Urbanization impact on energy demand and CO_2 emission in China

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Abstract: Urbanization has been believed a driving force of GDP growth in China. In the other hand, urbanization will also impose some impact on energy demand and CO_2 emissions. The calculation method of this impact is presented in this paper. It has been assumed that in 2003 the urbanization rate in China will have a unit (1 %) growth, GDP growth and its partition in agriculture, secondary industry and tertiary industry are calculated. The corresponding energy demand for GDP growth, household and transportation and CO_2 emissions are further calculated. The calculation has been carried out by a computer program NICE III developed in LCA Research Center AIST Japan. It has been found that 1 % increase of urbanization rate will cause 1 % of total energy demand and 1.2 % CO_2 emissions in China in 2003.

Keywords: urbanization; energy demand; CO_2 emissions; China

1. Introduction

Urbanization is going on in many developing countries. Up to now, urbanization rate in China is probably 35 %, lower than many developing countries. From World Development indicators published by World Bank, in 1999, Brazil was 80.72 %, Malaysia was 56.6 %.

Some Chinese experts have stated that urbanization rate is a driving force of GDP growth in China (Wu Liangyong, 2003). We use empirical production function, build a national GDP model, and find that urbanization in China is an integrated indicator of labors and education level of labors. GDP has been growing with the increase of urbanization rate in China (YAGITA, WEI et al, 2003).

In the other hand, urbanization will have some impact on energy demand and CO_2 emissions. The impact is from twofold: GDP increase and immigrants from rural area to cities.

With the growth of GDP, energy demand will increase in the first, secondary and tertiary industry sectors. Disposable income of a family will also increase with the GDP growth, and that will stimulate people to buy more electrical facilities such as air-conditioners and consume more energy in families. Economic activity needs support of transportation; the growth of GDP will also cause the growth of transportation and requires more energy. The increased disposable income will cause more transportation by travelers via private cars and public transportation. Immigrants from rural area to cities consume more energy because of the energy consumption difference between rural area and cities. This mainly includes energy consumption in household and transportation.

This paper has been organized as following. The calculation method of urbanization impact is in the next section, the results are in the third section, and followed by some conclusions in the end.

2. Calculation method and calculation tool

This section introduces the calculation method of impact on some important aspects. Those mainly include the impact on national GDP, the impact on energy in secondary industry and energy in household section, and transportations. The increased amounts of various types of energy demand in industry sectors, and transportation are calculated by energy intensity in baseline year 1999. CO_2 emission is calculated by the CO_2 emission coefficient multiplied by the corresponding energy amount.

2.1. GDP and its energy demand

Some researchers have studied to use production function to calculate national GDP. Chow et al (2002) used Cobb-Douglas production function established GDP models for China mainland and Taiwan. From statistics point of view, McCoskey Suzanne and Kao Chihwa (1999) proved that urbanization rate is a shift variable in this sort of GDP model.

As has been found in our paper (YAGITA, WEI et al, 2003), based on empirical production function, national GDP in China can be expressed as:

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$$GDP = 0.8025 \times K^{0.902} \times UR^{0.521} \quad (1)$$
$$R^2 = 0.99$$

where K is capital stocks; UR is urbanization rate; R is regression coefficient.

To calculate the GDP increment because of the increase of urbanization rate, a derivative operation has been carried out. The derivative of GDP reads:

$$\mathrm{d}GDP = \frac{\partial GDP}{\partial UR}\mathrm{d}UR + \frac{\partial GDP}{\partial K}\mathrm{d}K = 0.418 \times K^{0.902} \times UR^{-0.479} \times \mathrm{d}UR \quad (2)$$

$\mathrm{d}K$=0 has been assumed for the sake of investigation of urbanization.

Change this equation, and rewrite it in finite difference form, that reads:

$$\frac{\Delta GDP}{GDP} = 0.521 \times \frac{\Delta UR}{UR} \quad (3)$$

If 35.04% is the urbanization rate now, from the formula above, 1% increase of urbanization rate will result in 1.5% GDP increase.

This national GDP increase consists of GDP in agriculture, GDP in secondary industry and GDP in tertiary industry that are also related to urbanization rate in China (WEI, YAGITA et al, 2003).

$$GDP_A\% = 1565.9 \times UR^{-1.2761}$$
$$GDP_T\% = 2.31 \times UR^{0.777} \quad (4)$$

Using the same technology above, the relative increases of GDP percentage in agriculture and tertiary industry follow

$$\frac{\Delta GDP_A\%}{GDP_A\%} = -1.2761 \times \frac{\Delta UR}{UR}$$
$$\frac{\Delta GDP_T\%}{GDP_T\%} = 0.777 \times \frac{\Delta UR}{UR} \quad (5)$$

With those formulas, it can be concluded that the GDP percentage in agriculture is going to drop rapidly with the urbanization process, while the percentage of tertiary industry will grow. The percentage change of secondary industry depends on changes in agriculture and tertiary industry. Because the secondary industry consumes more than half of total energy demand in China, the secondary industry has been further divided into 11 sub-sectors. The GDP value in every sub-sector is calculated based on the government planning of industries.

2.2. Energy demand in household

Energy demand in household is directly related to disposable income in a family. When people have more money, they will buy more electricity facilities. Energy demand will increase. In the other hand, they will also use more efficient and more convenient energy types and energy saving facilities; energy like coal and facilities with very low energy efficiency will be phased out.

In China, there is a big difference of disposable income in a family between urban area and rural area. Using data from China Statistic Yearbook (2002), the regression model of disposable income per capital for urban area and rural area have been found that are related to GDP per capital. The disposable income will increase with the increase of GDP. Their relationships are:

Urban area

$$DispIncome_U = 1.2879 \times (GDP / Cap)^{0.94} \quad (6)$$

Rural area

$$DispIncome_R = 0.988 \times (GDP / Cap)^{0.836} \quad (7)$$

where GDP/Cap is GDP per capital.

DispIncome_U is disposable income per capital in urban area

DispIncome_R is disposable income per capital in rural area.

The increment of disposable income for urban area and rural area with respect to GDP can be expressed as:

$$\Delta DispIncome_U = 1.21 \times \frac{GDP^{-0.06}}{Population^{0.94}} \Delta GDP$$
$$\Delta DispIncome_R = 0.824 \times \frac{GDP^{-0.166}}{Population^{0.834}} \Delta GDP \quad (8)$$

where population is the population size in China

This increase of disposable income will result in the drop of coal use in household. The amounts are calculated by following equations:

In urban area

$$\Delta Coal/Cap_U = -1.29 \times DispIncome_U^{-2.7868} \times \Delta DispIncome_U \quad (9)$$

In rural area

$$\Delta Coal / Cap_R = -2E-08 \times \Delta DispIncome_U \quad (10)$$

where Coal/Cap_U is coal consumption per capital in urban area; Coal/Cap_R is coal consumption per capital in rural area.

In the other hand, the use of non-coal energy will increase. The calculation formulas are as following:

$$\Delta NonCoal / Cap_U = 8\times10^{-6}\times\frac{\Delta DispIncome_U}{DispIncome_U}$$

$$\Delta NonCoal / Cap_R = 1\times10^{-6}\times\frac{\Delta DispIncome}{DispIncome} \quad (11)$$

where *NonCoal/Cap_U* is non-coal energy demand per capital for household in urban area ; *NonCoal/Cap_R* is non-coal energy demand per capital for household in rural area.

There is also a big difference of energy consumption in household between urban area and rural area. People migrating from rural area to urban area use more energy than they did. The additional energy consumption is calculated by the difference of energy consumption between urban area and rural area multiplied by the migrating population size. That follows:

$$\Delta ED_i = (Coal/Cap_U - Coal/Cap_R + NonCoal/Cap_U - NonCoal/Cap_R)\times Pop\times\Delta UR \quad (12)$$

where ΔED_i is energy demand because of the consumption difference by the immigrants; Pop is the population size in China.

2.3. Transportation

Transportation volume will increase with the increase of GDP. The increment of passenger volume in China because of GDP growth is:

$$\Delta Total_P = 15.504\times\frac{\Delta GDP}{Pop} \quad (13)$$

where $\Delta Total_P$ is the increment of total passenger volume; *Pop* is population size

Total freight increment with GDP is:

$$\Delta Total_F = 18089\times\frac{\Delta GDP}{GDP} \quad (14)$$

where $\Delta Total_F$ is the increment of total freight volume.

2.4. Calculation tool

The calculation has been carried out in a computer program called NICE III and its application in China developed in LCA Research Center AIST Japan. NICE III computer program is based on NICE I (NIRE CO_2 Emission Model) and NICE II (National Integration of CO_2 Emission Model) (YAGITA et al, 2000). NICE I and NICE II are all targeted to the condition of Japan and were used to investigate the CO_2 emission reduction strategies in Japan. Newly developed NICE III is applicable in the world; it is a suitable tool for CO_2 emission analysis in various economic structures and other conditions in a national level or in a regional level. Up to now, NICE III has been successfully applied in Japan and China.

NICE III application in China (WEI, YAGITA et al, 2003) is intended to investigate CO_2 emission reduction strategies in China. In this application, the main variables are urbanization rate, capital stocks, and population. The energy types used in the application are coal, coke, crude oil, petrochemical product, LNG, natural gas, other gas and electricity. Electricity is from wind power, hydro power, nuclear power, natural gas and coal. Electricity has some supply scenarios for various sources. The demand side and supply side have been kept in balance by electricity supply from coal. The total energy consumption and total CO_2 emission in China and energy consumption in every economic sector and the composition of energy in every sector from 1999 to 2050 are the output of this application.

Some conditions in the application have been changed in order to investigate the impact of urbanization on energy demand and CO_2 emission. Those conditions mainly include: let capital stock and population unchanged in the investigating year; let urbanization rate have 1% increment. Those conditions will implement the calculation method presented above.

3. Calculation results

The studying year is 2003. The urbanization rate is assumed to change from 35.04 % to 36.04 %.

3.1. GDP and GDP ratio

It has been mentioned that 1 % increase of urbanization rate will result in 1.5 % GDP increase. Table 1 lists the changes of GDP ratios among agriculture, secondary and tertiary industry because of the 1% increment of urbanization rate. It can be seen that the percentage of GDP in tertiary industry has increased 0.8 %, and this percentage has been contributed by agriculture and secondary industry. GDP value in agriculture will decrease, while GDP in tertiary industry will increase. GDP in secondary industry will also increase although its percentage of

GDP will drop.

Table 1. GDP and GDP Ratio

	Agriculture		Secondary industry		Tertiary industry	
	GDP Ratio /%	GDP / $	GDP Ratio / %	GDP / $	GDP Ratio /%	GDP / $
Before	15.31	2.07E+11	48.07	6.52E+11	36.62	4.97E+11
After	14.72	2.02E+11	47.85	6.59E+11	37.43	5.15E+11

3.2. Energy demand

As can be seen in Tables 2 and 3, because of the 1% increase of urbanization rate in 2003, the total energy demand is 1.380 E+07 TCE (Ton Coal Equivalence). With respect to sectors, household followed by secondary industry are two main dominant sectors of this energy demand, transportation also has a big portion. With respect to energy types, petrochemical product, PLG and electricity they all have big portions.

By NICE III forecast, the total energy demand in China in 2003 is 1.373 E+9 TCE. This demand 1.380 E+07 TCE is 1 % of the total energy demand.

Table 2. Energy demand for different sectors Unit: 10 000 TCE

Agriculture	Secondary industry	House-hold	Commercial and service	Transportation	Other
-119.44	533.94	548.57	101.08	238.50	77.61

Table 3. Energy demand in energy type

Type	Demand /10^4 TCE	Percentage/%
Coal	186	13.5
Coke	333.51	24.2
Crude oil	-12.144	-0.9
Petrochemical Product	337.39	24.5
Natural Gas	45.57	3.3
PLG	203.99	14.8
Electricity	215.43	15.6
Other gas	70.12	5.1

3.3. CO_2 emissions

CO_2 emission is calculated by the energy demand multiplied by the coefficients. Those coefficients used in this paper are listed in Table 4. They are mainly from Zhang (2000), some are calculated based on the NICE III application in Japan (WEI, YAGITA, 2003). The coefficient of electricity is calculated by the total electricity generated and total CO_2 emission because of the electricity. Electricity can be generated from wind power, hydro power or coal, so the coefficient is changing every year. In case of China in 2003, NICE III forecasts that this coefficient is 15.18 (1000T-C/10000TCE).

As can be seen in table 4, the total CO_2 emission because of the energy demand is 1.02 E+07 T-C. NICE III forecasts that CO_2 emission in China in 2003 is 8.25 E+08 T-C. CO_2 emission is 1.2% of total CO_2 emission in 2003 with 1% increase of urbanization rate. This figure is bigger than the corresponding energy demand figure because of much electricity demand here.

Table 4. CO_2 emission and its coefficient

Type	Coefficient 1000T-C/10,000TCE	CO_2 emitted / 1000 T-C
Coal	6.51	1210.86
Coke	7.96	2654.7
Crude oil	5.43	-65.94
Petrochemical Product	5.43	1832.02
Natural Gas	4.04	184.10
PLG	4.04	824.12
Electricity	15.18	3270.21
Other gas	4.04	283.28

4. Conclusions

Urbanization in China is important. Using NICE III computer program developed in LCA Research Center AIST Japan, based on its application in China, it has been found that 1% increment of urbanization rate in China in 2003 will cause 1.5% increase of GDP. The GDP value in tertiary industry will have a big increase followed by GDP in secondary industry. The GDP in agriculture will decrease.

Urbanization impact on energy demand is mainly two folds: the energy demand because of the GDP increment and energy demand in household and transportation. It has been found that the energy demand is 1% of total energy demand in 2003 in China with 1% increase of urbanization rate. Household and secondary industry are two main sectors of this demand; transportation also has a big portion. CO_2 emission because of 1 % increase of urbanization rate is 1.2 % of total CO_2 emission in 2003 in China. This figure is bigger than the corresponding energy demand figure because of much electricity demand here.

It can be further concluded that the impact of

urbanization on energy demand and CO_2 emission is week, 1.5% GDP growth emits 1.2% CO_2, less than the average level. Much of the energy is used in household sector that obviously improves the life of people.

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