} = \mu_i + e_{it} \tag{9}$$

In the paper, Eq. (8) is called "capital equation" and Eq. (9) is called "labor equation". In capital equation, $y_{it}$ is economic growth rate at year t, and its first order lagged term $y_{i,t-1}$, which should satisfy stationary condition $|\eta| < 1$. $KNatr_{it}$ is capital input of natural resource sectors, $KManu_{it}$ is capital input of manufacturing, $KEdu_{it}$ is capital input of education sectors and $KRd_{it}$ is capital input of research and development sectors. $Z_{it}$ is the set of control variables, which include time effect (year dummy variable) to control for economic fluctuations during sample periods in order to obtain more effective estimations. The value of year dummy variable is 1 for this year, and 0 for other years. $\varepsilon_{it}$ is idiosyncratic errors, which consist of $\mu_i$, a regional specific component, and $e_{it}$, a remainder component. In the dynamic panel model, individual effect $\mu_i$ can be either fixed effect or random effect, but should be assumed to be I.I.D. The variables in the labor equation have similar definitions, but only replace capital input by labor input. Other variables are the same as in the capital equation. Among them, $KRd_{it}$ and $LRd_{it}$ represent technological progress of two perspectives. Variable descriptions are given in detail in Table 1.

In the following section, Eqs. (8) and (9) are estimated many times using China provincial panel datasets. The sample is China's 30 provinces (mainland provinces excluding Tibet) from 1998 to 2009. Firstly, we estimate Eqs. (8) and (9) for the whole country to investigate if the natural resource curse hypothesis holds for all samples. Furthermore, using the capital equation, we check the natural resource curse hypothesis of China's integral regions (east, middle and west region),[4] and then make comparisons.

### *2.1.2 Hypothesis Explanation: Test of Natural Resource Consumption Equation*

The previous part describes models to test the natural resource curse hypothesis, but does not offer explanations for the hypothesis. Following the analytical framework of Gylfason and Zoega (2006), we adopt the Cobb-Douglas production function, and expand it by adding natural resources input $N_{it}$, which considers natural resources as a key source of economic growth.[5] And the production function is set as

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{\beta} N_{it}^{\gamma} \tag{10}$$

[4] Refer to introduction part for detailed groups.

[5] Gylfason, T. and G. Zoega (2006) built a specific model with the natural resource component to examine the effect of resource on economic growth by the role of investment. In: Natural Resources and Economic Growth: The Role of Investment. *The World Economy*, 29, 8, 1091-1115.

In this equation, γ is resource elasticity coefficient. Its profit function is

$$\pi = pY_{it} - rK_{it} - wL_{it} - \varphi N_{it} \tag{11}$$

π, p, r, w and φ are profit, product price, saving rate, wage rate and natural resource price respectively. Combined with Eq. (10), the profit function can be written as

$$\pi = pA_{it}K_{it}^{\alpha}L_{it}^{\beta}N_{it}^{\gamma} - \gamma K_{it} - wL_{it} - \varphi N_{it} \tag{12}$$

Taking the derivative of Eq. (10) with respect to $N_{it}$ yields

$$\gamma A_{it}K_{it}^{\alpha}L_{it}^{\beta}N_{it}^{\gamma-1} = \frac{Y_{it}}{N_{it}} \cdot \gamma \tag{13}$$

Taking the derivative of both sides of Eq. (12) with respect to $N_{it}$ yields

$$\gamma pA_{it}K_{it}^{\alpha}L_{it}^{\beta}N_{it}^{\gamma-1} - \varphi = 0 \tag{14}$$

Based on Eq. (13), Eq. (14) becomes

$$\gamma p\frac{Y_{it}}{N_{it}} - \varphi = 0 \tag{15}$$

Thus

$$\frac{Y_{it}}{N_{it}} = \frac{\varphi}{p} \cdot \frac{1}{\gamma} \tag{16}$$

Taking it into Eq. (13) yields

$$\gamma A_{it}K_{it}^{\alpha}L_{it}^{\beta}N_{it}^{\gamma-1} = \frac{Y_{it}}{N_{it}} \cdot \gamma = \frac{\varphi}{p} \tag{17}$$

Taking natural logarithms of both sides of Eq. (17) yields

$$\ln\gamma + \ln A_{it} + \alpha\ln K_{it} + \beta\ln L_{it} + (\gamma - 1)\ln N_{it} = \ln\frac{\varphi}{p} \tag{18}$$

That is

$$\ln N_{it} = \frac{1}{1-\gamma}[\ln\gamma + \ln A_{it} + \alpha\ln K_{it} + \beta\ln L_{it} - \ln(\frac{\varphi}{p})] \tag{19}$$

Eq. (19) shows that natural resource consumption is depended on the level of technology, capital, labor, and the relative price between resource price and product price. Furthermore, as one important type of consumption, resource consumption, closely connected with individuals' habits and hobbies, has also significant dynamic characteristics. This means the consumption of last year would affect this year's consumption. Therefore, taking time effect into consideration, a first order lagged term of consumption should be included in the panel regression. Finally, we write the econometric model as

$$\ln N_{it} = \phi \ln N_{i,t-1} + \rho_1 \ln K_{it} + \rho_2 \ln L_{it} + \rho_3 \ln(\frac{\varphi}{p})_{it} + \rho_4 \ln(TFP)_{it} + \varepsilon_{it} \qquad (20)$$
$$\varepsilon_{it} = \mu_i + e_{it}$$

In the equation, variable $N_{it}$ is natural resource consumption at year t, including consumption of coal, petroleum, natural gas, hydro power and nuclear power. This equation is called "natural resource equation" in the paper. $N_{i,t-1}$ is the first order lagged term of $N_{it}$, which should satisfy the stationary condition $|\phi| < 1$. Thus, Eq. (20) is a dynamic panel data model, and the regional specific effect $\mu_i$ is independent on time and assumed to be I.I.D. Idiosyncratic errors $\varepsilon_{it}$ is white noise. $K_{it}$, $L_{it}$, $(\varphi/p)_{it}$ and $TFP_{it}$ are capital input, labor input, relative price between resource price and product price, and TFP index respectively. TFP has close connection with technological progress, and so can affect resource consumption. Detailed variable descriptions are given in Table 1.

We estimate natural resources Eq. (20) using panel data of China and integral regions. We mainly want to investigate the relationship between resource consumption and TFP, and explore whether the estimator of TFP in Eq. (20) is related to estimators of $KNatr_{it}$ and $LNatr_{it}$ in Eqs. (8) and (9), in order to explain the effect of TFP on the natural resource curse. At this stage, the groups of samples and estimation procedures are the same as in the capital equation and labor equation. It is unnecessary to go into details here.

*2.2 Variables and Data Sources*

In this paper, we need to calculate some indices and estimate parameters of Eqs. (8), (9) and (20) listed above. For regression Eqs. (8) and (9), since capital and labor inputs are restricted by different regions' economic development, population scales and geographic characteristics, the indices of absolute values are not proper for transverse comparisons. Variables used for calculations and econometric equations of Eqs. (8) and (9) are defined by relative values, and they are described in detail in the following table.

| Variable | Definition |
|---|---|
| $y_{it}$ | GDP growth rate at year t of every province: $y_{it} = \ln(GDP_{it} / GDP_{i,t-1})$ |
| $y_{i,t-1}$ | GDP growth rate at year t-1 of every province, first lag of $y_{it}$ |
| $KNatr_{it}$ | Capital input of natural resource sectors at year t of every province: (Agriculture, forestry, animal husbandry, fishery and mining investment in fixed assets / Gross investment in fixed assets)×100% |
| $KManu_{it}$ | Capital input of manufacturing sector at year t of every province: (Manufacturing investment in fixed assets / Gross investment in fixed assets)×100% |
| $KEdu_{it}$ | Capital input of education sector at year t of every province: (Education funds / GDP)×100% |
| $KRd_{it}$ | Capital input of research and development sector at year t of every province: (Intramural expenditure of R&D / GDP)×100% |
| $LNatr_{it}$ | Labor input of natural resource sectors at year t of every province: (Number of staff and workers in agriculture, forestry, animal husbandry, fishery and mining / Gross number of staff and workers)×100% |
| $LManu_{it}$ | Labor input of manufacturing sector at year t of every province: (Number of staff and workers in manufacturing / Gross number of staff and workers) ×100% |
| $LEdu_{it}$ | Labor input of education sector at year t of every province: (Number of full-time teachers of institutions of higher education / Gross number of staff and workers)×100% |
| $LRd_{it}$ | Labor input of research and development sector at year t of every province: (Number of full-time equivalents of R&D personnel / Gross number of staff and workers)×100% |
| $N_{it}$ | Gross natural resource consumption at year t of every province, including consumption of coal, petroleum, natural gas, hydro power and nuclear power |
| $N_{i,t-1}$ | Gross natural resource consumption at year t-1 of every province, first lag of $N_{it}$ |
| $K_{it}$ | Gross investment in fixed assets at year t of every province |
| $L_{it}$ | Gross number of staff and workers at year t of every province |
| $(\varphi/p)_{it}$ | Relative value of natural resource price to consumer price index at year t of every province: (Purchasing price indices of raw material, fuel and power / Consumer Price Index)×100% |
| $TFP_{it}$ | Total factor productivity at year t of every province: Calculated by Malmquist productivity index method |

**Table 1: Variable Definition**

To provide datasets for model estimations, we need to collect data of each variable. In this paper, the sample is China's mainland provinces during 1998 to 2009. Because it is difficult to obtain a complete dataset of Tibet, it is excluded from our samples. Thus the final panel dataset is 30 provinces in 12 years, and the number of observations is 360. All the data used in the paper are collected from *China Statistical Yearbook*, *China Compendium of Statistics*, *China Energy Statistical Yearbook*, *China Educational Finance Statistical Yearbook* and *China Statistical Yearbook of Science and Technology*.

## 3. ECONOMETRIC METHODS AND DATA ISSUES

### *3.1 Dynamic Panel Model Estimation: The GMM Estimator*

For panel estimation techniques, we have many models to choose from including pooled regression model, fixed effect model, random effect model, dynamic panel model, population average model and so on. But an appropriate model choice mainly depends on data structures and economic theories. For panel estimation of Eqs. (8), (9) and (20), the samples are China's 30 provinces and the time is 12 years from 1998 to 2009. We know that for "small T, large N" panels meaning few time periods and many individuals, dynamic panel data model is a good technique since it has some special advantages over other panel models.[6] Especially if the explanatory variables are endogenous, the common fixed effect and random effect models cannot derive an unbiased estimator. In this situation, we need to introduce proper instrument variables, and GMM estimation is a good method to solve problems of endogeneity and autocorrelation. In the study, we mainly take "Difference GMM" (Arellano-Bond, 1991) and "System GMM" (Arellano-Bover, 1995) as estimation methods for dynamic panel models, since they can increase estimators' efficiency and validity.

### *3.2 Calculation of Total Factor Productivity*

In the paper, we measure TFP by the Malmquist index which is an approach in consumer theory developed by Malmquist (1953) based on Shephard distance functions. In the past decade or so, beginning with the influential work of Caves, Christensen and Diewert (1982) and Nishimizu and Page (1982), the Malmquist quantity index frequently has been applied to the measurement of productivity change. Based on the Malmquist productivity index, we make calculations, list the results in Table 2, and obtain that the TFP of east China is greater than

[6] Roodman, D. makes a very detailed introduction about dynamic panel model and its applications. In: How to do xtabond2: An Introduction to "Difference" and "System" GMM in Stata. Center for Global Development, 2006, Working Paper No.103.

middle and west from 1998 to 2009. It indicates that the eastern economy grows more efficiently than the middle and west. Since most signs of TFP, TEC and TC of eastern provinces are positive, it shows that their economies grow relatively efficiently, and technologies and innovations grow positively. In contrast, for most middle and western provinces, signs of TFP, TEC and TC are negative, which indicates that although their economies grow positively during the 12 years, they have to input more factors than eastern provinces to achieve the same output level. Therefore, they grow relatively inefficiently, and technologies and innovations grow negatively.

**Table 2: Estimation Results of Total Factor Productivity Indices and Its Decomposition by Regions of China (1998-2009)**

| Region | TFP Index | TEC Index | TC Index | Region | TFP Index | TEC Index | TC Index |
|---|---|---|---|---|---|---|---|
| **Country** | 0.993 | 0.980 | 1.014 | **Jiangxi** | 0.955 | 0.956 | 0.999 |
| **Beijing** | 1.034 | 1.030 | 1.004 | **Henan** | 0.964 | 0.970 | 0.993 |
| **Tianjin** | 1.042 | 1.014 | 1.027 | **Hubei** | 0.994 | 0.995 | 0.999 |
| **Hebei** | 1.020 | 0.997 | 1.023 | **Hunan** | 0.962 | 0.966 | 0.996 |
| **Liaoning** | 0.977 | 0.972 | 1.005 | **Inner Mongolia** | 1.003 | 0.996 | 1.007 |
| **Shanghai** | 1.117 | 1.017 | 1.098 | **Guangxi** | 0.960 | 0.962 | 0.998 |
| **Jiangsu** | 1.090 | 1.010 | 1.079 | **Chongqing** | 0.986 | 0.964 | 1.023 |
| **Zhejiang** | 1.070 | 0.973 | 1.099 | **Sichuan** | 0.970 | 0.965 | 1.005 |
| **Fujian** | 0.983 | 0.971 | 1.012 | **Guizhou** | 0.952 | 0.969 | 0.982 |
| **Shandong** | 1.016 | 0.985 | 1.032 | **Yunnan** | 0.963 | 0.959 | 1.004 |
| **Guangdong** | 1.036 | 1 | 1.036 | **Shannxi** | 0.967 | 0.975 | 0.991 |
| **Hainan** | 0.981 | 0.986 | 0.995 | **Gansu** | 0.951 | 0.965 | 0.985 |
| **Shanxi** | 0.940 | 0.958 | 0.981 | **Qinghai** | 1.029 | 0.997 | 1.032 |
| **Jilin** | 0.955 | 0.960 | 0.995 | **Ningxia** | 0.990 | 0.988 | 1.002 |
| **Heilongjiang** | 0.935 | 0.957 | 0.978 | **Xinjiang** | 0.978 | 0.987 | 0.991 |
| **Anhui** | 0.967 | 0.958 | 1.009 | **Tibet** | 1.035 | 0.981 | 1.056 |

Note: The data are calculated from DEAP 2.1 by the author. The data are real values for TFP and its decomposition. TEC is technical efficiency change. TC is technological change. Growth rates for TFP, TEC and TC can be derived by (real value-1) ×100%.

### *3.3 Statistics Descriptions*

After calculation of TFP, we have all datasets prepared for GMM estimation. Descriptive statistics and the correlation matrix of variables used in the panel regression are reported in Table 3 and Table 4-6 separately. It is evident from Table 3 that China's middle and west region have more investment than east region in natural resources, since their mean values are bigger, and west region has the most resource investment of all. This also reflects the fact that natural resources are located unevenly in China. Moreover, the eastern TFP is bigger than the middle and west with a positive mean value, against negative mean values of TFP in the middle and west. It also explains why in past years China's east region grew faster and more efficiently than the middle and west. Additionally, from Table 3 standard deviations are very small and each group has little differences. This will help us conduct estimations more accurately. Finally, from correlation matrix tables, the correlation coefficients among variables are small, so multi-collinearity problems can be eliminated.

**Table 3: Descriptive Statistics**

| Variable | Obs | Mean | Std. Dev. | Minimum | Maximum |
|---|---|---|---|---|---|
| $y_{it}$ | 360 | 0.1305 | 0.0512 | 0.0135 | 0.2863 |
| $y_{i,t-1}$ | 330 | 0.1315 | 0.0508 | 0.0135 | 0.2863 |
| $KNatr_{it}$ | 360 | 0.0659 | 0.0615 | 0.0015 | 0.3255 |
| $KNatr_{it}$×East | 360 | 0.0131 | 0.0260 | 0.0000 | 0.1191 |
| $KNatr_{it}$×Middle | 360 | 0.0199 | 0.0437 | 0.0000 | 0.2136 |
| $KNatr_{it}$×West | 360 | 0.0329 | 0.0624 | 0.0000 | 0.3255 |
| $KManu_{it}$ | 360 | 0.1910 | 0.1048 | 0.0475 | 0.5113 |
| $KEdu_{it}$ | 360 | 0.0579 | 0.0380 | 0.0260 | 0.2240 |
| $KRd_{it}$ | 360 | 0.0101 | 0.0095 | 0.0008 | 0.0555 |
| $LNatr_{it}$ | 360 | 0.1015 | 0.0778 | 0.0024 | 0.3552 |
| $LManu_{it}$ | 360 | 0.2625 | 0.0884 | 0.0913 | 0.5231 |
| $LEdu_{it}$ | 360 | 0.0073 | 0.0034 | 0.0016 | 0.0173 |
| $LRd_{it}$ | 360 | 0.0103 | 0.0072 | 0.0012 | 0.0392 |
| $N_{it}$ | 360 | 8.6638 | 0.7918 | 6.0088 | 10.3865 |
| $N_{i,t-1}$ | 330 | 8.6178 | 0.7829 | 6.0088 | 10.3278 |
| $K_{it}$ | 360 | 7.4421 | 1.0487 | 4.6882 | 9.8540 |
| $L_{it}$ | 360 | 5.7342 | 0.6975 | 3.7016 | 6.9613 |
| $(\varphi/p)_{it}$ | 360 | 1.0189 | 0.0512 | 0.8590 | 1.1590 |
| $TFP_{it}$ | 360 | -0.0046 | 0.0835 | -0.2490 | 0.3810 |
| $TFP_{it}$×East | 360 | 0.0130 | 0.0518 | -0.1820 | 0.3810 |
| $TFP_{it}$×Middle | 360 | -0.0102 | 0.0411 | -0.2490 | 0.2070 |
| $TFP_{it}$×West | 360 | -0.0074 | 0.0479 | -0.2400 | 0.2830 |

Note: Detailed variable descriptions are given in Table 1.

**Table 4: Correlation Matrix of Explanatory Variables in Eq. (8)**

| | $y_{i,t-1}$ | $KNatr_{it}$ | $KManu_{it}$ | $KEdu_{it}$ | $KRd_{it}$ |
|---|---|---|---|---|---|
| $y_{i,t-1}$ | 1.0000 | | | | |
| $KNatr_{it}$ | 0.3065 | 1.0000 | | | |
| $KManu_{it}$ | 0.5937 | 0.0658 | 1.0000 | | |
| $KEdu_{it}$ | 0.3200 | 0.1296 | 0.1242 | 1.0000 | |
| $KRd_{it}$ | 0.1902 | -0.2597 | 0.0262 | 0.2195 | 1.0000 |

Note: Detailed variable descriptions are given in Table 1.

**Table 5: Correlation Matrix of Explanatory Variables in Eq. (9)**

| | $y_{i,t-1}$ | $LNatr_{it}$ | $LManu_{it}$ | $LEdu_{it}$ | $LRd_{it}$ |
|---|---|---|---|---|---|
| $y_{i,t-1}$ | 1.0000 | | | | |
| $LNatr_{it}$ | -0.0849 | 1.0000 | | | |
| $LManu_{it}$ | -0.0609 | -0.6421 | 1.0000 | | |
| $LEdu_{it}$ | 0.6504 | -0.2991 | 0.0653 | 1.0000 | |
| $LRd_{it}$ | 0.3312 | -0.5526 | 0.4460 | 0.5930 | 1.0000 |

Note: Detailed variable descriptions are given in Table 1.

**Table 6: Correlation Matrix of Explanatory Variables in Eq. (20)**

| | $N_{i,t-1}$ | $K_{it}$ | $L_{it}$ | $(\varphi/p)_{it}$ | $TFP_{it}$ |
|---|---|---|---|---|---|
| $N_{i,t-1}$ | 1.0000 | | | | |
| $K_{it}$ | 0.8744 | 1.0000 | | | |
| $L_{it}$ | 0.8237 | 0.7098 | 1.0000 | | |
| $(\varphi/p)_{it}$ | 0.0203 | -0.0088 | -0.0075 | 1.0000 | |
| $TFP_{it}$ | 0.1013 | 0.1769 | 0.0223 | 0.1378 | 1.0000 |

Note: Detailed variable descriptions are given in Table 1.

## 4. EMPIRICAL RESULTS AND IMPLICATIONS

### *4.1 Natural Resource Curse Hypothesis Test*

First of all, I test natural resource curse hypothesis for the whole of China. Panel data of its 30 provinces are used, and capital equation (8) and labor equation (9) are estimated respectively. The estimation results are shown in Table 7. Based on estimation methods of the dynamic panel model above, system GMM panel estimators in Columns (3) and (6) are robust and valid for the following reasons: (1) Hansen test of overidentifying restrictions cannot reject the null hypothesis that instrument variables are valid used in regression; (2) AR test for autocorrelation cannot reject the null hypothesis that there are no second order autocorrelations of error term in the first order difference equations, since p-value of AR (2) in both equations are greater than 5%; (3) System GMM estimator of first lagged variable is between pooled OLS estimator and fixed effect estimator. Also, we add some control variables into the estimation of Eqs. (8) and (9). During 1998 to 2009, China's government reformed and implemented some important policies on the administration of natural resources, and so to control for the impact of these events and economic fluctuations (like international financial crisis), four different year dummies are included in Eqs. (8) and (9) separately. Therefore, based on Columns (3) and (6), the econometric results are analyzed as follows.

At first, the first lagged term's estimators, in both capital and labor equation, are positive at 1% significance level, and satisfy stationary condition, because their absolute values are between 0 and 1. This indicates that GDP growth has a significant lagged effect, meaning last year's GDP growth has an impact on GDP growth this year. So provinces with good economic foundations tend to grow faster than long-term underdeveloped provinces, in accordance with our expectations.

Second, natural resource estimators do not support the natural resource curse hypothesis. This finding is also in agreement with results of previous research using panel data (Lederman and Maloney, 2002). The estimators in both capital and labor equations are significantly positive, so in China the natural resource sectors' expansion positively promotes economic growth, against the pessimistic opinions of the resource curse hypothesis. If the ratio of investment in resource sectors increases 1%, GDP growth rate will rise around 0.16%; if the ratio of staff and workers in resource sectors increases 1%, GDP growth rate will rise around 0.14%. This is the same conclusion as in Figure 1, that from 1998 to 2009, investment and employment in China's natural resource sectors generally increased.

Additionally, other variables' estimators, including manufacturing, education and research and development, generally accord with our expectations. Increasing inputs of capital and labor in these sectors can significantly promote economic growth. Especially for $LEdu_{it}$, the estimator is as large as 8.32, showing great contributions of education to economic development in China. If the ratio of full-time teachers of institutions of higher education to the gross number of staff and workers rises, there will be more talent and academic achievements. These are valuable factors for modern economic growth relying on technological progress. Moreover, the negative sign of $LRd_{it}$ has connection with frequent job-hopping in China's R&D personnel these years leading to a great "brain drain". These years, job-hopping becomes frequent in China's research and development sectors especially for the big institutions and high-tech enterprises. They have to afford more costs to develop new researchers and skilled personnel, which leads to a great "brain drain". Furthermore, the frequent flow of researchers slows down the development process and technological progress, which decreases the spillover effect of the technology. These will exert an adverse negative impact on economic growth. More capital input is necessary to remedy the defect by absorbing and retaining skilled personnel as much as possible.

Finally, from 2004 China began to control the over-exploitation of natural resources, especially the usage of land. The government designed evaluation systems in detail to save energy and protect farmland. In 2008, the worldwide financial crisis also affected China's economy, especially decreasing the exports significantly. Both policy and events had a negative impact on China's economic growth.

**Table 7: Estimation Results of Capital Equation and Labor Equation for China (1998-2009)**

| Capital Equation | | | | Labor Equation | | | |
|---|---|---|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | | **(4)** | **(5)** | **(6)** |
| **Dependent Variable** | $y_{it}$ | | | **Dependent Variable** | $y_{it}$ | | |
| **Estimation Method** | Pooled OLS | FE | SYS-GMM | **Estimation Method** | Pooled OLS | FE | SYS-GMM |
| $\mathbf{y_{i,t-1}}$ | 0.5858*** (10.36) | 0.3207*** (4.70) | 0.4118*** (3.65) | $\mathbf{y_{i,t-1}}$ | 0.4771*** (8.94) | 0.2406*** (3.46) | 0.2749*** (2.79) |
| $\mathbf{KNatr_{it}}$ | 0.0650* (1.92) | 0.4454*** (4.95) | 0.1642** (2.38) | $\mathbf{LNatr_{it}}$ | -0.0296 (-0.80) | 0.0780 (0.45) | 0.1397* (1.75) |
| $\mathbf{KManu_{it}}$ | 0.0727*** (3.12) | 0.1183*** (3.52) | 0.1370*** (2.98) | $\mathbf{LManu_{it}}$ | -0.0071 (-0.23) | -0.0277 (-0.29) | 0.1108† (1.48) |
| $\mathbf{KEdu_{it}}$ | 0.0662 (0.44) | -0.1530 (-0.71) | 0.5474† (1.57) | $\mathbf{LEdu_{it}}$ | 3.5171*** (3.55) | 10.048*** (5.72) | 8.3180*** (3.98) |
| $\mathbf{KRd_{it}}$ | 0.3903* (1.75) | 1.2471† (1.28) | 0.6019* (1.86) | $\mathbf{LRd_{it}}$ | -0.8913** (-2.18) | -3.2717*** (-4.09) | -2.1018** (-1.86) |
| **year2004** | 0.0364*** (5.45) | 0.0332*** (5.08) | 0.0333*** (7.69) | **year2004** | -0.0195*** (-2.67) | -0.0161** (-2.21) | -0.0171*** (-4.48) |
| **year2005** | -0.0037 (-0.51) | 0.0011 (0.15) | -0.0006 (-0.05) | **year2005** | -0.0138* (-1.91) | -0.0155** (-2.19) | -0.0153*** (-4.20) |
| **year2008** | 0.0088 (1.20) | 0.0089 (1.22) | 0.0074 (1.03) | **year2008** | -0.0085 (-1.17) | -0.0103† (-1.44) | -0.0096** (-1.96) |
| **year2009** | -0.0637*** (-3.07) | -0.0360† (-1.29) | -0.1240*** (-2.84) | **year2009** | 0.0275*** (3.77) | 0.0217*** (2.94) | 0.0222*** (4.20) |
| **AR(1)** | - | - | 0.000 | **AR(1)** | - | - | 0.000 |
| **AR(2)** | - | - | 0.819 | **AR(2)** | - | - | 0.174 |
| **Hansen Test** | - | - | 1.000 | **Hansen Test** | - | - | 0.999 |
| **Observation Number** | 330 | 330 | 330 | **Observation Number** | 330 | 330 | 330 |
| **Instrument Number** | - | - | 93 | **Instrument Number** | - | - | 65 |

Note: (1) Superscripts ***, **, * and † are statistically significant at 1%, 5%, 10% and 20% levels respectively; (2) t statistics for coefficients are in parentheses; (3) In capital equation, $gY_{i,t-1}$, $KNatr_{it}$, $KManu_{it}$, $KEdu_{it}$ and $KRd_{it}$ are taken as endogenous variables, all others exogenous variables; (4) In labor equation, $gY_{i,t-1}$, $LNatr_{it}$ and $LRd_{it}$ are endogenous variables, all others exogenous variables; (5) To improve instrument variables' validity, third lags and second lags of endogenous variables are used as instruments for capital equation and labor equation respectively.

It is necessary for dynamic panel models that the number of time periods should be smaller than the number of cross sections. Therefore, I do not estimate Eq. (8) using different regions' datasets, but add region dummy variables into the equation to estimate the capital equation again, to derive the impact of three region's natural resources on growth[7]. The estimation results are shown in Table 8. Similarly, difference GMM panel estimators in Column (9) are robust and valid[8]. Also, in the process of estimation, we add four year dummy variables as above. Based on this, firstly, first order lag's estimator is stationary ($|\eta| < 1$) and positive, which shows that GDP growth has a significant lagged effect.

Secondly, natural resource investment in the three regions has different impacts on growth. There exists a resource curse in the east region, and if resource sectors' investment ratio rises by 1%, the GDP growth rate will drop around 0.56%. In contrast, the middle and west regions are not troubled by the resource curse effect, although they have great natural resources. If investment ratios rise by 1% in the two regions, their GDP growth will speed up by approximately 0.48% and 0.64% separately. Therefore, the relation between natural resources and economic growth has great disparities even in integral regions of a homogeneous country. We cannot simply define a country or area as suffering resource curse without sufficient evidence.

Other variables estimators tally with expectations on the whole. Manufacturing and R&D investment significantly contribute to GDP growth. But here the estimator of education investment is negative but not significant, against the result of Column (3) in the capital equation. Because the variable $KNatr_{it}$ is divided into three cross-term dummy variables, the correlation coefficients become bigger, and collinearity problem may lead to bigger variance of estimator and also insignificant estimator.

[7] Andersen and Nielsen (2007) also adopt this method.

[8] The reason is: (1) Hansen test of overidentifying restrictions cannot reject the null hypothesis that instrument variables are valid used in regression; (2) AR test for autocorrelation cannot reject the null hypothesis that there are no second order autocorrelations of error term in the first order difference equations, since p-value of AR (2) are greater than 5%; (3) difference GMM estimator of first lagged variable is between pooled OLS estimator and fixed effect estimator.

**Table 8: Estimation Results of Capital Equation: Test by China's Integral Regions (1998-2009)**

| | (7) | (8) | (9) |
|---|---|---|---|
| **Dependent Variable** | $y_{it}$ | | |
| **Estimation Method** | Pooled OLS | FE | DIF-GMM |
| $y_{i,t-1}$ | 0.5479*** (9.46) | 0.1750*** (3.99) | 0.1808* (1.91) |
| **$KNatr_{it}$×East** | -0.0506 (-0.64) | -0.2839 (-1.44) | -0.5586* (-1.89) |
| **$KNatr_{it}$×Middle** | -0.0058 (-0.13) | 0.3773*** (2.69) | 0.4838** (2.31) |
| **$KNatr_{it}$×West** | 0.1094*** (2.89) | 0.5567*** (5.62) | 0.6375*** (4.58) |
| **$KManu_{it}$** | 0.0947*** (3.85) | 0.1533*** (4.40) | 0.1294** (1.98) |
| **$KEdu_{it}$** | -0.0667 (-0.42) | -0.1608 (-0.76) | -0.3262 (-1.31) |
| **$KRd_{it}$** | 0.5225** (2.30) | 1.2981† (1.35) | 3.2801** (2.51) |
| **year2004** | 0.0365*** (5.51) | 0.0341*** (5.30) | 0.0360*** (7.96) |
| **year2005** | -0.0025 (-0.34) | 0.0026 (0.37) | 0.0068 (0.67) |
| **year2008** | 0.0093† (1.27) | 0.0083 (1.16) | 0.0105* (1.73) |
| **year2009** | -0.0467** (-2.15) | -0.0355† (-1.29) | -0.0159 (-0.49) |
| **AR(1)** | - | - | 0.0001 |
| **AR(2)** | - | - | 0.7024 |
| **Sargan Test** | - | - | 1.0000 |
| **Observation Number** | 330 | 330 | 300 |
| **Instrument Number** | - | - | 176 |

Note: (1) Superscripts ***, **, * and † are statistically significant at 1%, 5%, 10% and 20% levels respectively; (2) t statistics (Columns 7 and 8) and z statistics (Column 9) for coefficients are in parentheses; (3) $KManu_{it}$ and $KEdu_{it}$ are taken as endogenous variables; (4) If a province belongs to one of the three areas, the dummy variable for this area is equal to 1, or else 0; (5) To improve instrument variables' validity, first lags of endogenous variables are used as instruments for differenced equation.

### 4.2 Natural Resource Consumption Equation Test: An Explanation of Resource Curse Hypothesis

In this part, we estimate the natural resource equation (20) mainly in order to derive the impact of TFP on natural resource consumption. In China, the main consumption of natural resources contain coal, petroleum, natural gas, hydro power and nuclear power. Because they are measured in different methods, here we unify units and measure them using ton of standard coal equivalent (called tce for short), given by *China Energy Statistical Yearbook*.

Under the same procedures as above, firstly, I test the natural resource consumption equation for the whole of China. Eq. (20) is estimated using panel data of China's 30 provinces and estimation results are shown in Table 9. In the same way, system GMM panel estimators in Column (3) are robust and valid[9]. From this point, at first, the first lagged term's estimator is positive at 1% significance level and satisfies stationary condition ($|\phi| < 1$). This indicates that natural resource consumption has a significant lagged effect, showing that last year's resource consumption affects this year's consumption.

Second, TFP has a negative impact on resource consumption at 5% significance level, meaning a TFP rise reduces resource consumption remarkably. If TFP increases by 1%, natural resource consumption will decrease by approximately 0.17%. Since technology contributes to TFP, this means technological progress can significantly reduce resource demand. With the development of modern technology and government encouraging polices of developing new energies, advanced designs, techniques and methods are created and applied in natural resource sectors. These can reduce resource waste and pollution, and also produce new resource-saving goods. Traditional resources and crafts are updated by new energy and equipment. As a result, natural resource consumption declines. From the text above, since there exists no resource curse in middle and west China, we can infer that, due to the negative effect of TFP on resource consumption, the country can partly reduce reliance on resource consumption, and avoid falling into the natural resource curse. To check the robustness of the conclusion, we will investigate it for integral regions in the following text.

Finally, other variables' estimators are in accordance with theories and expectations. Capital and labor input can promote economic growth as the classical Solow growth model tells us. Here, $L_{it}$ is positive only at 20% significance level, perhaps due to high collinearity shown in Table 7. Also, the relative value of natural resource price to CPI is significantly positive. This shows disparities between resource price and consumer price index does not hamper consumer

[9] The reason is same to the explanations of Footnote 8 for Table 8.

demand for resources. Because natural resources, such as gasoline and natural gas, are mostly inelastic goods and daily necessities of consumers, no matter how price changes every day, basically demand is not affected much.

**Table 9: Estimation Results of Natural Resource Equation for China (1998-2009)**

| | (1) | (2) | (3) |
|---|---|---|---|
| **Dependent Variable** | $N_{it}$ | | |
| **Estimation Method** | Pooled OLS | FE | SYS-GMM |
| $N_{i,t-1}$ | $0.9609^{***}$ (69.06) | $0.7943^{***}$ (23.44) | $0.8588^{***}$ (17.38) |
| $K_{it}$ | $0.0413^{***}$ (4.77) | $0.1135^{***}$ (6.80) | $0.0909^{***}$ (3.20) |
| $L_{it}$ | $-0.0158^{\dagger}$ (-1.46) | -0.0490 (-0.99) | $0.0269^{\dagger}$ (1.29) |
| $(\varphi/p)_{it}$ | $0.4861^{***}$ (5.71) | $0.4948^{***}$ (5.77) | $0.6723^{***}$ (9.09) |
| $TFP_{it}$ | $-0.1290^{**}$ (-2.38) | $-0.1764^{***}$ (-3.04) | $-0.1726^{**}$ (-2.72) |
| **AR(1)** | - | - | 0.001 |
| **AR(2)** | - | - | 0.185 |
| **Hansen Test** | - | - | 0.994 |
| **Observation Number** | 330 | 330 | 330 |
| **Instrument Number** | - | - | 55 |

Note: (1) Superscripts $^{***}$, $^{**}$, $^{*}$ and $^{\dagger}$ are statistically significant at 1%, 5%, 10% and 20% levels respectively; (2) t statistics for coefficients are in parentheses; (3) $N_{i,t-1}$, $K_{it}$ and $(\varphi/p)_{it}$ are taken as endogenous variables, all others are exogenous variables; (4) To improve instrument variables' validity, third lags of endogenous variables are used as instruments for the natural resource consumption equation.

Furthermore, natural resource equation (20) is estimated for China's integral regions. With the same method as above, I do not estimate Eq. (20) using different regions' datasets, but add region dummy variables into the equation to estimate the natural resource equation again to derive the individual effect of the three region's TFP on resource consumption. The estimation results are listed in Table 10. In the same way, system GMM panel estimators in Column (6) are robust and valid[10]. Based on this, firstly, the first lagged term's estimator is still positive at 1% significance level and stationary ( $|\phi| < 1$ ), which indicates resource consumption has a noticeable lagged effect.

Secondly, the three regions' TFP are all negatively correlated with natural resource consumption, showing that the technological progress of China's interior regions all lead to resource saving. If TFP growth rate increases by 1%, natural resource consumption will reduce by 0.186%, 0.192% and 0.258% for east, middle and west respectively. Therefore, consumption in the resource-abundant middle and west regions decline more than that in the east region. Table 10 shows that the east region falls into the resource curse with no resource curse effect in middle and west regions. From this point, it indicates that owing to the stronger negative effect of TFP on resource consumption, middle and west regions can get rid of constraints of negative impact of abundant resources. For the east, since the effect of TFP on resources is weaker, economic growth suffers negative impact brought by natural resources. This can also account for the reason why the east region's economic growth rate decreases faster than the middle and west since 2007, comparing their performances in Figure 2.

Lastly, other variables' estimators coincide with our expectations except for labor input. They have similar explanations to Table 9. $K_{it}$ and $(\varphi/p)_{it}$ can account for natural resource consumption. The estimator of labor input is negative, but not significant against results of Column (3) in Table 9. Since the variable $TFP_{it}$ is divided into three cross-term dummy variables, correlation coefficients become bigger, and collinearity of variable $L_{it}$ leads to bigger variance, and also small t-value and insignificant estimator.

[10] The reason is same to the explanations of Footnote 8 for Table 8.

**Table 10: Estimation Results of Natural Resource Equation: Test by China's Integral Regions (1998-2009)**

| | **(4)** | **(5)** | **(6)** |
|---|---|---|---|
| **Dependent Variable** | $N_{it}$ | | |
| **Estimation Method** | Pooled OLS | FE | SYS-GMM |
| $\mathbf{N_{i,t-1}}$ | $0.9614^{***}$ (68.67) | $0.7907^{***}$ (22.89) | $0.9606^{***}$ (37.54) |
| $\mathbf{K_{it}}$ | $0.0411^{***}$ (4.74) | $0.1142^{***}$ (6.77) | $0.0418^{***}$ (2.96) |
| $\mathbf{L_{it}}$ | $-0.0155^{\dagger}$ (-1.42) | -0.0570 (-1.13) | -0.0159 (-1.42) |
| $\mathbf{(\varphi/p)_{it}}$ | $0.4904^{***}$ (5.73) | $0.4934^{***}$ (5.75) | $0.6261^{***}$ (7.13) |
| $\mathbf{TFP_{it}\times East}$ | $-0.1594^{*}$ (-1.79) | $-0.2750^{***}$ (-2.64) | $-0.1858^{***}$ (-3.70) |
| $\mathbf{TFP_{it}\times Middle}$ | -0.0591 (-0.56) | $-0.1380^{\dagger}$ (-1.27) | $-0.1915^{**}$ (-2.35) |
| $\mathbf{TFP_{it}\times West}$ | $-0.1501^{*}$ (-1.64) | $-0.1257^{\dagger}$ (-1.36) | $-0.2576^{*}$ (-1.97) |
| **AR(1)** | - | - | 0.001 |
| **AR(2)** | - | - | 0.164 |
| **Hansen Test** | - | - | 1.000 |
| **Observation Number** | 330 | 330 | 330 |
| **Instrument Number** | - | - | 101 |

Note: (1) Superscripts $^{***}$, $^{**}$, $^{*}$ and $^{\dagger}$ are statistically significant at 1%, 5%, 10% and 20% levels respectively; (2) t statistics for coefficients are in parentheses; (3) $N_{i,t-1}$, $K_{it}$, $(\varphi/p)_{it}$, $TFP_{it}\times$Middle, and $TFP_{it}\times$West are taken as endogenous variables, all others are exogenous variables; (4) If a province belongs to one of the three areas, the dummy variable for this area is equal to 1, otherwise 0; (5) To improve instrument variables' validity, second lags of endogenous variables are used as instruments for the natural resource consumption equation.

## 5. CONCLUSION

This paper makes use of panel datasets of China's 30 provinces from 1998 to 2009 and GMM method of dynamic panel model, to calculate Malmquist index of TFP, test the natural resource curse hypothesis, and estimate natural resource consumption equation. The TFP index shows that China's high economic growth is less efficient and interior provinces have large disparities. Moreover, the estimation results of capital equation and labor equation show that, for the whole country, natural resource sector's investment and employment promote GDP growth, namely no natural resource curse exists in China overall. If the ratio of investment in natural resource sectors increases by 1%, GDP growth rate rises by around 0.16%; if the ratio of staff and workers in resource sectors increases by 1%, GDP growth rate rises by around 0.14%. In addition, estimation results of natural resource consumption equation indicate that TFP has a significantly negative effect on natural resource consumption. If TFP increases by 1%, natural resource consumption falls by approximately 0.17%. Since TFP has close connection with technological progress, new techniques and resource-saving products are adopted more and more, which leads to decline of resource consumption. Based on this, the paper infers that due to the negative effect of TFP on resource consumption, the country can partly reduce reliance on resource consumption, and avoid falling into the natural resource curse.

After that, we grouped China's provinces into three regions, tested natural resource curse hypothesis, and estimated natural resource consumption equation for them. The estimation results of capital equation by integral regions indicate that the east region is restrained by resource curse, and if investment ratio rises by 1%, the GDP growth rate drops by around 0.56%. Conversely, the middle and west region are not troubled by resource curse effect, although they have abundant natural resources. If capital input ratios rise by 1% in the two regions, their GDP growth speeds up by approximately 0.48% and 0.64% separately. This can be explained from estimation results of the resource consumption equation that the three regions' TFP are all negatively correlated with resource consumption. Technological progress of China's interior regions contributes to resource saving. If the TFP growth rate increases by 1%, resource consumption decreases by 0.186%, 0.192% and 0.258% for east, middle and west respectively. From this point, the paper infers that, owing to the stronger negative effect of TFP on resource consumption, the middle and west regions can get rid of the negative impact of abundant resources. For the east region, since the impact of TFP on resource consumption is weaker, economic growth suffers a negative effect brought by natural resources. Since 2007, the east region's growth rate has shown a sharper decline than the middle and west. Based on the literature and econometric findings, this paper reckons that if TFP rise can reduce natural resource consumption sufficiently, the country or region can eliminate natural resource curse effect; or else, it has to suffer negative impact of excessive resource reliance.

The paper has several policy implications. Firstly, natural resource is a two-edged sword. On one hand, it is a basic input of economic growth; on the other hand, excessive reliance on natural resources will lead to resource curse. Although there is no resource curse in China on the whole, the east region’s economy begins to be restrained by resources. Therefore, to prevent the situation from deteriorating, it is necessary to reduce resource waste and save resources as much as possible. One effective measure is to promote technological progress of natural resource sectors, and encourage research and development of new energies and materials, which can improve the productivity of resource utilization. The other measure is to adjust natural resource taxation in order to reduce consumption of resources and improve consumption structures. The final target is to transform China’s economic growth into a style of resource saving. Furthermore, based on the findings, there are large disparities of economic growth productivity and resource consumption between east, middle and west. To avoid further resource curse traps, China’s government must attach importance to lowering the increasing regional disparities. According to econometric results, TFP plays an important role in reducing resource demand. Therefore, policies should favor activities of invention and innovation, especially for the less developed areas, in order to improve the quality of economic growth instead of only the quantity.

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