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Original Research

Urbanization Effect on Energy-Related Carbon Emissions in Jiangsu Province from the Perspective of Resident Consumption

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Abstract

Controlling carbon emissions without impairing urbanization and economic development highlights the necessity of researching energy-related carbon emissions. Urban areas have become the main source of energy consumption and carbon emissions. This paper has developed a modified version of the Kaya identity, which incorporates urbanization and resident consumption, to analyze urbanization effect on carbon emissions in Jiangsu Province. Then, the Kuznets curve theory was introduced to estimate the inflection point of the marginal urbanization effect. The results indicated that the urbanization effect was still an important factor that influences total carbon emissions. The marginal urbanization effect will still increase until the urbanization rate reaches 78.94%. Therefore, Jiangsu should also pay attention to the urbanization effect even though it may increase slowly or decrease, and the results of this paper on marginal urbanization effect make it clear that controlling the carbon emissions without the expense of urbanization growth and economic development is still a big challenge for Jiangsu Province. We have proposed some policy recommendations, which include paying attention to the quality of development of urbanization, adjusting the industrial structure, making changes to lifestyles, and so on.

Keywords: urbanization effect, marginal urbanization effect, carbon emissions, extended Kaya identity, Jiangsu Province

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Introduction

Global warming has become an indisputable fact, and increases in greenhouse gases will bring about disaster for humanity and the earth. The fourth report of the Intergovernmental Panel on Climate Change (IPCC) has shown that carbon dioxide accounts for about 76.7% of total greenhouse gas emissions [1], and it is the main component of greenhouse gases. This illustrates that the key to reducing greenhouse gas emissions is to control carbon emissions. At the United Nations Climate Change Conference, the Chinese government promised to cut its carbon intensity by 40-45% by 2020 with respect to 2005 levels [2]. In 2014 China made a promise to reach peak carbon emissions before 2030 in a joint statement on climate issued by China and the United States [3]. Therefore, fulfilling these emissions reduction commitments while maintaining rapid and stable socio-economic development will be an important and urgent task that also highlights the necessity of the study of energy-related carbon emissions.

With the rapid growth in global urbanization, more people have lived in urban areas than in rural areas since 2007 [4]. Besides, urban areas have also become the main source of energy consumption and carbon emissions. Urban areas account for only 2% of the world's surface area, but contribute 75% of the world's total energy consumption [4] and more than 70% of the world's carbon emissions [5]. Therefore, an increasing number of researchers have begun to pay attention to urbanization effect on carbon emissions.

According to empirical studies, urbanization influences carbon emissions through economic growth, changes in residents consumption, industrial restructuring, and various other factors [6]. For instance, urbanization leads to the agglomeration of people and economic activities, which in turn can promote increases in energy consumption and carbon emissions. In contrast, agglomeration effects and the scale effect caused by urbanization contribute to improving the efficiency of energy utilization and promote clean energy technology, which will thus contribute to control and inhibit carbon emissions. A regional urbanization effect on carbon emissions can be mainly subdivided into driving effects and inhibiting effects. Some studies have indicated that urbanization promotes carbon emissions:

– Cole and Neumayer (2004) revealed that a higher urbanization rate would increase carbon emissions using data from 86 countries for the period from 1975 to 1998 [7].
– York (2007) studied the urbanization rates and carbon emissions of 14 European Union countries, and found that urbanization led to an increase in carbon emissions during the period 1960-2025 [8].
– Wang et al. (2016) studied the relationship between urbanization, energy use, and carbon emissions within the Association of Southeast Asian Nations countries, and observed that a rise in an urban population of 1% resulted in an increase in carbon emissions of 0.20% over the period 1980-2009 [9].
– Wu et al. (2016) indicated that a higher urbanization rate would lead to an increase in carbon emissions in China before 2020 [10].

Other studies, however, have indicated that urbanization controls or limits carbon emissions:

– Fan et al. (2006) indicated that urbanization had a significant negative impact on carbon emissions in some high-income countries over the period 1975-2000 [11].
– Poumanyvong and Kaneko (2010) used panel data from 99 countries over the period 1975-2005 to indicate that the impact of urbanization on carbon emissions varied across the stages of development, and that further modernization might diminish this impact [12].
– Hu and Wang (2016) indicated that the growth of urbanization slowed down the growth in carbon emissions in China over the past 30 years [13].
– Zhang et al. (2013) indicated that there was an inverted U-shaped relationship between urbanization and carbon emissions from 1995 to 2011 [14]; and Martínez and Maruotti (2011) indicated that an inverted U-shaped relationship between urbanization and carbon emissions existed in developing countries over the period 1975-2005 [15].

With the growth of urbanization, both driving effects and inhibiting effects will change. Nevertheless, these studies examined the urbanization effect mainly from the perspective of time series. In fact, the urbanization effect, which is caused by each percentage point growth in urbanization, will also change [9, 16]. Therefore, marginal utility theory is used to analyze the relationships between urbanization and carbon emissions.

The main methods used for research into urbanization effect on carbon emissions are the IPAT [17], STIRPAT [18-20], SDA [21-22], GTWR [23-25], co-integration analysis [9, 26-28], the Kuznets curve [14, 15], and panel data models [29-30]. Most recent studies of residents' consumption and carbon emissions used SDA to analyze the effects, such as those by Wang et al. (2016) [21] and Minx et al. (2011) [31]. Total emissions were always decomposed into population, energy intensity, GDP per capita, and carbon emissions coefficient using Kaya identity. Therefore, recent studies using Kaya identity always considered urbanization effect indirectly [10]. Owing to the short history of the publication of input-output tables in China and the long timescale involved, using the SDA method to analyze the resident consumption effect faces the problems of the study period being short and the relevant time interval long. This paper develops a modified version of the Kaya identity that incorporates urbanization and resident consumption. This method can consider urbanization directly and overcome some restrictions faced by some studies based on an input-output table. This method can examine different effects; however, this paper only considers the urbanization effect.

There are obvious differences in urbanization, resident consumption, energy consumption, and carbon emissions across the different regions within China [31-32]. Without a sufficient understanding of regional carbon emissions, it is difficult to implement national policies or strategies effectively and efficiently [33]. Jiangsu Province, which is a relatively developed area of China, is currently going through a period of rapid urbanization that has made the urban population grow rapidly during the past 20 years. Meanwhile, resident consumption, including that of both urban and rural residents, has also increased with the growth of urbanization and economic development. Besides, the total energy consumption of Jiangsu was 298 million tons of coal equivalent in 2014, and only Shandong Province consumed more energy than Jiangsu. Therefore, carbon reductions in Jiangsu will have an important influence on national carbon reductions. Promoting the urbanization process is still the principal development strategy of Jiangsu, and it is a major challenge for Jiangsu Province to reduce carbon emissions without impairing the growth in urbanization and economic development. Estimating the change in urbanization effect, caused by a growth in urbanization of 1%, can better explain the relationship between urbanization and its effects, therefore, the concept of the marginal urbanization effect is introduced. This paper aims to find the inflection point at which the marginal urbanization effect will begin to decrease.

In comparison with current studies, the innovation and contribution of this paper lie in the following aspects. First, the extended Kaya identity incorporates urbanization and resident consumption, and it can consider urbanization directly and overcome certain restrictions faced by some studies based on input-output tables. Secondly, the concept of the marginal urbanization effect is introduced, which can better explain the relationship between urbanization and its effects. Thus, this paper aims to provide theoretical guidance for policymaking in Jiangsu.

Material and Methods

Estimation of Energy-Related Carbon Emissions

Energy-related carbon emissions were calculated using the formula given by the IPCC Guidelines for National Greenhouse Gas Inventories [35-37], which can be expressed as follows:

$$C_t = \sum_i E_i^t \times EF_i \times CV_i \times O_i \tag{1}$$

…where C_t denotes the total energy-related carbon emissions in year t, subscript i denotes the different fuels considered in this study (10^6 tons), E_i^t denotes the total energy consumption of fuel i in year t (10^6 tons, 10^8 m^3), EF_i denotes the lower calorific value of fuel i, CV_i denotes the carbon emissions factor of fuel i, and O_i denotes the carbon emissions factors of fuel i. These coefficients are shown in Table 1.

Urbanization Effect

The Kaya identity [41] establishes a quantitative relationship between carbon emissions and various factors, including population, energy, and economic activity. The relevant equation is shown as follows:

Table 1. Conversion factors, lower calorific value (LCV), oxidation rate, and carbon emission factors of different fuel.

Fuels	Conversion factors (t ce/t or tce/10^3m^3)[a]	LCV (MJ/t or MJ/Mm^3)[b]	Carbon emission factors (TC/TJ)[c]	Oxidation rate[c]
Raw coal	0.714	20.908	25.8	0.918
Cleaned coal	0.900	26.344	27.680	0.918
Other washed coal	0.286	8.363	25.800	0.918
Coke	0.971	28.435	29.410	0.928
Crude oil	1.429	41.816	20.80	0.979
Gasoline	1.471	43.070	18.900	0.986
Kerosene	1.471	43.070	19.600	0.980
Diesel oil	1.457	42.652	20.170	0.982
Fuel oil	1.429	41.816	20.000	0.980
LPG	1.714	50.179	17.200	0.990
Refinery gas	1.571	46.055	18.200	0.989
Other petroleum products	1.429	41.816	20.000	0.980
Gas	1.330	38.931	17.200	0.990

[a]Data resource: [38]; [b]Data resource: [39]; [c]Data resource: [40]

$$C = \frac{C}{E} \times \frac{E}{GDP} \times \frac{GDP}{P} \times P \tag{2}$$

…where *C, E, GDP,* and *P* denote total carbon emissions, total energy consumption, gross domestic product, and population, respectively. In order to study urbanization's effect on carbon emissions from the perspective of resident consumption, both rural and urban population and consumption should be included in the equation. The Kaya identity can be extended as follows:

$$C = \frac{C}{E} \times \frac{E}{GDP} \times \frac{GDP}{CON} \times \frac{CON}{P} \times P \tag{3}$$

…where *CON* denotes total resident consumption, which includes urban consumption (*UCON*) and rural consumption (*RCON*). *PU* and *PR* are used to denote the urban and rural populations, respectively. Total resident consumption can be expressed as follows:

$$CON = \begin{pmatrix} \frac{UCON}{PU} \\ \frac{RCON}{PR} \end{pmatrix} \times \begin{pmatrix} \frac{PU}{P} & \frac{PR}{P} \end{pmatrix} \times P \tag{4}$$

By merging equations (3) and (4) into one equation, both rural and urban population and consumption can be included, as in Equation (5).

$$\begin{aligned} C &= \frac{C}{E} \times \frac{E}{GDP} \times \frac{GDP}{CON} \times \begin{pmatrix} \frac{UCON}{PU} \\ \frac{RCON}{PR} \end{pmatrix} \times \begin{pmatrix} \frac{PU}{P} & \frac{PR}{P} \end{pmatrix} \times P \\ &= CE \times EG \times GC \times \begin{pmatrix} UCP \\ RCP \end{pmatrix} \times \begin{pmatrix} PUP & PRP \end{pmatrix} \times P \end{aligned} \tag{5}$$

…where $CE = C/E$ denotes the carbon emissions coeffi-cient; $EG = E/GDP$ denotes energy intensity; $GC = GDP/CON$ denotes the ratio of *GDP* to resident consumption, which is inversely proportional to the residents' consumption rate and reflects the relationship between *GDP* and the residents' consumption rate; $UCP = UCON/PU$ and $RCP=RCON/PR$ reflect the per capita consumption of urban and rural residents, respectively; and finally, $PUP = PU/P$ and $PRP = PR/P$ reflect the proportions of the urban and rural populations, respectively.

Both sides of equation (5) first undergo logarithmic processing, and then processing using differential coefficients.

$$\begin{aligned} d\ln C &= d\ln CE + d\ln EG + d\ln GC + \\ &+ \frac{d(PUP \times UCP + PRP \times RCP)}{PUP \times UCP + PRP \times RCP} + d\ln P \\ &= d\ln(CE \times EG \times GC \times PUP^{SU} \times PRP^{SR} \times \\ &\times UCP^{SU} \times RCP^{SR} \times P) \end{aligned} \tag{6}$$

…where $SU = \frac{PUP \times UCP}{PUP \times UCP + PRP \times RCP}$ and $SR = \frac{PRP \times RCP}{PUP \times UCP + PRP \times RCP}$ denote the proportions of urban and rural resident consumption, respectively. Therefore, in order to decompose the carbon emissions, Equation (5) can be rewritten as follows:

$$C = CE \times EG \times GC \times PUP^{SU} \times PRP^{SR} \times UCP^{SU} \times RCP^{SR} \times P \tag{7}$$

Energy-related carbon emissions can be decomposed into the contributions of different determinant factors. According to the logarithmic mean divisia index (LMDI) model, urbanization's effect (ΔCU) on carbon emissions from the perspective of resident consumption between the baseline year 0 and year t can be expressed as follows:

$$\Delta CU = \frac{C^t - C^0}{\ln C^t - \ln C^0} \times \left(\frac{\ln PUP^{SU^t}}{\ln PUP^{SU^0}} + \frac{\ln PRP^{SR^t}}{\ln PRP^{SR^0}}\right) \tag{8}$$

It can be seen that the urbanization effect depends upon the proportions of the urban and rural populations and urban and rural resident consumption in this paper.

Marginal Urbanization Effect

Marginal utility theory examines the increase in satisfaction that is derived from consuming an extra unit of a good; however, the level of utility is not constant [42-43]. Therefore, the marginal urbanization effect refers to the effect that is caused by each percentage point increase or decrease in urbanization, while other conditions remain unchanged. Therefore, the marginal urbanization effect can be expressed as follows:

$$MCE = \frac{CU_t - CU_0}{U_t - U_0} = \frac{\Delta CU}{\Delta U} \tag{9}$$

…where CU_t and CU_0 denote the urbanization effect in years *t* and *0*, respectively; U_t and U_0 denote urbanization in years *t* and *0*, respectively.

Estimating the Relationship between Marginal Urbanization Effect and Urbanization

The Kuznets curve theory was introduced to estimate the relationship between the marginal urbanization effect and the rate of urbanization. The use of logarithmic processing can eliminate the influence of heteroscedasticity [44-45]. Therefore, on the basis of the Kuznets curve theory and typical studies [15, 46], the Kuznets curve model was established as follows:

$$\ln MCE = \beta_0 + \beta_1 \ln U + \beta_2 (\ln U)^2 + \beta_3 (\ln U)^3 + \varepsilon \tag{10}$$

… where β_0, β_1, β_2, and β_3 denote estimated parameter and ε denotes random error. Different numerical values of β_0, β_1, β_2, and β_3 can reflect the nature of the curve that describes the relationship between the marginal urbanization effect and urbanization. The curve describing the relationship may be linear with a positive or negative correlation, a U-shaped curve, an inverted U-shaped curve, an N-shaped curve, or an inverted N-shaped curve.

Data Sources

In this paper, urbanization refers to the process of a population shift from rural to urban areas. The people living in urban areas will increase gradually. Therefore, this paper uses the proportion of urban people to represent urbanization.

The data of population and resident consumption is obtained from the Jiangsu Statistical Yearbook (1996-2015). Energy data includes all fuel types obtained from the Energy Balance Table by Region of the China Energy Statistical Yearbook (1996-2015). Data about resident consumption is taken in constant prices of 1995 in order to avoid the influence of inflation.

Results and Discussion

Process of the Evolution of Energy-Related Carbon Emissions and Urbanization

According to the results of calculations (Fig. 1), energy-related carbon emissions between 1995 and 2014 in Jiangsu exhibited an overall increasing trend. The total amount of carbon emissions increased from 68.84 million tons in 1995 to 250.31 million tons in 2014, which represents an increase by a factor of about 3.64 over a 20-year period. The change in carbon emissions showed two stages. During the period 1995-2002, the average annual growth rate was only 1.32%. During the period after 2002, carbon emissions increased much faster, albeit with fluctuations, from 80.41 million tons to 250.31 million tons, with an average annual growth rate of 10.91%.

The rate of urbanization had been growing steadily. It grew from 27.30% in 1995 to 65.21% in 2014, which represents an increase by a factor of about 2.39, with an average annual growth rate of 4.78%. The urban population increased from 19.29 million in 1995 to 51.88 million in 2014; meanwhile, the rural population decreased from 51.36 million to 27.69 million. During this 20-year period, resident consumption also grew rapidly, with a growth rate of 13.52%. The per capita consumption of urban and rural residents increased by factors of 4.13 and 3.89, respectively, whereas the total consumption of residents in urban and rural areas increased by factors of 11.11 and 2.10, respectively. Therefore, the total consumption of residents, in particular in urban areas, increased rapidly.

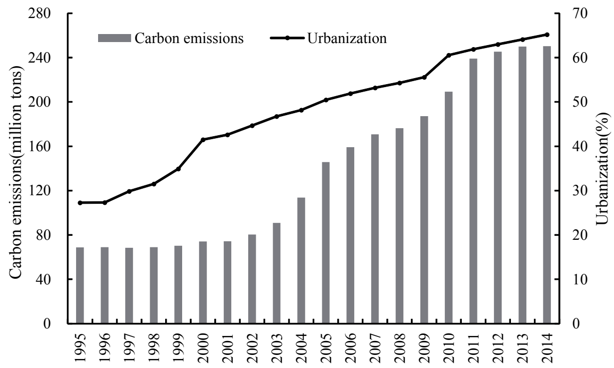

Fig. 1. The evolution process of energy-related carbon emissions and urbanization.

Contribution of Urbanization to Carbon Emissions

On the basis of the extended Kaya identity, using Equation (8), the total increase in emissions and urbanization effect were calculated as shown in Table 2. The total increase of 181.47 million tons between 1995 and 2014, and the total contribution of urbanization was 39.05 million tons, which accounted for 21.52% of the total. This illustrates that the evolution of urbanization was an important influencing factor that contributed to the increase in energy-related carbon emissions in Jiangsu. Therefore, the carbon emissions caused by the evolution of urbanization were huge; nevertheless, fluctuations were also large in different years (Fig. 2). As shown in Fig. 2, fluctuations in the urbanization effect and changes in the rate of urbanization were also similar.

During the process of urbanization the industrial structure changed constantly, which had a significant influence on energy consumption and carbon emissions. During the period 1995-2014, Jiangsu's economy developed rapidly, with a growth rate of 11.97%, and the value of industrial output accounted for more than 40% of GDP during this period. Owing to the speed of economic and industrial development, the demand for high-carbon energy also increased rapidly. In the meantime, the proportion of tertiary industry was also increasing. Until 2014, the value of tertiary industrial output was slightly less than the value of secondary industrial output. Although the energy consumption of tertiary industry was lower

Table 2. Total effect and urbanization effect in Jiangsu from 1995 to 2014.

Years	Total effect (ΔC)/million tons	Urbanization effect (ΔCU)/million tons	Years	Total effect (ΔC)/million tons	Urbanization effect (ΔCU)/million tons
1995-96	0.150	0.01	2005-06	31.95	1.76
1996-97	-0.51	1.23	2006-07	13.61	1.69
1997-98	0.57	0.93	2007-08	11.56	1.50
1998-99	1.18	2.13	2008-09	5.40	1.86
1999-2000	3.99	4.61	2009-10	10.92	7.93
2000-01	0.19	0.71	2010-11	22.15	2.17
2001-02	6.02	1.41	2011-12	29.76	1.92
2002-03	10.55	1.63	2012-13	6.27	1.88
2003-04	22.77	1.26	2013-14	4.71	1.77
2004-05	0.150	2.65	Total	181.47	39.05

than that of secondary industry, the rapid development of tertiary industry could also promote energy consumption and energy-related carbon emissions [10, 47]. Therefore, owing to the process of urbanization together with rapid economic development and evolution of the industrial structure, Jiangsu's energy consumption and carbon emissions also increased.

The rapid growth in resident consumption had an influence on carbon emissions. There was considerable migration from rural areas to cities and towns during the process of urbanization. This migration also changed consumer demand, consumer behavior, and life-style of migrants, therefore these changes influenced energy consumption and carbon emissions. The influence of urbanization on resident consumption and energy-related carbon emissions mainly comprised three aspects:

1. Households could be partly self-sufficient in rural areas, but urban residents had to purchase necessities. Commercial production's demand for energy was much greater than that of self-sufficient rural households, and therefore the indirect energy consumption caused by residents' consumption of goods would also increase [48]. Furthermore, traditional forms of energy accounted for a significant proportion of the total in rural areas, whereas fossil energy was the main form of energy used in commercial production. Therefore, these all led to increases in energy-related carbon emissions.
2. The income of urban residents became relatively higher than that of rural residents during the evolution of urbanization in Jiangsu. The increase in income levels further stimulated residents' consumption, and energy consumption and carbon emissions also increased.
3. With the increase in income levels, living standards improved and the consumption structure also changed. In comparison to rural residents, urban residents' consumption goods generally had the characteristics of a large carbon footprint.

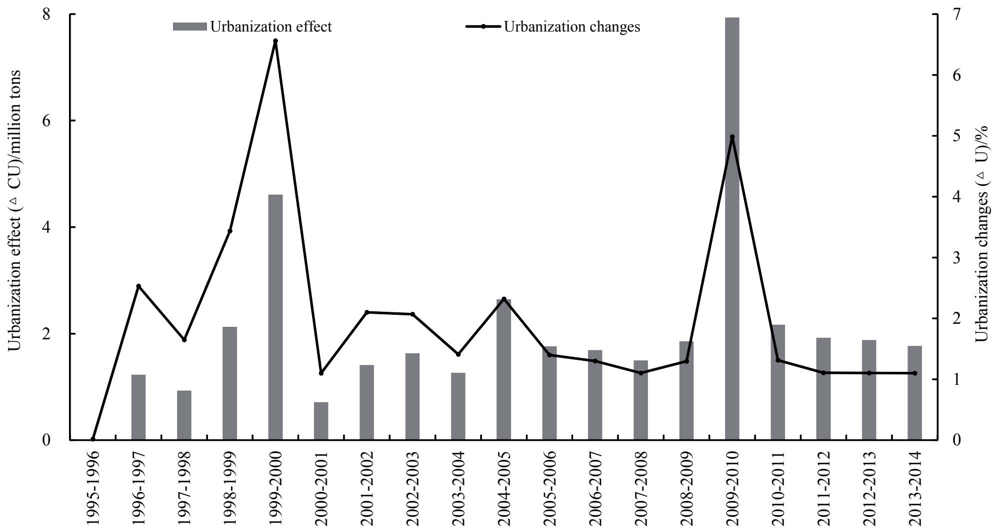

Fig. 2. Urbanization effect and urbanization changes from 1995 to 2014.

Table 3. Marginal urbanization effect.

Years	*MCE* (Million tons)	Years	*MCE* (Million tons)
1995-96	0.530	2005-06	1.258
1996-97	0.486	2006-07	1.300
1997-98	0.564	2007-08	1.362
1998-99	0.626	2008-09	1.428
1999-2000	0.699	2009-10	1.593
2000-01	0.650	2010-11	1.641
2001-02	0.671	2011-12	1.749
2002-03	0.788	2012-13	1.692
2003-04	0.896	2013-14	1.624
2004-05	1.140	average	1.089

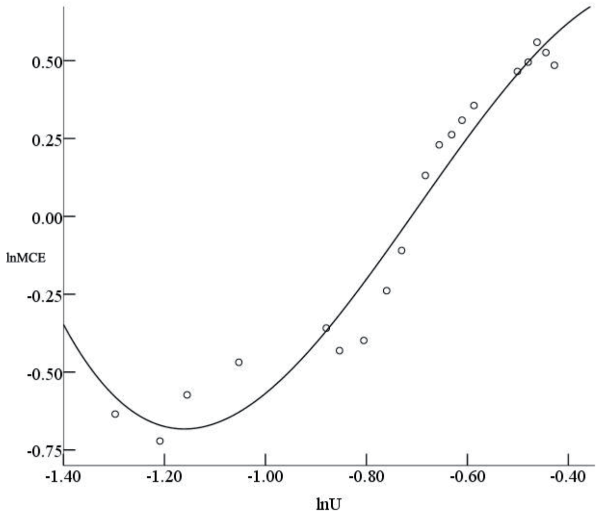

Fig. 3. Fit curve of marginal urbanization effect and urbanization.

Besides, the evolution of urbanization promoted urban construction, which increased the demand for high-rise buildings and infrastructure. Therefore, the demand for energy-intensive raw materials such as cement increased. The increase in transport distances within urban areas also influenced energy-related carbon emissions.

Marginal Urbanization Effect

According to Equation (9) the marginal urbanization effect was calculated, as shown in Table 3. During the period of 1995-2014, the marginal urbanization effect exhibited an overall increasing trend and its contribution to emissions increased from 0.530 million tons in 1996 to 1.089 million tons in 2014, with an average growth rate of 6.42%. As the average marginal urbanization effect is 1.089 million tons, this illustrated that the marginal carbon emissions caused by urbanization increased to 1.089 million tons when the rate of urbanization increased by 1%, and also that their average growth rate was greater than the rate of growth in urbanization during this period. From Table 3 it can be seen that the change in the marginal urbanization effect showed two stages. During the period 1995-2004, the marginal urbanization effect was less than 1 million tons, which illustrated that the rate of growth in marginal urbanization effect was slower than the rate of growth in urbanization. During the period after 2004, the marginal urbanization effect was greater than 1 million tons, therefore it grew faster than the rate of urbanization.

Relationship between the Marginal Urbanization Effect and the Rate of Urbanization

In order to analyze the relationship between the marginal urbanization effect and the rate of urbanization, the Kuznets curve theory was used to test whether there existed a U-shaped curve, an inverted U-shaped curve, an N-shaped curve, or an inverted N-shaped curve. In order to eliminate the influence of heteroscedasticity, each variable needed to undergo logarithmic processing [44-45]. SPSS 16.0 statistical software was used to perform regression analysis, and the results are shown in Table 4.

It can be seen from Table 4 that the R^2 value in type 3 is maximum, which illustrates that equation (13) ($\ln MCE = 0.412-2.966\ln U-7.548(\ln U)^2-3.602(\ln U)^3$) can be effectively used to explain the relationship between these two variables, and the fitting curve is an inverted N-shaped curve (Fig. 3). When $\ln U$ = -0.236 or -1.160 (i.e., U = 78.94% or 31.33%), the value of $\ln MCE$ reaches its extreme points. The marginal urbanization effect exhibits a decreasing trend until the urbanization rate reaches 33.13% and 78.94%. When the urbanization rate is between 33.13% and 78.94%, the marginal urbanization effect will increase with the growth of urbanization. The marginal urbanization effect will begin to decrease and the rate of urbanization will continue to grow, when the urbanization rate reaches 78.94%. According to Planning of New-Type Urbanization and Integration of Urban-Rural Development (2014-20) in Jiangsu

Table 4. Kuznets curve estimation results of marginal urbanization effect and urbanization.

Types	Equations	R^2	F	Sig.
Equation (11)	$\ln MCE = 1.191+1.599\ln U$	0.899	150.696	0.000
Equation (12)	$\ln MCE = 2.113+4.062\ln U+1.467(\ln U)^2$	0.945	137.776	0.000
Equation (13)	$\ln MCE = 0.412-2.966\ln U-7.548(\ln U)^2-3.602(\ln U)^3$	0.957	112.324	0.000

Province and Urban System Planning of Jiangsu Province (2015-30), Jiangsu's urbanization rate will reach 72% in 2020 and 80% in 2030. Therefore, the inflection point of the marginal urbanization effect will likely appear during the period 2020-30.

According to the trend in the marginal urbanization effect, it can illustrate that the urbanization effect caused by each 1% growth of urbanization will continue to increase until the inflection point, and will decrease only after the inflection point. In other words, when the urbanization rate reaches 78.94%, the urbanization effect caused by each 1% growth in the rate of urbanization will decrease. Therefore, Jiangsu will still face the urgent situation of emission reductions during the process of urbanization.

Discussion

The Kaya identity has been used in different modified versions based on the different study perspective. In this paper, urbanization and resident consumption were incorporated directly into the extended Kaya identity. Therefore, this paper studied the urbanization effect by analyzing changes in the urban and rural population and resident consumption. In general, the rate of growth in urbanization will slow down when the urbanization rate is higher. For instance, if Jiangsu's urbanization rate reaches 80% in 2030 in accordance with *Urban System Planning of Jiangsu Province (2015-30)*, the average growth rate is only 1.29% from 2014 to 2030, whereas the average growth rate was 4.69% from 1995 to 2014. The urbanization effect may increase more slowly or decrease because of the decrease in the growth rate with time. Therefore, the marginal urbanization effect can better reflect the change in urbanization effect with each 1% growth in the rate of urbanization. It can also reflect the quality of urbanization to some extent. Jiangsu Province is a relatively developed area of China, and its urbanization rate is also relatively high. However, the marginal urbanization effect will still increase, and Jiangsu will still face the urgent situation of emission reductions during the process of urbanization. Therefore, Jiangsu should also pay attention to the urbanization effect even though it may increase slowly or decrease, and the results of this paper on marginal urbanization effect make it clear that controlling carbon emissions without impairing the growth in urbanization and economic development is still a major challenge for Jiangsu Province. Besides, this study on Jiangsu Province can also provide a new approach for other or less developed areas that are in the process of rapid urbanization.

During the process of urbanization, economic activities, the industrial structure, lifestyles, the demand for transportation, and spatial distributions will all change, and these changes will influence carbon emissions. Therefore, urbanization's effect on carbon emissions involves not only environmental problems but also complex socio-economic problems. Future studies on the urbanization effect need to combine different disciplines such as demography, sociology, economics, and geography.

Conclusions and Policy Recommendations

This paper analyzed the urbanization effect on energy-related carbon emissions from the perspective of resident consumption using an extended version of the Kaya identity, the LMDI model, marginal utility theory, and the Kuznets curve theory. Some conclusions were drawn as follows:

1. Energy-related carbon emissions from 1995 to 2014 in Jiangsu exhibited an overall increasing trend. The change of carbon emissions showed two stages. After 2002 carbon emissions increased much faster, whereas urbanization had been increasing steadily, and resident consumption had also grown rapidly.
2. The carbon emissions caused by the evolution of urbanization were very high, nevertheless, fluctuations were also large in different years. The fluctuations in the urbanization effect and changes in the rate of urbanization were similar. During the process of urbanization, the industrial structure, lifestyles, the demand for transportation, spatial distributions, and so on will all change, and these changes will influence carbon emissions.
3. The marginal urbanization effect exhibited an overall increasing trend. The change in the marginal urbanization effect showed two stages. During the period 1995-2004, growth in the marginal urbanization effect was slower than the growth in the rate of urbanization. During the period after 2004, the marginal urbanization effect grew faster than the rate of urbanization.
4. The marginal urbanization effect will begin to decrease, but the rate of urbanization will continue to grow when the urbanization rate reaches 78.94%. The inflection point will be likely to appear during the period 2020-30. When the rate of urbanization reaches 78.94%, the urbanization effect caused by each 1% growth in the rate of urbanization will also decrease.

In light of the above-mentioned findings, some policy implications are proposed:

1. Attention needs to be paid to the quality of the development of urbanization. According to the above-mentioned findings, the effect of urbanization caused by each 1% growth in the rate of urbanization begins to decrease only after the urbanization rate reaches 78.94%. Jiangsu therefore needs to use innovative ideas to promote the development of urbanization. According to the Ministry of Education, Jiangsu ranks first in the number of universities that are located in the province and can take advantage of their innovations. Jiangsu should also employ these advantages to promote its scientific and technological innovation in low-carbon technology and the adjustment of its industrial structure, lifestyles, and structure of energy consumption, which will all promote the quality of the development of urbanization.
2. Highly energy-intensive enterprises should be eliminated, and industries with low energy consumption and high added value should be given

priority in development. Besides, the carbon emissions of construction and its related industries should not be ignored. Green building technologies should be popularized, and research into low-carbon materials should be strengthened. During the future progress of urbanization science and technology will be very helpful for upgrading the pattern of development and structural transformation of the economy.
3. During the process of urbanization attention should be paid to improving urban residents' quality of life and encouraging low-carbon consumption patterns. With the growth of urbanization, tens of millions of rural residents have become urban residents. Meanwhile, economic development and the growth in living standards have changed residents consumption patterns. Therefore, during the process of urbanization attention should be paid to carbon emissions caused by resident consumption, in particular by urban residents. Therefore, the government needs to encourage the public toward low-carbon consumption such as buying energy-conserving products and automobiles powered by new energy sources.
4. Currently, coal is still the major source of energy in Jiangsu. Optimizing the structure of energy consumption and improving energy efficiency are very important for Jiangsu for controlling its carbon emissions. The consumption of wind energy and other forms of clean energy should be increased, and the consumption of coal should be controlled. Low-carbon technology should be developed to improve energy efficiency.

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