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HOT WEATHER AND ELECTRICITY CONSUMPTION BY MIGRANT WORKERS IN CHINA

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ABSTRACT

China's urbanization has entered a new phase, and more and more migrant workers have become urban residents, and rapid urbanization is expected to further increase global energy consumption. Meanwhile, climate change will increase the refrigeration demand of residents, which is generally met with electric air conditioners and fans. It is necessary to be concerned about the energy consumption of migrant workers to ensure that society develops sustainably and stably. This paper compares the influence of temperature on the electricity consumption by rural residents, migrant workers and urban residents in Guangzhou in 2017.The results show that the 1°C rise in temperature leads to a 3% increase in electricity consumption by rural households, a 7% increase by rural migrant worker, a 9% increase by urban household. More seriously, the actual price of the migrant workers cost burden of electricity consumer spending is the biggest of the three types of families, make life in the city of migrant workers families facing serious electricity consumption inequality in hot weather.

Keywords: climate change, hot weather, electricity consumption inequality, Chinese migrant workers

1. INTRODUCTION

Global climate change is among the most visible environmental concerns of the recognized contemporary and future global environmental issues, and these climate changes have the potential to affect environment, ecology, economics and human health, both directly and indirectly[1].Especially extreme heat presents new challenges to the increasing socioeconomic inequality and precariousness of workers[2]. The direct effects of hot weather could lead to increased energy use for indoor cooling in the summer[3].

China, as the largest consumer of energy worldwide, is responsible for 24.3% of the global energy consumption[4].Meanwhile, China is currently in the process of rapid urbanization. The large scale of rural-urban migration is regarded as the key to the urbanization in China[5]. The number of rural migrants working in Chinese cities grew from approximately 39 million in 1997 to 174 million[1] in 2019[6]. According to The World Bank, China's urbanization rate is expected to reach 65% in 2030[7]. It is estimated that there will be more than 300 million migrant workers(a number almost as large as the entire population of the U.S.) moving from countryside to urban areas to seek job opportunities and a better life[8]. With China's urbanization accelerating, energy consumption in the residential sector will inevitably grow rapidly. Electricity consumption expenditure will be the most amount of residential energy consumption expenditure for rural and urban family[9]. Therefore, a focus on the issues of equal energy consumption rights for migrant works in the hot weather is important for policy decisions in this area.

Because of the rapid global urbanization trend, urban heat island (UHI) phenomena are now part of the climatological effects where local air temperatures of urban environments are higher than the suburban rural areas especially in summer[10].Extreme heat heighten the risks of heat-related morbidity and mortality[11]. The risks will be even more severe in urban environments compared to the rural or suburban surroundings, as the UHI effect exacerbates uncomfortable and unhealthy heat stress, which leads to significant increase in heat-

[1]See http://www.stats.gov.cn/tjsj/zxfb/202004/t20200430_1742724.html

related mortality[12]. The different forms of heat-related illness include heat exhaustion, heat rash (prickly heat), heat syncope(fainting), dehydration, heat stroke, and complications of many chronic disease. In addition, continued heat exposure also contributes to mental health problems such as anxiety, depression, and suicide; chronic kidney disease, possibly due to recurrent dehydration and other factors[1]. While heat-related mortality and exacerbated diseases are associated with elevated night-time indoor temperatures[14]. The mortality rate caused by heat is not negligible. In 2003, about 15,000 people died due to the heat in France, and there were also heat-related deaths in the UK (2,000), Portugal (2,100), Italy (3,100), Holland (1,500) and Germany (300). [2]

People who are socially, economically, culturally, politically, institutionally or otherwise marginalized are particularly vulnerable to the effects of climate change[15]. Especially workers working outdoors, with lower economic or social power, are often the first to be exposed and more vulnerable to the effects of high temperatures[1]. Under the Chinese scenario, migrant workers are placed on the edge including social security, working environment, children's education, living conditions and other collective consumption areas[16]. Migrant workers (such as traffic wardens, fire fighters, road sweepers, landscapers' petty traders, construction workers etc.) are often required to exposure to the sun directly and restricted to areas without air ventilation. Therefore, they face an additional 3–5 °C increase in temperature during the hottest periods [17]. In this condition, the body's natural heat dissipation ability cannot balance the metabolic heat generated during work result in heat accumulates, making migrant workers who perform heavy work at high temperatures vulnerable to heat stress, heat-related illness, chronic dehydration and chronic kidney disease[18]. From 1993 through 2013 in Mexico and Central America, increased temperature with resultant dehydration may have caused deaths related to chronic kidney disease in approximately 20,000 agricultural workers [19].

It is well known that the living conditions, especially air conditioning, have a significant effect on reducing the risk of heat-related illness[20]. Post-work cooling, through technology such as ventilation fans, air conditions ,increase the air velocity of microenvironment thereby promoting convective and evaporative heat transfer ,and help heat-strain recovery and keep cooling effect[21]. As a result, high-temperature weather causes cooling electricity demand and consumption.

Research on changed climate—a warmer climate affect residential electricity demand and consumption has been carried out in various countries throughout the world. Anna Alberini et al.[22] used hourly electricity demand from a sample of Italian residences over a full year to examine how sensitive residential demand is to temperature, they found that electricity increases sharply with temperature of about 24.4 ◦C. Li Y et al.[23] also used daily data on household electricity consumption to estimate how climate change influence electricity consumption in Shanghai .The results revealed that 1 ◦C increase in daily temperatures leads to a 14.5% increase in electricity consumption when temperatures rises above 25 ◦C. De Cian et al.[24] used data from 31 countries for the period 1978–2000, the result suggested that with higher temperatures there will be higher consumption during summer in warmer countries. Mahmood et al.[25] used Pakistan's monthly temperature data to explore the relationship between electricity demand and temperature. The results showed that demand for electricity will rise sharply in the summer due to climate change.

Currently, there are relatively few studies on this topic in China, and the study of Chinese residential energy consumption mainly focused on two types of residents, urban and rural. It's mainly because there are only two types of residents, urban and rural, are included according to officially published energy statistics in China[26]. Asadoorian et al. [27] used panel data to analyze the impact of temperature on electricity demand in urban and rural areas of China at the national level. According to China's provincial annual data from 1996 to 2014, Yang et al. [28] analyzed urbanization's impact on residential energy consumption through a panel data model. The results showed that urbanization has a different impact on residential energy consumption at different per capita income levels and urbanization stages; an increase in the urbanization rate helped to

[2] See https://www.metoffice.gov.uk/weather/learn-about/weather/case-studies/heatwave

Table 1
Residential electricity tariff in Guangzhou in 2017

	Tiered pricing for household electricity		unified electricity price
	Summer(May-Oct)	Non-summer(Nov-Jap)	
The first block	≤260(0.5921CNY/KW·h)	≤200(0.5921CNY/KW·h)	
The second block	260-600(0.6421CNY/KW·h)	260-400(0.6421CNY/KW·h)	0.6291
The three block	＞600(0.8921CNY/KW·h)	＞400(0.8921CNY/KW·h)	

narrow the gap on electricity consumption between urban and rural residents.

More importantly, although migrant workers have been living in cities for a long time, they still maintain rural consumption habits to some extent because they have been deeply influenced by the traditional rural consumption concepts. Thus, the consumption patterns of migrant workers are significantly different from those of urban and rural residents, leading to differences in energy consumption[29].

Therefore, the total energy consumption related to the migrant workers is important to solve the problem of energy equity and energy poverty. In this study, we explore the influence of temperature on the electricity consumption inequality of migrant workers from the perspectives of consumption physical quantity and consumption expenditure. We use household electricity meter reading data of Guangzhou City with 100% coverage rate of electricity. Guangzhou, the capital city of Guangdong Province as well as the most important industrial city in the PRD region, is one of the most prosperous cities in China as a result of production globalization[30]. Additionally, Guangzhou is undergoing rapid urbanization and urban expansion, and attracting a large number of rural migrants[31]. Therefore, researching on Guangzhou has significant reference meanings to other developing cities.

The rest of the paper is organized as follows. Section 2 comprises the methodology and data. Section 3 presents the results and discussion. Following this, the conclusions and implications are given in Section 4.

2. METHODOLOGY AND DATA SOURCE

In this study, we randomly selected the households of Guangzhou with "0" at the end of the household, and collected the monthly consumptions data of electricity of each family in 2017 recording by the meter readings from 10732 households. Due to the lack of direct energy consumption data of migrant workers, this study replaced the consumption of migrant workers with the consumption of electricity in urban villages. That's because Chinese rural migrant workers are restricted by the hukou and segregated by the urban housing market, so they mainly live in the urban village with lower rent shelter and poorer living conditions for migrant workers[31].According to statistics, more than 61% of migrant workers in Chinese cities rent in urban villages and other informal accommodation(NBS 2018).[3]

Since 2012, China has been implementing the tiered pricing for household electricity (TPHE), which divides household electricity consumption into several blocks and charges higher prices for electricity consumption in higher blocks[32]. But for urban village, each household live in multiple households and cannot install electricity meters alone. Thus, their electricity price belongs to the unified electricity price, which is the same for any consumption throughout the year. The electricity price of residents in Guangzhou in 2017 is shown in Table 1.

In addition, this article uses a series of weather data, such as temperature, humidity, wind speed, rainfall, these data are from the National Meteorological Science Data Center. After matching the weather data with the electricity data, we excluded the abnormal household samples whose electricity consumptions were 0 for several consecutive months. Meters with less than 1 kWh/day are outliers were also dropped[33].The final sample used in the study consists of 4,4549 valid samples, including 8278 in village, 25086 in city, and 11185 in urban village.

Each meter reading data is the actual meter reading time of the electricity consumption in the previous two months, as follows: The data of March records the total electricity consumption in January and February. Summary statistics for key variables are presented in Table 2.

From January to May, household electricity consumption of the three categories was basically stable.

[3]See http://www.stats.gov.cn/tjsj/zxfb/201904/t20190429_1662268.html

Table 2
Descriptive statistics of data variables

Variable	N	mean	sd	min	max
Electricity consumption	44549	1216.42	2882.53	60	105440
Electricity expenditure	44549	823.05	1931.51	35.53	66332.3
Family	44549	-	-	1	3
Temperature（℃）	44549	22.18	4.93	15.21	28.3
Wet（%）	44549	81.34	2.8	77.82	84.44
Wind（m/s）	44549	2.17	0.20	1.98	2.52
Rainfall（mm/h）	44549	175.82	137.82	19.57	413.73

Notes:Monthly electricity use per household (unit: KW·h).

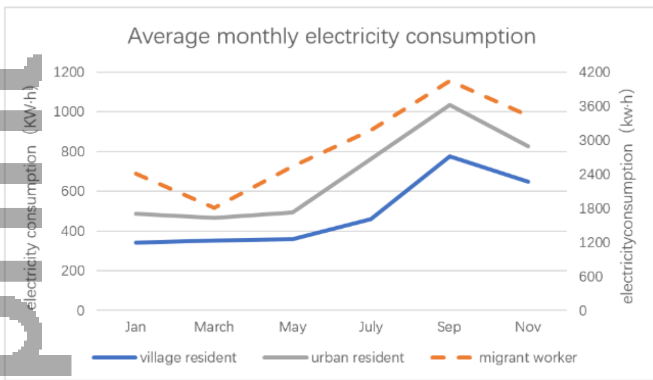

Fig. 1 Average monthly electricity consumption of village, urban, migrant worker

From May to September, household electricity consumption of the three categories increased significantly, while from September to November, household electricity consumption of the three categories showed a downward trend.

And we use the OLS empirical econometric model to analyze the difference influences of temperature on electricity consumption and expenditure of household in villages, urban and urban villages. The specification is represented by the following equation:

$$lnEC_i = \beta_0 + \beta_1 T_i + Z_i'\beta + \lambda_i + \varepsilon_i$$

Here, $lnEC_i$ is the logarithm of average monthly electric consumption or expenditure of household, T_i is the average monthly temperature, Z_i' is a vector of controls for weather conditions including rainfall, wind power and calculated relative humidity, λ_i is family fixed effects, β_0 is constants, ε_i is error terms.

3. RESULTS

3.1 The influence of temperature on three types of household electricity consumption

We report selected coefficients from running OLS on equation in Table 3 and Table 4. All standard errors are clustered at the household level. Briefly, we find evidence that temperature does influence electricity consumption and expenditure. It is noteworthy that the temperature has the greatest impact on urban household electricity consumption, followed by urban village households and rural households. Further, based on the test of the seemingly unrelated model SUR, it is found that the coefficients of the three are significantly different in pairs.

Firstly, rural areas do not have urban heat island effect, and rising temperatures do not affect their electricity demand as much as the other two types of households. The electricity consumption of urban village residents and urban residents are more sensitive to temperature. For every +1°C, household electricity consumption of urban villages increases by 7% and urban household electricity consumption increases by 9%. Similarly, migrant workers electricity consumption expenditure increased by 10% and urban household electricity consumption increased by 9%. This difference in data indicates that in summer, the electricity demand of consumption demand of urban village residents is not as strong as that of urban residents. However, in theory, residents would adopt measures of using air condition and fan to cool in high temperature. But why is household electricity demand in urban villages less sensitive to temperature than in urban households?

Based on the previous discussion, migrant workers living in urban villages with poorer living conditions but high cost of household electricity. Due to the particularity of “one table with multiple households” in urban villages, households in urban villages cannot adopt the tiered electricity price, but adopt the combined electricity price.

Table 3
The impact of temperature on the electric consumption of different household

Variables	(1)	(2)	(3)
	Migrant Workers	Village residents	Urban residents
Temperature	0.07674***	0.03061***	0.09022***
	(0.00172)	(0.00225)	(0.00123)
Rain	-0.00126***	-0.00028***	-0.00032***
	(0.00007)	(0.00009)	(0.00005)
Wet	0.04703***	0.05689***	-0.03947***
	(0.00419)	(0.00554)	(0.00300)
Wind	0.54920***	0.60731***	-0.18324***
	(0.05531)	(0.07315)	(0.03950)
Constant	0.90858**	-0.67208	7.77517***
	(0.46056)	(0.60843)	(0.32932)
N	11185	8278	25086
R-squared	0.21780	0.46846	0.41650
P-value（SUR）1-2	P<0.01		
P-value（SUR）2-3		P<0.01	
P-value（SUR）1-3			P<0.01

Note:The values in brackets are standard error ;*p<0.10,**p<0.05,***p<0.01.

Table 4
The impact of temperature on the electric expenditure of different household

Variables	(1)	(2)	(3)
	Migrant Workers	Village residents	Urban residents
Temperature	0.07664***	0.03440***	0.10380***
	(0.00172)	(0.00251)	(0.00141)
Rain	-0.00125***	-0.00038***	-0.00043***
	(0.00007)	(0.00010)	(0.00006)
Wet	0.04681***	0.06466***	-0.04344***
	(0.00420)	(0.00617)	(0.00343)
Wind	0.54600***	0.67084***	-0.20714***
	(0.05539)	(0.08146)	(0.04518)
Constant	0.47237	-1.93607***	7.46076***
	(0.46124)	(0.67759)	(0.37664)
N	11185	8278	25086
R-squared	0.21665	0.17402	0.41461
P-value（SUR）1-2	P<0.01		
P-value（SUR）2-3		P<0.01	
P-value（SUR）1-3			P<0.01

Note:The values in brackets are standard error ;*p<0.10,**p<0.05,***p<0.01.

The electricity charge is uniformly collected by the landlord. According to the investigation, the landlord imposes a high electricity charge on the tenant without his authority during this progress. The actual electricity price paid by the residents in the urban villages is generally 1.5 CNY/KW·h, which is 2.4 times the price of the unified electricity price specified (0.6291 CNY/KW·h) and higher than the most high-end electricity price (0.8921 CNY/KW·h) in urban households using tiered electricity prices.

Therefore, the cost of electricity consumption expenditure borne by urban village residents is the

Table 5
The impact of temperature on household electricity consumption at different power consumption levels in migrant workers

	(1) Low-consumption	(2) Mid-consumption	(3) High-consumption
Temperature	0.05168***	0.04377***	0.07704***
	(0.00319)	(0.00142)	(0.00224)
Rain	-0.00095***	-0.00072***	-0.00138***
	(0.00013)	(0.00005)	(0.00008)
Wet	0.04449***	0.03289***	0.05753***
	(0.00747)	(0.00316)	(0.00524)
Wind	0.45925***	0.39129***	0.74975***
	(0.09645)	(0.04054)	(0.07244)
Constant	0.68027	3.17319***	0.61021
	(0.81345)	(0.34655)	(0.58801)
N	3729	3729	3728
R-squared	0.15639	0.12180	0.23703
P-value（SUR）1-2	P<0.001		
P-value（SUR）2-3		P<0.001	
P-value（SUR）1-3			P<0.001

largest of the three types of households, which will undoubtedly make the urban village households scared and reluctant to use electricity, resulting in a smaller and smaller difference between the electricity consumption expenditure of urban village households and urban households in summer. Even electricity consumption of households in urban villages will exceed urban households, leading to increasing electricity inequality.

3.2 The influence of temperature on low, medium and high power consumption level of migrant workers' families

In fact, the difference of electricity consumption also reflects the three income levels of high, middle and low objectively. We speculate that there is an imbalance of electricity consumption in urban villages. Specifically, low-consumption groups bear the electricity consumption expenditure of high-consumption groups. To verify our conjecture, households in urban villages were divided into three groups according to the physical quantity of electricity consumption to explore the influence of temperature on the power consumption of households with low, medium and high consumption levels in urban villages.

Table 5 reports that the urban villages electricity consumption of different income levels on the sensitivity of the temperature from low to high of 5.6%, 4.3% and 7.7% respectively, namely households with low consumption levels are the least sensitive. In hot weather, electricity consumption inequality mainly comes from the low and middle level consumption household, resulting in the sharper gaps between the high family.

For low- and middle-consumption households in urban villages, the data recorded by one household electricity meter shows that the average monthly consumption is below 650KW·h. According to the use of one electricity meter by 5 households (the actual situation is that one electricity meter is higher than 10 households) [4], the electricity consumption of low-consumption households has only reached the first level of the tiered electricity price in Guangzhou (200KW·h under November-April in winter, 260KW·h under May-October in summer). From this, we can see that the low-consumption households can only maintain the electricity consumption for lighting (average daily 1KW·h), and electric fans, air conditioning and other cooling measures are not available. Thus, their living environment at night temperature may be higher, resulting in more vulnerable and susceptible suffer from heat stroke. However, the low-consumption households have to bear the same high cost as other high-consumption households. This may be linked to the inability to access sufficient cooling, which makes the migrant workers with lower electricity consumption face

[4] See https://news.pchouse.com.cn/70/704592_1.html; and http://energy.people.com.cn/n/2014/0719/c71661-25302751.html

more serious inequality in electricity consumption and health.

4. CONCLUSIONS AND POLICY IMPLICATIONS

In this paper, we use the electricity consumption data of Guangzhou residents in 2017 collected by China Southern Power Grid to study the issue of temperature's equal energy use right for migrant workers in China. There are two main findings:

The rise in temperature has a great impact on the equal electricity consumption of migrant workers. Migrant workers actually paid the price is 1.5 yuan/KW·h generally, the actual price is unified electricity price of 2.4 times, 1.68 times that of ladder price the most high-end price, so the migrant workers cost burden of power consumer spending is the biggest of the three types of families. Secondly, for migrant workers in low and middle consumption family, their actual use electricity only within the scope of the first a ladder electricity, but they must pay the same high cost of electricity as other households, which makes they face more serious power consumption inequality and health inequality.

At present, China's energy policy ignores the basic rights and interests of migrant workers to use power equality. Not only Guangzhou, other cities also have the phenomenon of urban villages charging a high price of electricity. The price of electricity in urban villages of Zhengzhou is 1 yuan/kW · h, while the price of electricity in urban villages of Dongguan is 1.2 yuan/kW · h, and the price of electricity in urban villages of Shenzhen is as high as 2 yuan/kW · h.

With the speeding up of urbanization in China, there will be more and more rural workers moved to the city, and they will live in the urban village during the transition period. Therefore, the energy consumption of migrant workers, especially the inequality of electricity consumption, should be paid enough attention to and solved. How to reduce the electricity cost of migrant workers and ensure their normal demand to maintain health for electricity in the hot summer weather is an important issue for policy makers to pay attention to. Policies can be adopted such as energy subsidies, "electricity vouchers" for migrant workers or authorization for migrant workers to apply for electricity fee compensation. The government needs to publish relevant policy measures focused on lowering the cost of the power of the urban village residents assume actually, such as implement ladder electricity price. Migrant workers rent in urban villages can apply to the local electric power department equipped with independent meters which will have a positive effect on overall electricity consumption inequality for migrant workers.

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