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# Laspeyres Decomposition of Energy Intensity in Hebei Province

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**Abstract**

The method of Laspeyres index was used to decompose changes in energy intensity of Hebei province over the period 2005-2009. The results indicate that the technological effect has been the major factor causing the reduction of the energy intensity. The contribution of the technological progress accounts for as much as 92%, 99.11%, 72% at the area level, industry level and sub-sector level respectively. While the structural effect has also played a positive but a very minor role on the decline of energy intensity. Therefore, the main approaches to reducing energy intensity in Hebei province are to increase in R&D investment for promoting technology progress, accelerate the structure adjustment, attach great importance to the structural shift towards less energy-intensive subsectors, and enhance the supervision over important prefectures including such areas as Tangshan, Handan.



*Keywords*: energy intensity; Laspeyres index; technological effect; structurual effect

## 1. Introduction

Energy consumption intensity（defined as the quantity of energy used per unit of output or activity）can be used to reflect energy usage efficiency of an economy in the process of production and consumption of economy output. Fig. 1 depicts the changing of energy intensity in Hebei province during the period 1980-2009(at 1978 constant prices). It can be seen that the energy intensity of Hebei's regional domestic product(RDP) decreased overall except for several years, indicating the improvements in energy efficiency. However, it is still high compared to the national average level. According to the communique jointly issued by National Bureau of Statistics, National Development and Reform Commission and

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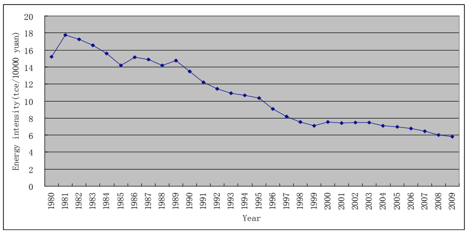
National Energy Administration, Hebei's energy intensity ranks 23rd among all 30 provinces in china. The energy consumption per unit of RDP in Hebei is 1.64 tce/ $10^4$ RMB (at 2005 constant price) in 2009, Which is equivalent to the national average value 1.2 times, and Beijing's (ranks the first) 2.7 times. The question then arises as to what are the driving factors of the changing energy intensity. It is crucial to fully understand these driving factors for analysts and policy makers concerned about Hebei's energy issues, especially those interested in future directions of energy demand, energy conservation, and preservation of environment.



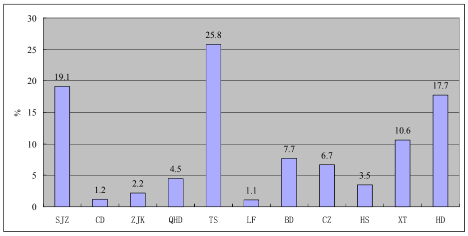




Fig. 1. change of energy intensity in Hebei province during 1980-2009; Fig. 2. The contribution share of each area

There have been a number of studies in the literature investigating factors influencing aggregate energy consumption intensity in China. Many studies have attempted to identify quantitatively the structure effect and efficiency effect of energy intensity, which respectively, capture the contribution of industrial structure change and the contribution of energy intensity change (also interpreted as technology change) to the change of energy intensity. Results can be categorized into three groups [1]: (1) Early studies show that structural shift plays more important role to China's energy intensity. Smil (1990) and Kambara (1992) have asserted that structural shifts from more energy intensive to less intensive sectors were the main factors responsible for the decline of energy intensity. World Bank and Zhang and Zhou [2] also argued that structural change is the main reason for the decline of energy intensity. (2) Real intensity change and structural shift play different roles over different periods of time. Zha et al. [3] analyzed the structural and intensity effects that affect energy consumption of 36 industrial sub-sectors from 1993 to 2003. The results showed that the real intensity change had played a more important role before 1998 while structural shift dominated after 1999. (3) However, more other studies hold that technological changes are more important factor in reducing energy intensity. Sinton and Levine [4] suggested that real intensity changes resulted in approximately 70% of the overall energy intensity decrease experienced in the industrial sector during this period, while structural changes contributed to approximately 30%. A similar conclusion was made by Garbaccio et al. (1999) for the 1987 to 1992 period, where they concluded that the fall in energy use during that time was mostly due to a fall in real energy intensity. In addition to determining that real intensity decreases was the major causal factor in leading to overall energy decline, they found that structural changes actually increased the use of energy over this period. Zhang [5] studied the energy use and industrial value added of 29 industrial sub-sectors for the 1990s, finding that the overwhelming contributor to the decline in energy use during this later time was a decline in real energy intensity. Besides,Wu and Cheng(2006), Qi and Chen (2006) and Han, Wei and Fan(2004) all confirmed that technological progress is the decisive factor of the energy efficiency improvement.

Although there have been these above examples in literature examining energy intensity in China, little attention has been given to understand the determinants of Hebei's energy intensity. Hebei located in northen China, with a population of about 70 million, is characterized with more heavy industry and consumed almost 10% of the country's total energy consumption. The demand for primary energy has outpaced its energy production since 1988. Nowadays, more than 50% of the energy has to be transferred from other provinces or to be imported from abroad. Low self-sufficiency rate of energy and a high degree of external dependence resulted in the balance of energy supply and demand always being a problem to be solved. Hebei's energy problem indicates some common with the national situation, and some personality problems. Given this fact, it is necessary to re-understand the influencing factors of the energy intensity in Hebei province.

The rest of this paper is organized as follows. Section 2 describes the decomposition methodologies and discusses the data to be used. Our results and analysis are presented in section 3. Section 4 concludes the paper.

## 2. Methodology and data

### *2.1. Methodology*

In this paper, we choose Laspeyres index method to decompose the changes of Hebei's energy consumption intensity between 2005 and 2009 into effects of structura1 shift and technological shift from three different aespects, i.e. area, industry and above designated size of sub-sectors.

We define the following terms:

$I_t$ :overall energy intensity of Hebei in year t

$E_t$: total energy consumption of Hebei in year t

$Y_t$: regional domestic product (RDP) of Hebei in year t (2005 constant prices)

$E_{i,t}$: energy consumption of different area($i$=11), different industry($i$=3), and different sub-sector($i$ =38) of Hebei in year t

$Y_{i,t}$: production of different area, different industry, and different sub-sector in year t (2005 constant prices)

$I_{i,t}$:energy intensity of different area($i$=11), different industry($i$=3), and different sub-sector($i$ =38) of Hebei in year t ($=E_{i,t}/Y_{i,t}$)

$S_{i,t}$::production share of different area, different industry, and different sub-sector in year t ($=Y_{i,t}/Y_t$)

The overall energy intensity of Hebei can be specified as follows:

$$I_t = \frac{E_t}{Y_t} = \frac{\sum_i E_{i,t}}{Y_t} = \sum_i \frac{E_{i,t}}{Y_{i,t}} \times \frac{Y_{i,t}}{Y_t} = \sum_i I_{i,t} \times S_{i,t} \tag{1}$$

And the change in total energy intensity from year (t-1) to year t can be decomposed as follows:

$$\Delta I = I^t - I^{t-1} = \sum_i (S_i^t - S_i^{t-1})I_i^{t-1} + \sum_i (I_i^t - I_i^{t-1})S_i^{t-1} + \sum_i (S_i^t - S_i^{t-1})(I_i^t - I_i^{t-1}) \tag{2}$$

$$\Delta I = \Delta I_{str} + \Delta I_{eff} \tag{3}$$

$$\Delta I_{str} = \sum_i (S_i^t - S_i^{t-1})I_i^{t-1} + \frac{1}{2}\sum_i (S_i^t - S_i^{t-1})(I_i^t - I_i^{t-1}) \tag{4}$$

$$\Delta I_{eff} = \sum_i (I_i^t - I_i^{t-1})S_i^{t-1} + \frac{1}{2}\sum_i (S_i^t - S_i^{t-1})(I_i^t - I_i^{t-1}) \tag{5}$$

Where $\triangle I_{str}$ represents energy intensity variation generated by structure effects of areas, industries or sub-sectors; $\triangle I_{eff}$ symbolizes energy intensity change resulting from energy utilization efficiency. If $\triangle I_{str}$ and $\triangle I_{eff}$ are less than zero, which means that the changes of them contribute to the reduction of the overall energy intensity. Otherwise, if $\triangle I_{str}$ and $\triangle I_{eff}$ are greater than zero, which indicates that the changes of them contribute to the rising of the the overall energy intensity.

The contribution share of the structural effect and technological effect can be calculated as follows:

$$C_{str} = \frac{\Delta I_{str}}{\Delta I} \times 100\,\% \tag{6}$$

$$C_{eff} = \frac{\Delta I_{eff}}{\Delta I} \times 100\,\% \tag{7}$$

*2.2. The data*

Considering the data limitation, we selected 2005-2009 as our study period and the data on energy consumption and corresponding output at different levels from 2005 to 2009 are collected accordingly. Concretely, at the regional level, there are 11 cities in Hebei province, the data of RDP and energy consumption of each city are collected from Hebei Economic Yearbook. RDP are converted to constant prices in 2005. In industrial aspect, the whole economy can be divided into three industries: primary, secondary, and tertiary industries. The secondary industry can be further disaggregated into 38 sub-sectors. We then classified the structural effect into two levels of industris (primary, secondary, and tertiary) and 38 sub-sectors. Just as a slight clarification, the data on the sub-sectors are "above Designated Size Industrial Enterprises by Industrial Sector". Since the price indices are only available at the levels of industries and sectors, value-added at constant prices at the level of sub-sector is derived using the price indices of associated sectors, assuming that the price indices of all the sub-sectors within each sector are the same as that of the sector. For the lack of data on value added of 38 sub-sectors in 2008, we calculated using interpolation method.

## 3. Results and discussion

In this section, Laspeyres index was used to the three sets of data to explore the contributions of the various effects to the changes in Hebei's energy intensity. The decomposition results are listed in Tables 1-3.

Table 1. Decomposition results at area level during 2005-2009

| Areas | Structure effect (*SE*) | Efficiency effect(*EE*) | Contribution share of *SE* | Contribution share of *EE* |
|---|---|---|---|---|
| Shijiazhuang(SJZ) | -0.0113 | -0.0507 | 0.08 | 0.82 |
| Chengde(CD) | 0.0075 | -0.0113 | -1.97 | 2.96 |
| Zhangjiakou(ZJK) | 0.0104 | -0.0175 | -1.46 | 2.46 |
| Qinghuangdao(QHD) | -0.0030 | -0.0116 | 0.21 | 0.79 |
| Tangshan(TS) | 0.0151 | -0.0985 | -0.18 | 1.18 |
| Langfang(LF) | 0.0012 | -0.0048 | -0.33 | 1.33 |
| Baoding(BD) | -0.0005 | -0.0200 | 0.20 | 0.80 |
| Cangzhou(CZ) | -0.0138 | -0.0078 | 0.64 | 0.36 |
| Hengshui(HS) | -0.0079 | -0.0033 | 0.71 | 0.29 |
| Xingtai(XT) | -0.0122 | -0.0221 | 0.36 | 0.64 |
| Handan(HD) | -0.0070 | -0.0502 | 0.12 | 0.88 |
| TOTAL | -0.0261 | -0.2977 | 0.08 | 0.92 |

A finding of Table 1 is that both technical progress and the change in the mix of cities decrease the energy intensity. The accumulated effect of technical progress is an decrease of 0.2977 tce/$10^4$ RMB, which accounts for 92% of the total intensity change. While the accumulated effect of the change in the mix of cities is an decrease of 0.0261 tce/$10^4$ RMB, which accounts for only 8% of the total intensity change. Which indicates that technical progress plays the dominant role in decreasing the energy intensity. Fig. 2. concretely depicts the contribution of the 11 areas, each area in Hebei province has a positive effect on the reduction of energy intensity over the observed period. Tangshan is the primary contributor, followed by Shijiahzuang and Handan. The accumulated contribution of Tangshan, Shijiahzuang and Handan are 25.8%, 19.1% and 17.7%, respectively. The least contributers are Langfang and Chengde, which respectively accounts for only 1.1~1.2%.

Table 2 also indicates that technical effect played the dominant role in decreasing energy intensity during 2005-2009. Hebei's energy intensity drops a total decline of 1.106tce/$10^4$ RMB. The accumulated effect of technical progress is an decrease of 1.096 tce/$10^4$ RMB, which accounts for 99.11% of the total intensity change. While the accumulated effect of the structure change is an decrease of 0.010 tce/$10^4$ RMB, which accounts for only 0.90% of the total intensity change.

Table 2. Decomposition results at the industrial level during 2005-2009

| Periods | Structure effect (*SE*) | Efficiency effect(*EE*) | Contribution share of *SE* | Contribution share of *EE* |
|---|---|---|---|---|
| 2005-2006 | 0.0636 | -0.2314 | -0.0575 | 0.2092 |
| 2006-2007 | -0.0311 | -0.2944 | 0.0281 | 0.2662 |
| 2007-2008 | 0.0923 | -0.4465 | -0.0835 | 0.4037 |
| 2008-2009 | -0.1348 | -0.1239 | 0.1219 | 0.1120 |
| 2005-2009 | -0.0100 | -1.0960 | 0.0090 | 0.9911 |

Table 3. Decomposition results at sub-sectors level during 2005-2009

| Sub-sectors | Structure effect (*SE*) | Efficiency effect(*EE*) | Contribution share of *SE* | Contribution share of *EE* | Contribution share of overall sub-sectors |
|---|---|---|---|---|---|
| Mining and Washing of Coal | 0.0750 | -0.2097 | -0.0465 | 0.1300 | 0.0835 |
| Processing of Petroleum, Coking, Processing of Nucleus Fuel | 0.0007 | -0.1334 | -0.004 | 0.0827 | 0.0823 |
| Manufacture of Raw Chemical Material and Chemical Products | -0.0262 | -0.1368 | 0.0163 | 0.0848 | 0.1010 |
| Manufacture of Non-metallic Mineral Products | 0.0085 | -0.1119 | -0.0053 | 0.0694 | 0.0641 |
| Smelting and Pressing of Ferrous Metals | -0.0310 | -0.4443 | 0.0192 | 0.2755 | 0.2947 |
| Production and Distribution of Electric Power and Heat Power | -0.4740 | 0.0311 | 0.2939 | -0.0193 | 0.2747 |
| The top-6 Energy-consuming Industries | -0.4470 | -0.10049 | 0.2772 | 0.6231 | 0.9003 |
| Other Industrial Sectors | -0.0014 | -0.1594 | 0.0009 | 0.0988 | 0.0997 |

A deeper looking at the sub-sectors, we can find that the top-6 energy-consuming industries play an critical and decisive role in decreasing the energy intensity. More than 90% of the reduction is attributed to the top-6 energy-consuming industries, while the contribution of other industrial sub-sectors is less tan 10%. Table 3 summarizes the decomposition results for all sub-sectors. From table 3, it can be seen that the sub-sector of “Smelting and Pressing of Ferrous Metals” makes the most contribution to the accumulated reduction in overall energy intensity. Of the 1.6127tce/$10^4$ RMB accumulated reduction in real energy intensity, the sub-sector accounts for 0.4753 tce/$10^4$ RMB, a contribution of 29.47%. Followed by the sub-sector of “Production and Distribution of Electric Power and Heat Power”, which accounts for 27.47% to the reduction. Furthermore, the contribution share of “Mining and Washing of Coal”, “Processing of Petroleum, Coking, Processing of Nucleus Fuel”, “Manufacture of Raw Chemical Material and Chemical Products”, “Manufacture of Non-metallic Mineral Products” are 8.35%，8.23%，10.1% and 6.41%, respectively.

## 4. Conclusions

This paper decomposed the energy consumption intensity in Hebei province over the period 2005-2009 into efficiency effect and structure effect by using refined Laspeyres index(a complete decomposing model) through three aspects of areas, industries and above designated size industrial enterprises. The results indicate that the technological effect has been the major factor causing the slowdown of the intensity decrease. The contribution of the technological progress accounts for as much as 92%, 99.11%, 72% at the area level, industry level and at the level of value-added structure of industries above the designated scale respectively. But more than that, the structural effect has also played an positive but a very minor role on the decline of energy intensity. Therefore, the main approaches to reducing energy intensity in Hebei province are to increase in R&D investment for promoting technology progress, accelerate the structure adjustment, attach great importance to the structural shift towards less energy-intensive subsectors, and enhance the supervision over important prefectures including such areas as Tangshan, Handan.

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