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Would income inequality affect electricity consumption? Evidence from China

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A B S T R A C T

Recently the expansion of urban-rural income inequality and the rapid growth of fossil-energy consumption have become two significant challenges China should address to achieve its ambitious goals. For the first time, this study uses the Chinese provincial panel data during the period of 1996–2013 to perform a quantitative analysis on the relationship between the urban-rural income gap and the per capita electricity consumption. Fully considering the potential endogeneity problem, this paper uses the orthogonal-difference Generalized Method of Moments (GMM) as the benchmark estimation method. To ensure the robustness of the estimations, the Theil index and per capita urban-rural income are utilized to measure the urban-rural income gap. The estimation results indicate that the influences of urban-rural income inequality on electricity depend on the income level. At the current stage of economic development, the income disparity has significantly negative impacts on provincial per capita electricity consumption. Moreover, there is also strong evidence for the existence of the inverted U-shaped relationship between per capita electricity consumption and GDP per capita. Furthermore, other economic and social factors, including the enhancement of urbanization and industrialization levels, the adjustment of the population structure, and the development of import-export trade may also promote electricity consumption.

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1. Introduction

Despite the remarkable achievements of economic development in the past three decades since the reform and opening up in the late 1970s, criticisms and suspicions have been recently looming over the sustainability of China's neck-breaking growth.[1] Currently, the increasing inequality in development between urban and rural areas and deteriorating environmental quality have become the main barriers to China's sustainable development.[2] Due to the dualistic economic structure and the specific tax and fiscal policies that favored the development of urban areas, the huge gap in development between urban and rural areas has long been a problem in China (e.g., [89,94]. As shown in Fig. 1, since 2002, the ratio of China's urban-rural residential income has been consistently over 3.0. Particularly, in 2009, this ratio achieved its highest level of 3.33. In recent years, the urban-rural income gap has slightly narrowed, although the level remained high at 3.03 in 2013. Among China's three main regions (east, center and west), the urban-rural income disparity is lowest in the prosperous eastern region while largest in the relatively less developed western region.

Partly because of the accelerated industrialization, urbanization and rapid economic growth, in recent years, China's consumption of fossil energy surged (e.g., [47,102]. The impact of urbanization and migration may significantly affect energy consumption and

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[1] According to *China Statistical Yearbook 2015*, from 1979 to 2014, the average annual growth rate of China's GDP was 9.7%. For more information, please refer to http://www.stats.gov.cn/tjsj/ndsj/2015/indexch.htm.

[2] There has been growing anecdotal evidence that the urban-rural development gap and environmental problems may impede China's sustainable growth. For instance, refer to http://www.bbc.com/news/business-13945072 and https://www.weforum.org/agenda/2015/11/will-china-become-a-global-climate-leader/.

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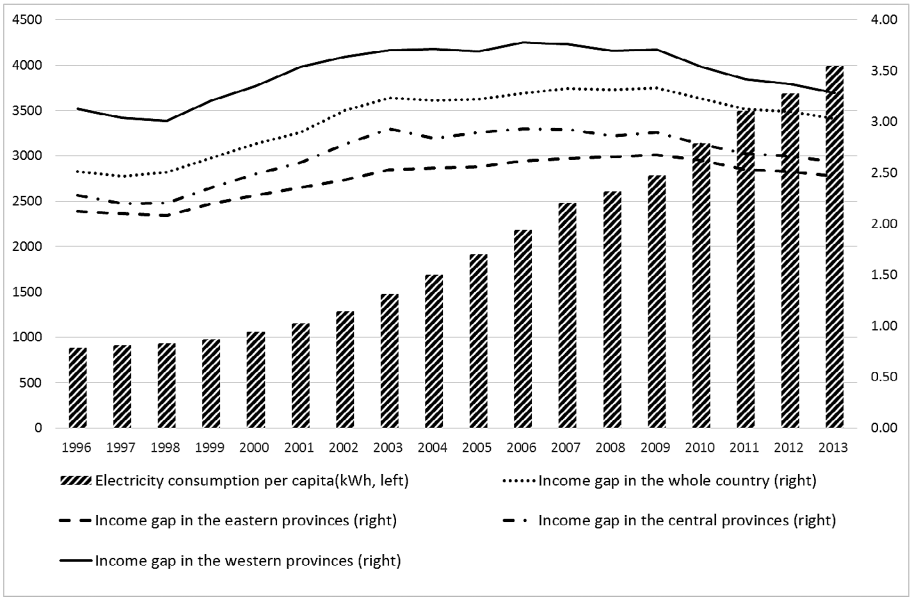

Fig. 1. Per capita electricity consumption and the income gap between urban and rural areas in eastern, central and western provinces as well as in the whole country, 1996–2013. Notes: The eastern provinces include Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan; the central provinces include Heiloingjiang, Jilin, Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan. The western provinces include Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shannxi, Gansu, Qinghai, Ningxia, Xinjiang.
Data sources: China Statistical Yearbooks and Chinese Energy Statistical Yearbooks of various years

carbon emissions, and therefore bring pressure to the energy system [57,97]. Consequently, China's CO_2 emissions ballooned, which garnered the increasing focus of the international community as global warming has become a growing threat to the world. In recent years, due to the improvement of production efficiency, China's carbon dioxide intensity (i.e., CO_2 emissions per unit of GDP) has been dramatically decreased. However, the total amount of CO_2 emissions continues to soar. In 2009, to promote energy conservation and emission reduction, the State Council of China, for the first time, formulated carbon emission reduction targets; by 2020, China's carbon intensity (CO_2 emissions per unit of GDP) is set to be decreased by 40%–45% of the 2005 level. Since then, China has announced a series of ambitious goals to curb CO_2 emissions. Before the 2015 UN Climate Change Conference in Paris, China vowed to peak total CO_2 emissions by 2030, and the carbon intensity is expected to be decreased by 60%–65% in 2030 compared with the level of 2005. Therefore, the ensuing 10–15 years are a critical period for China to accomplish its goals in constraining CO_2 emissions and enhancing green development.

The promotion of the usage of electricity, the relatively cleaner energy source, particularly the increase in renewable energy power generation, is an important measure to promote energy conservation and reduction of CO_2 emissions (e.g., [43,62]. In China, the amount and the importance of electricity consumption have grown very rapidly in recent years, and the ratio of traditional fossil energy in the energy mix is declining. According to *Chinese Energy Statistical Yearbook 2014*, China's electricity consumption per capita had increased by over four-and-a-half times from 894 kW-hours (kWh) in 1996–3993 kWh in 2013 (as shown in Fig. 1). During this period, the average annual growth rate of China's electricity consumption per capita was 9.3%, which was slightly higher than the annual growth rate of GDP per capita (9.1%). In a recent study, Hao et al. [33] found that China's consumption of coal, the main source of CO_2 emissions and haze pollution, is expected to peak around 2020. The reduced proportion of fossil energy was partly absorbed by renewable energy. According to Renewable 2015 Global Status Report, China's renewable energy power generation represented 23% of the global level in 2014.[3] In the same year, the investment in renewable energy power generation initially exceeded the net investment of fossil energy power plants, among which wind power generation was more than 100 GW-hours (GWh), and hydropower represented 27% of the global level. The growth of electricity consumption, particularly power generated from renewable energy, contributed to the cleaning of China's energy structure and the reduction of CO_2 emissions, which could further help to improve China's environmental quality [19,35]. There has been much research on the factors that affect the electricity consumption. For instance, Shiu et al. [69] found that there was a co-integration relationship between actual GDP and electricity consumption in China. Jacobson et al. [42] indicated that the quality of energy services, as well as the level of industrialization and economic development of a country, has a significant impact on electricity consumption. Sanquist et al. [68] concluded that household income, local electricity prices, access to natural gas and consumption characteristics in an electricity market are important factors that affect energy consumption.

In the context of China, there is remarkable disparity in urban-rural income inequality and electricity consumption across different regions. As shown in Fig. 2, the disparity in the distribution of electricity consumption across Chinese provinces was persistent during the sample period between 1994 and 2013. Specifically, in both 1994 and 2013, certain central and western provinces, including Henan, Hubei, Hunan, Sichuan, Chongqing and Yunnan, had a relatively higher urban-rural income gap, and the electricity consumption in these provinces was relatively low.[4] Additionally, as represented in panels b) and d) of Fig. 2, the Theil

[3] For more information, please refer to http://www.climatechangenews.com/2015/06/19/renewable-energy-in-numbers-ren21-report/and http://www.ren21.net/status-of-renewables/global-status-report/.

[4] Currently, there are 23 provinces, four Centrally Administered Municipalities, and five autonomous regions in China. Because these entities are administratively equal, the term “province” is utilized throughout the paper. Tibet and Taiwan are excluded due to data unavailability.

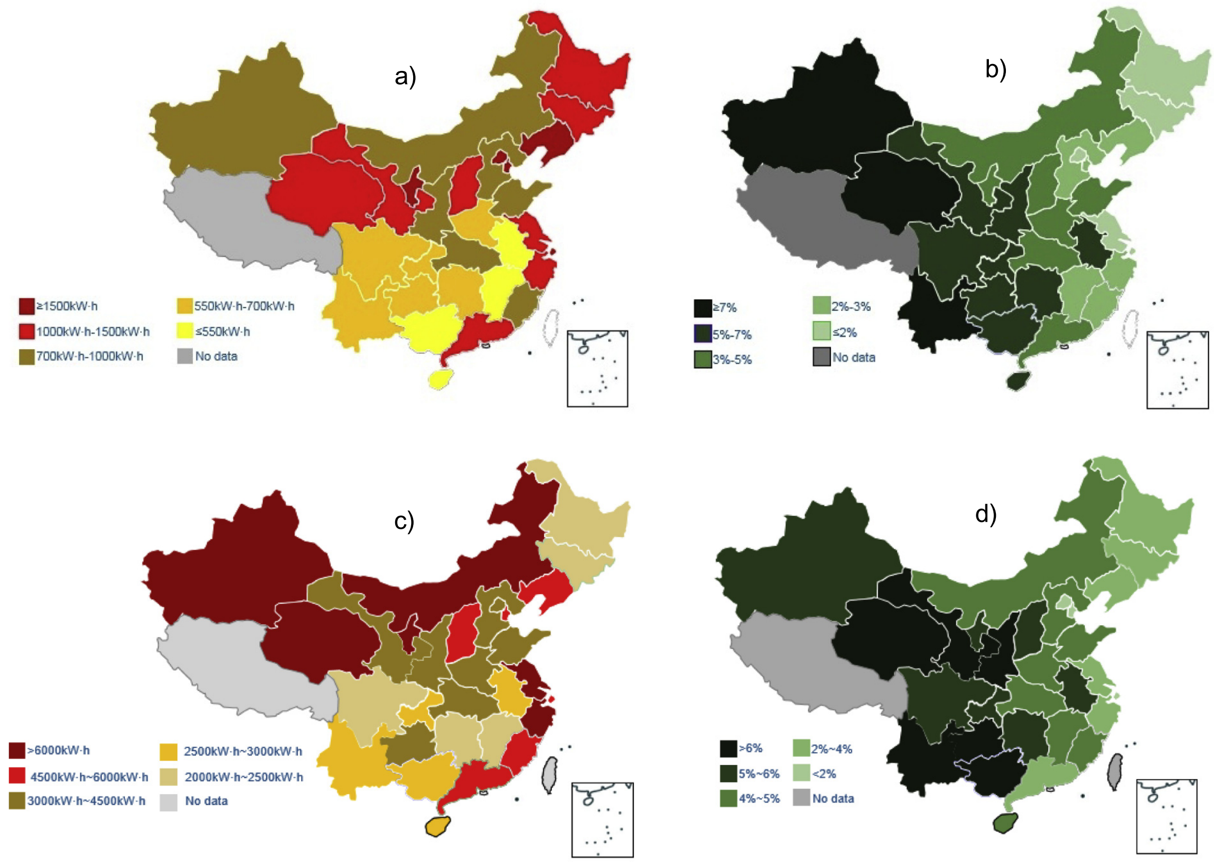

Fig. 2. Electricity consumption per capita and the Theil index by province in 1996 and 2013. a) Electricity consumption per capita in 1996; b) Electricity consumption per capita in 2013; c) Theil index in 1996; d) Theil index in 2013.
Data sources: China Statistical Yearbooks and Chinese Energy Statistical Yearbooks of various years

indices of Chinese provinces remained approximately the same at the beginning and ending years of the sample period, suggesting that the imbalance in economic development remained during the sample period.[5]

Since the rapid development of China's urbanization in 1990, the gap in development between urban and rural areas has become increasingly prominent, which may have important influences on the electricity consumption. On the one hand, China's urban-rural dual economic structure favors urban development at the expense of rural areas. The urban-biased policies may lead to relatively backward infrastructure constructions and lower income in rural areas, which affect the level and growth rate of rural electricity consumption. The consistently widening gap between urban and rural electricity consumption may, in turn, restrain the speed of growth in electricity consumption of the whole nation. On the other hand, with the acceleration of urbanization and industrialization, the demand for electricity consumption in urban areas may rise (e.g., [61,67,80]. Specifically, the large-scale immigration from rural areas to cities and towns further pushes up the demand for electricity usage in urban areas (e.g., [44,55,100]. Therefore, if the growth rate of the electricity consumption of urban areas is sufficiently high, the widening of the urban-rural gap may lead to a further increase in per capita electricity consumption. However, although the urban-rural income disparity may potentially affect electricity consumption, minimal research has been performed to investigate this important impact. Given that electricity is a relatively clean energy source, the increase in the ratio of electricity in China's energy structure may improve the environmental quality [95]. This observation is particularly the case if there is sufficient technology progress in renewable energy generation and power generation efficiency.

The Chinese government has promised to achieve sustainable growth, of which two important pillars are "harmonious society" and "green development".[6] To build a "harmonious society", the disparity in urban-rural development should be reduced and eventually eliminated. To pursue "green development", the consumption of relatively clean energy, electricity should be greatly promoted. Although apparently uncorrelated, these two issues may have a significant relationship, which has important policy implications for Chinese policy makers. If higher urban-rural income inequality is proven to be associated with lower electricity consumption, the policy measures to reduce income disparity and to enhance electricity consumption are compatible. In other words, the "green development" could be improved at the same time as "harmonious society" is constructed. Otherwise, the two political

[5] The Theil index is a statistic used to measure the inequality of economic and social indicators. More explanations of the Theil index are provided in subsection 3.2.

[6] For a comprehensive understanding of "harmonious society", one could refer to the report China 2030: building a modern, harmonious, and creative society, which is available at http://documents.worldbank.org/curated/en/2013/03/17494829/china-2030-building-modern-harmonious-creative-society.

goals are contradictory and could not be achieved at the same time.

Specifically, the following key questions need to be answered: Does urban-rural income inequality indeed affect per capita electricity consumption? If so, what is the direction of the impacts? Do the influences change at different levels of economic development? To answer these questions reasonably and convincingly, in this study a panel data of 29 Chinese provinces for the period between 1996 and 2013 is utilized to quantitatively analyze the impacts of the urban-rural income gap on electricity consumption, which is the main contribution of this paper. To control for potential endogeneity and the fixed effects that may affect electricity consumption but are generally invariant over time, the orthogonal-difference Generalized Method of Moments (GMM) estimator is employed as the benchmark estimation approach. Furthermore, to check the robustness of empirical results, two indicators measuring the urban-rural income disparity are utilized: the Theil index and the rate of urban and rural residents' income per capita. Considering that the relationship between electricity consumption and urban-rural income gap may differ at different levels of economic development, the full sample is divided into two subsamples (i.e., the relatively richer eastern provinces and less developed inland provinces), and the relationship is re-estimated within each subsample.

The remainder of this paper is organized as follows. Section 2 briefly reviews the relevant literature. Section 3 introduces estimation methods and data utilized in this study. In section 4, the empirical estimation results are reported and discussed. Finally, the last section summarizes the main conclusions and provides corresponding policy suggestions.

2. Literature review

The relationship between inequality and growth has been a popular academic subject for a long time. For instance, Murphy et al. [59] establish a multi-sector model to analyze from the perspective of consumer demand and found that the widening income gap would reduce the consumer's demand and affect economic growth negatively to an extent. Regarding China, the income gap in Chinese society, particularly the income inequality between urban and rural areas, has been widening since the early 1990s [60]. Thus far, there has been a growing body of literature examining the nexus of income inequality and economic growth in China. In an early research study, Chen and Fleisher [17] found evidence for the conditional convergence of per capita GDP across Chinese provinces, suggesting that regional income gap may decrease during the sample period 1978–1993 [8]. used the household level data from 1986 to 1999 and found a negative correlation between economic growth and income inequality. Wan et al. [79] employed a polynomial inverse lagged (PIL) model and verified that there was an all-time imbalance in the development of Chinese society, and the nexus of inequality and growth was non-linear and negative. Atems and Jones [6] utilized a panel VAR model to estimate the dynamic response of inequality and per capita income. The results indicate that the relationship between inequality and per capita income varies with time and is sensitive to specific events in history. Lee and Son [41] employed GMM model to analyze the panel data and found that the negative impact of income inequality on economic growth was more pronounced in economically underdeveloped countries.

On the other hand, there have been many studies investigating the causes and economic consequences of the urban-rural income disparity in China. For instance, using household survey data, Yang [89] found that urban-biased policies and institutions, such as labor mobility restrictions and inflation subsidy financial policies, welfare systems should be responsible for the rising rural-urban disparity in China. More recently [26], found that the determinants of regional dispersion of the growth rates of GDP and total factor productivity (TFP) in China include the physical and human capital, the infrastructure investment, the infusion of new technology and its regional spread, as well as market reforms. Wang et al. [80] argued that the great income gap between urban and rural areas leads to different lifestyles in China, and the main drivers of the widening urban-rural gap include urbanization level, per capita disposable income, Engel's coefficient, the strength of energy consumption, and the relative importance of secondary and tertiary industries. Afridi et al. [1] conducted an experimental study, of which the results indicated that China's household registration (hukou) system is beneficial to city dwellers and may cause discrimination in wealth distribution that favors urban residents. Guo [51] constructed a simultaneous equation model and revealed that the increase in household income inequality may lead to a decline in consumer demand and higher investment.

Furthermore, there have been a huge number of studies on the relationship between economic development and energy/electricity consumption. The extant research in this field could be classified into two categories. The first category investigates the causality between economic development and energy/electricity consumption. For instance, Yoo [91] utilized the data of Association of South East Asian Nations (ASEAN) for the 1971–2002 period and found evidence for bilateral causality between electricity consumption and economic growth in Malaysia and Singapore and unidirectional causality running from economic growth to electricity consumption in Indonesia and Thailand. Huang et al. [39] used a panel data of 82 countries for the 1972–2002 period to examine the causal relationship between energy consumption and GDP. The researchers concluded that, in the middle-income countries, the economic growth leads energy consumption positively, while in the high-income countries, economic growth leads energy consumption negatively. In a recent study, Stern and Enflo [73] utilized a Swedish time series spanning 150 years and found the energy-growth nexus changed over time. Specifically, energy causes output in the full sample period, while output causes energy consumption in more recent samples. Considering the income disparity, Lin and Du [50] estimated the transportation energy consumption of 30 provinces in China during the period of 1997–2011 and found that there was a clear correlation between urbanization and transportation energy consumption. A comprehensive review of the studies on the causality relationship between electricity consumption and economic growth could be found in Zhang et al. [99,101]. The other type of literature focuses on how energy/electricity consumption evolves as economy grows. The most commonly utilized empirical framework of these studies is the Environmental Kuznets Curve (EKC), which was originally raised by Refs. [28,29]. This framework states that the relationship between environmental quality and energy consumption is inverted-U shaped; at the early stage of economic development, environmental quality deteriorates as GDP per capita increases, while the environmental quality may gradually improve as economy grows after a certain level of GDP per capita is achieved. Certain researchers have borrowed the idea of EKC to investigate the relationship between energy/electricity consumption and economic development. For instance, in a pioneer research study, Suri and Chapman [76] utilized the panel data of 33 countries over the 1971–1991 period and verified the inverted-U shaped relationship between commercial energy consumption and GDP per capita. Yoo and Lee [92] also found evidence for the existence of EKC for electricity consumption by employing the data of 88 countries. In a recent study, Ahmad et al. [2] verified the existence of a long-term cointegration relationship between energy consumption and economic growth and that the EKC for CO_2 existed in India using both aggregated and disaggregated data. However, not all studies supported the existence of EKC for energy/electricity consumption. For example, using a large dataset consisting of 113 countries over the time span 1971–2014, Luzzati and Orsini [56] failed to find solid evidence for the energy-EKC hypothesis. Similarly, Zilio and Recalde [103] used panel data of 21 Latin American and Caribbean countries during the 1970–2007 period, and the estimation results reject the validity of the EKC hypothesis for energy consumption. The inconsistency of the empirical results is also considered a problem that needs to be addressed for EKC studies [71,72].

Because the previous literature indicates that income inequality may affect economic growth and there may be relationship between energy/electricity consumption and economic development, income inequality may have influences on the energy/electricity consumption. However, the research on this topic remains scarce. Thus far, there have only been a few studies on the relationship between inequality and environmental quality. In a seminal research study, Torras et al. [78] used a dataset of 58 countries covering years spanning 1977–1991 and analyzed the impact of income distribution on the quality of the environment; they found that the expansion of the income gap synchronizes with the reduction of the environmental quality in the low-income countries. In the follow-up studies, Ravallion et al. [65] and Heerink et al. [36] both verified that income inequality is negatively related to environmental degradation by employing panel data of 42 countries over the period of 1975–1992 and cross-sectional data of 64 countries in 1985, respectively. In the context of China, Hao et al. [32] provides a recent study that investigated the impacts of income disparity within provinces (measured with Gini coefficient) and provincial CO_2 emissions. Despite the limited studies on the nexus of inequality and environment, to the best of our knowledge, there has been no research that focuses on the relationship between income inequality and energy consumption particularly electricity consumption.

Consequently, in sum, compared with the previous research, the contribution of this paper is threefold. First, this study is the first examining the explicit relationship between income disparity and electricity using panel data at the province level. As previously noted, this study can fill the gap in academics and may have important policy implications. Second, urban-rural income inequality is carefully investigated as the key indicator for disparity in China's development, which reflects crucial characteristics of China's development. Currently, China has the typical characteristics of a "dual economy" as the development gap in urban and rural areas persists.[7] Furthermore, the Theil index and the urban-rural income ratio are utilized to measure the urban-rural income disparity; therefore, the results using these two indicators could be treated as robustness checks of each other. Third, this paper fully considers the potential endogenous problems and utilizes the orthogonal difference of the generalized method of moments as the benchmark estimation method to control for it. As Carson [14] stressed, the endogeneity caused by omitted variables and measurement errors may lead to biased estimations of EKC relationship. Consequently, to obtain reasonable and meaningful results, the endogeneity should be well addressed.

3. Methodology and data

3.1. Estimation model and methods

Conventionally, EKC interprets the relationship between economic development and environmental performance, and the emissions or/and concentrations of various pollutants are commonly utilized as indicators for the level of environmental quality [71,74] ; [14]. However, because the estimation results using different indicators for environmental quality are very controversial, and because many ambient pollutants particularly air pollutants are generated from the combustion of fossil energy, certain researchers utilized energy consumption as a proxy of environmental pressure (e.g., [76,103]. Based on the EKC framework, the regression model utilized in this paper is as follows in Eq. (1):

$$\ln ele_{it} = \alpha + \gamma_1 gap_{it} + \gamma_2 \ln PGDP_{it} + \gamma_3 (\ln PGDP_{it})^2 + \gamma_4 \ln PGDP \cdot gap_{it} + \gamma_5 \vec{X} + \eta_i + \varepsilon_{it} \quad (1)$$

where the logarithmic electricity per capita ($lnele_{it}$) is the dependent variable. Among the regressors, the urban-rural inequality (*gap*) is the key explanatory variable. *PGDP* stands for the per capita real GDP. $\vec{X}$ represents a series of control variables. The subscripts i = 1, 2 …, 30 represents the 30 provinces of China included in the sample.[8] t = 1, 2 …, 18 represent a specific year during the sample period from 1996 to 2013. η_i represents time-invariant individual characteristics. ε_{it} represents an independent and identically distributed (i.i.d.) random disturbance term.

In Eq. (1), the logarithmic GDP per capita and its squared term are introduced to capture the possible EKC relationship between electricity consumption and GDP per capita (e.g., [92]. In addition, to control for the potential endogenous and fixed effects, the first-difference GMM method raised by Holtz-Eakin and Newey [37] and Arellano and Bond [5] is used. After conducting the first-difference transformation of data to remove the time-invariant fixed effects, the first-difference GMM approach deals with endogeneity by utilizing the lagged endogenous variables as the instrumental variables. This method has recently gained popularity in the research on ecological and environmental economics, and a growing body of literature in this field has utilized the GMM estimator as the main empirical study technique, such as that by Giovanis [27] and Hao et al. [32]. It is noteworthy that another commonly utilized type of GMM method is system GMM, which was developed by Arellano and Bover [4] and Blundell and Bond [10]. As Huang [40] noted, although first-difference GMM is less efficient than the system GMM, it is more suitable for the panel data with small N (the number of cross-section units), because the asymptotic properties of the system GMM could only be satisfied when N is sufficiently large. However, as Roodman [66] pointed out, the main weakness of the first-difference GMM is that the transformation of the first-order differencing may expand the gaps in

[7] The "dual economy" refers to the economy in which there are two separate economic sectors, divided by different levels of economic development, technology, and/or differentiated patterns of demand. This theory was originally raised by Ref. [46]; who divided a typical developing economy into two sectors: the traditional agricultural sector with relatively low productivity and abundant labor force and modern manufactural sector that has higher productivity and attracts labor from agricultural sector. In recent years, the characteristics of China's "dual economy" have been investigated and verified by a growing number of research studies (e.g., [13,15].

[8] Currently, the mainland of China has 22 provinces, four Centrally Administered Municipalities, and five autonomous regions. Because these entities are administratively equal, the term "province" is utilized throughout the paper. Tibet is excluded simply because of data unavailability.

unbalanced panels where there are missing values in dependent variable. To cope with this problem, Arellano and Bover [4] developed orthogonal-difference GMM approach, in which the data lose is minimized by subtracting the average of all future available variables observations rather than subtracting the previous observation from the current one.[9] As a result, in this paper, the orthogonal-difference GMM estimation that contains more data information and allows forward orthogonal deviation is utilized as benchmark while the first-difference GMM estimation is used as robustness check.

3.2. Data

Because the main purpose of this study is to investigate the impacts of the urban-rural income disparity on electricity consumption, the main explanatory variable is the urban-rural income inequality. Additionally, in this study, we added the first order lag of the dependent variable as the explanatory variable. In accordance with the previous similar research on the EKC relationship in China, the control variables contained in $\vec{X}$ include the population density, the level of urbanization, the ratio of secondary industry value-added to GDP, and the trade openness (the ratio of total amount of import and export to GDP). Specifically, the explanatory variables utilized in this study are introduced as follows:

(1) Urban-rural income inequality (denoted as *Gap*). For ease of calculation, the ratio of urban and rural residents' average income is commonly and widely used as a measure of the income gap between urban and rural areas [49,70]. Another popular measurement for income inequality is the Theil index, which was originally proposed by Theil [77]. Primarily used to measure economic inequality and other economic phenomena, the Theil index has previously been broadly used in the academic research for the measurement of inequality for different aspects of the economy and society. Recently, a growing body of literature has utilized Theil index to investigate inequality of energy consumption across countries (e.g., [3,24]. Based on China's urban-rural dual economic structure, Wang et al. [83] determined a calculation method of the Theil index to measure the gap between urban and rural areas in China as follows:

$$\begin{aligned} Theil_{it} &= \sum \left(\frac{I_{ijt}}{I_{it}}\right) \ln\left[\left(\frac{I_{ijt}}{I_{it}}\right) \Big/ \left(\frac{P_{ijt}}{P_{it}}\right)\right] \\ &= \left(\frac{I_{i1t}}{I_{it}}\right) \ln\left[\left(\frac{I_{i1t}}{I_{it}}\right) \Big/ \left(\frac{P_{i1t}}{P_{it}}\right)\right] + \left(\frac{I_{i2t}}{I_{it}}\right) \ln\left[\left(\frac{I_{i2t}}{I_{it}}\right) \Big/ \left(\frac{P_{i2t}}{P_{it}}\right)\right] \end{aligned} \tag{2}$$

where i represents the province i, j represents urban areas ($j = 1$) and rural areas ($j = 2$). *Pijt* represents the population size in urban areas ($j = 1$) or rural areas ($j = 2$) of each province in year t. Pit represents the total population of urban and rural areas of each province in time t. *Iijt* represents the total income of urban areas ($j = 1$) or rural areas ($j = 2$) in various provinces in year t. *Iit* represents the total income of urban and rural areas in each province at time t. In accordance with Wang and Ouyang [83]; in this study Eq. (2) is utilized to calculate Theil index for all Chinese provinces.

(2) GDP per capita (denoted as *Gdp*). In accordance with a large number of studies on EKC (e.g. [28,29,33], the relationship between environmental quality/energy consumption and GDP per capita may be nonlinear. To capture the potential nonlinear relationship, GDP per capita and its squared term are both incorporated into benchmark regression Eq. (1). To eliminate the effects of price change, the data for GDP per capita have been converted to real term at a constant 1978 price.

(3) Urbanization level (denoted as *Urb*). Many previous studies have tested and verified the close relationship between urbanization and energy consumption in China (e.g., [21,53,81,82]. Thus, it is necessary to add the level of urbanization (represented by the proportion of urban residents to the total population) as a control variable for electricity consumption per capita in China.

(4) Ratio of secondary industry value-added to GDP (denoted as *Str*). Because the rapid development of the secondary industry contributed significantly to the surge of energy consumption and CO_2 emissions in China during the last two decades, the change of industrial structure may be an important influential factor of China's electricity consumption [82]. In accordance with previous studies such as Auffhammer and Carson [7] and Hao et al. [33]; in this research, the ratio of secondary industry value-added to GDP is utilized as an explanatory variable for electricity consumption in China.

(5) Trade openness (denoted as *Tra*). The relationship between trade openness and energy consumption has been investigated by many scholars (e.g., [23,64,76]. Moreover, as Du et al. [23], stressed, trade openness may affect energy consumption and CO_2 emissions in two opposite directions. On the one hand, greater trade openness may lead to more energy consumption and related pollution through more exports of energy-intensive goods. On the other hand, international trade may also trigger advanced technology diffusion such that energy consumption in the production may be reduced. In this paper, in accordance with Du et al. [23]; the total value of import and export as a proportion of GDP is utilized to measure trade openness.

This paper utilizes the provincial panel data of China for the period between 1996 and 2013. Due to the lack of data, Tibet is excluded from the sample. The data for per capita electricity consumption are cited from *China Energy Statistical Yearbook*. Certain economic and social statistics, including urban citizens' disposable income, the net income of rural residents and the provincial population density are mainly collected from various years of *China Statistical Yearbook*. The other data are taken and/or calculated based on the statistics of CCER Economic and Financial database and statistical yearbooks of each province. As a summary, the descriptive statistics of the variables utilized in this study are shown in Table 1.

Before conducting empirical estimations, to exhibit the relationship between electricity and income inequality intuitively, the scatter diagram of electricity consumption per capita against the Theil index as well as corresponding fitness line is plotted in the following Fig. 3. It is clearly shown in Fig. 3 that the fitness line has a negative slope, suggesting that the association between these two variables is negative. However, the goodness of fit for the fitness line (R^2) is only 0.04. Therefore, to explore the precise relationship between the two, more sophisticated and elaborate estimation techniques should be utilized, which is the main content of the next section.

4. Empirical results and discussions

The estimation results of benchmark regression Eq. (1) are reported in the following Tables 2 and 3. All results are obtained using the software STATA 14.0. The Theil index is utilized as the indicator for urban-rural income inequality in Table 2, while in Table 3, the

[9] For more detailed information about the differences between the first-difference GMM and orthogonal-difference GMM, one could refer to Roodman [66] and Hayakawa [34].

Table 1
Descriptive statistics of the variables used in the empirical study.

Variable	Definition of the variable (unit)	Mean	Std. Dev	Min	Max
Ele	The electricity consumption per capita (Ten thousand tons of standard coal)	2382.043	1836.684	452.976	12284.45
Theil	Theil index	0.054	0.025	0.008	0.128
Gap	The residents' income ratio between city and country	2.880	0.620	1.599	4.759
Urb	Urbanization level	0.439	0.165	0.139	0.896
Str	The ratio of secondary industry value-added to GDP	0.453	0.078	0.197	0.590
GDP	GDP Per capita (Ten thousand yuan)	5093.346	4657.630	616.549	31956.660
Tra	The total value of import and export as a proportion of GDP	0.278	0.393	6.00e-06	1.722

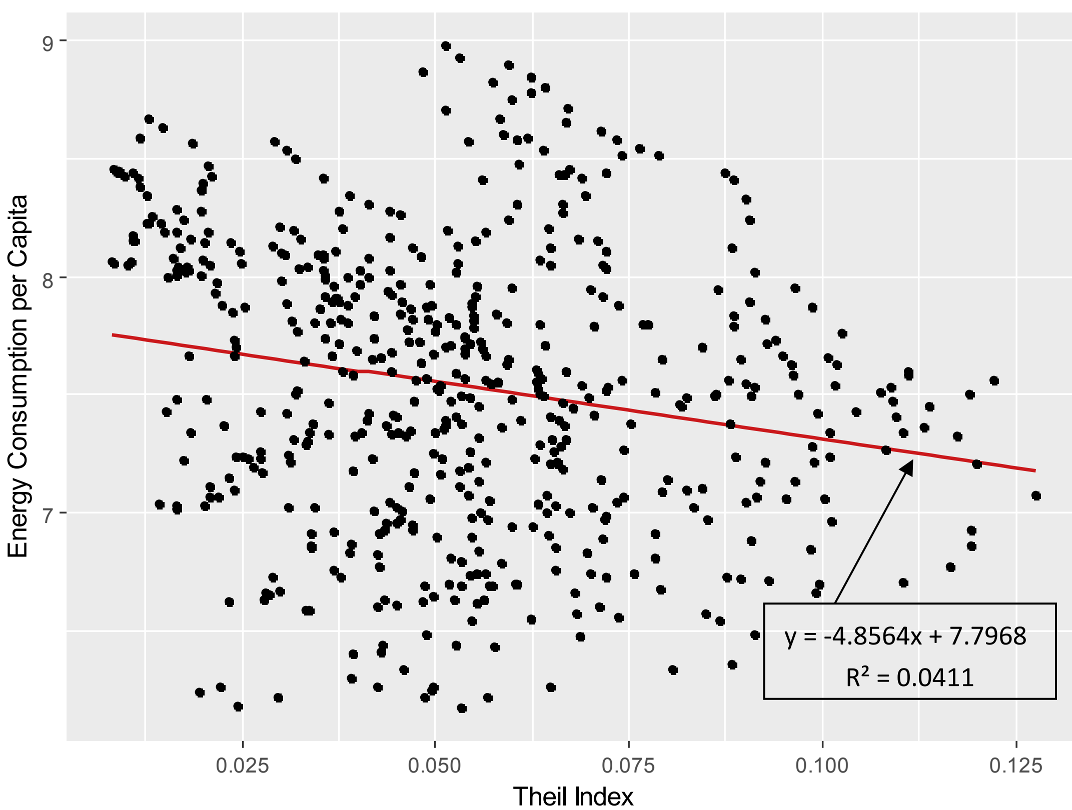

Fig. 3. The scatter diagram of electricity consumption per capita against the Theil index and the corresponding fitness line.

Table 2
The estimation results when the Theil index is utilized.

Dep. Var: ln (Ele)	OLS	FE	FE	First-diff GMM	First-diff GMM	Orthogonal-diff GMM	Orthogonal-diff GMM
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
L. ln (Ele)	0.995*** (0.00857)	0.847*** (0.025)	0.852*** (0.025)	0.478*** (0.050)	0.402*** (0.056)	0.773** (0.043)	0.856*** (0.049)
Theil	3.298 (2.111)	0.770** (0.350)	3.225 (2.894)	1.162*** (0.368)	12.069** (6.135)	0.717* (0.407)	9.035* (4.823)
ln (GDP)	0.514*** (0.126)	0.505*** (0.113)	0.611*** (0.168)	0.631*** (0.143)	1.365*** (0.362)	0.573*** (0.143)	0.969*** (0.326)
$\ln^2$ (GDP)	−0.029*** (0.007)	−0.025*** (0.007)	−0.031*** (0.009)	−0.014* (0.008)	−0.051*** (0.019)	−0.026*** (0.008)	−0.051*** (0.017)
Urb	−0.011 (0.051)	0.314*** (0.084)	0.316*** (0.084)	0.185 (0.156)	0.261 (0.188)	0.262*** (0.141)	0.335** (0.164)
Str	0.060 (0.052)	0.369*** (0.105)	0.371*** (0.105)	1.279*** (0.246)	1.664*** (0.313)	0.527*** (0.175)	0.482** (0.206)
Tra	0.007 (0.012)	0.064** (0.028)	0.064** (0.028)	0.101** (0.046)	0.115** (0.054)	0.116** (0.045)	0.148*** (0.052)
ln (GDP)*Theil	−0.318 (0.270)		−0.333 (0.390)		−1.566* (0.838)		−1.150* (0.653)
Constant	−2.181*** (0.563)	−1.560*** (0.441)	−2.072*** (0.744)				
Sargan test				0.318	0.278	0.148	0.773
A-B test for AR (1)				0.000	0.029	0.000	0.000
A-B test for AR (2)				0.708	0.543	0.710	0.577
Observations	510	510	510	480	480	480	480
Number of provinces	30	30	30	30	30	30	30
R-squared	0.990	0.985	0.985				

Note: First-diff GMM and Orthogonal-diff GMM represent the first-difference GMM and the orthogonal-difference GMM methods, respectively. The dependent variable is ln(Ele), logarithmic electricity consumption per capita. L. ln(Ele) represents the first-order lag of the dependent variable. ln(GDP) and $\ln^2$(GDP) represent the logarithmic GDP per capita and its squared term, respectively. ln(GDP)*Theil is the interaction of the logarithmic per capita GDP and the Theil index. The standard errors are reported in the parentheses. The statistics are presented for the tests. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively.

Table 3
The estimation results when the ratio of urban and rural residents' average income is utilized.

Dep. Var: ln (Ele)	OLS	FE	FE	First-diff GMM	First-diff GMM	Orthogonal-diff GMM	Orthogonal-diff GMM
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
L. ln (Ele)	0.997*** (0.009)	0.845*** (0.025)	0.852*** (0.025)	0.464*** (0.053)	0.411*** (0.058)	0.704*** (0.054)	0.706*** (0.034)
Gap	0.157** (0.075)	0.022* (0.013)	0.158 (0.097)	0.037** (0.015)	0.433*** (0.200)	0.041** (0.018)	0.308** (0.147)
ln (GDP)	0.578*** (0.113)	0.564*** (0.106)	0.683*** (0.135)	0.754*** (0.151)	1.219*** (0.281)	0.742*** (0.159)	1.154*** (0.219)
ln^2 (GDP)	−0.031*** (0.006)	−0.029*** (0.006)	−0.033*** (0.007)	−0.021** (0.009)	−0.038*** (0.013)	−0.031*** (0.009)	−0.051*** (0.010)
Urb	−0.0241 (0.048)	0.330*** (0.084)	0.331*** (0.084)	0.158 (0.168)	0.318* (0.187)	0.164 (0.177)	0.347** (0.140)
Str	0.0513 (0.052)	0.359*** (0.105)	0.347*** (0.105)	1.201*** (0.262)	1.605*** (0.318)	0.475** (0.228)	0.479*** (0.166)
Tra	0.004 (0.012)	0.0623** (0.028)	0.065** (0.028)	0.127** (0.052)	0.119** (0.057)	0.105* (0.055)	0.083* (0.044)
ln (GDP)*Gap	−0.017* (0.010)		−0.018 (0.013)		−0.055** (0.027)		−0.038** (0.019)
Constant	−2.585*** (0.546)	−1.806*** (0.416)	−2.504*** (0.645)				
Sargan test				0.203	0.161	0.213	0.103
A-B test for AR (1)				0.000	0.000	0.000	0.000
A-B test for AR (2)				0.733	0.586	0.802	0.758
Observations	510	510	510	480	480	480	480
Number of provinces	30	30	30	30	30	30	30
R-squared	0.990	0.985	0.985				

Note: Same as in Table 2 ln(GDP)*Gap is the interaction of logarithmic per capita GDP and the ratio of urban and rural residents' average income.

Table 4
The long-run estimates of explanatory variables by GMM shown in Tables 2 and 3.

Dep. Var: ln (Ele)	Var: Theil First-diff GMM	Var: Theil Orthogonal-diff GMM	Var: Gap First-diff GMM	Var: Gap Orthogonal-diff GMM
Method	(1)	(2)	(3)	(4)
Theil Gap	20.182**	63.743*	0.735***	1.048**
ln (GDP)	2.283***	6.729***	2.070***	3.925***
ln^2 (GDP)	−0.085***	−0.354***	−0.065***	−0.173***
Urb	0.436	2.326**	0.540*	1.180**
Str	2.783***	3.347**	2.725***	1.629***
Tra	0.192**	1.028***	0.202**	0.282*
ln (GDP)*Theil ln (GDP)*Gap Turning point of GDP per capita	−2.619* (2224)	−7.986*(2583)	−0.093** (2625)	−0.129** (3312)

Note: Same as in Tables 2 and 3. The long-run estimates of the variables are equal to their short-run estimates divided by one minus the corresponding estimated coefficients of the first-order lag of dependent variable [31].

ratio of urban and rural residents' average income is used.[10] As noted previously, to address the potential problems that may exist in the model, the first-difference GMM and the orthogonal-difference GMM approaches are employed; the corresponding results are shown in the last three columns of each table. To ensure the effectiveness of the dynamic panel data estimation results, the benchmark results of the orthogonal-difference GMM and alternative first-difference GMM estimations are also compared with the pooled OLS and Fixed Effects (FE) estimates as Bond [11] suggested. Therefore, in the first three columns of each table, the conventional OLS and FE estimation results are reported.

The results of the Sargan tests and the Arellano-Bond tests are also reported in Tables 1 and 2 The Sargan tests are performed to test the overall validity of the instruments, while the Arellano-Bond (A-B) tests are conducted to examine whether the first- and second-order lags of the residuals have autocorrelations. The test results indicate that the Sargan statistics are higher than 0.1, and the A-B tests for AR (1) and AR (2) are lower than 0.1 and higher than 0.1, respectively. Therefore, the instrumental variables chosen in the GMM estimations are reliable and suitable [66]. It is noteworthy that the GMM estimates of the first-order lag of dependent variable (*L.* ln*(Ele)*) by the first-different GMM and orthogonal-difference GMM are generally lower than the OLS estimate but are relatively close to the corresponding FE estimates. These results are basically in line with Bond [11]; as in the pooled OLS model, the lagged dependent variable is positively related with the error terms and this makes an upward biased estimation for the lagged dependent variable coefficient.[11] Besides, compared with first-difference GMM estimates, the orthogonal-difference GMM estimate of the first-order lag of the dependent variable is closer to the

[10] It is noteworthy that, as a panel GMM is applied on the first difference of the data, it is essential to examine the stationary properties of the series as a pre-test. The panel unit root tests indicate that all variables have unit roots. In other words, all variables follow the I(1) process. Therefore, the panel cointegration tests have also been conducted, and the results indicate that there is strong evidence for panel cointegration. Consequently, the first-difference and orthogonal-difference GMM estimations could be safely performed because the long-run relationship among the variables has been verified by the cointegration test results. Due to the space limit, the results of the panel unit root tests and the panel cointegration tests are not provided here but are available upon request.

[11] Bond [11] argued that theoretically for a micro panel data with large N (cross-section number) and small T (time-series period), the within group (fixed-effects) estimator is downward biased, as only in one orthogonal-difference GMM estimation (model 7 of Table 2) the estimated coefficient of first-order lag of the dependent variable lies between the corresponding OLS and FE estimates. However, in this study, the within group estimator seems to be also upward biased. There are two possible reasons for these results. First of all, the numbers of N (30) and T (16) are comparable in this study, while in Bond [11] T is much smaller than N, therefore the that the negative correlation between the transformed lagged dependent variable and the transformed error term might be offset by the positive correlations between other components. Second, Bond [11] focused on large samples with more than 3000 observations. In this study, the sample size is at most medium with 480 observations. Therefore, for such limited size of sample the within estimator might not be downward biased. The similar results that the first-difference GMM and orthogonal-difference GMM estimates of the first-order lag of dependent variable do not lie exactly between the pooled OLS and FE estimates could also be found in some extent studies using medium- or small-sized sample data, including Weeks and Yao [86] and Du et al. [23].

FE estimates. This is partly because the orthogonal-difference GMM allow forward orthogonal deviations to control for the time-invariant individual provincial effects while only the backward differences are conducted in first-difference GMM. Moreover, the relatively close results of the estimated coefficients of first-order lag of dependent variable by orthogonal-difference GMM and FE also to a certain degree reflect the validity of choosing orthogonal-difference GMM as the benchmark estimation method, as Bond [11] stressed that a consistent and reasonable estimator should not be significantly higher than the OLS estimator or significantly lower than the FE estimator.

The primary finding from the estimation results presented in Tables 2 and 3 is that the estimated coefficients of the key explanatory variables, the Theil index and the income gap between urban and rural residents are basically significant and positive in all estimations (except for the FE estimates presented in the third columns of both tables). Moreover, the interactive terms of the inequality indicator and GDP per capita are negative and significant in the GMM estimations. These results indicate that the impacts of inequality on electricity consumption depend on the level of economic development.

It should be noted that the estimated coefficients of the explanatory variables shown in Tables 2 and 3 reflect the short-run effects. To gauge the long-run effects, in accordance with the suggestions of Halkos and Paizanos [31]; the short-run coefficients of the explanatory variables are divided by the difference between 1 and the coefficient of lagged dependent variable. Because the GMM estimates are more accurate and reasonable, by controlling for endogeneity and introducing dynamics, the long-run estimates by first-difference and orthogonal-difference GMM are reported in Table 4. The following discussions are based on the long-run estimates shown in Table 4, and the orthogonal-difference GMM estimates are treated as benchmark estimates unless otherwise stated. The benchmark orthogonal -difference GMM estimation results indicate that the influences of inequality on electricity consumption hinge on the level of GDP per capita. Although the coefficients of Theil and Gap are significantly positive, the significantly negative coefficients of the interaction of inequality and GDP per capita imply that, when income level is sufficiently high, the income inequality may affect electricity consumption per capita negatively. The turning point of GDP per capita when the total effect of income inequality on electricity consumption is negative could be calculated by comparing the coefficients of the inequality indicator and the corresponding interactive term. In the last row of Table 4, this level of GDP per capita is calculated for each set of the GMM estimates. It could be clearly observed that this level is between approximately 2200 and 3300 yuan (at constant 1978 price). It should be noted that, since 2000, the levels of GDP per capita in most of the provinces had previously entered this interval. In this regard, since early 2000, the income inequality had begun to negatively affect electricity consumption per capita. As China's economy expanded rapidly during the last two decades, the negative effect of income inequality on electricity consumption became increasingly large over time. This finding is very robust, because the results persist regardless of whether the income disparity is measured by the Theil index or the income ratio of urban and rural residents. Several important implications could be derived from this conclusion. First, the urban-rural income disparity indeed negatively affects electricity consumption from a long-term perspective. As [96] and Zhang et al. [99,101] have discovered, electricity consumption is closely associated with and would causally lead to economic growth in China; therefore urban-rural income disparity may impede economic development via its negative influences on electricity consumption. Consequently, this finding can deepen the understanding of why urban-rural disparity is harmful to the sustainable development of China's economy [22,48,54]. Second, according to the definition Eq. (2), the Theil index also reflect the changes in the urban and rural population structure, namely, the process of urbanization. In the past several decades, China's urbanization was characterized by large-scale migration from less developed rural areas to relatively prosperous urban areas [45,84]. This urbanization process fostered growth in urban development areas at the cost of rural areas and consequently affected the electricity consumption of the whole economy.[12] Moreover, as Oi [63] and Lin and Yu [52] noted, the price scissors between industrial and agriculture products consistently favored urban citizens at the cost of peasants. Consequently, the development of the national economy mainly depends on the development of the urban area. Because there appears to be a new trend that China's urban-rural income has begun to decrease in recent years [18,85], the narrowing of the income gap between urban and rural areas is conducive to the promotion of electricity consumption. Although, in the case that the dominant position in thermal power has not changed, which may lead to an increase in emissions in the short term, since electricity is a relatively clean energy, and the proportion of renewable energy power generation in China is rising rapidly, it is conductive to the environment in the long run. Therefore, at the current stage, narrowing the income gap between urban and rural areas, accelerating the new urbanization process, and reducing the Theil index all have important significance to improving the quality of the environment.

As shown in Table 4, there is a nonlinear relationship between per capita electricity consumption and GDP per capita. Specifically, because the coefficient of per capita GDP is significantly positive, while the coefficient of its square term is significantly negative, there is an Inverted-U shaped relationship between economic growth and per capita electricity consumption during the sample period. Consequently, the basic findings of this study are essentially consistent with the theoretical framework raised by Heerink et al. [36]; when an inverted-U shaped EKC exists, higher income inequality would lead to lower environmental pressure. Despite the consistently rising ratio of renewable energy, the thermal power generation continued to dominate electricity production in China (e.g., [16,20]).[13] Consequently, at the current stage, the electricity consumption could be used as a proxy for environmental pressure in China. In this regard, this finding, to a degree, verifies the hypothesis proposed by Boyce [12] that the expansion of the income gap between urban and rural areas is harmful to the performance of the environment. The relationship between income inequality and electricity consumption is depicted with the existence of the inverted-U shaped EKC for electricity consumption in Fig. 4 below.

As shown in Fig. 4, when the inverted-U shaped EKC exists, if the urban-rural income inequality is large (e.g., the urban income level is Y_2, while rural income level is lower at Y_1), the average level of electricity consumption per capita is $\bar{E}$, which is lower than the

[12] According to the statistics of the World Bank, China's Gini coefficient increased from 0.357 in 1996 to 0.421 in 2010. The gap between urban and rural areas has been widening, and the contribution of the urban economy to the national economy was obviously higher than that of the rural areas. Moreover, since the reform and opening up, particularly since the early 1990s, when market economy was set as the direction of the reform, the rural surplus labor force has been continually exported to the urban areas. The data from *China Labor Statistics Yearbook 2014* indicate that China's rural employed persons grew to 382.4 million in 2013, which represented 49.7% of the total employed population, a ratio that was 3.1% higher than that in 2012. To an extent, these statistics reflect that the rural labor force continues transferring into the city (e.g., [25,58]).

[13] According to *Report on the Research and Development Trend of China's Thermal Power Market in 2015-2020*, China's thermal power represented 75.20% of the total power generation in 2014. For more information, please refer to http://www.chyxx.com/industry/201509/346368.html.

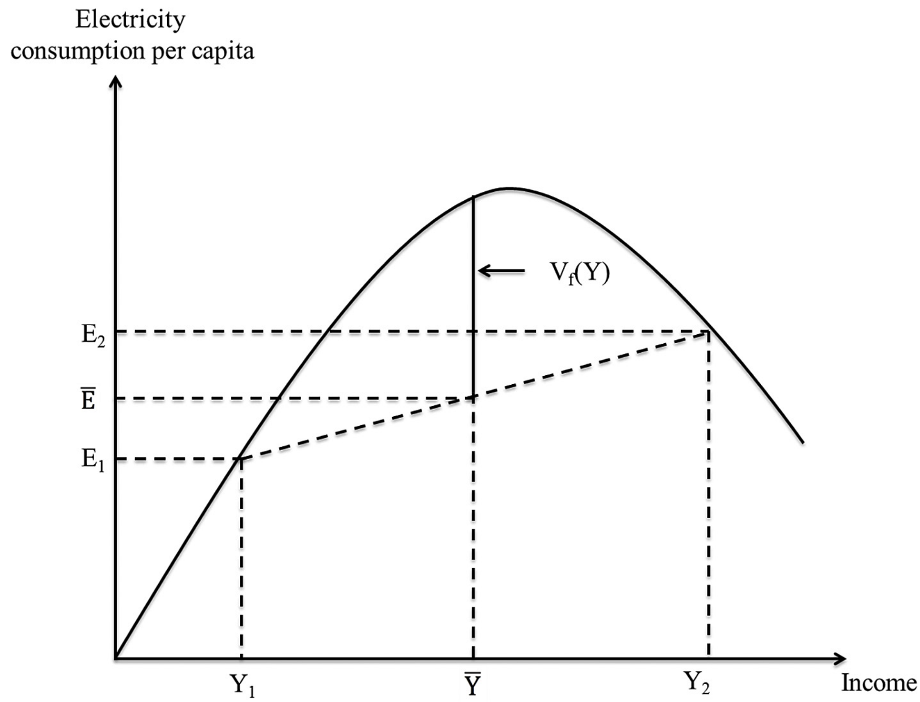

Fig. 4. Urban-rural income disparity and the inverted-U shaped EKC for electricity consumption.

electricity consumption level corresponding to the average income (i.e., the value on the curve corresponding to $\overline{Y}$). The amount of $V_f(Y)$ is the difference between the two levels of energy consumption.[14]

For the control variables, both the level of urbanization and the proportion of second industry (a measurement for the level of industrialization) in most estimations have significantly positive coefficients, suggesting that the improvement of the level of urbanization and the promotion of the level of industrialization have played a significant role in promoting per capita electricity consumption. According to the statistics released by the National Bureau of Statistics (NBS), China's urbanization rate had increased from 36.2% to 56.1% during the past 15 years from 2000 to 2015. As an important engine for economic growth, rapid urbanization fosters China's economic growth. However, rapid urbanization also spurred a remarkable increase in energy demand and the continued expansion of carbon dioxide emissions as well as growing air pollution (e.g., [21,53,82,98]. The estimation results also indicate that the trade openness is positively and significantly associated with electricity consumption. In addition to rapid economic growth, China's import and export volumes ballooned. According to the data from NBS, China had previously surpassed the U.S. as the world's largest trading country in 2013.[15] Although foreign trade has dramatically promoted China's economic growth and created many employment opportunities, energy consumption, particularly demand for electricity, surged with the rapid growth in trading volumes. Considering that China's electricity consumption is highly related with coal consumption and CO_2 emissions [9,74], this finding is approximately consistent with certain previous studies such as that by Halicioglu [30] and Hossain [38].

Given the considerable gap in development across China's regions and provinces [75], to further explore the impact of urban and rural gap on the per capita electricity consumption in areas with different levels of economic development, this paper further conducted empirical analysis by dividing various provinces into the western provinces and other provinces. In 2000, the “Western Development Program” was launched with the purpose of reducing the regional disparity between the western region and other parts of China. Under this program, the western region consists of six provinces (Gansu, Guizhou, Qinghai, Shaanxi, Sichuan and Yunnan), five autonomous regions (Guangxi, Inner Mongolia, Ningxia, Tibet and Xinjiang), and one municipality (Chongqing). Considering that the western region is relatively backward in economic and social development compared with the coastal and central regions and to maintain sufficiently large sample sizes for reasonable estimations, in this study, China is divided into two regions: Western China and Eastern China. Western China is the western region defined by the “Western Development Program”, while Eastern China includes all provinces that do not belong to Western China. It should be noted that, by this classification, the central and eastern regions that are suggested by China's Bureau of Statistics and commonly used in other studies are, in fact, incorporated in Eastern China. The results are shown in Table 5.

Similar to the previous discussions, the long-run estimates of the explanatory variables are also calculated and reported in Table 6. As shown clearly in Table 6, in both Western and Eastern China, the estimation results are consistent with the basic findings obtained from Tables 2 and 3 that the influences of inequality on electricity consumption depend on the income level. However, it is noteworthy that the level of GDP per capita at which the effect of inequality on electricity consumption becomes negative is higher in Eastern China (between 1400 and 1800 yuan) than in Western China (between 5600 and 10000 yuan). To an extent, this conclusion reflects the imbalance of regional economic development across China's regions. As Yang et al. [90] noted, China must

[14] In other words, $V_f(Y)$ could be understood as the premium of electricity consumption due to urban-rural income disparity. For more information, refer to Heerink et al. [36].

[15] As a reference, please see https://www.theguardian.com/business/2014/jan/10/china-surpasses-us-world-largest-trading-nation.

Table 5
The estimation results for Western China and Eastern China.

Dep. Var: ln (Ele)	Western China		Eastern China	
Method	First-diff GMM	Orthogonal-diff GMM	First-diff GMM	Orthogonal-diff GMM
	(1)	(2)	(3)	(4)
L.ln_ele	0.341*** (0.061)	0.751*** (0.062)	0.483*** (0.073)	0.760*** (0.092)
Theil	28.807*** (8.391)	16.995** (7.867)	24.289** (9.847)	37.009** (14.50)
ln_gdp	2.368*** (0.796)	1.493** (0.581)	−1.639*** (0.552)	−0.535 (0.799)
ln_gdp2	−0.0969** (0.045)	−0.069** (0.031)	0.116*** (0.032)	0.0416 (0.047)
Urb	0.167 (0.394)	−0.109 (0.339)	0.706*** (0.126)	0.743*** (0.194)
Str	1.487*** (0.349)	0.575* (0.298)	2.590*** (0.294)	2.207*** (0.561)
Tra	0.065 (0.302)	0.020 (0.240)	0.045 (0.043)	−0.029 (0.066)
lngdptheil	−3.975*** (1.197)	−2.270** (1.085)	−2.631** (1.277)	−4.282** (1.871)
Sargan test	0.567	0.539	0.182	0.958
A-B test for AR (1)	0.000	0.001	0.000	0.000
A-B test for AR (2)	0.868	0.922	0.588	0.957
Observations	176	176	304	304
Number of provinces	11	11	19	19

Note: Same as in Table 2. Tibet is excluded due to data unavailability; therefore, Western China has 11 provinces.

Table 6
The long-run estimates of explanatory variables by GMM for Western and Eastern China shown in Table 5.
- The impact of urban-rural income inequality on electricity consumption in China is investigated.
- Theil index and urban-rural income ratio are used as indicators of income disparity.
- Generalized Method of Moments (GMM) estimator is employed to control for potential endogeneity.
- Urban-rural income inequality is estimated to be negatively related with electricity consumption.
- Empirical findings suggest that the goals of "Harmonious Society" and "Green Development" are compatible.

Dep. Var: ln (Ele)	Western China First-diff GMM	Western China Orthogonal-diff GMM	Eastern China First-diff GMM	Eastern China Orthogonal-diff GMM
Method	(1)	(2)	(3)	(4)
Theil	43.713***	42.365**	46.981**	154.204**
ln (GDP)	3.593***	3.864**	−3.170***	−2.229
$\ln^2$ (GDP)	−0.147**	−0.168*	0.224***	0.173
Urb	0.253	0.493	1.366***	3.096***
Str	2.256***	2.631***	5.010***	9.196***
Tra	0.099	0.215	0.087	−0.121
ln (GDP)*Theil Turning point of GDP per capita	−6.032*** (1404)	−5.795** (1784)	−5.089** (10217)	−17.842** (5670)

Note: Same as in Tables 2 and 3. The long-run estimates of the variables are equal to their short-run estimates divided by one minus the corresponding estimated coefficients of the first-order lag of dependent variable.

confront more challenges of sustainable development due to the economic development gap of different regions. Wei [87] suggested that social and economic factors, such as the added value of the secondary industry, the scalable industrial output value, the infrastructure investment, the GDP, residents' deposits, and the medical and health insurance status are the important reasons that result in the imbalance of China's regional economic development. Therefore, it is of great significance for China to gradually narrow the gap between regional economic development and the income gap between urban and rural areas to optimize the energy structure and improve the environmental quality. Furthermore, the coefficients of the control variables in both parts of China are approximately in accordance with the estimates for all of China as shown in Table 4. There is only one exception that deserves attention: the EKC for electricity consumption per capita exists in Western China as it does for the whole nation, while the EKC relationship does not exist in Eastern China. Literally, the nexus of electricity consumption and GDP per capita is "U" shaped for Eastern China, although the orthogonal-difference GMM estimates of ln (GDP) and $\ln^2$(GDP) are statistically insignificant. The differences in the relationship between electricity consumption and income level may be caused by the gap in economic development. Eastern China is considerably more developed in the levels of industrialization and urbanization, and in recent years has comparatively higher economic growth rates than Western China. Consequently, there has been no signs of any easing in the growth of electricity consumption in Eastern China until recently.

5. Conclusions and policy implications

For a very long time, the relationship between economic development and electricity consumption has received the attentions of scholars. However, the influence of the unbalanced development between urban and rural areas on the electricity consumption per capita is largely neglected. Given China's wide urban-rural disparity and the income distribution imbalance, this paper utilizes the provincial panel data for the period of 1996–2013 to investigate whether and how the widening urban-rural income gap affects the electricity consumption per capita. The most striking conclusion of this study is that the impact of urban-rural income inequality on electricity consumption is dependent on the income level. At current stage of economic development, widening urban-rural income inequality has significant negative effects on electricity consumption per capita. Furthermore, it was found that other factors may also affect China's electricity consumption; the advancement of urbanization and industrialization and the development of foreign trade aid in increasing the electricity consumption per capita. Based on these estimation results, several important policy implications could be derived as follows:

First, the estimation results of this study suggest that the two important politic goals for sustainable economic growth, the establishment of "harmonious society" and the pursuit of "green development", could be accomplished at once. Currently, the Chinese government should devote more effort to deepen the reform of the income distribution system and formulate more specific policies that favor rural areas to narrow the income gap between urban and rural areas. Specifically, the government should focus more on improving the efficiency of energy utilization [88], making the market play an "invisible hand" role and expanding the basic medical insurance and welfare coverage in rural areas. Through these measures, not only would the urban-rural income gap be reduced but the consumption of electricity, which is relatively cleaner energy, could also be promoted.

In addition, the Chinese government should increase the proportion of renewable energy in energy production, particularly electricity generation [93], and further optimize the structure of energy consumption. According to the official Program for the Development of Renewable Energy during the 13th "Five-year Plan (2016–2020)", the ratio of renewable energy consumption in the energy mix should be at least 15% by 2020 and further increased to 20% by 2030.[16] Given that the renewable energy production is generally in the form of electricity, the increase in the ratio of renewable energy may efficiently reduce pollutant emissions and improve the environmental quality, particularly when electricity consumption in China surges due to the rapid economic development and the reduction of urban-rural income inequality.

Finally, to enhance electricity consumption, China should further promote industrialization and urbanization and optimize the industrial structure. Moreover, although the government's environmental policies often have a lag effect [99,101], the Chinese government should also exert a great effort to promote sustainable development by encouraging energy conservation and emissions reduction. All these measures, together with the efforts in reducing urban-rural income gap and enhancing electricity consumption, would help realize the construction of a resource-conserving and environmental friendly society and adjust the pattern of economic development as soon as possible.

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