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Decomposition Analysis of Energy Intensity in Beijing during the 12th Five-Year Plan from Micro Panels

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***Abstract*—This manuscript first analyzes the significant energy productivity improvement during the 12th Five-Year Plan (FYP) in Beijing, and then gives a separate decomposition in the factors that affect energy intensity in Beijing based on Theil Index. The influencing factors on energy intensity is decomposed into the structural effect and the technical effect. The conclusion shows that the technical effect is the decisive factor in the reduction of energy intensity in Beijing in recent years, and the structural effect is becoming more and more prominent in its contribution to the cut down of energy intensity. The manuscript uses the energy consumption data of the key energy-using units in Beijing, which are the main targets for the government to decrease energy intensity.**

Keywords-energy intensity; decomposition; Theil Index

I. INTRODUCTION

Global warming is one of the significant conundrums of the world and has already drawn attention on global scale. The international community has reached consensus on reducing greenhouse gas, which is considered as a key determinant to global warming, therefore the establishment of low-carbon economy is on high agenda. China as a developing, but also a large energy consumption country, its energy-saving emission reduction efforts have attracted worldwide attention.

In 2006, the central government of China enunciated an ambitious goal of decreasing its energy intensity by 20% during the 11th FYP,[1]and achieved the target with energy intensity cut down by 19.1% and GDP growth at an annual rate of 11.2%.[2]During the 12th FYP period, China's carbon intensity achieved a cumulative decline about 20%; in 2015, non-fossil energy accounted for 12% of the primary energy consumption, both exceeding the objectives set for the 12th FYP.[3]

The 13th Five-Year Comprehensive Energy-Saving Emission Reduction Program Working Plan released in January 2017 pointed out that by 2020, the carbon emissions per million yuan GDP would be reduced by 15% from the 2015 level, and total energy consumption constrained within 5 billion tons of standard coal equivalent.[4]

In order to achieve the relevant objectives, the government executes a double control on both the total energy consumption and the intensity of emission, stressing more attention on the the target responsibility decomposition mechanism. Thus, the national energy consumption control and energy-saving targets are divided into various regions, industries and key energy units. All regions shall, according to the tasks assigned by the government, clarify the annual working objectives and decompose them at all levels, make clear the responsibility of the relevant departments and key energy units at inferior level, and gradually establish the provincial and municipal governments budget management system of energy-using. On this basis, the Top-1,000 Energy-Consuming Enterprises Program was carried out in 11th FYP [5] and Top-10000 Energy-Consuming Enterprises Program was carried out in 12th FYP.[6][7]

Beijing as the capital of China, its energy-saving emission reduction has been in a leading position. Beijing, in the response to the target responsibility decomposition mechanism, releases the major targets for its emission-reduction objectives, called key energy-using units.[8]The list of key energy-using units is publicized annually, and the person in charge of energy management is responsible for updating energy-using condition and get examined.

In this paper, we try to decompose the factors that affects energy intensity using the data from the key energy-using units of Beijing. Plenty of scholars have decompose the influencing factors in many aspects: Garbaccio et al. (1999) uses the input-output method considering that the main influencing factors were improvements in sectorial technologies and that the import of energy-intensive products also contributes to energy efficiency.[9]Fisher-Vanden et al. (2004) use enterprise-level data to find that rising relative energy prices, research and development expenditures, and ownership reform in the enterprise sector, as well as shifts in China's industrial structure are the principal drivers of China's declining energy intensity and use.[10]Ma and Stern (2008) found that technological progress on the energy intensity is of industry heterogeneity characteristics, of which the chemical industry technological progress has largest effect.[11]He Canfei et al. (2007)

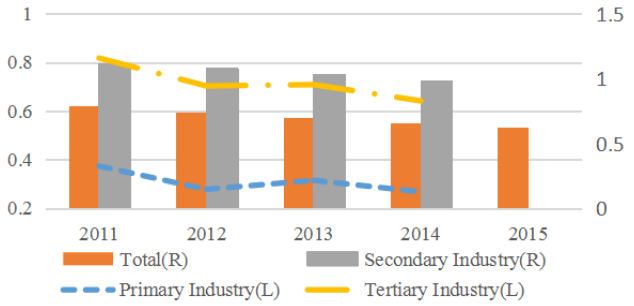
analyze China's 30 provincial-level administrative regions and verify economic transition (conceptualized as a triple process of marketization, decentralization, and globalization) can reduce energy intensity.[12]All the studies reviewed above shed some light on the decomposition of influencing factors on energy intensity, however they mostly analyze from a single angle, and verify their conclusion by macroscopic data. In this article we intend to bridge this gap by decomposing the influencing factor using the energy consumption data of 311 key energy-using units in Beijing from 2012 to 2015.

The remaining portion of this study is arranged as follows: Section 2 analyzes the significant energy productivity improvement during the 12th FYP in Beijing and the nation, Section 3 describes the data sources - the key energy-using units and their characteristics, Section 4 introduces the Theil Index method used in this study, then decomposes the influencing factors based on Theil Index, Section 5 concludes the article.

II. ENERGY CONSUMING SITUATION DURING THE 12TH FYP

A. *National Energy Consuming Situation during the 12th FYP*

From 2011 to 2015, China's economic scale gradually expanded. From the perspective of the industrial structure, with rapid economic development level, the demand for productive and living services has been expanding, and the service industry plays a more important role in the national economy. The proportion of the primary industry remained stable, the proportion of the secondary industry decreased, the proportion of the tertiary industry increased.



a. energy intensity in this paper is calculated through Energy Consumption/GDP, the unit is million tce/billion RMB

FIGURE I. NATIONAL ENERGY INTENSITY DURING THE 12TH FYP

With the changes in the size and structure of the economy, the total energy consumption in the 12th FYP period increased significantly. The secondary industry accounted for the largest proportion of the absolute use of energy consumption, the primary industry accounted for the smallest proportion. As the same trend of economic scale development, the total energy consumption also showed a slowdown in the growth trend. From the perspective of energy intensity, the three major industries and the overall economic energy intensity are decreased with the primary industry having lowest energy intensity, followed by the tertiary industry lower than the economic average, the secondary industry relatively high.

B. *Energy Intensity decreasing during the 12th FYP in Beijing*

Beijing has witnessed a rapid economic development which is ahead of the national economic growth level during the 12th FYP, however the energy intensity of overall economy and the three major industrial has shown a steady downward trend. The tertiary industry plays a more important role in the economic development than the first and second industries. During the 12th FYP period, Beijing continues to show shift trend from the secondary industry to the tertiary industry.

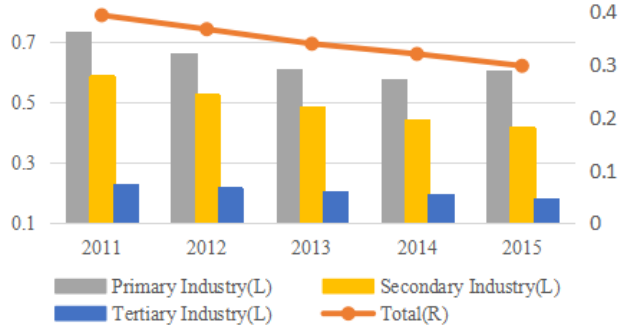


FIGURE II. ENERGY INTENSITY OF BEIJING DURING THE 12TH FYP

During the 12th FYP period, the overall economy in Beijing and the three major industries have significantly cut down energy intensity. Only the tertiary industry has a significant lower energy intensity and a higher energy intensity decreasing rate than the overall level of Beijing's economy. The primary and the secondary industries' energy intensity are above the overall situation of the Beijing economy, and the secondary industry has a lower energy intensity than the primary industry. Compared with the national energy intensity, the overall economic intensity of Beijing's economy is lower than the national economic energy intensity; the secondary and tertiary industry energy intensity is lower than the national counterparts, especially the tertiary industry, which accounted for the main part of economic scale. The primary industry energy intensity is higher than the national primary industry energy intensity level, but the total energy consumption in the primary industry in 2015 of Beijing accounted for only 1.6% of Beijing's total energy consumption. This explain the leading part Beijing played in the national emission reduction.

III. THE EXECUTION OF TARGET RESPONSIBILITY DECOMPOSITION MECHANISM

A. *Top-10,000 Energy-Consuming Enterprises Program*

In 2011, the National Development and Reform Commission, the Ministry of Education, the Ministry of Industry and Information Technology, the Ministry of Finance, the Ministry of Housing, Urban and Rural Development, the Ministry of Transport and other 12 departments jointly issued the "The Top 10,000 Energy-Consuming Enterprises Program". The Program, which is expanded from the Top 1,000 Program of 11th FYP, is a mandatory program in the 12th FYP. Approximately 15,000 industrial enterprises that use more than 10,000 tones of standard coal equivalent per year, around 160

large transportation enterprises, and public buildings (including schools and universities), hotels and commercial enterprises that use more than 5,000 of standard coal equivalent per year are included in the program. The target of the program is to save 250 million tce by 2015.[7]

B. *The Key Energy-Using Units in Beijing*

Beijing, in respond to the Top-10,000 Energy-Consuming Enterprises Program, set the enterprises which has the previous year's comprehensive energy consumption of more than 5,000 tons of standard coal equivalent as the key energy-using units in Beijing. The list of key energy-using units is publicized annually, and the person in charge of energy management is responsible for updating energy-using condition and getting examined.[8]

The key energy-using units in Beijing are divided into five categories: Industry, Wholesale and Retail Trades, Transport, Storage and Post, Hotels and Catering Services and Education. During the four years of the survey, there were only minor changes in the number of enterprises in relevant industries.

TABLE I. ENERGY INTENSITY OF KEY ENERGY-USING UNITS IN BEIJING

Sector	2012	2013	2014	2015
Industry	1.154	1.021	0.848	0.773
Wholesale and Retail Trades	0.033	0.031	0.029	0.033
Transport, Storage and Post	1.010	0.998	0.980	0.821
Hotels and Catering Services	0.286	0.344	0.370	0.347

FIGURE III. ENERGY INTENSITY OF KEY ENERGY-USING UNITS IN BEIJING

In terms of energy intensity, Wholesale and Retail Trades are most efficient in energy consumption, followed by Hotels and Catering Services, the Industry (the secondary industry) and Transport, Storage and Post is the least efficient.

This study makes a simple estimation on Beijing's key energy-using units' overall energy intensity by adding up four industries' energy intensity. The results are shown in Fig. 4.

From 2012 to 2015, industrial energy intensity has a clear downward trend with an obviously emission reduction. The increase in Transport, Storage and Post between 2012 and 2014 is relatively small, with a clear downward trend in 2015. The Hotels and Catering Services has shown a downward trend from 2012 to 2013 and a slight increase in 2014-15. The Wholesale and Retail sector is on the downswing in 2012-14, but increase in 2015.

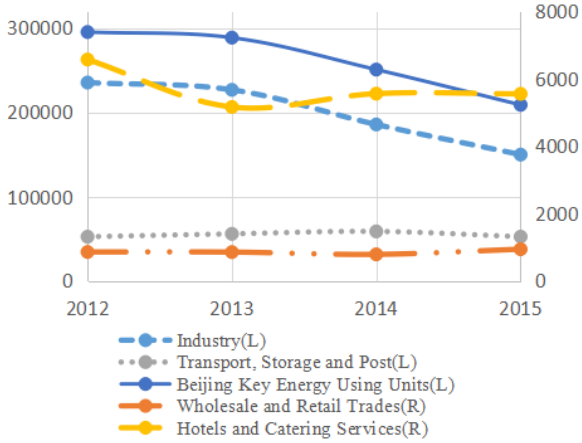


FIGURE IV. TOTAL ENERGY INTENSITY OF KEY ENERGY-USING UNITS IN BEIJING

The energy intensity of Beijing key energy-using units has steadily decreased with an accelerated speed. Industrial energy intensity has decreased steadily, and the decreasing speed is almost same as the key energy-using units in Beijing.

IV. DECOMPOSITION OF INFLUENCING FACTORS

A. *Influencing Factors Decomposition Model*

In this study, the impact of energy intensity is summarized as two paths: first, the adjustment of industrial structure: that is, in the case of constant economic scale, if the productivity shifting from high energy consumption industry to lower energy consumption industry, this adjustment does not change the size of the economy, but the total energy consumption of economic production will decline; or else, energy consumption will rise. This study define such changes in industrial structure as *structural effects*.

Second, the upgrading of production technology, based on the same department of economics assumptions. The production technology refers to the same industry sector level of technology. On the same economic scale and the same industrial structure, if one or some of the industry's production technology upgrade (this article assumes that changes in production technology refers to the technological upgrading, due to the degradation of technology is very rare) and lead to energy intensity decrease; otherwise, will increase the total energy intensity. This study define such industry technology upgrade as the *technical effect*.

Based on the decomposition of the two factors: structural effects and technical effects on the change of energy intensity, this paper introduces the decomposition method of Theil Index, and quantifies it.

B. *Theil Index and Decomposition*

The Theil Index[13][14]is currently widely used to measure the difference in income inequality. The decomposition of the index is used directly to measure the difference in income within the same groups and the difference in income between different groups.

Thus the model can be applied in this article to test the energy intensity differences between industries and the

decomposition of the differences within the industry. The technical effect is the change in energy intensity caused by the technological upgrading in the same industry. The structural effect is to examine the difference between the different industries and their effect on the overall energy intensity. [11] [12]

The Theil Index can be decomposed into two parts, namely: the difference between groups Tb (1) and the group difference Tw (2).

k stands for the industry,in this paper, *k*=1,2,3,4 represents Industry, Wholesale and Retail Trades,Transport, Storage and Post and Hotels and Catering Services; i represents the key energy-using unit.

$$Theil_b = (1/n)\sum_{k=1}^{k}\left[n_k(\overline{EI_k}/\overline{EI})\lg(\overline{EI_k}/\overline{EI})\right] \quad (1)$$

$$Theil_w = (1/n_k)\sum_{i\in k}(EI_i/\overline{EI_k})\lg(EI_i/\overline{EI_k}) \quad (2)$$

And $Theil_b+Theil_w=Theil$ is satisfied. *Theil* represents the difference in the energy intensity between the key energy units.

In this paper, T_b corresponds to the structural effects; T_w corresponds to the technical effects; y is the energy intensity, k represents four industries.

C. Results of the Decomposition

Based on the energy consumption data of 311 key energy-using units in Beijing Energy Saving and Climate Change Database (2012-2015), this paper analyzes the influencing factors.

TABLE II. DECOMPOSITION OF INFLUENCING FACTORS OF KEY ENERGY-USING UNITS IN BEIJING

	2012	2013	2014	2015
Theil	0.415	0.400	0.396	0.391
$Theil_b$	11.55%	10.11%	13.21%	13.29%
$Theil_w$	88.45%	89.89%	86.79%	86.71%

Data Sources: Beijing Energy Saving and Climate Change Database

TABLE III. ECONOMIC SCALE AND ENERGY CONSUMPTION OF BEIJING

	2011		2012		2013		2014		2015	
	GDP	Energy Consumption	GDP	Energy Consumption	GDP	Energy Consumption	GDP	Energy Consumption	GDP	Energy Consumption
Total	16251.9	5077.3	17879.4	5147.2	19800.81	5285.6	21330.83	5326.6	23014.59	5299.9
Primary Industry	134.4	98.3	148.1	98.1	159.64	97.3	158.99	91.7	140.21	84.6
Secondary Industry	3678	2160.1	3962.6	2082.1	4292.56	2079.2	4544.8	1998.4	4542.64	1902.7
Tertiary Industry	12439.5	2818.9	13768.7	2967	15348.61	3109.1	16627.04	3236.5	18331.74	3312.6

GDP: [Billion Yuan]; Energy Consumption: [Tons of Standard Coal Equivalent]
Data Sources: Beijing Statistical Information Net (http://www.bjstats.gov.cn)

TABLE IV. NATIONAL ECONOMIC SCALE AND ENERGY CONSUMPTION

	2011		2012		2013		2014		2015	
	GDP	Energy Consumption	GDP	Energy Consumption	GDP	Energy Consumption	GDP	Energy Consumption	GDP	Energy Consumption
Total	489300.6	387043	540367.4	402138	595244.4	416913	643974	425806.1	689052	430000
Primary Industry	46163.1	7675.2	50902.3	7803.6	55329.1	8054.8	58343.5	8094.3	60862.1	—
Secondary Industry	227038.8	284099.5	244643.3	291048.9	261956.1	298147.6	277571.8	303206	282040.3	—
Tertiary Industry	216098.6	95268.3	244821.9	103285.5	277959.3	110710.6	308058.6	114505.8	346149.7	—

GDP: [Billion Yuan]; Energy Consumption: [Tons of Standard Coal Equivalent]
Data Sources: National Bureau of the People's Republic of China (http://www.stats.gov.cn/)

The results of Table 4 show that the difference in energy intensity (*Theil*) of key energy-using units in Beijing is decreasing year by year. The contribution of technical effect ($Theil_w$) is dominant, and the contribution rate is more than 85%. However, the results of 2014 and 2015 show that the contribution of structural effect ($Theil_b$) is on the increase, indicating that structural effect is becoming more and more prominent in its contribution to the reduction of energy intensity.

V. CONCLUSIONS AND RECOMMENDATIONS

In this paper, Theil index is introduced to measure the difference of energy intensity. The influencing factors on energy intensity is decomposed into the structural effect and the technical effect. On this basis, the article uses energy consumption data of 311 key energy-using units in Beijing from 2012 to 2015 to make empirical test. The conclusion shows that the technical effect is the decisive factor in the decreasing of energy intensity in Beijing in recent years, and the structural effect is becoming more and more prominent in its contribution to the decreasing of energy intensity.

From the perspective of technical effects, it is vital to encourage enterprises carry out energy-saving emission reduction technology innovation and development through the market mechanism or industrial policy. Such as giving tax incentives to leading emission reduction enterprises, etc. In

addition, the government should make full use of the carbon market and other market mechanisms, commercialize the carbon emissions and make enterprises see energy-saving emission reduction as a way to lower their cost.

From the perspective of structural effects, it is vital to continue to transfer production capacity to low-power, low-emission industries, so as to further optimize the industrial structure upgrading. At the same time, government should release relevant policy helping the cooperation between enterprises and sharing energy-saving technologies.

From the perspective of monitoring and management, the key enterprise monitoring system will be gradually extended to all enterprises. On the one hand, it can clearly illustrate the Beijing and the country's energy-saving emission reduction situation, on the other hand, through carbon audit verification, enterprises will be more spontaneous in the emission reduction behavior.

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