

Analysis of urban sprawl, economic structure and energy consumption in Shanghai, China during 1995-2006

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Abstract: Concerning about the rapid energy consumption growth in recent China, this study takes Shanghai as a case and puts forward that energy consumption has high relationship with urban land use area, economic structure and sectoral energy efficiency, and then employed the index decomposition analysis (IDA) to measuring the contribution of these three indices, which has become critical tools for clearing the effect of related indicators.

Keywords: urban sprawl, economic structure, energy consumption, Shanghai

1. Introduction

Energy consumption is one of the essential issues to control climate change and global warming. The governments of both developed and developing countries have made continuous efforts in the past years to work on the controlling energy consumption for the purposes of sustainable development and environmental protection. Numerous practices in the energy efficiency have been carried out in developed countries such as [ADEME, 1999](#) and [Asia Pacific Energy Research Centre, 2002](#).

China is the country with the largest population in the world and its economic is growing fast. If this economic growth persists, Chinese energy consumption will represent an increasingly significant fraction of global energy consumption for its energy use has been of 8-10% per year. As a consequence, future developments in China are of great importance to the future of the global energy system and its related environmental impacts.

This study has two objectives: first, as a case study of Shanghai, China, analyze the historical land use change, economic structural transformation and energy consumption; second, what is the relationship between land use change, economic structural change and energy consumption; calculate the drive forces of energy consumption changes from quantitative perspective.

2. Methodology

In general, energy consumption change over time for a variety of reasons, for examples, growth in economic output, changes in economic structure, changes in sectoral energy intensities and changes in land use, etc. A key method for understanding the relative contribution of each of these effects is index decomposition analysis ([Ang, B.W., 1995](#)). Many energy researchers have proposed and adopted the index decomposition analysis to study the impacts structural change and sectoral energy intensity change (i.e. changes in the energy intensities of industrial sectors) on trends in energy use in industry ([Greening et al., 1997](#); [Ang and Zhang, 2000](#); [Ang and Liu, 2001](#); [Chris, 2001](#); [Ang, B.W., 2004](#)).

Given the rapid changes in the Shanghai energy consumption system, the log mean Divisia index (LMDI) method is employed which is recommended for general use, to analyze the affection of Shanghai's economic structure and land use to aggregate energy consumption.

Following the derivation in [Boyd et al. \(1988\)](#) and [Liu et al. \(1992\)](#) and using the logarithmic mean weighting scheme of [Ang et al.\(1998\)](#), this aggregate energy consumption changes may be decomposed into the following components:

$$\Delta E_{tot} = \Delta E_{urban} + \Delta E_{str} + \Delta E_{int}$$

where the terms on the right hand side are related to the urban land use area, economic structure and sectoral energy intensity respectively. Through this approach, we are purchasing the relationships between energy consumption, land use and economic structure.

3. Results

Fig. 1 shows the calculated decomposition results including urban sprawl, economic structure and energy intensity factors.

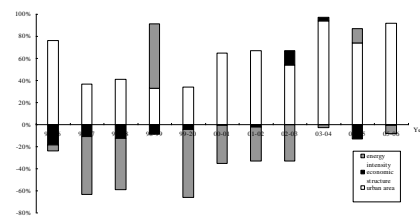


Fig. 1 Presentation of energy change decomposition result: 1995-2006

ΔE_{tot}	ΔE_{urban}	ΔE_{str}	ΔE_{int}
28.34	49.05	-4.61	-16.10

Table 1 Results of energy consumption decomposition for Shanghai, 1995-2006. Unit: Mtce

Results from aggregate energy consumption changes IDA at the sector level are shown in Fig. 1 and Table. From Fig. 1 and Table 1, it can be seen that Shanghai aggregate energy consumption increased by 89.7% or 28.34 Mtce from 1995 to 2006. The decomposition results show that: The urban sprawl increased led to an increased almost 1.73 times to the aggregate energy consumption increased. The result suggests a strong relationship between the two sets of variables, which implies that the impact of urban sprawl on energy consumption of Shanghai is very significant as predicted. Due to economic structural change and a reduction in total energy intensity, energy consumption growth is lower than urban sprawl speed. The economic structural change caused an energy consumption reduction about 4.61 Mtce, and energy intensity change caused 16.10 Mtce reductions. The impact of economic structural change is not as significant as expected and its impact is lower than the energy intensity, but relatively speaking the contribution is stable, which ranges from -1.23 Mtce to 1.08 Mtce as Table 2 suggested. On the other hand, the energy intensity caused changes is not smooth but generally has improved the aggregate energy consumption.

Year	ΔE_{urban}	ΔE_{str}	ΔE_{int}	ΔE_{tot}
1995-1996	5.13	-1.23	-0.39	3.51
1996-1997	3.76	-1.10	-5.40	-2.74
1997-1998	2.98	-0.92	-3.38	-1.32

1998-1999	3.24	-0.84	5.68	8.09
1999-2000	3.83	-0.51	-6.96	-3.64
2000-2001	3.14	-0.02	-1.67	1.45
2001-2002	3.69	-0.11	-1.72	1.85
2002-2003	4.34	1.08	-2.64	2.77
2003-2004	5.19	0.20	-0.13	5.26
2004-2005	6.28	-1.10	1.12	6.31
2005-2006	7.47	-0.05	-0.61	6.81
Total	49.05	-4.61	-16.10	28.34

Table 2 Variables' results of energy consumption decomposition for Shanghai, 1995-2006. Unit: Mtce

Year	Agriculture	Industry	Services
1995-1996	0.12	-1.93	0.19
1996-1997	-0.11	-6.51	0.12
1997-1998	-0.05	-4.47	0.22
1998-1999	0.00	4.72	0.12
1999-2000	-0.03	-7.57	0.13
2000-2001	0.07	-2.25	0.49
2001-2002	-0.11	-2.21	0.49
2002-2003	-0.11	-1.88	0.42
2003-2004	-0.13	-2.05	2.25
2004-2005	-0.22	0.24	0.01
2005-2006	-0.28	-0.82	0.44
Total	-0.86	-24.73	4.88

Table 3 Results of economic structure decomposition for Shanghai, 1995-2006. Unit: Mtce

Table 3 shows the sectoral detail decomposition results obtained using the decomposition formulae. The sectoral impacts on aggregate energy consumption can be described as following: ①Industry is the most important attribution in reduction of energy consumption which caused -24.73 Mtce reduction of energy consumption totally. The number of years that energy consumption reduction (-) occurred in industry sector, meaning that the energy-intensive industry operated with "sufficient" energy efficiency. The industry intensity changes caused energy saving shows this point by locating most of the results in improvement region, which is -19.74 Mtce totally. The general trend of a decreasing in industry energy intensity associated low increase rate of total industry energy consumption may be attributed to the technologies used and the management experiences accumulated over the years. ②The occurrence of energy reductions (-) caused by industry sector change does not guarantee the same reduction rate of energy consumption for the services sector's energy consumption increased so rapidly. Both of aggregate impacts on the aggregate energy consumption in economic structural change variable and sectoral energy intensity variable are positive, 1.29 Mtce for economic structural change and 3.85 Mtce for sectoral energy intensity variable. ③The agriculture sector improved aggregate energy consumption but very limited. For the economic structural change variable, the agriculture sector has positive contribution on the improvement of energy consumption most of the years, which is 0.90 Mtce (-). Compared in the sectoral energy intensity variable, it generated about 0.05 Mtce (+) energy consumption increase.

Overall, the decomposition analysis yielded results from quantitative point of view about the drive forces of energy consumption and that confirmed and reinforced the findings from the previous analysis. While energy consumption increase are thought to urban sprawl more strongly than economic structure and sectoral energy

intensity. Nevertheless, there are limits to the urban sprawl, how to change economic structure and improve the sectoral energy intensity must cause more attention in the future.

4. Conclusion

The application results indicate that the selected indices can capture the typical features and interior sectoral differentia of energy consumption in Shanghai. Urban area in Shanghai has kept fast growing with large amount during 1995-2006 period, economic structure improvement and increased sectoral energy efficiency indicating the energy consumption growing tendency of Shanghai. The following conclusions are identified by the results obtained: (1) spatial sprawl—rapid urban expansion, irregular of landscape, acted to drive up energy consumption increased sharply, and the relationship between them is complex nonlinear; (2) unadvisable pattern of economic structure did limited contribution to reduce aggregate energy consumption; and (3) considering uneven development in different industries plus urban sprawl, it is a most arduous task to reduce energy consumption further for Shanghai city.

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