Energy Consumption Growth and Industrial Network in China

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Abstract

Energy demand forecast is the precondition for analyzing future pattern of energy demand and supply. Methods based on trend extrapolation emphasized too much on the influence of economic growth on energy consumption. In this paper we are trying to make up the inadequacies of the trend extrapolation, and suggest to understand the energy consumption in China more by the economic structure, represented by the industrial input-output network, than by the size of GDP. Our results show that there is a close relationship between the eigenvector centrality of the high energy intensity industries and the energy income elasticity, and energy consumption estimation without the high energy consuming industries, especially electricity, cement and steel, would lead to omitted variable bias. We found that "Rapid economic structure scenario" perfectly predict the energy demand in China from 2014 to 2016. Therefore, in order to achieve sustainable energy development, it is crucial to readjust industrial structure, especially regulating the development of high energy consuming industries.

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1 Introduction

Over the past three decades, the energy consumption in China has been escalating and China has overtaken the US and become the biggest energy consumer. The aggregate energy consumption increased from 570 million tce.(ton of standard coal equivalent) in 1978to 4.26 billion in 2014, with an average growth rate of 5.8%. The growth rate of energy consumption has not been stable over time, however. As it shows in Figure 1, the growth rate of energy consumption were between -1.4% and 16.8%, with a fluctuation range of close to 20%. The uncertainties involved in energy consumption pose challenges in forecasting energy demand, which is the precondition for analyzing future trend of energy demand and supply.[1]

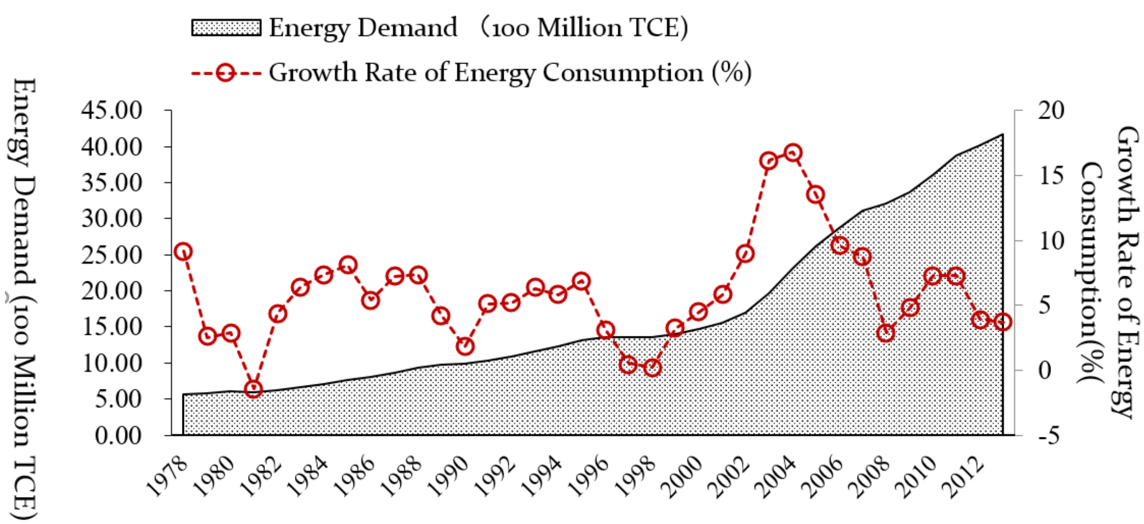


Figure 1: Energy consumption and growth rate in China (1978-2013)

[1]Based on definition of State Statistic Bureau, energy consumption refers to the energy consumed by all industries and residents in a given period. It is an aggregate indicator used to show the levels, composition and growth rate of energy consumption. Energy demand refers to the quantity of energy products households and firms are willing to and capable of purchase. The former is a statistical term, while the latter is an economic term. Energy consumption tends to mean energy demand already taking place. We make no distinction of these two terms in this paper.

The importance of energy consumption forecast can never be overestimated. For one thing, good judgment on energy trend can help to improve energy investment and reduce risks. Due to the long time horizon in developing energy projects and huge money involved, investments on energy projects usually involve more uncertainties. Sound judgment on energy trend will provide precious information for investors, and reducing risks resulted from information asymmetry. For the other, precise forecast can provide foundations based on which future environmental and energy policies can be made and therefore, adjustments and transition of energy structure can be encouraged (Bhattacharyya & Timilsina, 2009; Lin al., 2010). Fast growth in energy consumption also brings about sharp increase of green house gases and other polluting gases, which leads to certain ecological problems. What makes things worse is that energy consumption in China is centered on coal. Therefore, it is necessary to make sound forecast for future trend of energy demand, helping the government in setting appropriate energy consumption target and structural readjustment policies accordingly. In addition, the energy forecast is closely related to economic development plan and orderly growth of social economy in China(Kazemi et al., 2012). With a lower forecasting level, energy industries would reduce energy supply, and the shortfall in energy supply would make those energy intensive industries unsustainable; on the other hand, with an overestimated forecast, energy industries would increase energy supply, and the economic downturn would cause losses in over-produced energy industries, which in turn preclude economic development. Therefore, in order to make efficient and effective energy investments, promoting readjustment of energy structure and guaranteeing smooth economic growth, it is crucial to make accurate judgment of energy trend, which in turn calls for the precise understanding of the relationship between GDP and energy consumption. Based on the previous literature, changes in income levels are usually taken as the most significant factors in shaping energy demand. Nonetheless, stylized facts in energy demand transition in China as well as in other countries show that along with the ever increasing economic growth, the link between GDP and energy demand would be severed.

Low prediction Power of Existing Literature

Many previous studies have tried to predict the future energy demand in China using extrapolating methods such as coefficients for energy elasticity, sector analysis and time series and so on (Figure 2). Earlier studies predicts that energy consumption would reach 2-3 billion TCEs in 2020 (Dong, 2000; EIA, 2000; IEA, 2000; LU et al., 2003). It turned out that by 2010 energy consumption already got to 3 billion TCEs. All previous studies exhibit higher than 20% prediction errors. In recent years think tanks from China and other countries readjust their energy consumption forecast to be around 5 billion TCEs in 2020 (BP, 2013; EIA, 2013; IEA, 2014; IEEJ, 2014). These extrapolation methods implicitly assume that economy and social environment would change according to certain rules and forecasts are being made based on changes in GDP. However, the assumptions are inconsistent with current situation in China. Slowing down of economic growth, adjustment of economic structure, deepening of economic reform and changes in environment and energy policies would possibly lead to slow down of energy demand over a long period of time.

IO Structure and Energy Demand

Some literature also raises the idea that energy demand in China has been delinked from economic growth. Based on a long-run electricity demand model, Lin (2003)finds that the high growth in GDP has not been accompanied by higher demand in electricity. Structure changes and efficiency improvement are also important factors influencing electricity demand. Line and Ouyang (2014) investigate the changes in energy demand and economic growth and validate the long-run and short-run energy Kuznets Curve. Zhao and Fan (2007) apply nonlinear STR model and find that in China economic growth affect energy consumption nonlinearly and the effects differ by stages of development. Lin and Su (2010) also stress that the changes in industrial structure leads to the inconsistency of economic growth and electricity consumption in China. Sun and

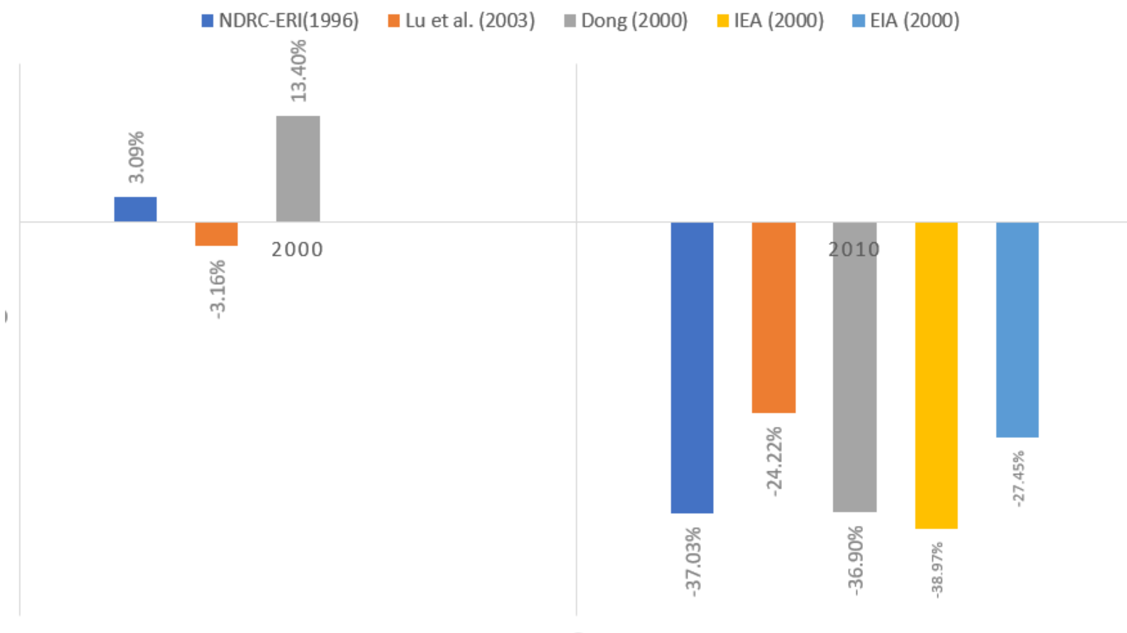
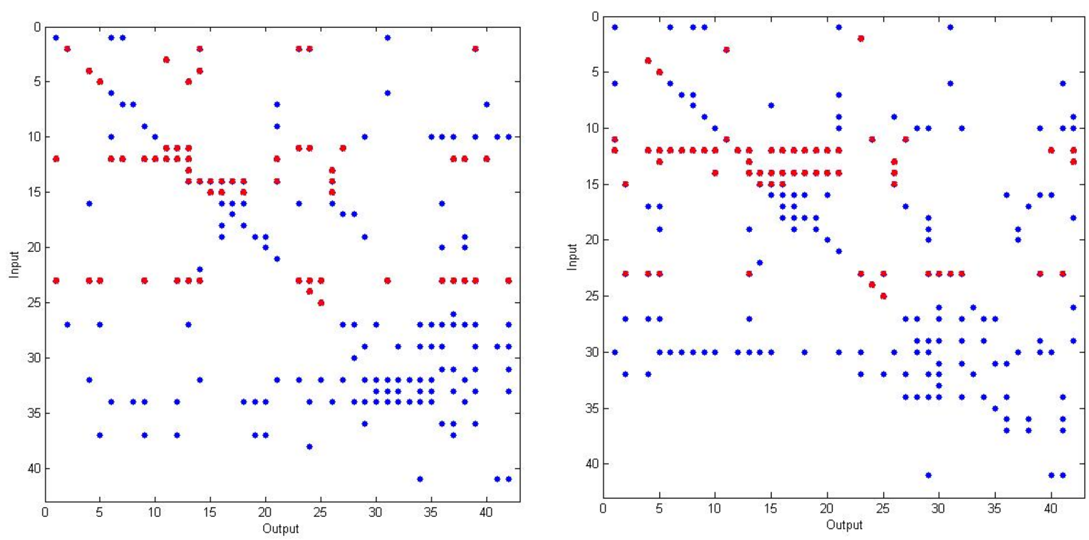


Figure 2: Prediction compared to real energy consumption in 2000 and 2010

Cheng (2011) introduced industrialization and urbanization into their analysis and find that energy demand and economic growth is showing an inverted U shape, and other than economic growth, industrial structure is an important factor in shaping energy demand.

In this paper, we address the question how differences in economic structure across countries - as captured by IO linkages between sectors - affect cross-region differences in aggregate energy consumption per capita. To this end, we combine data from the China Input-Output Database, we investigate how the IO structure interacts with the economic development level to determine aggregate per capita energy consumption. To begin with, we document that in all provinces there is a relatively small set of sectors which have very large IO multipliers and whose performance thus crucially affects aggregate outcomes. Moreover, despite this regularity, we also find that there do exist substantial differences in the network characteristics of IO linkages between different regions. In particular, if we group all industries into high energy intensity industries and low energy intensity industries, we can see that for some regions, there is a cluster of high energy intensity industries possess high-multiplier and high centrality in the industry network, while other regions have a more dense input-output network. To visualize these differences, in Figure 3 we plot a graphical representation of the IO matrices of two regions: Heilongjiang (a typical heavy industry region) and Beijing (one of the most developed region in China). The columns of the IO matrix are the producing sectors, while the rows are the sectors whose output is used as an input. Thus, a dot in the matrix indicates that the column sector uses some of the row sectors output as an input and a blank space indicates that there is no significant connection between the two sectors.[2]



(a) Beijing (Year = 2002) (b) Heilongjiang (Year = 2002)

Figure 3: IO-matrices by province

By comparing the matrices it is apparent that in Heilongjiang there are only four sectors

[2]The figure plots IO coefficients defined as cents of industry j output (row j) used per dollar of output of industry i (column i). To make the figure more readable, we only plot linkages with at least 5 cents per dollar of output.

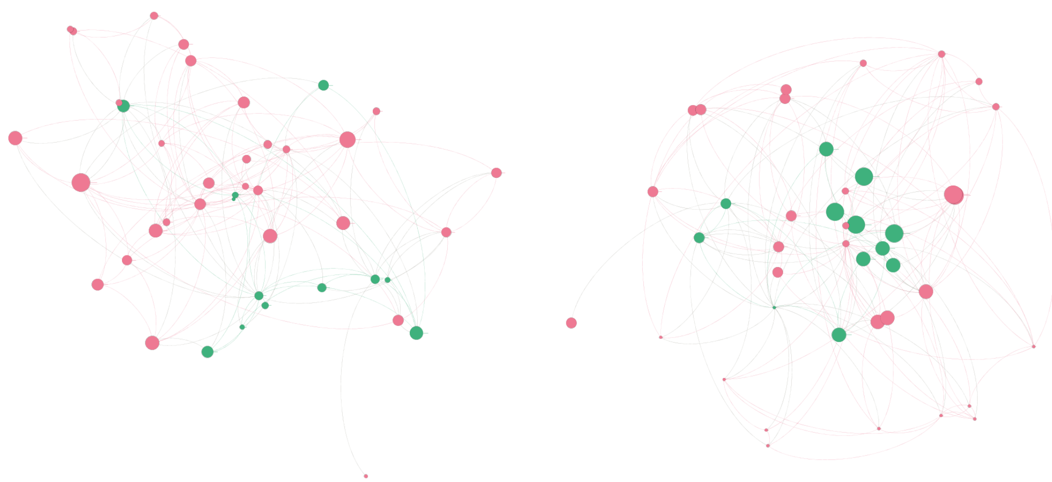
which supply to most other sectors.These are Chemistry (row 12), Metal Production (row 15), Electricity (row 23), and Wholesale and Retail Trade (row 30). These sectors are the high-IO-multiplier sectors, where a change in sectoral output has a relatively large effect on aggregate output and three of those four are high energy intensity industries. Most other sectors are quite isolated in Heilongjiang, in the sense that their output is not used as an input by many sectors. In contrast, Beijing has a much larger number of sectors that supply to many others: Chemicals (row 12), Metal Production (row 14), Electricity(row 23), Transport (row 27), Wholesale and Retail Trade (row 30), Real Estate (row 33), Business Services (row 34), Travel Industry (row 35), General Technologies (row 37) among others. The IO structure is much denser so that outputs of many more sectors have a significant impact on aggregate output.

Since the Input-output matrix cannot display the relative connections among industries, we can also visualize the structural differences using using tools from network theory as in Figure 4. In Figure 4, each vertex represents one industry and each edge represents an input-output flow between industries. For clearer distinction, we use green for high energy intensity industries and red for the others, and the sizes of vertices represent the corresponding eigenvalue centralities which are defined as:

Let $A = (a_{i,j})$ be the matrix of a graph with weight (in our case, the "weight" is the IO-multiplier). The eigenvector centrality x_i of node i is given by:

$$x_i = \frac{1}{\lambda} \sum_{k \in N(i)} a_{k,i} \, x_k$$

where $\lambda \neq 0$ is a constant. The eigenvector centrality is an important statistical property of a network. It is an indicator of its centrality or importance in the network. From Figure 2 we can see that compared with Heilongjiang, Beijing has a lot more industries with relatively high eigenvector centralities and the low energy intensity industries possess the central positions in the industrial network instead of the other way around.



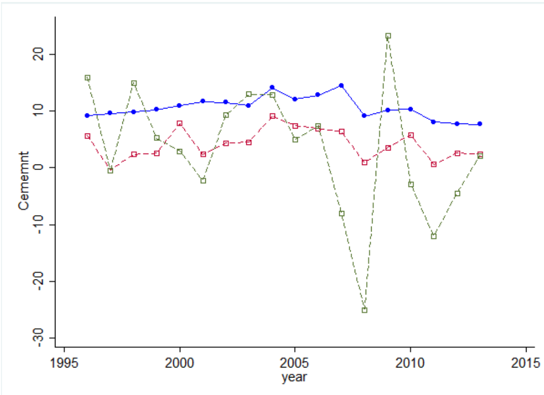
(a) Beijing (Year = 2002)　　(b) Heilongjiang (Year = 2002)

Figure 4: Eigenvector centralities by provinces

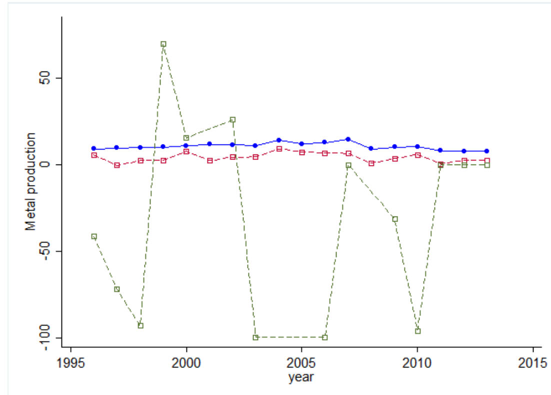
Now we turn to the relationships among high energy consuming industries, economic growth and energy consumption in time series (Figure 5), it's clear that in heavy industry centered economy like Heilongjiang, the energy consumption shows similar trend as production of cement and metal, as the energy consumption and production of cement and crude steel exhibit the same pattern in peaks and valleys. While in service industry centered economy like Beijing, GDP exhibits quite decent prediction power on energy demand.

All those trends suggest that in order to find out the reason for energy consumption growth, special focus should be put onto the growth of high energy consuming industries (WU & Zhang, 2011). For that reason, we put GDP, economic structure and energy consumption in the same framework and try to identify the important channels through which energy consumption grows.

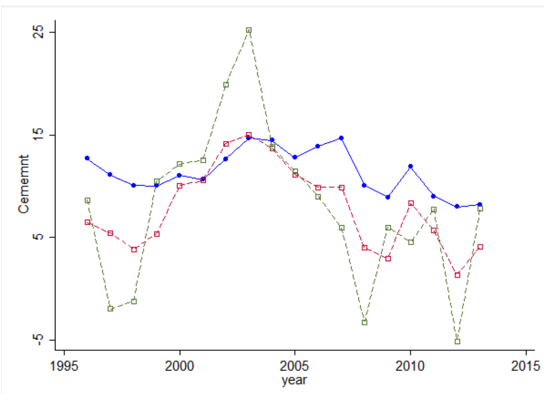
The outline of the paper is as follows. In the following section, we lay out our theoretical logic and give out a regression equation for energy consumption in terms of the IO



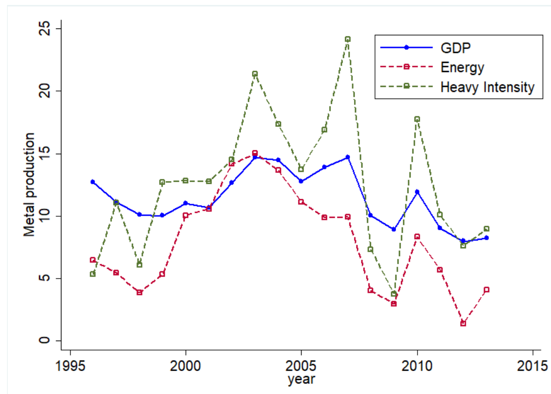
(a) Beijing - Cement production



(b) Beijing - Metal production



(c) Heilongjiang - Cement production



(d) Heilongjiang - Metal production

Figure 5: GDP, Energy demand and High energy intensity industries

network characteristics. The next section describes our dataset and present some descriptive statistics. Subsequently, we turn to the estimation and model fit and finally, we make some predictions with different scenario setups. The final section presents our conclusion.

2 Theoretical framework and Regression Equation

In this section we present our theoretical framework, which will be used in the remainder of our analysis. Consider a static multi-sector economy. n competitive sectors each produce a distinct good that can be used either for final consumption or as an input for production. The technology of sector $i \in [1, n]$ is Cobb-Douglas with constant returns to scale. Namely, the output of sector i, denoted by q_i,is

$$q_i = \Delta_i (k_i^{\alpha_i} l_i^{1-\alpha_i})^{1-\gamma_i} d_{1i}^{\gamma_{1i}} \dots d_{ni}^{\gamma_{ni}}$$

where Δ_i is the exogenous total factor productivity of sector i, k_i and l_i are the quantities of capital and labor used by sector i and d_{ji} is the quantity of good j used in production of good i (intermediate goods produced by sector j).14 The exponent $\gamma_{ji} \in [0, 1)$ represents the share of good j in the production technology of firms in sector i, and $\gamma_i = \sum_{j=1}^{n} \gamma_{ji} \in (0, 1)$ is the total share of intermediate goods in gross output of sector i. Parameters $\alpha, 1\alpha \in (0, 1)$ are shares of capital and labor in the remainder of the inputs (value added)

Given the Cobb-Douglas technology and competitive factor markets, γ_{ji}s also correspond to the entries of the IO matrix, measuring the value of spending on input j per dollar of production of good i. We denote this IO matrix by Γ. Then the entries of the jth row of matrix Γ represent the values of spending on a given input j per dollar of production of each sector in the economy. On the other hand, the elements of the ith column of matrix are the values of spending on inputs from each sector in the economy per dollar of production of a given good i. Output of sector i can be used either for final consumption, y_i, or as an intermediate good:

$$y_i + \sum_{j=1}^{n} d_{ij} = q_i, i \in [1, n]$$

The important observation is that the vector of multipliers is closely related to the eigenvector centrality corresponding to the intersectoral network of the economy. This means that sectors that are more "central" in the network of intersectoral trade have larger multipliers and hence, play a more important role in determining aggregate output. Thus, productivity changes in a sector that supplies its output to a larger number of direct and indirect customers should have a more significant impact on the overall economy.

In our case, when the high energy intensity industries take the central role in the industry network, then their energy intensity would be dominant in the economy and have higher prediction power.

Our theory is consistent with the energy Kuznets Curve (Medlock III & Soligo, 2001; Sun, 1999), as per capita GDP goes up, per capita energy demand would rise, and then start to decrease once the peak is arrived. At lower level of economic development, both residential and commercial energy consumption were lower. As economy grows, energy consumption rises substantially since energy is employed in productions, with scale effects far exceeding technology effects and structure effects. The main feather in this stage is that industrial structure has been transforming from light industry dominated to heavy industries and basic industries. Size and intensity of energy consumption approach the peak of the parabola. When it got to certain stages of industrialization and urbanization, heavy industry shrank and the tertiary industry with low energy intensity flourished. The advancement in technology and improvement in energy efficiency cut down per capita energy consumption, which exhibits a trend of rise first, then decline, an inverted U shape. As it shown in Figure 6, a lot of developed countries have passed the turning points in their energy consumption, with descending per capita energy consumptions.

In reduce form, we can have the following basic regression equation:

$$E_{it} = \eta_i + \alpha_{1i} price_{it} + \alpha_{2i} lnY_{it} + \sum_{j=1}^{N(i)} \beta_{ji} lnZ_{it} + \Gamma_i \mathbf{X_{it}} + u_{it}$$

in which:

$$X_{it} = a_{2i} + \lambda_i f_t + \gamma_i g_t + e_{it}$$

$$u_{it} = a_{1i} + \lambda_i f_t + \varepsilon_{it}$$

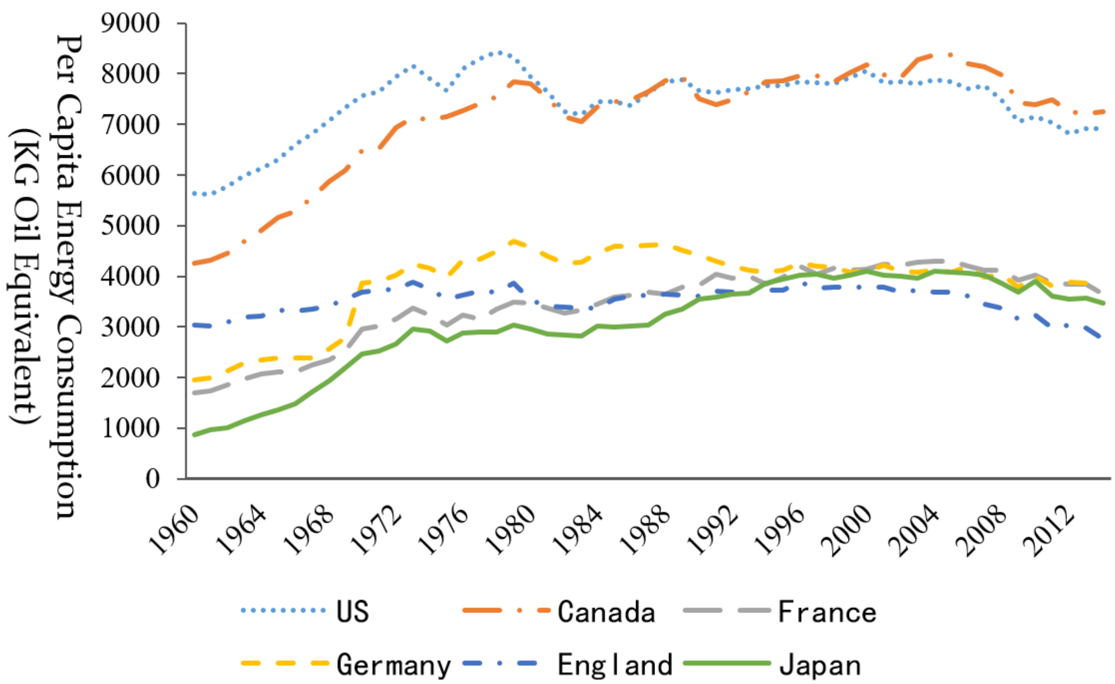


Figure 6: Trends of energy consumption in selected developed countries
3

in which Z indicates the per capita production in high energy intensity industries of region i. We choose six high energy consuming industries, including crude steel (steel), cement(cement), thermal powered electricity (power), ten nonferrous metal (metal), coke (coke) and caustic soda (soda). The dependent variable is level of energy demand, measured by per capita energy consumption (E). Other major explanatory variables are levels of economic development and price levels, with economic development is measured by real per capita GDP (Y)(take 1991 as base year). Since we use aggregate energy consumption in this paper, price changes for different energy products might not be clearly identified in our empirical analysis, we proxy price level by purchasing price index of industrial production(price), let 1995=100. And X includes other control variables, like urbanization rate, average energy intensity level etc.

For estimation, since in our case, the relationship of economic structure and energy consumption is crucial, and we discussed earlier, with different centrality level for high energy intensity industries, the relationships among energy consumption, GDP and high energy intensity industries would be heterogeneous. Hence, we need to implement a panel time series estimator which allow for heterogeneous slope coefficients across group members. In specific, to allow dependence across group members, we use the Augmented Mean Group estimator (AMG) which was developed in Eberhardt and Teal (2010).The AMG procedure, which is further discussed and tested using Monte Carlo simulations in Bond and Eberhardt (2009), is implemented in three steps:

1. A pooled regression model augmented with year dummies is estimated by first difference OLS and the coefficients on the (differenced) year dummies are collected. They represent an estimated cross-group average of the evolution of unobservable trend over time. This is referred to as "common dynamic process".

2. The group-specific regression model is then augmented with this estimated process: either (a) as an explicit variable, or (b) imposed on each group member with unit coefficient by subtracting the estimated process from the dependent variable. Like in the MG case the regression model includes an intercept, which

captures time-invariant fixed effects.

3. Like in the MG and CCEMG the group-specific model parameters are averaged across the panel.

Also, we follow the literature of assessing energy consumption forecasts and implement the Autoregressive integrated moving average (ARIMA) as well (with one lag). The regression equation is :

$$E_{it} = \eta_i + \alpha_{0i} E_{i,t-1} + \alpha_{1i} price_{it} + \alpha_{2i} lnY_{it} + \sum_{j=1}^{N(i)} \beta_{ji} lnZ_{it} + \Gamma_i \mathbf{X_{it}} + u_{it}$$

in which:

$$X_{it} = a_{2i} + \lambda_i f_t + \gamma_i g_t + e_{it}$$

$$u_{it} = a_{1i} + \lambda_i f_t + \varepsilon_{it}$$

3 Data and Regression Results

In this paper, we adopt a panel data set covering 29 provinces (excluding Tibet and Hainan) in China during the 1995-2013 periods. All data are publicly available. Energy data are from various issues of China Energy Statistic Yearbooks. Per capita GDP is from China Statistic Yearbook, deflated with 1991 as base year. Other data are from provincial statistic yearbooks, with a few observations missing. Table 1 presents the summary of statistics for the variables.

Regression Results

In this part, we show the regression results based on different regression techniques. First, we conduct several tests for model specification with the results shown in Table 2. We conduct the heteroscedasticity test using modified Wald test, with the null hypothesis that the disturbance term is of equal variance. We can see that for both the baseline model with only GDP and the full model, the null hypotheses are rejected,

Table 1: Summary Statistics

Variables	Obs	Unit	Mean	Std
Per capita energy consumption	551	ton TCE	2.29	1.45
Per capita GDP	551	10,000 Yuan	0.92	0.76
Per capita coke	546	ton	0.22	0.38
Per capita caustic soda	550	ton	0.01	0.02
Per capita cement	551	ton	0.83	0.57
Per capita crude steel	549	ton	0.29	0.37
Per capita ten nonferrous metal	541	ton	0.03	0.08
Per capita electricity	551	104kW/h	0.23	0.21
purchasing price index of industrial production	551	1995=100	134.79	37.98

which is consistent with our theoretical model that different economies with different industrial network would have display heterogeneity. Also, we test for within group autocorrelation by Wooldridge test, with null hypothesis of no first-order autocorrelation. The results show that all results reject the null at 1% significant level, which means there is first-order within group autocorrelation and implying AR(1) model should be used. The cross correlation is test by Pesaran test, with null hypothesis of no cross correlation. All the results reject the null significantly. The production and consumption of high energy products are usually separated, thus changes in demand for high energy products in certain provinces might affect production plan in provinces of production and therefore their energy demand. This indicts we should consider the cross-province links for regression, i.e. separate ARIMA model for each province is inappropriate. All of these problems would make the results estimated with two way fixed effects inaccurate. Therefore, we should will adopt AMG model with AR(1) process.

In Table 3, we list the results from a baseline model with only GDP and price included, iterative feasible generalized least square model (FGLS) with individual effects and time effects, AMG model with time trend and without AR process and finally AMG model with both time trend and AR(1) process.

Table 2: Test results

Test	Baseline	Full Model
heteroscedasticity Wald Test	6974***	1257***
Cross correlation(Pesaran)	-2.82***	-2.91***
Autocorrelation	51.91***	70.53***

We can see that when only the two basic variables are considered in Column 1, Income elasticity for per capita energy consumption is 1.046, which means when per capita GDP increase by 1%, energy consumption will increase by 1.046%. But when we add the high energy intensity products into the regression, the coefficient of per capita GDP decrease gradually from 1.046 to 0.667. It means that taking into account of the impacts from high energy consuming industries, when per capita GDP increase by 1%, magnitude of energy demand growth diminish from 1.046% to 0.667% on average, which provides evidence that for the heavy industry-centered economy, the prediction power from the high energy intensity products are relatively high, in other words, the high energy intensity products are omitted variables in the energy consumption estimation in previous studies.

Comparing the column (1) with column (3), in which the heterogeneity are taking into consideration, we can see that the AMG model decreases the energy income elasticity, which suggests that not taking the economic structure into consideration would lead to bias in estimation.

Goodness of Fit

In this part, we evaluate the goodness of fit of our models by comparing the true energy consumption and the predicted values from AMG model and FGLS model. We can see that allowing for heterogeneous parameters significantly increases the goodness of fit.

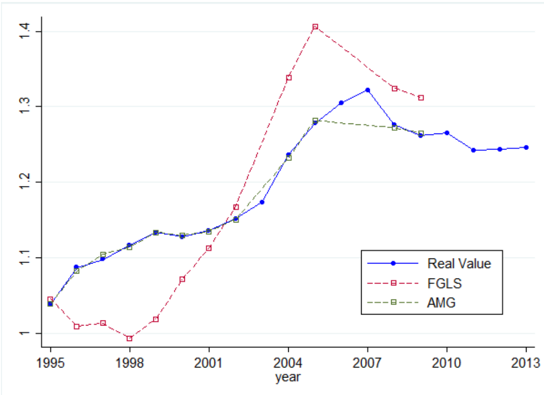
Table 3: Regression Results

VARIABLES	Baseline	FGLS	Baseline	AMG with AR(1)
Energy lag				-0.0286
				(-0.0391)
GDP	1.046***	0.667***	0.820***	0.738***
	(0.074)	(-0.0743)	(0.175)	(-0.144)
Price	-0.080	-0.165**	-0.0331	0.0247
	(0.080)	(-0.0738)	(0.0936)	(-0.0397)
Coke		0.0355***		0.00267
		(-0.00798)		(-0.022)
Metal		0.0118**		0.0345**
		(-0.00489)		(-0.0167)
Soda		0.0500***		0.00281
		(-0.0107)		(-0.00851)
Steel		0.0442***		0.00951
		(-0.011)		(-0.0242)
Cement		0.0795***		0.0389
		(-0.0151)		(-0.0254)
Constant	1.586***	2.055***	1.373**	0.134
	(0.390)	(-0.424)	(0.598)	(-0.424)
Year dummy (trend)	Yes	Yes	Yes	Yes
Observations	551	538	538	499
Group	29	29	29	28
MSE			0.0496	0.0066

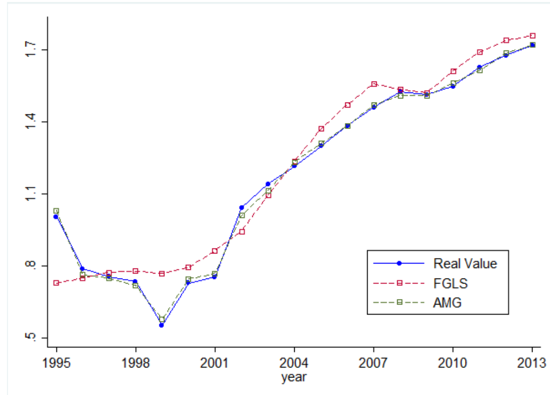
Centrality and Energy Elasticity

In this part, we directly prove our hypothesis that the centrality of high energy intensity industries would affect energy income elasticity. In Figure 7, we depict the heterogeneous energy income elasticity with respect to the average eigenvector centrality of the high energy intensity industries[4]. We can see that, consistent with our hypothesis, the higher the average eigenvector centralities of the high energy intensity industries, the higher the energy income elasticity, indicating that for an economy highly depend on the heavy industries, the energy cost of increasing per capita GDP by one percent is much higher.

[4]We drop two outliners with extremely high eigenvector values



(a) Beijing



(b) Heilongjiang

Figure 7: Goodness of fit by province

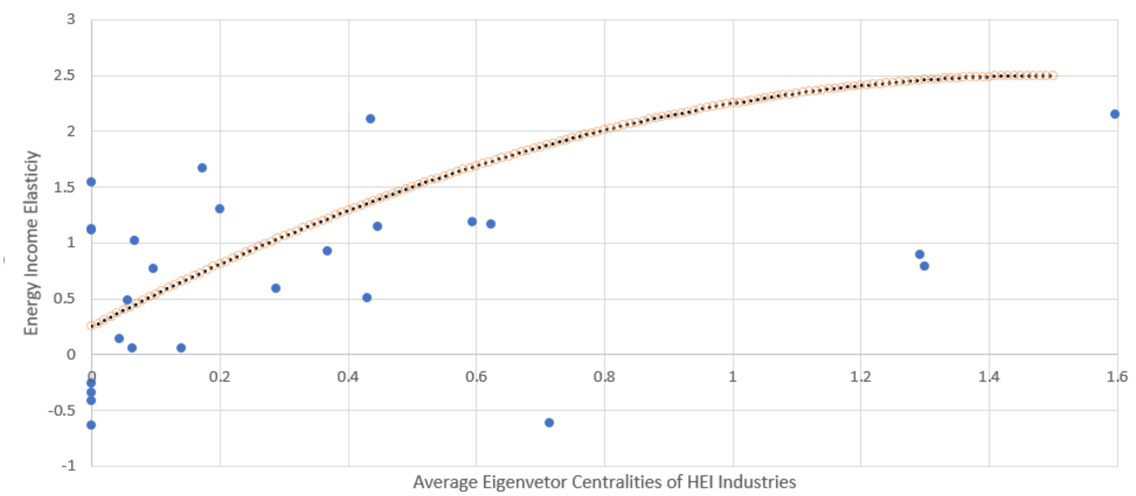


Figure 8: Eigenvector Centrality and Energy Income Elasticity

Energy Kuznets Curve

We can also partly proves the validity of the energy Kuznets Curve hypothesis, which argues that when one economy passes the stage of heavy industrialization and advances into high development level, the energy demand will decrease with the heavy industry shrinks. As depicted in Figure 8, the higher the economic development level in China (per capita GDP), the higher the energy income elasticity.

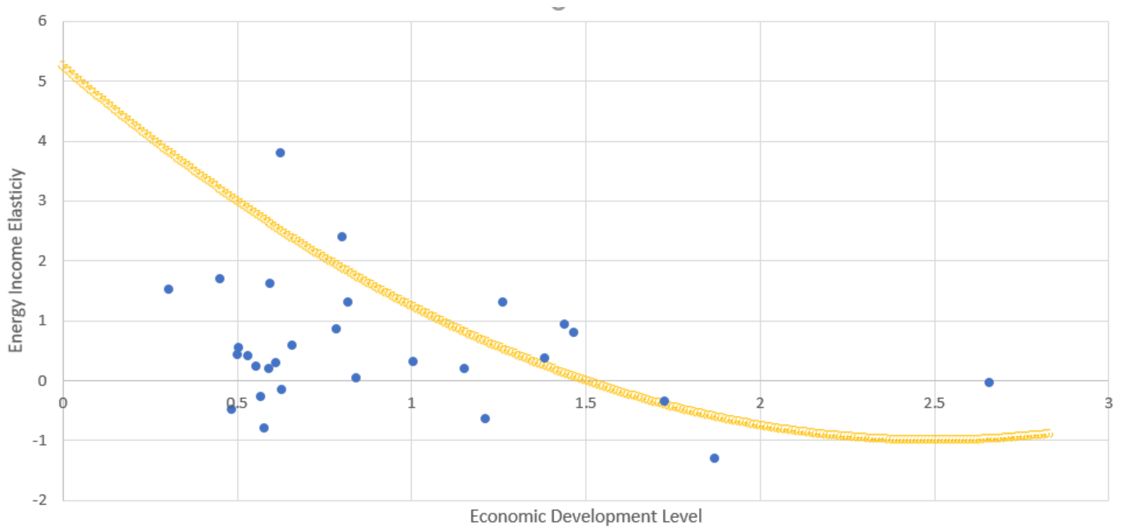


Figure 9: Energy Kuznets Curve

4 High Energy Consumption industries and Forecast of energy demand

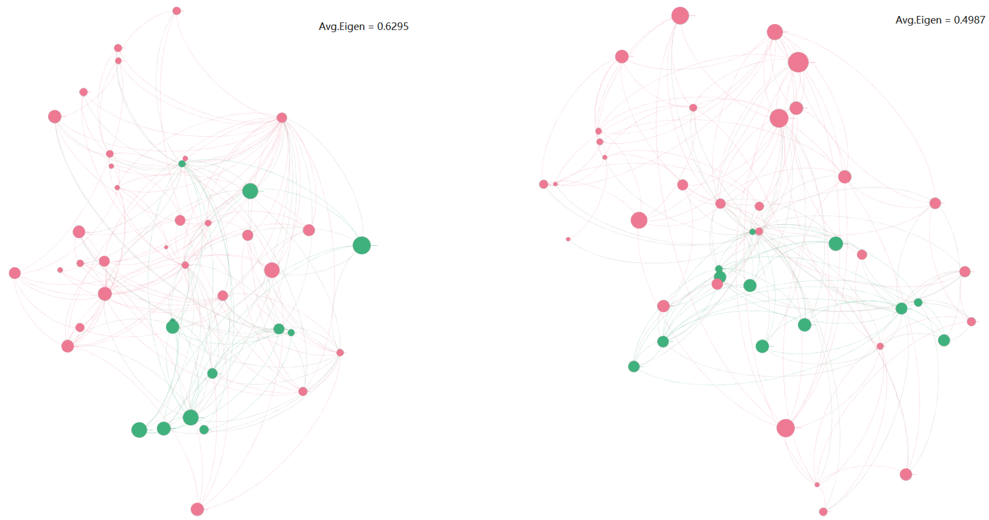
Based on the research above, we can include that the high energy products are omitted variables in the previous research and the economic structural change would lead to the centrality change of the heavy industries and therefore incur parameter changes. In the following section we carry out analyses under different scenarios. To reduce the standard errors of forecasts and also with the purpose of emphasizing the consequence of not taking economic structural changes into consideration, we use the baseline model which only includes the economic development level and price.

Scenario Description

population growth in China, according to data provided in United Nations Population outlook, the baseline population growth rate between 2015 and 2020 is 0.39% , with a range between 0.21% and 0.56%. Hence we take the population growth rate as 0.39% in our scenario analysis. As for GDP growth rate, World Economic Outlook 2016 by IMF gives the GDP growth rates in 2015-2020 of 6.9%, 6.6%, 6.2%, 6%, 6% and 5.9%. Based on this, the average GDP growth rate in 2015-2020 should be 6.27%, which we take as the hypothesized growth rate in our scenario analysis. Since in 2012 and 2013, the average industrial price were relatively stable, with increase rates around -1.5%, hence we assume the industrial price doesn't change from 2014 to 2020. This assumption cannot be generalized to other countries, since the energy price in China has been kept lower than other countries by administrative power for a long time. Though as the energy price reform advances, full cost pricing will necessitate higher energy price, we assume the pricing reform will not take place in the next 5 years.

The major part is to predict the economic structural changes in the next 5 years. In Figure 10, we show the industrial network for China from 2002 to 2012, in which we can see the average eigenvector centrality for high energy intensity industries deceased from 0.6295 to 0.4987, or 20% in 10 years.

Among the 29 provinces, we chose 2 provinces with similar starting economic structure (similar average eigenvector centrality for high energy intensity industries) in 2002 with China as a whole in 2012. And define one province as the "moderate structure change scenario", whose average eigenvector centrality decreased from 0.5306 in 2002 to 0.3984 in 2012, and the other as "rapid structure change scenario", whose average eigenvector centrality decreased from 0.5153 in 2002 to 0.1412 in 2012. And the third scenario is "no structure change", in which we assume the economic structure in China as a whole stay the same. The estimated parameters are in Table 4 and the forecasts are in Figure 11.



(a) Year = 2002 (b) Year = 2012

Figure 10: Industrial Networks for China in year 2002 and 2012

Table 4: Three scenario

	No change	Moderate	Rapid
GDP	0.82	0.6570	0.4100
Price	-0.0331	-0.1064	1.4252
Energy lag	0.00584	0.0275	-0.0052
constant	1.373	0.9610	-6.1394

Discussion

We can see that among these three, the "Rapid structure change" scenario successfully forecast the energy demand for year 2014,2015 and 2016. We can take a more careful look into the heavy industries and discuss the underlying reasons for this forecast.

As a typical product in nonmetallic mineral products industry, cement has been the important primary materials in economic construction and also relies greatly on energy. The cement industry is of low production concentration and usually involves serious

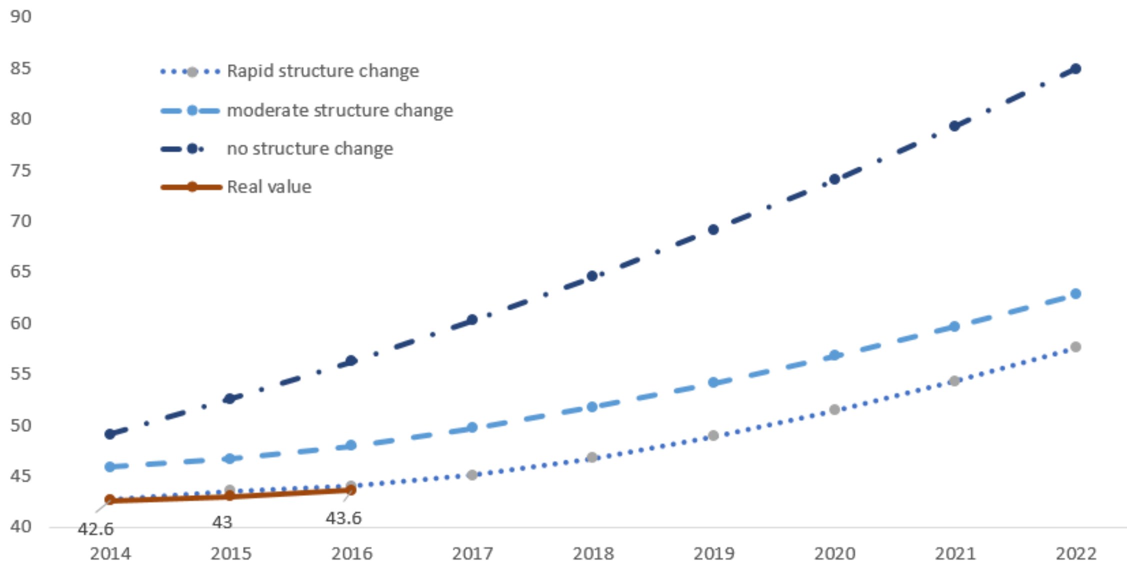


Figure 11: Forecasts for three scenario

waste of energy. In order to achieve fast growth of national economy, following the pollute first and then clean up notion, small scale cement factories sprung up and become significant component of cement industry. These small factories emphasize more on the quantity than on the quality of production and compete with each other by reducing cost and increasing production. As a result, the production technology falls far short of those of the advanced counterparts, and also leads to waste of energy. Meanwhile, the rapid economic growth accelerates urbanization and promotes fixed capital investment. With faster pace of new rural construction and paved road and railway construction, the cement production increases greatly. However, with higher standard of environment regulation and rising costs of energy resources, the over production resulted from the local governments blind pursuing of GDP and investors speculation would change. As the cement industry will suffer from contraction in production, and so will be the energy demand.

Steel has been the major components of ferrous metal smelting and rolling processing industry. China became the largest steel producer in 1996 and has been staying in the 1st place for many years, with steel production growing at an annual rate of 6.5%. In 2013, the crude steel production in China was close to half that of the global production. The steel industry has provided important primary inputs to the national economy and created huge wealth, but at the same time it has consumed enormous energy. The expansion of economic scale pushes up fixed capital investment and stimulates production potential of steel industry. The development of high-speed railway and urban railway systems uphold the demand for steel. Increasing living standards also call for rise of car industry and real estate industry, which encourage the demand for steel. The industry concentration of steel industry in China is low compared with developed countries, and the energy waste is common. Currently, the real estate industry is declining and manufacture is criticized for overcapacity. With the structure readjustment of steel-consuming industries, the steel industry is confronted with requirements in structural demand adjustments, and increase in production becomes insignificant. Data show that the consumption and production of crude steel exihibited turning points in 2013 and 2014, which means the steel demand is on the downside, and so does the energy demand in steel industry.

Electricity has been utilized in every aspects of national economy and has become indispensible to the development. Development in industries, transportation and service industry and improvement in peoples living standard would necessitate the growing demand for electricity. Hasty rise in different high-electricity-consuming products, including steel, machinery manufacturing equipment, and metal smelting equipment, would raise enormous demand for electricity. The repeated electricity famines in 2002 promoted the development in electricity industries, with fast growing investments in the industry and an annual growth rate of 17.8%. it is obvious that economic growth has stimulated the development of electricity industry and also indirectly promoted the energy consumption in the industry. As the economy transits from high-speed growth to mid-high growth, the development of high energy consuming industries slows down, and the pattern of electricity consumption also changes, hence the demand for electricity would go down. With the advancement in reforms focusing on direct trading of electricity, many provinces have reduced planned electricity usage greatly. The overproduction and the reform in electricity would inevitably impose great challenges to the development of electricity industry.

5 Conclusion

Our paper contributes to the current literature in the following aspects. (1) Academically, we take the development of high energy consuming industries as one of the possible channels through which GDP can affect energy consumption, and make up the deficiency of making forecast based on the simple linear relationship between economic growth and energy demand. (2) We argue that the industrial structure readjustment in three sectors has been an incremental process, with changes induced by development in different industries. Analyses based on rough estimate of structure of primary, secondary and tertiary industries are not sufficient to envelop the impact of changes from high energy consuming industries. (3) In reality, if we assume high energy consuming industries is one of the important channels through which economic growth affect energy consumption, then it is crucial to take into account of the future development trend of high energy consuming industries and quantitatively analyze the direct and indirect impact of GDP on energy demand. Not only it is helpful to understand and make accurate forecasts for future energy consumption in China, but also it will be of great implications for making energy planning at country level and investment decision at enterprise level.

There is still weakness in the current research, including our measure of the development of high energy consuming industries, the selection of representative products in high energy consuming industries, the selection of forecasting model for energy demand, as well as the discussion on the scenario hypothesis for the high energy consuming industries, which would be the direction for our future research.

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