

# The Influence of Urban Sprawl on Household Power Intensity—Evidence from China's Urban Panel Data

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**Abstract:** The paper measures the yearly urban sprawl index and household power intensity of 285 prefecture-level and Municipality cities in China from 2004 to 2017. Through the establishment of a fixed effect model, random effect model and systematic GMM model, this paper empirically analyze the impact of urban sprawl on household power intensity, and found that there is a significant and positive effect of urban sprawl on household power intensity, that is, the higher the urban sprawl, the lower the efficiency of household electricity energy utilization will be, and this effect has a cogent robustness. On this basis, the establishment of a mediating effect model found that population agglomeration plays a significant role of the partial mediating effect in the process of urban sprawl affecting household power intensity. The conclusion of this paper provides some policy implications for the scientific and reasonable urban planning in the process of urbanization in China from the perspective of optimizing household power intensity.

## 1 Introduction

Urban sprawl has become a common phenomenon for most countries in the world. According to the OECD's measurement of 1156 cities in 29 OECD countries, the extent of urban sprawl in many countries has risen sharply since the 1990s. As a phenomenon of urban spatial structure, urban sprawl is manifested in that the rate of urban area expansion exceeds the rate of population growth, a large number of people in the central city spread to satellite cities or suburbs. Land use intensity and population density decreases, while the urban spatial pattern becomes more polycentric and decentralization.

Since the acceleration of economic growth starting at early 1980s, China's urbanization process has been progressing fast, and the urbanization rate measured by urban permanent residents has increased from 17.9% in 1978 to 59.58% in 2018. The rapid progress of China's urbanization has brought about changes in the spatial structure of the cities, which has brought a profound impact on firm production and family living. At present, the central government focuses on the future urban blueprint and is trying to coordinate and optimize the urbanization development process. Compared with the previous development, it pays more attention to the construction of urban ecological civilization, and pays more attention to improving the quality of urban development and the quality of family

living. The city has a high concentration of industrial, commercial and family production and living activities in a certain area. As a result, in terms of space, cities have gradually become concentrated consuming places of various energy sources. Modern cities that occupy only 2% of the world's area consume 75% of the world's energy.

Electricity, as the most easily and commonly used energy source in modern cities, has become an important energy foundation for urban development. In recent years, China has actively encouraged the transition from traditional urban energy consumption such as coal burning to electricity consumption, and has taken the proportion of electricity in the final energy consumption as an important indicator to measure the national and urban final energy structure and the degree of electrification. Household power consumption is an important part of urban power use. With the acceleration of urbanization and the improvement of family living standards, the electric energy consumed by families for daily transportation, heating, cooling, cooking, lighting in production and life will continue to increase, which will lead to a greater threat to the environment. Considering the rapid urban development and power consumption growth and the increasing environmental protection pressure and the arduous international emission reduction task, China's future household power intensity needs to be further reduced. Therefore, improving household electricity use efficiency and

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reducing household electricity intensity have become a heated discussed issue which raises common concern in the fields of urban economics and environmental economics.

The concept of household power intensity is similar to household energy intensity. Simply put, it is household power consumption per unit of GDP, which reflects the efficiency of household power utilization in the process of promoting economic growth. Since the 18th National Congress of the Communist Party of China in year 2017, China's overall household power intensity has been declining, but there is still a gap compared with developed countries in Europe and America. From a city perspective, on the one hand, the degree of application and promotion of energy-saving and environmental protection technologies needs to be further strengthened, and the green lifestyle and energy consumption structure of urban residents need to be further transformed and optimized. On the other hand, different cities have different urbanization processes, different degrees of economic openness and spatial agglomeration effects, which lead to different changing trend in urban household electricity intensity in China. Since human society is consisted by numerous families, in the process of urbanization, we choose to take the families residing in cities to study the relationship between urban sprawl and household electricity intensity and its influence mechanism. It is useful to comprehend the law of household electricity consumption, reduce household electricity intensity, and further explore a reasonable urban spatial structure under optimal power intensity. In this view, promotion of energy conservation, emission reduction, and green city construction have significant theoretical and practical values.

## 2 Literature review and mechanism analysis

### 2.1 Literature review

The current research on power intensity mainly focuses on the study of its changing trends, influencing factors, and the discussion of the relationship between urban characteristics and power intensity.

Research on the trend and influencing factors of power intensity. Regarding the study of changing trends, Ouyang and Lin (2014) established a co-integration model to study the long-term equilibrium relationship between power intensity and technological progress, power prices, and enterprise scale. Zha et al. (2012) showed that factor substitution, budget effect and technical effect contributed 62.5%, 20.06% and 17.44% to the annual fluctuation of power intensity, respectively. Some scholars such as Herrerias and Liu (2013) used provincial-level data to study the spatial convergence or club effect of power intensity. For another example, Vaona (2013) analyzed the dynamic changes of energy intensity and per

capita power consumption in various regions and the convergence of power intensity in various regions of Italy through panel data from 1997 to 2007 in various regions of Italy. Some also conduct comparative analysis between countries or regions. For example, Inglesi-Lotz and Blignaut (2012) compared the power intensity of South Africa and OECD countries and found that the former is much higher than the latter. In addition, Verbic et al. (2017) studied the impact of European residential electricity prices on electricity intensity. Taking other control variables into consideration, residential electricity prices have a significant negative impact on electricity intensity.

Discussion on the relationship between city characteristics and power intensity. The study of Larson and Yezer (2015) found that the increase in density caused by the urban "green belt" has significantly reduced per capita energy consumption, while restrictions on building height or density have increased per capita energy consumption. Li and Li (2015) further pointed out that the reduction in thermal energy consumption in a compact city is much greater than the increase in electricity consumption due to the use of refrigeration equipment. Some scholars have also studied the relationship between population density and residents' transportation energy consumption. For example, Molnarova et al. (2011) in areas with low population density, per capita investment in transportation is relatively large, residents' utilization of transportation networks and services is low, and residents' transportation behavior is also relatively scattered, which will reduce the scale efficiency of public transportation and increase transportation energy consumption. Xu et al. (2018) Used detailed traffic data to estimate transportation energy consumption in the Netherlands, the regression results show that compared to low-density urban areas, commuters in high-density urban areas have lower energy consumption. On this basis, some scholars have carried out research on power intensity from the aspects of city area and city scale. Liang (2010) constructed a fixed-effect panel model to empirically analyze the correlation between city characteristics and urban power consumption relationship. Cheng and Xu (2019) analyzed the impact of urban sprawl on power intensity based on panel data from cities at prefecture level and above in China, and pointed out that there is a U-shaped nonlinear relationship between city size and power intensity.

It can be seen that most of the existing studies stop at the study of comprehensive power intensity, without subdividing industrial power intensity and household power intensity, and ignore the impact of urban heterogeneity in the process of urban sprawl affecting household power intensity. The estimated results may be biased, and the conclusions are unconvincing. In addition, considering the dependence of China's urbanization on household power consumption, it is more practical to study the trend of household power intensity from the level of prefecture-level city data. In view of this, the possible marginal contributions of

this paper are as follows: Firstly, from the research perspective, the domestic economic effects on urban sprawl mainly focus on the perspectives of government behavior, wage income, financial burden, and production efficiency, and get involved in urban sprawl and household electricity intensity. There is less research on the relationship between urban sprawl and household electricity intensity, and this paper provides a new perspective supplement. Second, take population agglomeration as an intermediary variable to construct a mediating effect model that includes urban sprawl, population agglomeration and household power intensity, and empirically analyze the impact mechanism of urban sprawl on household power intensity, and deepen the spatial form of urban sprawl and household power intensity Cognition of the internal mechanism of action.

## 2.2 Mechanism analysis

Urban sprawl is essentially embodied as an urban development model with low density and decentralization as its core characteristics. It has two typical characteristics: (1) The residential sector extends outwards around the city center and the density of housing decreases. (2) The area of urban built-up areas is rapidly expanding, which exceeds the rate of population growth, resulting in a decline in population concentration. The disorderly expansion of urban built-up areas caused by urban sprawl can dissipate the pull of agglomeration to improve energy efficiency.

In the process of urban sprawl, the disorderly expansion of built-up areas gradually prevailed, leading to excessively decentralized residential layout, reduced population concentration, and further loss of spatial externalities, which had a profound impact on household power transmission, transportation, production, and life. First, urban sprawl will significantly reduce the layout and building density of residential areas. However, the per capita living area in high-density areas is small, and most residents live in apartment-style multi-unit housing. The comprehensive efficiency of lighting, cooking, air conditioning, cooling and heating is high, and electricity energy consumption is less than that in low-density areas. Second, urban sprawl increases the number of people in the periphery of the city and reduces the concentration of urban population. In areas with low population concentration, the per capita investment in transportation is relatively high, the utilization rate of the transportation network and services by residents is small, and the transportation behavior of residents is also relatively scattered. This will reduce the scale benefits of public transportation, and the per capita transportation energy consumption also increase. At the same time, the sprawling urban development model will also cause companies to move away from urban areas, resulting in separation of work and residence, increasing the transportation distance for residents to commute to get off work, and

increasing household transportation energy consumption. Third, urban sprawl can also significantly increase losses in power transmission and power distribution. The highly sprawling urban development model often requires more investment in the construction of public service facilities, such as the network and water, electricity and sewage pipelines, to meet the needs of residents whose living space is far from the city center, while at the same time longer and more dispersed electricity Transmission lines lead to a substantial increase in the power transmission time, and a large amount of power consumption is generated during the power transmission process under the action of the electric current heating effect caused by the resistance, which leads to an increase in household power supply costs and household power intensity.

In addition, urban sprawl has led to a large number of new houses and relocation of factories on the edge of the city. The lack of agglomeration economy has led to inefficiencies in the use of electric energy and high levels of energy consumption. At the same time, due to low housing prices in suburban areas, residents in urban sprawl areas are more inclined to choose single-family detached houses and large-family houses to improve living comfort (Liu et al., 2016), resulting in high residential electricity energy consumption. Due to the urban heat island effect, the average additional energy consumption of residents in sprawling areas is higher in summer than in compact areas.

## 3 Research design

### 3.1 Measurement model

Based on the previous mechanism analysis, in order to empirically test the impact of urban sprawl on household power intensity, the following measurement model is constructed:

$$\ln HPI_{it} = \alpha_0 + \alpha_1 \ln SPR_{it} + \alpha_2 X + city_i + year_t + \varepsilon_{it} \quad (1)$$

Among them,  $HPI_{it}$  Indicates the household power intensity of the  $i$ -th city in year  $t$ ;  $SPR_{it}$  stands for urban sprawl index;  $X$  is the control variable vector, including the six control variables in this paper;  $city_i$  indicates the urban fixed effect,  $year_t$  represents the year fixed effect,  $\varepsilon_{it}$  represents a random disturbance term. In the empirical analysis, the core explanatory variable and the explained variable are taken logarithm at the same time, and the coefficient of the core explanatory variable reflects the elastic relationship between the two.

### 3.2 Variable selection

1. Dependent variable: Household Power Intensity Index ( $HPI$ ). The household power intensity in this

paper is defined as the ratio of the actual household power consumption per unit time of a city to the city's GDP, which is simply the household power consumption per unit GDP. Based on the regional GDP and urban household electricity consumption data in the "China City Statistical Yearbook", the household electricity intensity from 2004 to 2017 was calculated.

The research object of this paper is the municipal districts of prefecture-level and above cities. According to the previous mechanism analysis, urban sprawl mainly affects household power consumption by changing the layout of urban households. Therefore, household power consumption data in municipal districts are selected to calculate household power intensity. In fact, urban sprawl may indirectly affect the energy consumption of households in non-municipal areas through other means, but this is not the subject of this paper.

2. Independent variable: Urban Sprawl Index (*SPR*). Adopt urban sprawl index designed by Wang et al. (2015), which is expressed as the ratio of the growth rate of the built-up area of the city to the population growth rate of the municipal district. The specific calculation is as follows:

$$SPR_{it} = \frac{urb_{i,t+n} / urb_{i,t}}{pop_{i,t+n} / pop_{i,t}} \quad (2)$$

Among them,  $SPR_{it}$  stands for urban sprawl index,  $i$  and  $t$  respectively indicate the city and start year,  $t+n$  indicates the end year.  $urb$  is the built-up area of the city,  $pop$  indicates the population of the municipal district. We treat year 2003 year as the base period.

At the same time, taking into account the measurement error of the average urban density change, combined with the decentralized characteristics of urban sprawl, residents and economic activities originally concentrated in the central area of the city spread to the periphery of the city, and urban density and land use intensity have declined. Learn from Li and Liu (2018)'s approach, the decentralization of urban spatial structure is measured by the proportion of the population of non-municipal districts to the population of municipal districts, as another measure of urban sprawl.

3. Control variables. In order to minimize the endogenous influence in the estimation process, and strive to obtain unbiased test results, refer to Liu et al. (2016)'s research, Using household natural gas intensity (*Hec*), measured by the ratio of urban household natural gas usage to the city's GDP to control the household energy consumption structure, the proportion of the city's population in the total population (*Urb*) to control the urbanization process, and the logarithm of per capita green area (*LnGreen*) is used to control the green lifestyle of residents, the centralized treatment rate of sewage treatment plants is used to control the intensity of environmental

regulations (*Eri*), the harmless treatment rate of household garbage (*Htr*) is used to control the application of energy-saving and environmental protection technologies, and the ratio of the amount of foreign investment actually used in the year to the regional GDP is used to control the level of opening up (*Open*).

### 3.3 Data Sources

We select the balanced panel data of prefecture-level and above cities across the country from 2004 to 2017 to conduct an empirical analysis of the impact of urban sprawl on household power intensity. In order to ensure the authenticity and validity of the sample, the city samples with more data missing, affected by the adjustment of administrative divisions, and statistical errors are eliminated; for the city samples with relatively few data missing, the moving average method is used to fill in missing data and the outliers is replaced by the average of the previous and subsequent years. Finally, the balance panel data of 285 prefecture-level and above cities within 30 provincial administrative regions was obtained. The data corresponding to the explained variables, core explanatory variables and control variables are all from the "China City Statistical Yearbook" (2005-2018), and the data processing and empirical analysis are all completed in the STATA15.1 software.

## 4 Empirical analysis

### 4.1 Baseline results

**Table 1.** The Impact of Urban Sprawl on Household Electricity Intensity

Variable	FE		RE		Sys-GMM	
<i>LnSPR</i>	0.0698** (4.29)	0.0655*** (4.02)	0.0775** (4.88)	0.0765*** (4.79)	0.1190*** (5.20)	0.0458*** (2.83)
<i>Hec</i>		0.0066** (2.37)		0.0075*** (2.68)		0.0061 (0.72)
<i>Urb</i>		-0.0382* (-1.66)		-0.0694*** (-3.08)		-0.1311* (-1.81)
<i>LnGreen</i>		-0.0073 (-0.70)		-0.0378*** (-3.86)		-0.1321*** (-7.05)
<i>Eri</i>		0.0005* (1.94)		0.0002 (0.68)		-0.0018*** (-4.87)
<i>Htr</i>		-0.0001 (-0.32)		-0.0003 (-1.33)		-0.0008*** (-2.95)
<i>Open</i>		-1.26e-16 (-0.31)		-1.54e-16 (-0.38)		-4.80e-17* (-2.10)
Fixed year	YES	YES	YES	YES	YES	YES
City fixed	YES	YES	YES	YES	YES	YES
R-sq	0.1607	0.1661	0.1606	0.1629		
Hansen test					0.652	0.558
Obs	3,840	3,809	3,840	3,809	3,809	3,809

Note: The Z value is in parentheses, \*\*\*, \*\*, \* indicate the significance level of 1%, 5% and 10%

respectively. The same as below.

Table 1 reports the benchmark regression results of urban sprawl on household electricity intensity. The estimation results in columns (1), (3), and (5) do not include control variables, and the estimated results in columns (2), (4), and (6) include control variables mentioned above. As shown in Table 1: Both the fixed effect estimate and the random effect estimate show that the coefficient of the urban sprawl index has passed the significance test, and the sign is positive, indicating that urban sprawl has a significant positive effect on household power intensity. In order to prevent the possible negative impact of household power intensity on urban sprawl from causing estimation bias in ordinary panel regression, the system GMM method is further adopted, and the lagged variable is selected as the instrumental variable of the corresponding variable for regression testing. The Hansen over-identification test results show that the P value corresponding to the Hansen statistic is greater than 10%, indicating that the design of the model and the selected instrument variables are reasonable, and the system GMM regression results still support the positive effect of urban sprawl on household power intensity. In addition, before and after adding the control variables, the significance of the coefficients and the signs of the coefficients of the core explanatory variables did not change, which supports the robustness of the regression results. Control variables also provide useful information. The system GMM estimation results show that the process of urbanization, the per capita green area, the degree of environmental regulation, the application popularity of energy-saving and environmental protection technologies, and the degree of openness can all restrain the increase of household power intensity to a certain extent and improve household power utilization efficiency.

#### 4.2 Robustness Test

**Table 2.** The Regression Results for Robustness Test

Variable	Non-linear relationship	Replace the independent variable	Delete some city samples
<i>LnSPR</i>	0.0684*** (4.01)	0.0171*** (2.79)	0.0503*** (2.89)
$(LnSPR)^2$	-0.0061 (-0.58)	-	-
Control variable	YES	YES	YES
Fixed year	YES	YES	YES
City fixed	YES	YES	YES
R-sq	0.1661	0.1633	0.1517
Obs	3,809	3,844	3,343

Although the previous research found that low-density, decentralized urban spatial structure will significantly increase household power intensity, it is possible that this relationship is nonlinear, that is, the degree of urban sprawl will help to improve the efficiency of household electricity use and reduce the household power intensity after crossing a certain threshold. Use efficiency to reduce household power

intensity. For this reason, we added the quadratic term of the urban sprawl index (SPR2) on the basis of the regression in Table 1 to re-estimate. The regression results are shown in column (1) of Table 2. The results under the fixed effects model show that the quadratic term of the urban sprawl index (SPR2) failed the significance test, and there is no evidence to show that there is a nonlinear relationship between the low-density, decentralized spread patterns and household power intensity.

The previous mechanism analysis has shown that the impact of urban sprawl on household power intensity is mainly realized through the decentralization of urban spatial structure leading to the decentralization of family housing. The classic sprawl index can mainly reflect the low density of the population, but it is not sufficient to reflect the characteristics of decentralization. In fact, while cities continue to spread outwards, they often lead to population migration to the suburbs. Residents and economic activities originally concentrated in the central area of the city spread to the periphery of the city. Urban density and land use intensity decrease, and the distribution of residences may become more dispersed. Therefore, the proportion of the annual average population of non-municipal districts to the annual average population of municipal districts is selected to measure the decentralization of the urban spatial structure and serve as a measure of urban sprawl. The regression results are shown in column (2) of Table 2. After replacing the independent variables, urban sprawl still has a significant positive effect on household electricity intensity, which is consistent with the benchmark regression results.

Considering that sub-provincial cities, provincial capital cities and municipalities have certain advantages compared with general cities in terms of political status, administrative authority, economic development level, policy preferences, and fiscal capacity. In order to further demonstrate the robustness of the results, the above-mentioned urban sample data that may be heterogeneous are eliminated here. After deleting the samples corresponding to sub-provincial cities, provincial capital cities, and municipalities directly under the central government, the regression results are shown in column (3) of Table 2. The coefficients of the core explanatory variables are consistent with the benchmark regression results in terms of significance and coefficient signs. be consistent. This shows that these cities with special administrative levels have not essentially changed the impact of urban sprawl on household electricity intensity.

#### 5 Mechanism analysis

The above analysis shows that urban sprawl has a significant role in promoting household electricity intensity. According to previous theoretical analysis, the impact of urban sprawl on household power intensity is mainly achieved by changing the layout of

houses and reducing the degree of population agglomeration. However, because it is difficult to obtain more accurate data on housing distribution, and at the same time, changes in housing distribution will also cause changes in population agglomeration, so population agglomeration (*Agg*) is used as an intermediary variable in this paper to construct the mediating effect model as formula (3), (4), and (5) to analysis the impact mechanism of urban sprawl on household power intensity.

$$Agg_{it} = \beta_0 + \beta_1 SPR_{it} + \gamma X + city_i + year_t + \varepsilon_{it} \quad (3)$$

$$HPI_{it} = \beta_2 + \beta_3 Agg_{it} + \gamma X + city_i + year_t + \varepsilon_{it} \quad (4)$$

$$HPI_{it} = \beta_4 + \beta_5 SPR_{it} + \beta_6 Agg_{it} + \gamma X + city_i + year_t + \varepsilon_{it} \quad (5)$$

Among them,  $Agg_{it}$  is the population agglomeration index, based on Wang (2020)'s method, measured by the proportion of urban permanent population in urban geographic area (The data for urban permanent population comes from "China Urban Construction Statistical Yearbook", and the data of urban geographic area comes from "China City Statistical Yearbook"). The definitions of other variables are the same as the benchmark regression model shown in Equation 1. The coefficient in formula (3)  $\beta_1$  tests the relationship between urban sprawl and population agglomeration; the coefficient in formula (4)  $\beta_3$  tests the influence of population agglomeration on household electricity intensity; Formula (5) adds an intermediary variable-population agglomeration on the basic of formula (1), and the coefficient  $\beta_5$  is to test the impact of urban sprawl on household electricity intensity after controlling for the intermediary variable. If both  $\beta_1$  and  $\beta_3$  are significant, the mediating effect is significant according to the stepwise regression coefficient method. On this basis, if  $\beta_5$  is not significant, population agglomeration will form a complete mediating effect; if  $\beta_5$  is significant, population agglomeration will form a partial mediating effect.

**Table 3.** The Regression Result of Intermediate Mechanism Test

Variable	<i>Agg</i>	<i>lnHPI</i>	<i>lnHPI</i>	<i>Agg</i>	<i>lnHPI</i>	<i>lnHPI</i>
<i>LnSPR</i>	-22.9242** (-5.99)		0.0647*** (3.97)	-17.9125** (-4.86)		0.0615*** (3.76)
<i>Agg</i>		-0.0003** (-3.82)	-0.0002** (-3.42)		-0.0002** (-3.38)	-0.0002** (-3.05)
Control variable	NO	NO	NO	YES	YES	YES
Sobel test	-			0.0070*** (Z= 3.363, P=0.0070)		
Fixed year	YES	YES	YES	YES	YES	YES
City fixed	YES	YES	YES	YES	YES	YES
R-sq	0.1433	0.1590	0.1635	0.1843	0.1642	0.1683
Obs	3,955	3,875	3,840	3,917	3,844	3,809

The Hausman test showed that the p value was

0.0000, which rejects that the disturbance term was not related to individual characteristics. A fixed-effects model was selected for regression analysis. Table 3 shows the results of the mechanism test. Columns (1) - (3) are regression results that do not include control variables, and columns (4) - (6) are estimated results that include all control variables. Among them, columns (1) and (4) are the estimation results of urban sprawl on population agglomeration. The estimated coefficient of urban sprawl on population agglomeration has passed the 1% level of significance test, and the coefficient is negative, indicating that urban sprawl has significantly suppressed population Agglomeration, which is consistent with traditional research conclusions. Columns (2) and (5) are the estimation results of population agglomeration on household power intensity. The estimated coefficient of population agglomeration on household power intensity is significantly negative at the 1% level, indicating that population agglomeration can suppress the increase in household power intensity. Sections (3) and (6) are the estimated results of urban sprawl on household power intensity after controlling population agglomeration as an intermediary variable. The regression results show that after controlling population agglomeration (*Agg*), the estimated coefficient of urban sprawl on household power intensity Still significantly positive. In summary, population agglomeration has played a significant part of the partial mediating effect in the process of urban sprawl affecting household power intensity. In addition, columns (4) - (6) show that the P value corresponding to Sobel's test is 0.0070, which is far less than 0.05, which also supports the significant mediating effect of population agglomeration. Sprawling urban spatial structure reduces the degree of population agglomeration, which in turn dissipates the power usage efficiency of the agglomerated households, causing an increase in household power intensity, and population agglomeration becomes an important transmission mechanism.

## 6 Conclusion

As China's urbanization process continues to deepen, urban residents' electricity consumption will account for an increasing proportion of China's total electricity consumption. From this point of view, reducing the residential urban power intensity, ensuring the sustainable economic growth and the continuous improvement of urbanization in a reasonable and healthy way has become an important issue in nowadays China. The paper measures the urban sprawl index and household power intensity index of 285 prefecture-level and Municipality cities in China from 2004 to 2017. Through the establishment of fixed effect models, random effects models, and system GMM models, empirical analysis of the impact of urban sprawl on household power intensity was constructed and we found following conclusions: urban sprawl has a significantly positive effect on

household power intensity, that is to say, the higher the degree of urban sprawl, the lower the efficiency of household electric energy utilization would be, and this effect is highly robust. Subsequently, the mediating effect model found that population agglomeration played a significant role of the partial mediating effect in the process of urban sprawl affecting household power intensity. From the perspective of optimizing household power intensity, the research conclusions of this paper provide a policy implications for scientific and rational urban planning in the process of urbanization in China.

Based on the previous conclusions, the following policy suggestions are proposed. Firstly, the concept of "compact city" is the key to improve the electric efficiency. For government decision-making departments, it is necessary to vigorously implement the concept of "compact city", appropriately reduce administrative intervention policies that excessively restrict the economy and population agglomeration, and actively promote the reasonable agglomeration of the economy and population within the city. In the future, urban development should follow the development concept of "intensive and low-carbon ecology", continuously improve energy efficiency, and effectively promote energy conservation and emission reduction. Secondly, optimize power transmission lines based on the distribution patterns of urban residential areas and population living characteristics. Urban sprawl may lead to problems such as low-density housing, scattered industries and municipal facilities, and higher requirements for the power supply system. In order to improve the efficiency of power energy use, it is necessary to follow the spatial pattern of urban population housing, industries and municipal facilities. Effective plan of the power transmission lines could promote ultra-high-voltage power transmission technology to reduce power transmission loss, build an efficient power supply system, and reasonably allocate power energy. Thirdly, the government should pay attention to the important construction of multi-center cities or multi-center agglomeration mode of urban functional zoning, so that residents can find jobs nearby, and avoid drastically increasing transportation energy consumption and commute distance due to the separation of daily work and residence. Multi-center agglomeration can also exert agglomeration effects and increase energy use efficiency. At the same time, it is necessary to help promote energy-saving and environmental -friendly technologies, enhance residents' environmental awareness, promote the transformation of residents' family lifestyles to green lifestyles, improve household power usage efficiency.

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