China's Energy Intensity Change from 1997 to 2007: A Structure Decomposition Analysis

Haiyan ZHANG [a]* and Michael L. LAHR [a]

ABSTRACT. China has relied on energy to stimulate its booming economy. Its share of world energy consumed rose to 14.2% in 2005 from 7.9% in 1978. Somewhat surprisingly, its rate of economic growth rate was about half its rate of energy consumption through 2000. This trend changed AFTER 2001 as energy consumption rose about 1.3 times more rapidly than did GDP through 2005. Through heavy governmental influence, energy intensity subsequently reduced through 2007, but just marginally. This paper uses the structure decomposition approach to understand key drivers behind China's energy intensity and China's energy consumption from 1997 to 2007. Using recently released Chinese economic input-output data; we decompose energy intensity into five determinants: energy efficiency, changes in share of value added, changes in production structure, changes in consumption volume, and changes in consumption structure. This paper provides insights into how changes in China's economic structure, technology, urbanization and lifestyle changes affect energy intensity.

Keywords: Energy intensity, Structure Decomposition Analysis, Urbanization, China

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[a] Bloustein School of Planning and Public Policy, Rutgers University, 33 Livingston Ave. New Brunswick, NJ 08901 USA.
[*] Corresponding author: *Email address:* haiyanz@eden.rutgers.edu (H. Zhang)

1. Introduction

Energy resources are an engine of economic growth for every country. Energy security and availability have always been hot topics in world political scene. However, energy is not only a necessity but also the main contributor to local air pollution and global climate change. The international dilemma for progress is finding a balance point among economic growth, energy security, and environmental protection across nations. This dilemma is even more troublesome for developing countries.

China is the largest developing country in the world. During the past three decades, China has enjoyed near double-digital annual economic growth. To support such rapid economic growth, China's energy consumption has increased fivefold from 603 million tons of coal equivalent (tce) in 1980 to over 3 billion tce in 2009. In 2009, China consumed 17% of the world's energy compared to 7.9% in 1978, making it the world's largest energy consumer. According to the International Energy Agency (IEA), this share will surge to 22% in 2035 (IEA, 2010a). Despite being the largest energy consumer, China's per capita energy consumption is only 1.60 tce/capita in 2008, about one third of the OECD average (IEA, 2010b). Given China's low consumption per-capita and its huge population size, potential for China's future energy consumption growth loams large. Since 1993, China has been a net energy importing country. In 2007, it was the second largest importer of oil and imports accounted for nearly half of its total oil consumption (IEA, 2010a). Energy security is and will be a big issue in China.

To alleviate energy security issue, China's energy policy focused most on improving energy efficiency. In its 11th five year plan, China self-imposed a goal of reducing energy intensity (energy consumption per GDP) by 20% from 2005 to 2010. Many administration policies, such as shutting down inefficient thermal power plants, contributed much to the steady declines of 14.38% of energy intensity from 2005 to 2009 (Chen & Chen, 2010). In the 12th five year plan, China introduce greenhouse gas emission into its energy-saving goals and announced it wanted reduce carbon intensity by 40%-45% by 2020 compared to 2005 levels (Seligsohn & Levin, 2010).

Although energy intensity tends to increase at the early stages of industrialization in many developing countries (Smil, 2003, p. 160), China's economic development during the 1980s and 1990s did not follow this pattern. It nearly halved from 0.512 tce/ thousand yuan in 1991 to 0.277 in 2000 (constant 1995 level). This trend reversed since 2001. Energy consumption grew 1.2-1.4 times more rapidly than GDP from 2001 to 2005. Although energy intensity declined rapidly from 1980 to 2000, it is still very high compared to other developed countries or even many developing countries. In 2005, China's energy intensity is 1.30 tce per one thousand dollars (2000 US dollar), which was 4.3 times the US level and 8.7 times the Japan level. The vast gap of energy intensity between China and other developed countries indicated there remained great potential for China to reduce its energy intensity. Understanding the major causes of China's recent energy consumption rise and changing energy intensity trend may help China manage the key driving factors and pave the way for the nation to fulfill its ambitious carbon-intensity target.

We use structural decomposition analysis (SDA) to analyze both the cause of China's recent energy consumption and energy intensity change. Changes in energy intensity are usually classified into two categories: efficiency improvement and structure shifts (Garbaccio, Ho, & Jorgenson 1999; Metcalf, 2008). Efficiency improvement refers to reduced energy use for a product within a particular sector while structure shifts refers to changes in the share of economic activities among sectors (shifting from energy-intensive activities to less energy-intensive activities).

Some SDA studies have analyzed the driving forces of China's energy consumption and CO_2 emission growth since economic reform. Lin and Polenske (1995) analyzed China's energy use from 1981 and 1987 and found that technical change nearly accounted for all of the energy intensity reduction, while structure shifts were actually responsible for a slight increase in energy intensity. Garbaccio, Ho, and Jorgenson (1999) extended the research boundary to 1987 and 1992 and found the similar result. Studying structural effect at different aggregation levels may have different results. Ma and Stern (2008) found that (1) structural shifts across major sectors increased energy intensity from 1980 to 2003; (2) structural change within major sectors decreased energy intensity from 1994 to 2003, and (3) the increase in energy intensity since 2001 was partly caused by technological regression. Peters, Weber, Guan, and Hubacek(2007) found that final demand growth led growth on China's CO_2 emissions from 1992 to 2002, while technology and efficiency improvements only partially offset the impact of consumption growth. Efficiency gains have little impact on China's CO_2 emission. Kahrl and Roland-Holst (2008) and Guan et al. (2008) argued that exports had become the largest source of energy demand and emission growth since China's accession to the World Trade Organization in 2001.

This study analyzes China's energy consumption and energy intensity from 1997 to 2007. In our SDA, we focus on the energy used to produce consumed goods and services. Energy directly consumed by households is not included in the SDA. Compared to previous studies, this paper examines the recent trajectory of both energy demand and energy intensity and compares the effect of these driving forces to both energy consumption and energy productivity from 1997 to 2007.

2. Method and Data

2.1 Structure Decomposition Analysis (SDA)

Structure decomposition analysis (SDA) is "the analysis of economic change by means of a set of comparative static changes in key parameters of an input-output table" (Rose and Miernyk, 1989). SDA is used to "disaggregate the total amount of change in some aspect of that economy into contributions made by its various components"(Miller and Blair, 2009, p. 593). SDA has been widely used in energy studies. SDA is based on input-output (I-O) tables that represent the monetary flows of goods and services between both economic sectors and production and consumption. Energy consumption change is decomposed into four partial effects: energy efficiency change ($\Delta\mathbf{e}$), changes in production structure ($\Delta\mathbf{L}$), changes in consumption structure ($\Delta\mathbf{B}$) and changes in consumption volume ($\Delta\mathbf{y}$). Energy consumption can be expressed as

$$E = \mathbf{e}\,(\mathbf{I}-\mathbf{A})^{-1}\,\mathbf{B}\,\mathbf{y} = \mathbf{e}\,\mathbf{L}\,\mathbf{B}\,\mathbf{y} \qquad (1)$$

Let n be the number of industries, the other definitions are as follows: E: total energy consumption; **e**: vector with elements e_i as energy input per unit of output of industry i. (n×1 vector); **I**: identify matrix; **L**: Leontif-inverse matrix, $\mathbf{L}=(\mathbf{I}-\mathbf{A})^{-1}$, it is a matrix of total input requirements; **B**: aggregated final demand for each of k categories (k=8, rural consumption, urban consumption, government consumption, gross fixed capital formation, inventory stock, export Import and other). (k×1 vector); **y**: final demand structure: (n×k matrix). Each cell is derived as the ratio of corresponding cell in final demand matrix to its column sum.

We could decompose energy consumption as:

$$\Delta E = \frac{E_1}{E_0} = \frac{\mathbf{e}_1\mathbf{L}_1\mathbf{B}_1\mathbf{y}_1}{\mathbf{e}_0\mathbf{L}_0\mathbf{B}_0\mathbf{y}_0} = \frac{\mathbf{e}_1\mathbf{L}_0\mathbf{B}_0\mathbf{y}_0}{\mathbf{e}_0\mathbf{L}_0\mathbf{B}_0\mathbf{Y}_0} \times \frac{\mathbf{e}_1\mathbf{L}_1\mathbf{B}_0\mathbf{y}_0}{\mathbf{e}_1\mathbf{L}_0\mathbf{B}_0\mathbf{y}_0} \times \frac{\mathbf{e}_1\mathbf{L}_1\mathbf{B}_1\mathbf{y}_0}{\mathbf{e}_1\mathbf{L}_1\mathbf{B}_0\mathbf{Y}_0} \times \frac{\mathbf{e}_1\mathbf{L}_1\mathbf{B}_1\mathbf{y}_1}{\mathbf{e}_1\mathbf{L}_1\mathbf{B}_1\mathbf{y}_0} \qquad (2)$$

$$= (2.1) \times (2.2) \times (2.3) \times (2.4)$$

Equation (2.1) represents the effects of changed energy input per unit of gross output by industry; Equation (2.2) represents the effects of changes in sub-industrial structure; Equation (2.4) is the effects of changed final demand structure; Equation (7.5) is the effects of changes in final demand.

The value added of each industrial sector (GDP) *V* can be represented as following:

$$V = \mathbf{v}\ (\mathbf{I}\text{-}\mathbf{A})^{-1}\ \mathbf{L}\ \mathbf{B} = \mathbf{v}\ \mathbf{L}\ \mathbf{B}\ \mathbf{x} \tag{3}$$

Where *V*: vector of value added. (*n*×1 vector); v: diagonal matrix with elements v_i as the value added per unit of output in industry in the diagonal. (*n*×*n* matrix);

Energy intensity could be written as:

$$\varepsilon = \frac{E}{V} = \frac{\mathbf{e}\ \mathbf{L}\ \mathbf{B}\ \mathbf{y}}{\mathbf{v}\ \mathbf{L}\ \mathbf{B}\ \mathbf{y}} \tag{4}$$

We can decompose the change of energy intensity as:

$$\frac{\varepsilon_1}{\varepsilon_0} = \frac{\left(\frac{\mathbf{e}_1\mathbf{L}_1\mathbf{B}_1\mathbf{y}_1}{\mathbf{v}_1\mathbf{L}_1\mathbf{B}_1\mathbf{y}_1}\right)}{\left(\frac{\mathbf{e}_0\mathbf{L}_0\mathbf{B}_0\mathbf{y}_0}{\mathbf{v}_0\mathbf{L}_0\mathbf{B}_0\mathbf{y}_0}\right)} = (5.1) \times (5.2) \times (5.3) \times (5.4) \times (5.5) \tag{5}$$

$$\frac{\mathbf{e}_1\mathbf{L}_0\mathbf{B}_0\mathbf{y}_0}{\mathbf{e}_0\mathbf{L}_0\mathbf{B}_0\mathbf{y}_0} \tag{5.1}$$

$$\frac{\mathbf{v}_0\mathbf{L}_1\mathbf{B}_1\mathbf{y}_1}{\mathbf{v}_1\mathbf{L}_1\mathbf{B}_1\mathbf{y}_1} \tag{5.2}$$

$$\frac{\mathbf{e}_1\mathbf{L}_1\mathbf{B}_0\mathbf{y}_0}{\mathbf{e}_1\mathbf{L}_0\mathbf{B}_0\mathbf{y}_0} \times \frac{\mathbf{v}_0\mathbf{L}_0\mathbf{B}_1\mathbf{y}_1}{\mathbf{v}_0\mathbf{L}_1\mathbf{B}_1\mathbf{y}_1} \tag{5.3}$$

$$\frac{\mathbf{e}_1\mathbf{L}_1\mathbf{B}_1\mathbf{y}_0}{\mathbf{e}_1\mathbf{L}_1\mathbf{B}_0\mathbf{y}_0} \times \frac{\mathbf{v}_0\mathbf{L}_0\mathbf{B}_0\mathbf{y}_1}{\mathbf{v}_0\mathbf{L}_0\mathbf{B}_1\mathbf{y}_1} \tag{5.4}$$

$$\frac{\mathbf{e}_1\mathbf{L}_1\mathbf{B}_1\mathbf{Y_1}}{\mathbf{e_1}\mathbf{L}_1\mathbf{B}_1\mathbf{Y}_0} \times \frac{\mathbf{v}_0\mathbf{L}_0\mathbf{B}_0\mathbf{Y}_0}{\mathbf{v}_0\mathbf{L}_0\mathbf{B}_0\mathbf{Y}_1} \tag{5.5}$$

Equation (5.1) represents the effects of changed energy input per unit of gross output by industry; Equation (5.2) represents the inversed effects of changes in value added's share of gross output by industry; Equation (5.3) represents the effects of changes in sub-industrial structure; Equation (5.4) is the effects of changed final demand structure; Equation (5.5) is the effects of changes in final demand levels.

2.2 Data Sources

This study required two types of data: I-O tables and corresponding energy consumption data. China has a long history of compiling I-O tables. The first I-O table in China was compiled in 1974 as physical forms for year 1973. Since 1987, Chinese government has started to compile both physical and monetary I-O tables every five years (Zhang & Zhao, 2009). To present, China has produced five benchmark tables for year 1987 (118 sectors), 1992 (119 sectors), 1997 (124 sectors), 2002 (122 sectors) and 2007 (135 sectors). China also constructed table for I-O tables at more aggregated level: for year 1990 (33 sectors), 1995 (33 sectors), 2000 (42 sectors), and 2005 (42 sectors).

The I-O tables used in this paper are the benchmark tables for 1997, 2002, and 2007 (National Bureau of Statistics [NBS], 1999, 2006, 2009). Since these tables have slightly different but comparable industry classification, we aggregated the I-O tables into a uniform classification with 92 sectors. In China's input-output model, final demand is divided into eight categories: 1) urban household consumption, 2) rural household consumption, 3) government consumption, 4) capital investment, 5) inventory change, 6) exports, 7) imports and 8) other. The "other" category is a residual term that ended the I-O accounts to balance.

The analysis of change in energy intensity over time requires all I-O tables to be used in the same set of prices. Since all the I-O tables used in this paper were published in current prices, they were adjusted to 2007 prices. As suggested by Yang and Lahr (2010), this paper uses the agriculture producer price index, free on board price index to adjust price for the first and second industry separately. For the tertiary and construction industries, an implicit GDP price index was used. It was dividing nominal GDP by real GDP of these industries. The primary source of energy flow data is *China Energy Statistical Yearbooks* (NBS, 2010). The energy data was produced for 44 industrial sectors.

3. Results

3.1 Energy End-Use Structure

According to IEA, industrial sector is the largest energy consuming sector in China in 2008. It accounted for 47.8% of total primary energy consumption. In US, it only accounted for 19.2%. In US, the sector consuming the most energy is transportation sector. It accounted for 39% of total primary energy consumption in 2008 while it only contributed 11.3% in China. Commercial sectors in China accounted for much a smaller share of energy consumption than it did the US (in Figure 1). These differences reflect the different stage of economic development of the two countries. China is a developing country that still heavily relies on its booming industrial sector, while both its transportation sector and commercial sectors are not yet as mature as developed western countries.

The *China Energy Statistical Yearbook* (2010) categorizes total primary energy consumption into agriculture sectors, industrial sectors, tertiary sectors and direct household consumption. In 2007, agriculture sectors account only 3.1% of total energy consumption.

Industrial sectors accounted for nearly 72% while manufacturing itself accounted for 59%. Tertiary sectors only accounted for 15% while direct household consumption accounted for 10%.

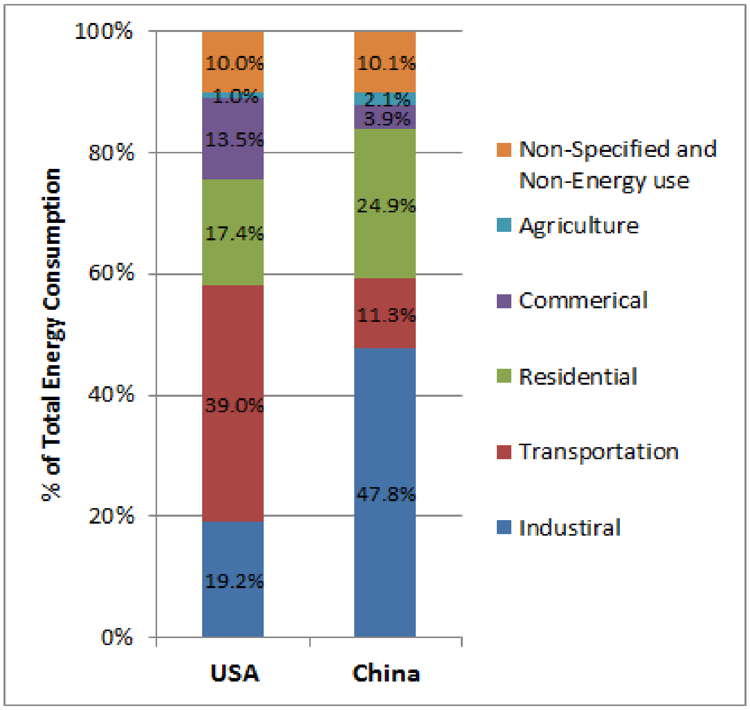

Figure 1: End-use energy consumption composition in 2008 Source: IEA 2011.

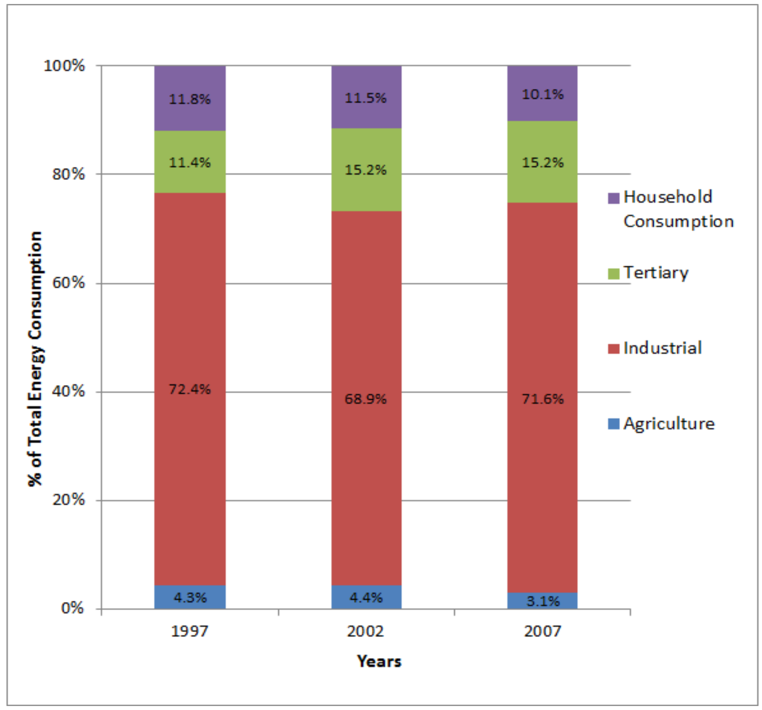

Figure 2: End-use energy consumption composition of China. Source: China Energy Statistical Yearbooks.

From 1997 to 2007, China's total energy consumption increased from 1.38 billion to 2.66 billion tce. About 8% of the rise happened between 1997 and 2002, while 92% happened during 2002 and 2007. During the earlier period, most energy consumption rise (67%) occurred in tertiary sectors. The tertiary sectors' share increased from 11.4% to 15.2%. Energy consumption in transportation, storage and postal services increased 47% and energy consumption in wholesale, retail trades, hotel, and catering services sectors increased 45%. From 2002 to 2007, most of the increment (75%) occurred in the industrial sector. Energy consumption increased 86% while energy consumption in manufacturing sector nearly doubled. Transportation's consumption of energy also grew fast from 2002 to 2007, it increased 86%. For construction sector, energy consumption increased 37% from 1997 to 2002 while it increased 150% from 2002 to 2007.

3.2 Driving Factors of Energy Consumption and Energy Intensity

As shown in Figure 3, China's production related to energy consumption had increased 7.4% from 1997 to 2002 and 60% from 2002 to 2007. Between 1997 and 2002, two main factors impact the growth in energy consumption: an increase of final demand level ($\Delta\mathbf{y}$) and efficiency gains ($\Delta\mathbf{e}$). Final demand level alone would drive 53.3% of energy consumption increase by keeping other driving forces constant. By contrast, efficiency gain was a strong driver (-39.6%) in offsetting energy consumption increase. Production structure ($\Delta\mathbf{L}$) and consumption structure ($\Delta\mathbf{B}$) are relatively week factors by offsetting only 1.6% and 4.8% of energy consumption increase. Between 2002 and 2007, three main factors impact the growth in energy consumption: efficiency gains, production structural shift and consumption level. Final demand level ($\Delta\mathbf{y}$) would drive 59.9% of energy demand increase while production structure change ($\Delta\mathbf{L}$) would increase energy demand by 23.3%. By contrast, efficiency gain ($\Delta\mathbf{e}$) only offset 23.3% of energy demand increase.

These factors played different roles during two five years from 1997 to 2007. The impact of efficiency gain ($\Delta\mathbf{e}$) decreased from 39.6% to 23.9%. Energy efficiency gain offsets most of impact of final demand level increase while this factor only offsets most of small part of final demand level ($\Delta\mathbf{y}$) increase. The decreasing impact of energy efficiency gain could be explained by the falling proportion of investment in energy efficiency, decreasing effect of technical innovation and price impact. Lin (2007) indicated that the declining commitment to energy efficiency in both financial and policy supports was responsible for a reversed energy intensity trend since 2001. Andrew-Speed (2009) also indicated that decreasing rate of technical innovation is responsible for the reversed energy intensity trend. Huang and Tu (2007) found that the role of price effects of electricity in increasing energy efficiency weakened after 1995 due to rapid income rises.

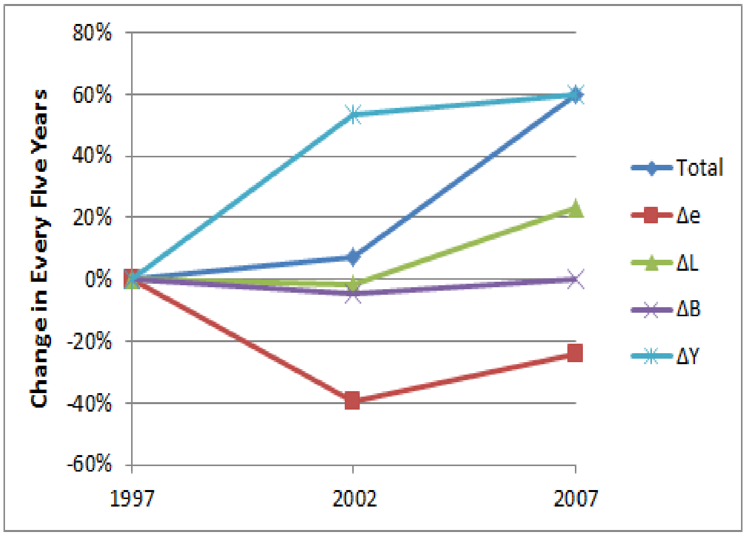

Figure 3: the contribution ratios of determinants of energy consumption.

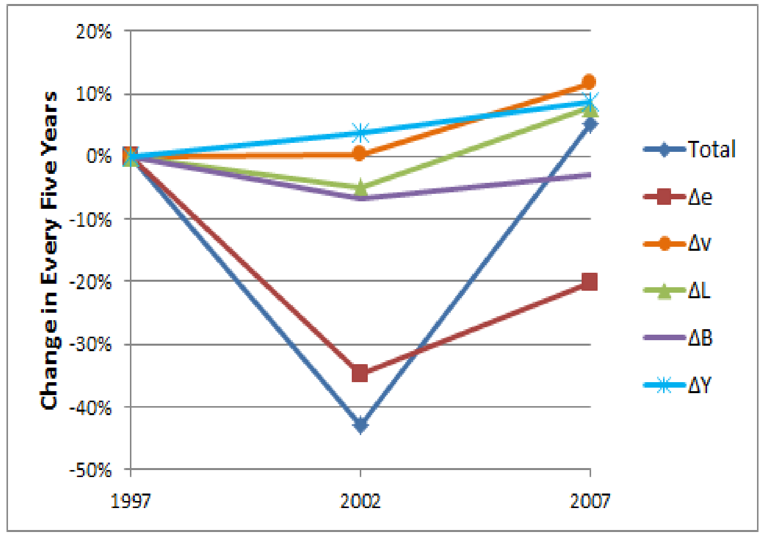

Figure 4: the contribution ratios of determinants of energy intensity.

Unlike the weak impact (-1.6%) between 1997 and 2002, structural shifts would drive 23.3% of energy consumption increase. Production shifted towards more energy intensive sectors between 2002 and 2007. Between 2002 and 2007, China's total economic output increased 112% of which 74% occurred in industrial sectors. Most of the output increment occurs in the heavy energy consuming sectors. Output of petroleum, chemical and nonmetal mineral sectors and metal smelting, pressing and metal products sectors increased 143% and 155% respectively. Output of manufacturing sectors increased 233% while utility sectors increased 234%. The shift of production towards heavy industrial sectors during 2002 to 2007 explained the driving effect of structural shifts.

Energy intensity indicates energy productivity in a country. Energy intensity decreased 42.9% from 1997 to 2002, while it increased 5.1% from 2002 to 2007. Between 1997 and 2002, efficiency gains (Δ**e**) is the main factor that drove energy intensity change. Efficiency gains (Δ**e**) accounted for 34.8% of the decrease in energy intensity. Production structural shift (Δ**L**) and consumption structure (Δ**B**) had relatively smaller factors, accounting for 5.1% and 6.8% of the energy intensity decrease. By contrast, final demand levels (Δ**y**) drove 3.7% of the energy intensity and the value added share of output had little impact on energy intensity. Between 2002 and 2007, efficiency gains (Δ**e**) induced 20.3% of the decrease in energy intensity while consumption structure (Δ**B**) affected 2.9% of the decrease. However, value added's share of output (Δv^{-1}), production structure (Δ**L**), and final demand level (Δ**y**) would cause 11.6%, 7.9% and 8.7% of energy intensity increase.

The SDA analysis of energy intensity shows that the effect of energy efficiency gains (Δ**e**) consistently decreased during the study period. Changes in the structure of final demand (Δ**B**) decreased energy intensity during these 10 years. This corresponds with the effect of consumption structure of energy consumption. Input mix (Δ**L**) also caused increases in energy intensity between 2002 and 2007 as production shifted to heavy energy-consumpting sectors.

Shift in final demand levels drove the increase of energy intensity during these 10 years. This effect was higher from 2002 to 2007 than from 1997 to 2002. This indicates that increasing final demand level did not have a scale effect on decreasing energy intensity, actually this drive up the energy intensity (*some explanation here*). Also, the ratio between GVO and GDP would drive energy intensity increase by 11.6%. This could be partly explained by the increasing trend in the GVO-GDP ratios from 1997 to 2007. The ratio increased from 2.53 in 1997 to 2.6 in 2002 to 3.28 in 2007. Also this effect of inversed value added effect indicated that increasing competition of productions domestically and internationally actually helped decrease energy intensity between 2002 and 2007.

3.3 Indirect energy consumption by final users

The indirect energy consumption of different final users' is shown in Figure 5. The indirect energy indicates energy consumed through goods and services. From 1997 to 2002, indirect energy consumed through final demand sectors increased 34 million tce while it rose 784 million tce from 2002 to 2007. From 1997 to 2002, 71.3% of the energy increase was due to household consumption while export sectors contributed 20.9% of the increment. From 2002 to 2007, 57.2% of the energy demand increase was due to the production of exported goods and services for consumption in other countries. Another 27.3% of energy demand increase was due to capital formation. Only 9.6% was triggered by energy demand of households and 6% was triggered by governmental expenditures. In summary, while household caused most of the change early on the study period, the boom of export production was the driving force to China energy consumption's recent surge.

From 2002 to 2005, the top three export production sectors that increased the energy consumption the most were metal smelting, stamping and metal products (24.4%), petroleum, chemical and nonmetal products (23.1%), and mining (10.6%). China tried to avoid direct export of raw material/ resource-intensive products and reined the surging export by reducing or removing export tax rebates. For example, China started to adjust export rebates to discourage export of oil products and raw metal (Xinhua News, 2005, 2006). However, from 2002 to 2007, China's export of rolled steel rose from 5.45 million tons in 2002 to 62.5 million tons in 2007 while exported refined petroleum products increased from 10.68 million tons to 15.51 million tons. In essence, despite pulling back export tax rebate, export of energy-intensive goods grew faster than other goods. Still, there is a rough balance between energy consumption embodied in exports and energy avoided by imports. This is determined by assuming that China has the same industrial energy-efficiency level as countries of imports. Actually, the energy efficiency in China is lower than that of its trade partners, so energy embodied in import products is higher actually overstated somewhat.

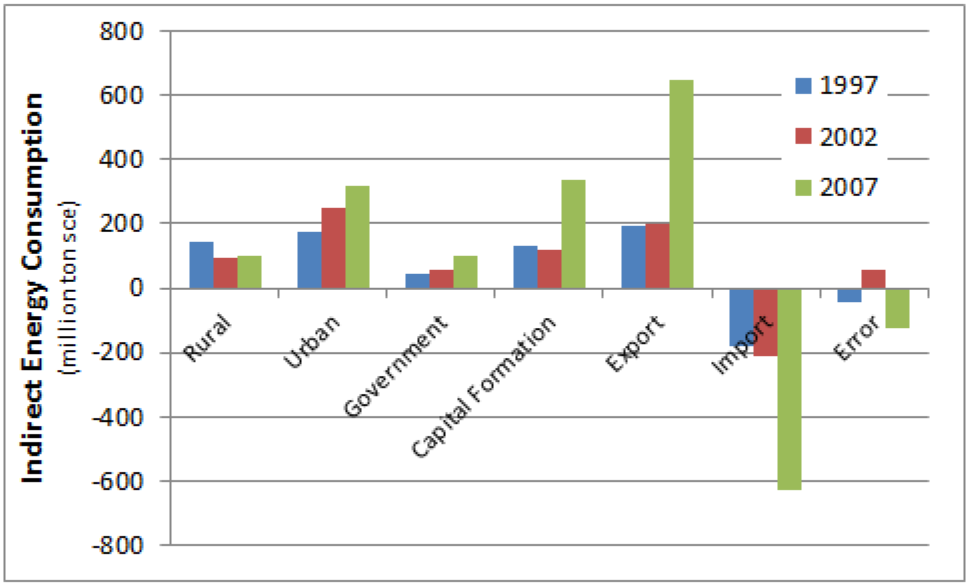

Figure 5: The final demand categories causing the increase in energy consumption

The export of electronic products represents the other side of the coin by displaying China's focus on encouraging exporting higher value-added items. For example, the production of motor vehicles and chassis parts nearly increased 13 folds from 43.5 thousand units in 2002 to 608 thousand units in 2007. The electronic products sectors accounted for only 6.4% of total rise in export-based energy use but contributing 35.9% of total export output increment.

3.4 The Role of Household Sectors and Urbanization

From 1997 to 2007, the direct composition of energy is decreasing from 11.7% to 10.1% of all household consumption. Among final demand categories, the households' share of indirect energy consumed decreased most from 46.6% to 27.8%. This is because household spending increased more slowly than did other final demand such as exports. Figure 5 may mask the energy consumption story of rural and urban households during the study period. However, household direct energy consumption increase 4.1% from 1997 to 2002 but surged by 57% from 2002 to 2007. Embodied energy consumed by household sector increased 7.7% from 1997 to 2002 and 22% from 2002 to 2007.

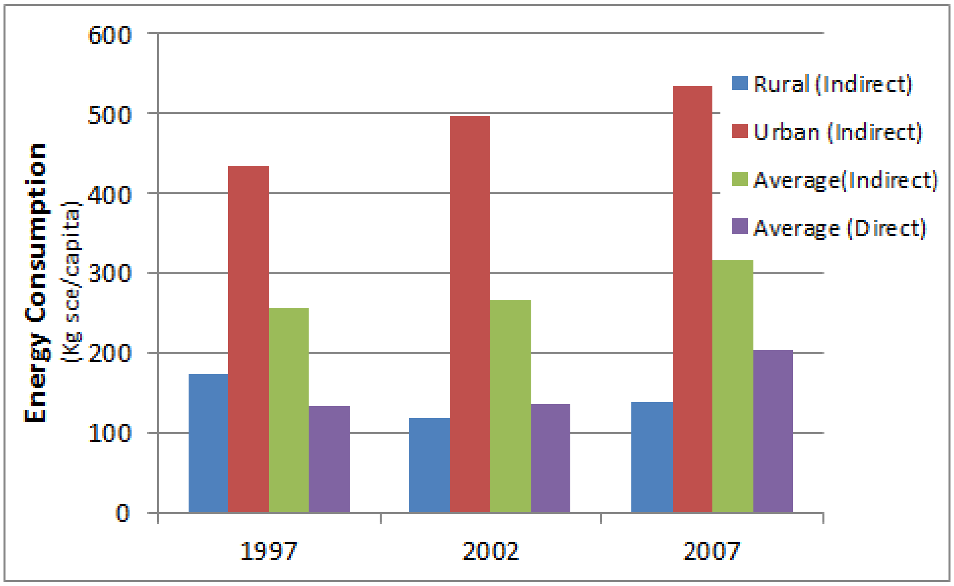

Figure 6: Per capita household energy consumption

Besides the rapid rise in overall energy use in the early 1980s, per capita residential direct energy consumption was fairly constant from 1985 to 2002. But it rose by 49% from 137 kg coal equivalent (kg ce) to 234 kg ce between 2002 and 2007. Beside direct energy consumption, household's consumption embodied large amounts of energy via the goods and services. In 2007, household indirect energy consumption is 55.5% higher than direct energy consumption. There is huge gap between rural and urban residents in indirect energy consumption. As shown in Figure 6, urban residents consumed 534 kg ce in 2007 while rural residents only consumed 138 kg ce. The disparity between urban and rural residents in indirect energy consumption increased from 1997 to 2007. The ratio of indirect energy consumption between urban and rural residents rose from 2.51 in 1997 to 3.86 in 2007. The disparity undoubtedly is explained by rising gap between urban and rural residents in their ratio of per capita annual income increased from 2.47 in 1997 to

3.33 in 2007. Most of the increment increased in the service sectors. Service sectors account for 66.7% of the increment from 1997 to 2002 and 52.1% of the increment from 2002 to 2007. Household expenditure in agriculture sectors increased 12.7% from 1997 to 2002. However, household expenditure in agriculture sector decreased 16.2% while expenditure in food and tobacco products increased 29.3% from 2002 to 2007. The expenditure shifting from agriculture sectors to food sectors indicates the improving living conditions.

China experienced rapid urbanization during the past 30 years. Its share of population in urban areas increased rapidly, from 19.4% in 1980 to 47% in 2010. According to UN estimates, this share will keep increasing to 62% in 2030 and 73% in 2050 (UNDESA, 2009). The number of households grew at an even faster pace from population as the average household size decreased from 4.5 to 3.5 from 1985 to 2000. This added 80 million households more in China (Liu & Diamond, 2005). Small household tend to be less energy efficient than larger ones, at least on a per capita bases. With rapid rises in direct per capita household energy consumption, increasing disparities between rural and urban household consumption, along with ever-rising household numbers, the household sectors will continue to have major effects on energy use and CO_2 consumption.

Increased household energy consumption in China is driven by a combination of both increasing rates of urbanization and rising urban households spending. Although urban households shift toward consuming services that are less energy-intensive. Their overall increased consumption of energy-intensive products such as homes and electrical/electronic appliances continue to outpace any efficiency gains and positive structural shift. Energy and environmental pressure will continue from increasing household consumption, and rising urbanization. It will possibly hampering continued development of China’s economy.

3.5 Inaccurate Statistics

Since we utilize sector-level energy and economic data from National Bureau of statistics in IOA and SDA analysis, data uncertainty may have significant effect on our result. According to reported data, total energy consumption in China is decreasing from 1996 to 1999. Many observers argued that the reported data is inaccurate. This is due to a significant decrease in coal consumption from 1996 to 2000. In late 1990s, China energy policy was target at shutting down inefficient small coal mines. Sinton (2001) argued that energy statistics may be understated as a result of omission by those small coal mines that supposed to be shut down. Satellite observation indicates that there was significant underreporting of coal consumption during 1996-2003 (Akimotom Ohara, Kurokawa, and Korii, 2006). So, two of the data points 1997 and 2002 are affected by the unusual coal consumption. Peters et al. (2007) found that only 2002 differ significantly from the historical trend. This may explain the low energy consumption increment rate between 1997 and 2002. Future research is needed to adjust the coal consumption in 2002 to reflect the historical trend.

4. Conclusions

Energy efficiency gains do not appear to have much impact on reducing China's energy consumption. The problem, however, was that the significant efficiency gains were offset by the effect of final demand rises. The net result was that China's commitment of reducing 40%-45% carbon intensity by 2020 to come true in doubt. The rise in energy demand caused sharp increases in investment in energy infrastructure over shadowing investment in energy efficiency measures since the mid-1990s. It appears that every demand will continue to rise in China. So, committing continued investment in energy efficiency in Beijing and encouraging technical innovation remain to permanent concerns for Beijing.

Increases in energy consumption related to household sectors appeared to be driven by a combination of urbanization and income-driven lifestyle changes. Although household expenditures are shifting towards less-energy intensive service sectors, increased overall household spending and direct energy consumption through lighting and household appliances greatly outpaced any efficiency gains. Since energy consumption per capita in China is only a third of that in OECD countries, the energy demand pressures from increased household consumption, urbanization and demographical change will continue to shape China's economic development.

Recent shifts in industrial structure also forced China to take backward steps in its energy goals. China's exports explained more than half of China's risen energy consumption. This is despite China's attempt to rein the export of energy-intensive goods by reducing tax rebate. Beijing should either tax its energy resources to recover cost of externalities or produce incentives to adjust the export structure toward higher value-added, less energy-intensive items.

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