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Laspeyres Decomposition of Energy Intensity including Household-energy Factors

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Abstract

In the previous study papers the change of the total energy intensity is decomposed to the structure factor and the efficiency factor, not considering the household energy factor, because GDP are not made only by household energy. Household energy is about ten percents in the total energy consumption and the household energy of unit GDP are always being decreased. In this paper the change of the total energy intensity is decomposed to the structure adjustment factor, the efficiency factor and the household energy factor. The result of decomposition shows the efficiency factor contribute most to the reduction of total energy intensity from 1985 to 2007, the household energy factor the next, and structure adjustment factor the last. The result of decomposition also explains the causation of the abnormal ascending of total energy intensity from 2002 to 2005.

Key words: household energy factor; energy intensity; factor decomposition; efficiency factor

1. Introduction

Among the tenth five-year plans, all targets were achieved except for energy saving, so that the eleventh specially stipulates a 20\% decline of energy consumption per GDP from the last phase of “the tenth five-year plan”. By the end of 2009, the energy consumption in GDP per unit had fallen 15.6\%
accumulatively while went up 0.09% compared with the same period of the first half year in 2010, which exemplifies a tough task for us in energy conservation.

The measuring unit for energy consumption in unit GDP is ton standard coal per ten-thousand yuan, i.e. so-called energy intensity in scientific thesis. As far as the research on energy intensity is mentioned, hierarchy regression method and factor-decomposing approach are applied, of which the former is illustrated by Zongcheng Yin, Taiwen Feng, Shidan, and etc[1-3]. The latter is discussed by Zhiyong Han and others (2004) who decompose energy intensity into structure and efficiency portions and furthermore make quantitative analysis of them, which leads to the conclusion that energy intensity had declined during 1998-2000 owing to energy utilization efficiency enhancement made by every industrial sector[4]. Qiaosheng Wu and Jinhua Cheng (2006) make full use of simple average differential method-PDM2 decomposition model to analyse energy consumption intensity of China in 1980-2004 and of its six sectors ranging from industry to agriculture, and also believe that technological advance is the main reason for our energy intensity decline[5]. Zhixin Qi (2007) studies the impact of industrial light-and-heavy structure on China’s energy intensity during 1993-2005 by adopting pull-type decomposition approach, and finds out that change in industrial structure has less influence on energy intensity than sectors intensity [6]. Chunbo Ma, David I. Stern (2008), by using LMDI-based means, dissemble energy intensity change during 1980-2003, and conclude that technological advance had played the most essential part in the energy intensity drop[7]. Xiaoli Zhao, Chunbo Ma, Dongyue Hong (2010) explore the reasons why the energy intensity sharply descended in 1980s and 1990s and why it rose exceptionally at the beginning of 21st century. It turns out that energy is saved by energy utilization efficiency improvement[8].

To sum it up, energy intensity decomposition is commonly practiced by Laspyeres and Divisia approaches. The LMDI method is prevailing in recent years, which classifies the change of energy intensity into two parts characterized by structure-related and efficiency-oriented change respectively. Since this brand-new decomposition approach is based on energy intensity of each of three major industrial sectors and household energy itself is unable to bring about GDP, the majority of decomposition results take no consideration into intensity variation from household energy consumption.

2. Laspeyres Energy Intensity Decomposition Approach Considering Household Energy Factor

China’s energy intensity is mainly influenced by industrial structure transformation, technological advancement, opening-up and so on. Take 2007 for instance as shown in table 1, compared with 1985, the three pillar industries in this year suffered decline in energy intensity. Among them, the secondary and tertiary industries drop sharply of 58.5% and 52.5% respectively, and the primary industry went down slowly but also reached 34.6%, which is attributed to higher energy utilization efficiency. Owing to the biggest proportion of the secondary industry among the three mentioned above as well as its highest energy intensity incurred thereby, technological progress of the secondary industry generates the most outstanding contribution to overall energy intensity decline. And of course, inside it, light industry differs from heavy industry greatly in energy intensity and contribution rate. The wide gap existing between the three industrial sectors in energy intensity leads to the total energy intensity variation with change of each individual proportion. Energy for daily life occupies 17.37% in 1985, which is followed by a continual decrease, and during 1997-2007 it maintains 11% and in 2007 drops to 10.09%. In addition, the household energy consumption per unit GDP falls from 1.042 in 1985 to 0.269 in 2007.
In conclusion, energy intensity changes from three aspects of industry adjustment, technological advancement and openness, and energy for personal consumption whose impact on overall energy intensity decline are explored by a modified Laspeyres factor-decomposing approach as follows.

When applying $e_t$ which stands for energy intensity in the year of t, $e_{it}$ the energy intensity of the ith industry in the year, and $y_{it}$ the proportion of the ith industry in GDP in the year, i=1, 2, 3; n=1, 2, ⋯ p, ⋯ n⋯, we get the formula as follows:

$$\sum_{i} e_{it} y_{it} = \sum_{i} e_{it} y_{it} + \sum_{i} e_{it} (y_{it} - y_{it}) + \sum_{i} (e_{it} - e_{it}) y_{in}$$

Decompose energy intensity variation:

$$\sum_{i} e_{it} y_{it} - \sum_{i} e_{it} y_{it} = \sum_{i} e_{it} (y_{it} - y_{it}) + \sum_{i} (e_{it} - e_{it}) y_{in} = \Delta e_{it} + \Delta e_{it}$$

$\sum_{i} e_{it} (y_{it} - y_{it})$ represents energy intensity variation generated by industry structure transformation from year p to n, and $\sum_{i} (e_{it} - e_{it}) y_{in}$ symbolizes energy intensity change resulting from energy utilization efficiency related with each industrial sector’s technological advancement and openness from year p to n.

Laspeyres decomposition method, however, fails to take into consideration household energy which actually accounts for a large proportion in our nation’s total energy consumed (10.09% in 2007). Owing to the fact that energy use for daily life is unable to produce GDP, no impact of it on overall energy intensity is expressed in above-mentioned formulas. In effect, no reasonable explanation is found in the domestic research related, which is probably because some put household energy in the tertiary industry and others subtract it from the total energy consumption when calculating energy intensity for three industries. This article modifies the above Laspeyres approach and divides energy intensity into three parts:

1. Energy intensity change led by industry structure adjustment(structure adjustment factor): $\sum_{i} e_{it} (y_{it} - y_{it})$

2. Energy intensity change resulting from energy utilization efficiency improvement brought about
by technological advancement and openness in each industry sector (efficiency factor):
\[ \sum_i (e_n - e_p) y_n \]

3. Energy intensity change generated by household energy consumption variation (household energy factor):
\[ (e_n - e_p) - \sum_i e_p (y_n - y_p) - \sum_i (e_n - e_p) y_n \]

In the formula, \( e_n \) and \( e_p \) are calculated via total energy consumption including household energy divided by GDP, and \( \sum_i e_p y_n \) is not equal to \( e_n \), and \( \sum_i e_n y_n \) must equals the energy intensity worked out by total energy consumption excluding household energy divided by GDP.

3. Decomposition Result and Analysis

3.1 Relevant Data

Though there are no energy intensity statistics for each industry sector in statistical yearbooks, the comprehensive energy balance sheet under China’s Statistical Yearbook covers distribution condition concerning every industry’s energy consumption. In accordance with national economic accounting classification included in China’s Statistical Yearbook, energy use for farming, forest, herding, fishing, irrigation works is the primary industry energy, energy utilized in manufacturing and building belongs to the secondary industry, and energy consumed in communications and transportation, storage and postal service, wholesale, retail, accommodation, catering service and the like is in the tertiary industry category. Then the energy intensity is derived for China as a whole and three industry sectors as well as household energy per unit GDP during 1985-2007. The relevant data is shown in Figure 1.

![Figure 1: Total energy intensity and every sector's energy intensity during 1985-2007](image)

Note: Energy intensity measuring unit is ton standard coal per ten thousand yuan, and GDP is based on price in 1990

It can be seen clearly from Fig.1 that from 1985 to 2007 energy intensity for the nation and the secondary industry has suffered a sharp decrease, and that energy intensity for the primary and the tertiary industry has slowed down, which is closely related with lower intensity of them alone. Additionally, the household energy per unit GDP descended greatly in 2007 with only 25.9% of that in 1985, which demonstrates not only that our energy utilization efficiency has been boosted but that the previous factor-decomposing practice without regard to household energy element is out of position. Besides, the abnormal increase of total energy intensity during 2002-2005 found in Fig.1 is worthy of further attention,
especially under the circumstances where energy utilization efficiency for each industry was increasingly strengthened.

3.2 Decomposition Result

By applying modified Laspeyres approach, the authors decompose energy intensity variation over the years into three categories, namely the structure adjustment factor, efficiency factor, and household energy factor. Details are shown in Fig. 2.

We learn from the figure that ranging from 1985 to 2007 efficiency factor makes the greatest contribution to overall energy intensity decline, which is followed by household energy and structure adjustment factor in turn. In details, energy intensity of the secondary industry outclasses the primary and the tertiary industries so that its change dramatically affects structure adjustment factor involved in energy intensity variation. The structure adjustment factors represent positive numbers in the five continuous years from 2002 to 2007 when proportion of the secondary industry has achieved ongoing growth while the other two fluctuated constantly. On the other hand, in the secondary industry, the percentage of heavy-scale industry value added ascended increasingly (rising from 60.9% in 2002 to 70.2% in 2007). These facts thus give rise to positive numbers in structure adjustment factors. The reason why efficiency factors help reduce energy consumption mostly lies in enhancement of high-tech introduction to energy utilization thanks to technological progress and openness interpreted by cooperation with modern world-wide enterprises who are featured by brand-new technology and advanced management. When referring to household energy, we have also realized its importance in lowering energy intensity though it is inferior to efficiency factors in contribution rate. Result analysis explains the reason why the energy intensity in total rose abnormally in 2002-2005. It is because of combined action made by structure adjustment, efficiency, and household energy factors in 2002-2003, and because of the former two in 2003-2004, and because of the first one in 2004-2005.

4. Conclusion and Implications

In conclusion, the overall energy intensity changes from industrial restructuring, technological progress and openness, and volume and utilization ratio of household energy. It is worthy of note that household energy has been playing an important role in total energy consumed so ignorance of its impact on energy intensity variation is reasonable in no way. As shown in result analysis based on modified Laspeyres decomposition method, it is up to efficiency portion, household energy portion, and restructuring portion according to the sequence order in lowering total energy intensity. Among them,
structure adjustment or restructuring factor plays a less important part owing to its slowness in transformation during a comparatively longer time span of twenty years which witness little influence on energy intensity drop as a whole. Besides, since we are, for the time being, in the mid-term of industrialization when the primary and secondary industries’ proportion in GDP is declining sharply in no way, it is easily understood that restructuring factor has limited contribution to overall energy intensity decrease.

It can be also learned from the article that in setting the objective and pathway in terms of energy-conservation under “the twelfth five-year plan” all industrial sectors involved, especially high-energy-consumption sectors should pay every effort on trade integration and technological advance in order to lessen energy intensity of the secondary industry. Having suffered from weaknesses of small scale, high energy consumption per unit product, fearful pollution in long run, the consuming enterprises specializing in metallurgy, non-ferrous metal, chemical engineering materials and so on are in bad need of business coordination and scale enlargement to strengthen their competitiveness and reduce energy consumption accordingly. In addition, it is indispensable to extend opening-up degree by cooperating closely with world well-known enterprises with high energy-saving technologies but low energy consumption and by cutting down imports of small-scaled and consuming projects. The research result in this paper also enlightens that the structure change and the utilization improvement of household energy can help accomplishing the project of energy saving, by guiding residents to use more clean energy and renewable energy and by promoting energy saving of buildings and household appliances.

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Reference


