Residential Electricity Consumption in China: The Roles of Weather and Household Income

Wang Chunhua

Published by WorldFish (ICLARM)– Economy and Environment Program for Southeast Asia (EEPSEA)
EEPSEA Philippines Office, SEARCA bldg., College, Los Baños, Laguna 4031 Philippines
Tel: +63 49 536 2290 loc. 4107; Fax: +63 49 501 3953; Email: admin@eepsea.net

EEPSEA Research Reports are the outputs of research projects supported by the Economy and Environment Program for Southeast Asia. All have been peer reviewed and edited. In some cases, longer versions may be obtained from the author(s). The key findings of most *EEPSEA Research Reports* are condensed into *EEPSEA Policy Briefs*, which are available for download at www.eepsea.org. EEPSEA also publishes the *EEPSEA Practitioners Series*, case books, special papers that focus on research methodology, and issue papers.

ISBN: 978-621-8041-68-4

The views expressed in this publication are those of the author(s) and do not necessarily represent those of EEPSEA or its sponsors. This publication may be reproduced without the permission of, but with acknowledgement to, WorldFish-EEPSEA.

Front cover photo: Power lines within a residential area in China. Photo by Pico Zhang under the creative commons license at https://www.flickr.com/photos/priscilla_p/5689850146/

Suggested Citation: Wang C. 2017. Residential electricity consumption in China: The roles of weather and household income. EEPSEA Research Report No. 2017-RR11. Economy and Environment Program for Southeast Asia, Laguna, Philippines.

Residential Electricity Consumption in China: The Roles of Weather and Household Income

Wang Chunhua

February, 2017

Comments should be sent to: Dr. Wang Chunhua
School of International Trade and Economics, University of International Business and Economics,
10 Huixin Dongjie, Chaoyang District, Beijing 100029, China
Tel: (86-10) 6449-3581
Fax: (86-10) 6449-3042
Email: chunhua.wang@rocketmail.com; wangc@uibe.edu.cn

The Economy and Environment Program for Southeast Asia (EEPSEA) was established in May 1993 to support training and research in environmental and resource economics. Its goal is to strengthen local capacity in the economic analysis of environmental issues so that researchers can provide sound advice to policymakers.

To do this, EEPSEA builds environmental economics (EE) research capacity, encourages regional collaboration, and promotes EE relevance in its member countries (i.e., Cambodia, China, Indonesia, Lao PDR, Malaysia, Myanmar, Papua New Guinea, the Philippines, Thailand, and Vietnam). It provides: a) research grants; b) increased access to useful knowledge and information through regionally-known resource persons and up-to-date literature; c) opportunities to attend relevant learning and knowledge events; and d) opportunities for publication.

EEPSEA was founded by the International Development Research Centre (IDRC) with co-funding from the Swedish International Development Cooperation Agency (Sida) and the Canadian International Development Agency (CIDA). In November 2012, EEPSEA moved to WorldFish, a member of the Consultative Group on International Agricultural Research (CGIAR) Consortium.

EEPSEA's structure consists of a Sponsors Group comprising its donors (now consisting of IDRC and Sida) and host organization (WorldFish), an Advisory Committee, and its secretariat.

EEPSEA publications are available online at http://www.eepsea.org.

ACKNOWLEDGEMENTS

This research was conducted under a grant from the Economy and Environment Program for Southeast Asia (EEPSEA).

First and foremost, I would like to express my deepest thanks to Dr. Herminia A. Francisco, Julienne V. Bariuan, Rhona Coronado, Mia Mercado, Noor Aini Zakaria, and other EEPSEA staff for their support and help throughout this study. I would also like to express my gratitude to Dr. Ted Horbulyk and Dr. Daigee Shaw for their valuable guidance and helpful suggestions.

Furthermore, I wish to thank all the participants at the EEPSEA conferences for their valuable feedback. My appreciation also goes to Dr. Zhongmin Wang and Resources for the Future for their hospitality while I was finishing writing the final report. Last but not least, I would like to express my gratitude to Jessica Chu, Wenqian Jiang, Na Liu, and Huishan Yang for providing me with able research assistance.

TABLE OF CONTENTS

EXECUTIVE SUMMARY **1**

1.0 INTRODUCTION **1**

2.0 LITERATURE REVIEW **3**

3.0 DESCRIPTION OF DATA **4**

3.1 Urban Household Electricity Consumption and Household Characteristics 4

3.2 Weather 5

3.3 Summary Statistics 6

4.0 METHODOLOGY AND RESULTS **8**

4.1 Empirical Models 8

4.2 Estimation Results 9

4.3 Robustness Check 12

5.0 SIMULATION ANALYSIS **14**

5.1 The Impacts of Climate Change 14

5.2 The Impacts of Socioeconomic Factors 17

6.0 CONCLUSIONS AND POLICY IMPLICATIONS **18**

6.1 Conclusions 18

6.2 Policy Implications 18

LITERATURE CITED **20**

APPENDIX **21**

LIST OF TABLES

Table 1.	Average daily mean temperatures (°C) by province	6
Table 2.	Summary statistics (1992–2009)	7
Table 3.	Estimated impacts of household characteristics	10
Table 4.	The impacts of extreme weather on household electricity consumption: Regional heterogeneity	11
Table 5.	The impacts of extreme weather on household electricity consumption: number of daily lows and highs	12
Table 6.	Simulated growth in electricity consumption (%): Impacts of climate change	16
Table 7.	Simulated growth in electricity consumption (%): Impacts of climate change by province	17

LIST OF FIGURES

Figure 1.	The study sites	4
Figure 2.	Daily mean temperatures for 1992–2009	5
Figure 3.	The distribution of the 15 weather bins (1992–2009)	6
Figure 4.	Average annual electricity consumption per household per province (1992–2009)	7
Figure 5.	Average electricity consumption per household per year	8
Figure 6.	The impacts of weather on residential electricity consumption	9
Figure 7.	The impacts of weather on per capita residential electricity consumption	11
Figure 8.	The impacts of weather on per capita residential electricity consumption: Subsample (2000–2009)	12
Figure 9.	The impacts of weather on residential electricity consumption from the log-level regression	13
Figure 10.	Distribution of annual daily mean temperatures in 2009 and predicted changes in distribution (Emissions Scenario B1)	15
Figure 11.	Distribution of annual daily mean temperatures in 2009 and predicted changes in distribution (Emissions Scenario A2)	15

RESIDENTIAL ELECTRICITY CONSUMPTION IN CHINA: THE ROLES OF WEATHER AND HOUSEHOLD INCOME

Wang Chunhua

EXECUTIVE SUMMARY

This study conducted an empirical investigation of the factors that influence residential demand for electricity. The roles of weather and household income were examined. We estimated an econometric model using a data set of households from 65 cities in five Chinese provinces annually from 1992 to 2009. It was found that as daily mean temperature increased from 9°C to 12°C, demand for electricity went up. One more day with temperatures higher than 30°C would cause a household to consume 0.54% more electricity in a year. This translated to about 7 kWh of electricity for a representative household over the period from 1993 to 2009. As for other important determinants, our results indicated that income elasticity of electricity consumption was about 0.26. The price elasticity was about –0.37, and the household floor area elasticity was 0.17. Our simulation analysis revealed that climate change would significantly increase residential consumption of electricity in Chinese cities. In the sampled cities from five provinces, the mean increase would be 10% in the low-emission scenario and 20% under the high-emission scenario by the end of the century. The results also indicated regional heterogeneity of the impacts of climate change. Generally, the highest increase in electricity consumption would happen in the southern provinces, with the lowest increases in the western and northern provinces. These results have implications for the capacity planning of electricity generation and distribution across regions in China.

1.0 INTRODUCTION

China's energy demand has increased dramatically in the past three decades. The country has become the largest consumer of energy and emitter of greenhouse gases in the world. The total electricity consumption in 2014 was 5,638 gigawatts (GW), which included 718 GW for residential consumption. From 1991 to 2014, the total electricity consumption grew by 780%. Meanwhile, the share of residential consumption also increased over the years. It was about 8.6% of the total electricity consumption in 1991 and 12.7% in 2014. It is expected that the demand and share of residential consumption will continue to rise for a long time into the future as the economy grows and household incomes increase. One contributing factor in this increase will be climate change.

China's electricity supply depends heavily on coal-fired power plants. Coal power in the country accounts for about 78% of total electricity production. The burning of coal is the main source of greenhouse gases and air pollutants such as sulfur dioxide and particulate matter. As a national strategy, the central government is trying hard to reduce coal consumption and increase the share of electricity supply from new and renewable sources. For policy makers, it is important to forecast electricity demand based on an understanding of the factors that determine such demand.

There is also a need to examine the issues at the regional level. The northern parts of the country usually experience electricity shortages in the winter due to increased heating demand.

That is particularly the case in those regions before central heating commences.[1] Furthermore, it is much more difficult to deliver coal to power plants in the northern regions during winter. Conversely, the eastern and southern regions are prone to electricity shortages in summer as temperatures and cooling demand rise, while reservoir levels and hydroelectricity outputs fall until the arrival of the summer rains in July and August. China has no national grid. Therefore, the allocation of electricity generation capacity across regions is important to meet the demands.

The overarching aim of this study was to examine the impacts of weather and household income growth on residential electricity consumption, and to forecast electricity demand at the national and regional levels. Specifically, the research questions were as follows:

1. What are the impacts of weather conditions and household income on residential electricity consumption?
2. Does the size of a household have a large effect on its electricity consumption?[2]
3. Can we simulate the impacts of climate change on residential electricity consumption in China?
4. What are the main policy implications for managing electricity supply in China?

In particular, we investigated the determinants of residential electricity consumption in urban China by constructing and then estimating a unique household-level data set. We focused on the roles of climate variability across cities over the years and on the increases in household income. A set of other control variables were included in the regression analyses. Based on the results of the analyses, we simulated the impacts of climate change on residential electricity consumption in China at both regional and national levels. This study will contribute to related literature on electricity consumption, impacts of climate change, and policy debates on electricity market reform in China. In particular, the estimates will be useful when discussing long-term planning of electricity supply in various regions of the country. The results also have implications for policies on coal consumption and emissions of carbon dioxide and pollutants from burning the coal by power plants.

Specifically, this study ran an econometric model using a data set of households in 65 cities from five Chinese provinces annually from 1992 to 2009. The estimation results suggested that as daily mean temperature increased from 9°C to 12°C, demand went up. For instance, one additional day with a mean temperature of higher than 30°C would cause a household to increase its electricity consumption by 0.54% annually. This was about 7 kWh of electricity per year for a representative household over the period 1993–2009. The results also indicated regional heterogeneity across the provinces. Our simulation analysis revealed that climate change would significantly increase residential consumption in Chinese cities. In the sampled cities from the five provinces, the mean increase would be 10% under the low-emission scenario and 20% under the high-emission scenario by the end of the century. The results also indicated regional heterogeneity of the impacts of climate change.

The remainder of this report is organized as follows. Section 2 provides a brief literature review. Section 3 describes the data and main variables. Section 4 presents the methodology and main results. Section 5 discusses the results of the simulation analysis for forecasting residential electricity demand. Section 6 focuses on conclusions and the policy implications of this research.

---

[1] In Northern China, the public utility bodies in many cities start to provide heating to their residents around mid-November.

[2] Other characteristics (e.g., age and gender structures) of a household may also affect its demand. However, we did not have such information in our data sample.

2.0 LITERATURE REVIEW

This study focused on understanding the major factors that determine a household's demand for electricity, and how to forecast electricity demand at both national and regional levels. The roles of weather and income were examined in particular.

Residential demand for electricity is affected by many factors, including weather conditions, electricity price, household income, and other household characteristics (e.g., size, age structure, gender structure, house floor area, etc.). There is a large body of literature on quantifying the impacts of socioeconomic factors that affect electricity demand. The estimation of price elasticity of electricity consumption has been done in many previous studies in various countries. Espey and Espey (2004) conducted a meta-analysis of residential electricity demand elasticities and found that the price elasticity for electricity consumption ranged from –0.2 to –0.4 across various studies.

Income is another factor that can significantly affect residential electricity consumption. The direct income effect is where higher income leads to more residential electricity consumption because of higher purchasing power. Indirect income effects refer to income growth that induces behavioral changes. For example, a household may purchase an air conditioner when its members can afford to do so.

Other characteristics of a household may also have significant impacts on its electricity consumption. For example, smaller families have higher levels of consumption per person. On the other hand, larger households are more open to weather adaptive technologies and practices (Deressa et al. 2009).

There is not much literature that specifically relates to the impacts of climate change on electricity/energy consumption; most of these looked at data from the United States and several other developed countries, mainly relying on aggregated data at different levels of the respective regions (Deschênes and Greenstone 2011; Eskeland and Mideksa 2010).

Climate change may have intensive margins (short-run response of electricity consumption to weather shocks) and extensive margins (e.g., purchase of air conditioners because of temperature increase). Deschênes and Greenstone (2011) used a panel data-based approach to estimate the impacts of climate change on residential electricity consumption. They explained the variation in the US state-level annual panel data of residential electricity consumption using flexible functional forms of daily mean temperatures. Using a panel of household-level electricity billing data, Auffhammer and Aroonruengsawat (2011) examined the impact of climate change on residential electricity consumption in California. In a recent study on China, Auffhammer (2014) provided estimates of the income and short-run weather sensitivity of air conditioner adoption across urban areas in 29 Chinese provincial entities. Meanwhile, Auffhammer and Mansur (2014) provided a review of literature on the impacts of climate change on residential electricity consumption.

There are a very limited number of studies looking at the issues in China. Among these, the majority analyze the industrial sector like Zhao, Li, and Ma (2012) and Asadoorian, Eckaus and Schlosser (2008). The latter provided an empirical investigation of the effects of climate on the use of electricity by consumers and producers in China. They estimated regression models for panel data at the provincial level. Yao, Chen, and Li (2012) used aggregated data to examine rural residential energy consumption from 2001 to 2008. Fei et al. (2011) used annual time series data at the provincial level, and found that the income elasticity of energy consumption in East China was more than double that in Western China. Murata et al. (2008) used a household survey conducted

in 13 Chinese cities to estimate equations on electricity consumption. They projected a 31% increase in electricity demand by 2020. Based on data from a household survey, Zheng et al. (2014) described the characteristics of residential energy consumption in China including electricity consumption.

We could not find any empirical peer-reviewed economics paper on the impacts of climate on residential energy consumption in China using household-level data. The present report assembles unique household-level data for Chinese cities and estimates the impacts.

3.0 DESCRIPTION OF DATA

3.1 Urban Household Electricity Consumption and Household Characteristics

The first data source was for household electricity consumption. We obtained a subsample of the data from the urban household survey (UHS), which is being administrated by China's National Bureau of Statistics (NBS). The Chinese government started doing rural and urban household surveys in the 1950s, but these were suspended in the 1970s. They contained variables such as standard socioeconomic characteristics of the sampled households. In particular, the data sets recorded the physical amounts of electricity consumed by the households. The UHS data set had about 30,000 observations each year from most provinces of the country in most of the years. We obtained access to annual household data for 66 cities in five provinces (i.e., Anhui, Guangdong, Jiangsu, Liaoning, and Shanxi) from 1992 to 2009.

Figure 1 shows the locations of the sampled cities. They are located in the northern, northeastern, eastern, and southern parts of China. They have quite different weather patterns. Appendix 1 gives a complete list of the cities.

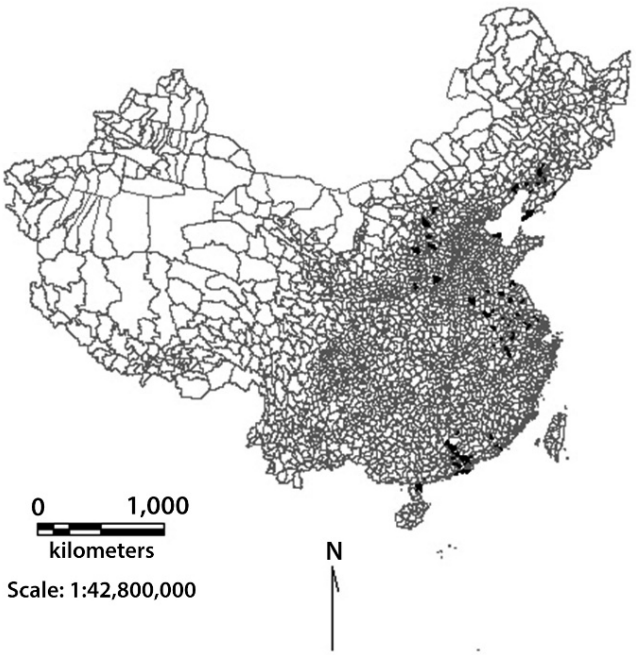

Figure 1. The study sites

Source: UHS sample (1992–2009)

In this study, we extracted several variables from the survey data: income, electricity consumption in kWh and expenditure in current CNY, number of household members, and house floor area. To measure income and expenditure in constant 1992 CNY rates, we used annual consumer price index (CPI) data for the urban parts of each province. The CPI data came from various versions of the China Statistical Yearbook (NBS 2013). The mean electricity price for households at city-year level (i.e., per city per year) could be then calculated.

3.2 Weather

The second data source was the China Meteorological Data Sharing Service System. From the 1950s, it has been recording, daily, the minimum and maximum temperatures, precipitation, wind speed, and other factors from 820 weather stations in China.[3] It gives exact coordinates of each weather station. Through the coordinates of the stations and the location of the cities from the UHS data, we were able to combine the two data sets.

Similar to many previous studies, this research project focused on the daily mean temperature, which is defined as the mean of daily minimum and maximum temperatures.[4] Figure 2 below illustrates the summary statistics of daily mean temperatures from 1992 to 2009 for the sampled cities. It shows that there are temporal variations of temperature. It can be observed that the minimum mean temperature increased significantly after 1998. This happened because Xinzhou (area code 140900) of Shanxi province had many cold days before 1997, according to the recorded data. This city was thus regarded as an outlier and removed from the analysis.

Table 1 below shows the average daily mean temperatures (by province) from 1992 to 2009. It can be seen that there were regional variations in weather conditions. Cities in Liaoning province in Northeastern China had the lowest mean temperatures, while those from Guangdong in Southern China had high temperatures with a mean of 23°C. Anhui and Jiangsu are neighboring provinces in Eastern China. The climatic patterns in the cities in these two provinces were similar.

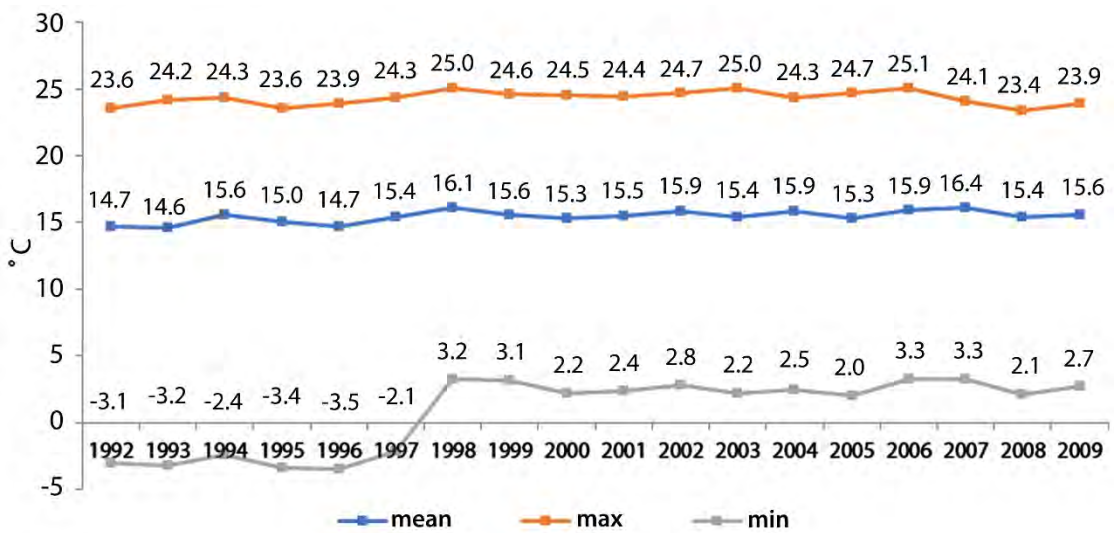

Figure 2. Daily mean temperatures for 1992–2009

[3] Some stations started reporting data in later years.

[4] We also used other weather measures to check the robustness of the empirical results.

We constructed 15 temperature categories or bins, which represented daily mean temperatures of between less than –9°C and greater than 30°C, with 13 bins of 3°C each in between. Figure 3 depicts the distributions of the bins over the years of 1992 to 2009 in the 65 cities. A small number of city-day observations had mean temperatures higher than 30°C or lower than –3°C. The bins of 21°C –24°C and 24°C –27°C had the largest numbers of days for the sampled cities. The next largest bin was for 27°C –30°C.

Table 1. Average daily mean temperatures (°C) by province

Province	Mean	Min	Max
Shanxi	11.18	3.36	15.93
Liaoning	9.91	6.86	12.66
Anhui	16.22	14.02	18.17
Jiangsu	16.14	8.00	18.91
Guangdong	23.12	20.66	25.07

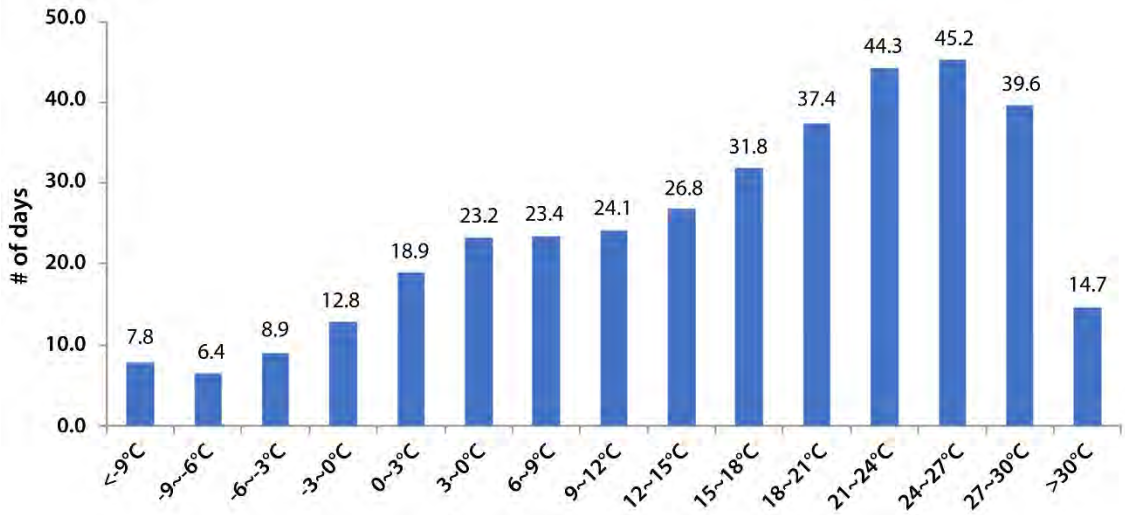

Figure 3. The distribution of the 15 weather bins (1992–2009)

3.3 Summary Statistics

From the UHS data, we deleted observations with missing information on several main variables. Those observations with non-positive values of income, electricity consumption, or house floor area were deleted from the sample. There were some extreme values in the variables. We dropped the observations where the values for each of the above variables were either larger than the 99 percentile or smaller than the 1 percentile in each city-year group.

Table 2 below provides the summary statistics of the main socioeconomic variables used for subsequent empirical investigations. There were about 108,000 household-year observations in the sample. The mean annual electricity consumption of an urban household was 1,303 kWh in the five provinces from 1992 to 2009. As a representative household had three members, this indicated that a person consumed about 434 kWh of electricity per year during the 1992–2009 period. It was also observed that the households differed significantly in terms of their income, family size, and house floor area.

Looking into the data of each province, we observed that the two northern provinces (i.e., Liaoning and Shanxi) had much lower electricity consumption per household. Figure 4 shows the average annual consumption per household in each of the five provinces.

As we moved from the northern to the southern provinces, we found that residential electricity consumption increased. The difference may be the result of varying income levels and weather patterns, among other factors. Southern provinces usually have hotter weather and more days with high temperatures for which buildings need cooling in the summer. Although the northern cities need more heating in the winter, it is mainly provided through coal, not electricity.

Table 2. Summary statistics (1992–2009)

Variable	Mean	Std.	Min	Max
Electricity consumption	1,302.66	836.57	300.00	8,828.00
Disposable income (1992 CNY)	15,407.21	11,401.74	438.22	144,801.80
Household population	2.98	0.87	1.00	15.00
House floor area (m^2)	83.95	46.16	5.00	1,400.00

Note: Number of observations: 108,137

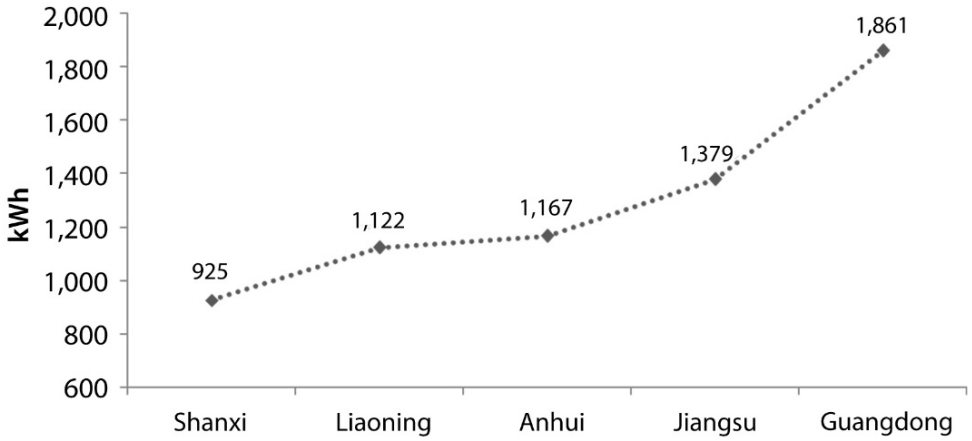

Figure 4. Average annual electricity consumption per household per province (1992–2009)

Figure 5 presents the average electricity consumption per household in our sample for each year. The level increased over the years. An urban household consumed 1,766 kWh of electricity in 2009. It was nearly triple the amount used in 1992.

An additional data source was from various interviews. We did that to familiarize ourselves with the people's views about the past, present, and future of residential electricity consumption in China. This was helpful in constructing our data and discussing the empirical results and policy implications.

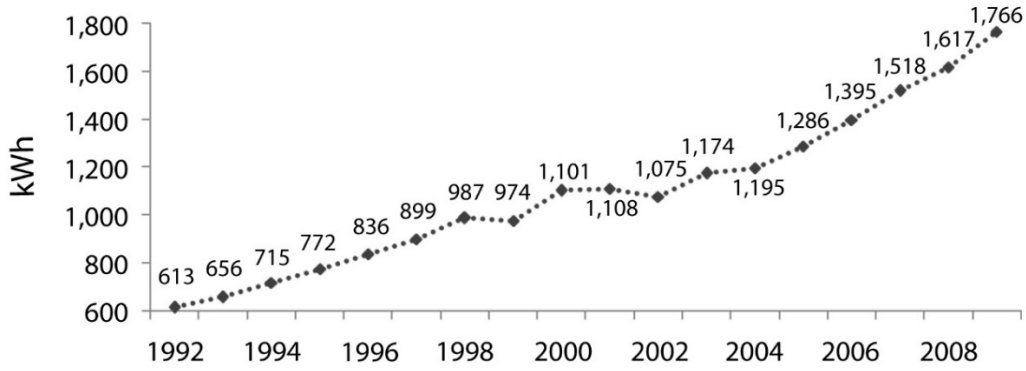

Figure 5. Average electricity consumption per household per year

4.0 METHODOLOGY AND RESULTS

4.1 Empirical Models

Our main empirical model for residential electricity consumption was a reduced-form one, written as follows:

$$log(c_{ijt}) = alog(I_{ijt}) + \beta log(P_{jt}) + \sum_{m=1}^{k} \gamma_m W_{mjt} + \rho H_{ijt} + \delta_i + \theta_j + \eta_t + v_{ijt} \qquad \text{Equation (1)}$$

where:

C_{ijt}	=	residential electricity consumption of household *i* from city *j* at year *t*,
I_{ijt}	=	household income,
P_{jt}	=	electricity price,
H_{ijt}	=	characteristics of the household such as household size and the logged value of house floor area,
W_{mjt}	=	binned weather observations, and
v_{ijt}	=	error term.

We followed Deschênes and Greenstone (2011) and controlled the number of days in many predetermined temperature intervals. Our way of constructing the weather variables considered flexible functional forms of the daily mean temperatures. As noted by Auffhammer and Aroonruengsawat (2011), the model "imposes a minimal number of functional form restrictions in order to capture potentially important non-linearities of the outcome of interest in weather."

The ideal data for our purpose was that which allowed us to estimate Equation (1) above, which controlled for observables including fixed effects for households. The UHS data had identification codes for households in the sample. However, one code over the years may not refer to the same household. It was also possible that a code used for the same household was not identical over two years. There was no way to adjust the household codes to make them consistent over the years. Thus, we applied a cross-section model to the data, while including city and year fixed effects to control for unobservables.

Various specifications of the above model were estimated and compared. We also performed heterogeneity analysis to help us see if the impacts of weather varied across different regions and income groups. Such analysis was used to check the validity of the baseline results of the regressions.

4.2 Estimation Results

This section reports the empirical results of applying the abovementioned model to our constructed data set. The dependent variable was the natural logarithm of a household's electricity consumption in kilowatt-hours (kWh) in a year. The ordinary least square (OLS) estimation of the equation suggested that the price variable was endogenous. We used price in the previous year as an instrument and report the two-stage least squares (2SLS) estimation results below.

Figure 6 plots the estimated coefficients for a day in 14 daily mean temperature bins (15 less one, the base case) relative to a day in the 9°C –12°C category.[5] These results came from estimating Equation (1) for the pooled data, while household characteristics and province and year fixed effects were controlled. Overall, the curve has a U-shape for the weather bins with the exception of the two lowest ones. The lowest temperature bins were mainly from winter days in the two northern provinces where central heating was mostly provided from non-electricity sources such as coal.[6] This may explain why the households did not use more electricity in the days with the lowest temperatures.

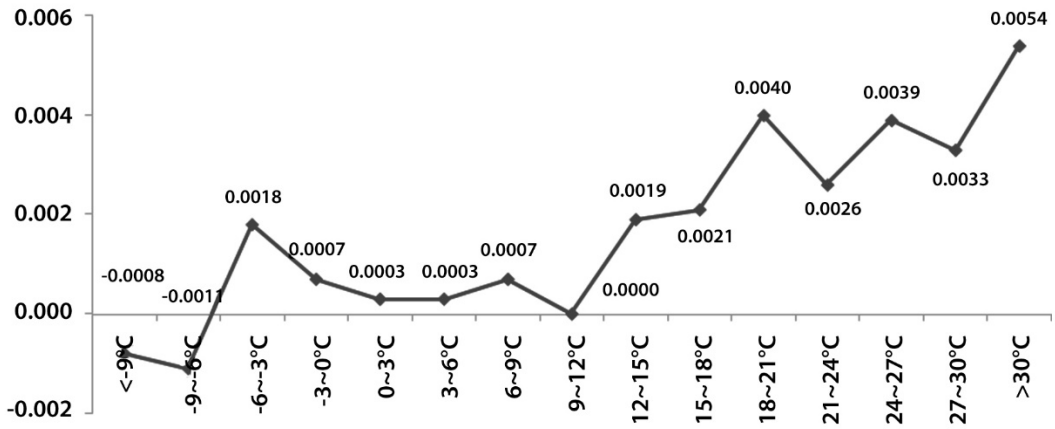

Figure 6. The impacts of weather on residential electricity consumption

Note: The y-axis refers to the estimated coefficients.

The curve indicates that the highest categories and the lower ones are associated with increases in residential electricity consumption. The highest category (>30°C) has a much larger estimated coefficient. One more day with daily mean temperatures in the >30°C category (and one day less in the base category of 9°C –12°C) would make a household consume 0.54% more electricity annually. As a household consumed about 1,312 kWh annually during the 1993–2009 period,[7] the increase would be about 7 kWh of electricity for a representative household. One more day with daily mean temperatures between –6°C and –3°C would cause a household to consume 0.18% more electricity. The increase in electricity consumption during cold days may happen in southern cities that need electricity to heat homes. It may also happen in northern cities on cold days when central heating from coal or gas has not yet started. Usually, most northern cities start to provide heating in late fall and end it in early spring each year.

---

[5] Deschênes and Greenstone (2011) used the category of 50°F –60°F (about 10°C–15.5°C) as the base.

[6] Details on this are provided in the discussion on the heterogeneity analysis.

[7] The data set we collated was for the years 1992–2009. However, only the 1993–2009 data on electricity consumption were applicable for regression purposes.

Our results were largely consistent with earlier studies. Using annual panel data for the United States, Dêschenes and Greenstone (2011) found a U-shaped temperature response function of weather, where energy consumption was much higher on very cold and hot days. They found that one more day with temperatures above 90°F (about 32°C) was associated with a 0.37% increase in annual residential energy consumption. The base temperature category in their study was 50°F–60°F (~10°C–16°C).

Household characteristics also affected residential electricity consumption. The regression results are reported in Column 2 of Table 3. Our results indicated that income elesticity was about 0.27. Annual consumption of electricity increased by 0.27% if the household's disposable income increased by 1%. The price elasticity was found to be –0.37, largely within the range reported in literature. If a household had one more member, then the household would increase electricity consumption by about 3%. Also as a household's floor area increased, its electricity consumption would go up. The elasticity was about 0.15. It is expected that China's household income and house floor area have great potential to rise in the near future. That will lead to significant electricity growth.

Table 3. Estimated impacts of household characteristics

Variable	Household Consumption	Consumption per Capita
Log(income)	0.2697***	0.2611***
	(0.0032)	(0.0032)
Log(price)	–0.3742***	–0.3732**
	(0.0750)	(0.0757)
Household size	0.0293***	–0.3043***
	(0.0019)	(0.0019)
Log(floor area)	0.1541***	0.1685***
	(0.0043)	(0.0043)
Weather	See Figure 6	See Figure 7
City FE	yes	yes
Year FE	yes	yes
Centered R^2	0.3879	0.4811

Notes: (1) ***, **, and * indicate values that are significant at the 1%, 5%, and 10% levels, respectively. (2) Values in ( ) are standard errors.

We also ran a regression for electricity consumption per capita. The dependent variable was the logged value of per capita consumption, while the explanatory variables were the same as those in Equation (1). Column 3 of Table 3 reports the estimated coefficients for major household characteristics. It shows that income, price, and floor area elasticities were very close to those from the first regression. The results indicated that smaller families had higher levels of consumption per person. This finding is consistent with previous studies in literature. Figure 7 shows the impacts of the weather bins on per capita electricity consumption. In general, the impacts were similar to those in Figure 6 for the total household consumption.

It is possible that the impacts of weather on electricity consumption vary across regions. We did a heterogeneity analysis by allowing for varying coefficients for weather bins across the provinces. That is, Equation (1) now included interactions of province dummies and weather bins. Each row of Table 4 reports the regression results for each province. For the purpose of comparison, we report estimates from the earlier regression (see Figure 6) in the bottom panel of the table.

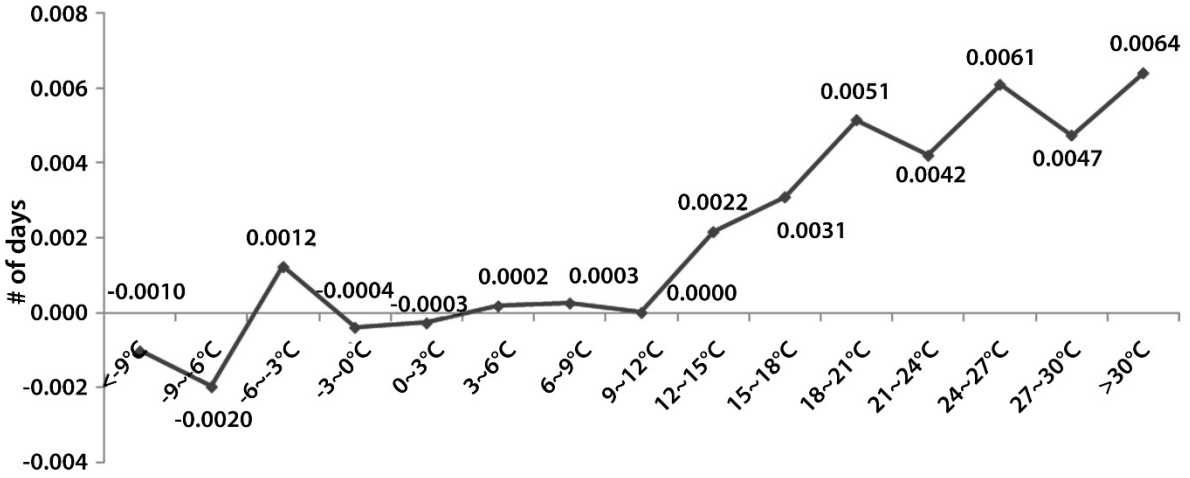

Figure 7. The impacts of weather on per capita residential electricity consumption

Note: The y-axis refers to the estimated coefficients.

Table 4. The impacts of extreme weather on household electricity consumption: Regional heterogeneity

Province	<–9°C	–9～–6°C	27°C～30°C	>30°C
Shanxi	0.0004	–0.0022	–0.0034**	–0.0054***
	(0.0013)	(0.0014)	(0.0015)	(0.0019)
Liaoning	–0.0037***	–0.0046***	–0.0042***	0.0046
	(0.0011)	(0.0012)	(0.0012)	(0.0040)
Anhui		0.0653***	0.0087***	0.0070***
		(0.0140)	(0.0011)	(0.0010)
Jiangsu	0.0140	–0.0048	0.0070***	0.0099***
	(0.0108)	(0.0089)	(0.0012)	(0.0012)
Guangdong			0.0023	0.0047**
			(0.0022)	(0.0022)
Pooled estimates	–0.0008	–0.0011*	0.0033***	0.0054***
	(0.0006)	(0.0006)	(0.0006)	(0.0006)

Notes: (1) ***, **, and * indicate values that are significant at the 1%, 5%, and 10% levels, respectively. (2) Values in ( ) are standard errors.

We found that the responses of extreme high temperatures in the southern provinces (i.e., Anhui, Jiangsu, and Guangdong) were evident. We also found that the impacts of extreme high temperatures in the cities from Shanxi were negative. This estimate might not be accurate because of insufficient data coverage in the high categories for this northern province. When the mean temperature was in the two lowest bins, it did not increase consumption in the northern provinces. However, it did so in cities from Anhui province.

Note that electricity shortages or power outages happened in some areas of the country, especially in the early years of the sampled period. In such cases, the observed consumption might not fully reflect the quantity demanded. This presented the risk of bias in our estimated impacts of weather and income. We hoped that year dummies would partially control the impacts of shortages or outages. On the other hand, urban areas were less likely to have the problem of shortages or outages, especially for those cities higher in the administrative hierarchy (e.g., province capitals). Our econometric model also controlled for city fixed effects.

4.3 Robustness Check

Earlier, we defined weather variables using 15 bins based on daily mean temperatures. We checked the robustness of the regression results with several other definitions of the weather variables. The first robustness check used 10 bins that represented daily mean temperatures of less than –10°C to above 30°C, with eight 5°C-wide bins in between. Not surprisingly, we obtained similar results as with the 15 bins.

The second check was to use only the number of days with extreme low and high temperatures in the regression. Table 5 below reports the estimated impacts. We again found that households consumed more electricity during hot days. The estimated coefficients for the two high categories were smaller than their counterparts when we used the weather bins based on daily mean temperatures. This was not a surprise. A day with a mean temperature of higher than 30°C has more hours of cooling demand than a day when only the highest temperature is more than 30°C. The regression again indicated that the number of days with extreme low temperatures (below –9°C) was not positively correlated with annual electricity consumption.

In the third robustness check of the results, we used only data for shorter periods of time during the sampled years 1992–2009. An example is using data for the year 2000 and after. Figure 8 plots the estimation results for the weather variables. The control variables here are the same as the regression results that were presented in Figure 6 and Column 2 of Table 3. This check can also be regarded as an informal check for the argument that electricity shortages or power outages may bias our baseline results. Shortages/outages may not be a serious problem in recent years. Regressing the data for more recent years in our sample suggested a similar pattern for the impacts of weather.

Table 5. The impacts of extreme weather on household electricity consumption: Number of daily lows and highs

	<–9°C	–9～–6°C	27°C～30°C	>30°C
Estimated impacts	–0.0006*	0.0007*	0.0017***	0.0013***
	(0.0003)	(0.0004)	(0.0003)	(0.0003)

Notes: (1) ***, **, and * indicate values that are significant at the 1%, 5%, and 10% levels, respectively. (2) Values in ( ) are standard errors.

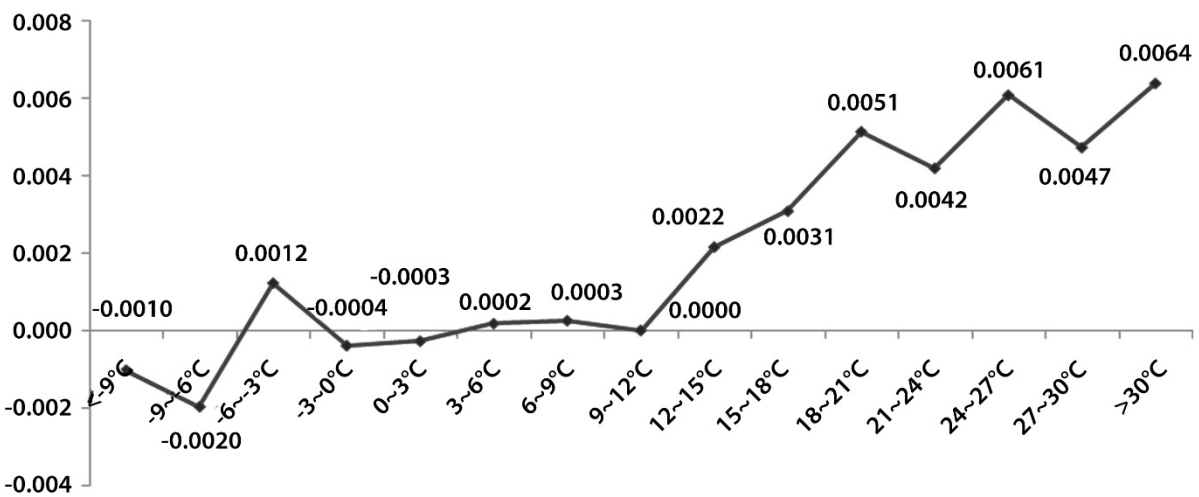

Figure 8. The impacts of weather on per capita residential electricity consumption: Subsample (2000–2009)

Note: The y–axis refers to the estimated coefficients.

In the previous regressions, we regressed the logged value of electricity consumption on logged prices and other variables. To check if the results for weather variables were stable if the model considered absolute price levels instead of the logged values, we ran such a model and found very similar results for the weather variables. Figure 9 plots the estimated coefficients from the log-level regression. A comparison with the baseline results (Figure 6) shows that the obtained coefficients were almost unchanged.

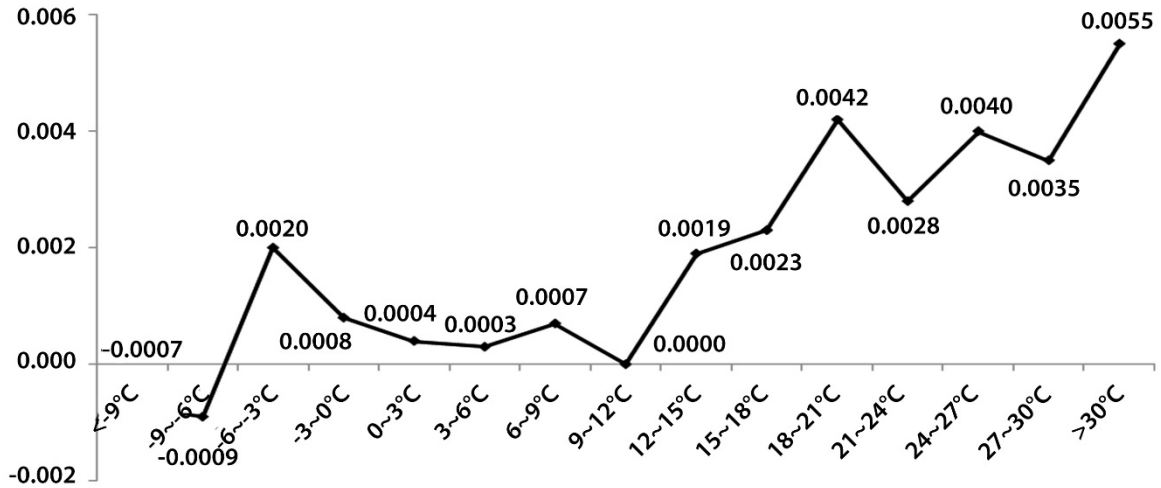

Figure 9. The impacts of weather on residential electricity consumption from the log-level regression

Note: The y-axis refers to the estimated coefficients.

We also regressed the econometric model using the data for the previous regressions, except for the price variable. This gave us estimated coefficients for the weather variables that were very similar to those from the baseline regression shown in Figure 6.

There were, however, limitations in our methodology:

1. Due to limited data availability, we were not able to construct household fixed effects to control for household-level observables.
2. We used average prices that were constructed at the city-year level. Although it is true that all households in a city pay the same unit price at a specific point of time, it is possible that this could change sometime during a year. The constructed price measure could impose a bias on our estimates of the climate variables.
3. We did not consider other dimensions of local weather besides temperature. There are dimensions that could influence electricity consumption via affecting air conditioning. Some previous studies considered precipitation (e.g., Deschênesand Greenstone 2011), while others did not consider other dimensions of weather (e.g., Auffhammer and Aroonruengsawat 2011). Strong multicollinearity was detected when precipitation was included in our regression. Thus, we decided to ignore it in the analysis.
4. The fourth limitation was about the existence of other types of energy such as kerosene and coal, which may substitute for electricity. As such, their prices should be considered in the empirical model when such data becomes available.

5.0 SIMULATION ANALYSIS

We conducted a simple simulation analysis of the impacts of climate change on residential electricity demand.

5.1 The Impacts of Climate Change

We were interested to find out how climate change would affect residential electricity consumption in China. Based on the empirical estimates from the regressions reported in the previous section, we did a simulation analysis after constructing several scenarios for climate change. It was done for the cities and provinces as a whole.

As in Auffhammer and Aroonruengsawat (2011), we forecasted that climate change would cause electricity consumption to change by the following rate:

$$\frac{c_{ij,t+h}}{c_{ijt}} = \frac{exp\{\sum_{m=1}^{k} \gamma_m W_{mj,t+h}\}}{exp\{\sum_{m=1}^{k} \gamma_m W_{mjt}\}} - 1 \qquad \text{Equation (2)}$$

where:

$W_{mj,t+h}$ = weather variables for city j in a future year $t + h$.

As standard in the literature on the impacts of climate change, the simulation assumed that the other right-hand side variables in Equation (1) were the same for both years t and $t + h$ as can be seen in Equation (2). We used pooled estimates of the coefficients from the previous regressions (Figure 6).

For the simulation analysis, we needed climate change prediction data. The predictions were based on the Hadley 3 model.[8] We considered two scenarios: a low-emission scenario (B1) and a high-emission scenario (A2) for both the 2040–2069 and the 2070–2099 periods.[9]

Figure 10 shows the distributions of annual daily mean temperatures for 2009 and the predicted climate changes under emissions scenario B1.[10] It suggests that, on average, there will be many more days with temperatures higher than 30°C in the future compared to 2009. By the end of the century, the increase will be very significant. The number of days with temperatures between 18°C –27°C is predicted to decrease for our sampled cities. Also, the number of extreme cold days is expected to be much lower than that in 2009. The changes in the number of days with mild weather (9°C –15°C) would be relatively small.

---

[8] The Hadley 3 model is a coupled atmosphere-ocean general circulation model developed at the Hadley Centre, United Kingdom. It was one of the major models used by the Intergovernmental Panel on Climate Change in its Third Assessment Report in 2001.

[9] The monthly future temperature data under the scenarios for the prefecture-level cities were extracted from Climate Wizard (http://CliamteWizard.org) through zonal statistics using GIS software (ArcView 10.3.1). Zonal statistics is a tool for calculating a statistic for a zone defined by a zone data set, based on values from a value raster, which is available in a Spatial Analyst Module. In our study, the digital polygon maps for the cities were used as the zone data set, while the monthly future temperature and precipitation raster layers were used as value rasters, and the averages of the values for each zone were calculated.

[10] Due to missing data on future temperatures for three cities (i.e., Foshan, Guangzhou, and Yangquan), the simulation analysis covered only 62 cities.

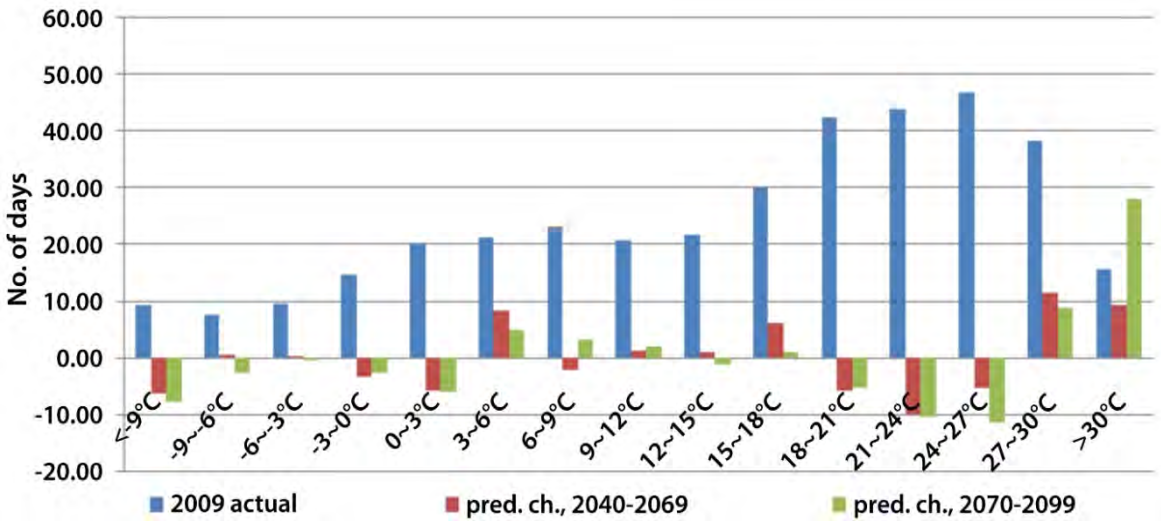

Figure 10. Distribution of annual daily mean temperatures in 2009 and predicted changes in distribution (Emissions Scenario B1)

Figure 11 summarizes the predicted changes in the distribution of annual daily mean temperatures under the scenario of high emissions (A2). Under this scenario, there would be many more days with temperatures above 30°C by mid-century and end-century compared to the low-emission scenario and the 2009 actual case. By the end of the century, it would be about four times as many as in 2009.

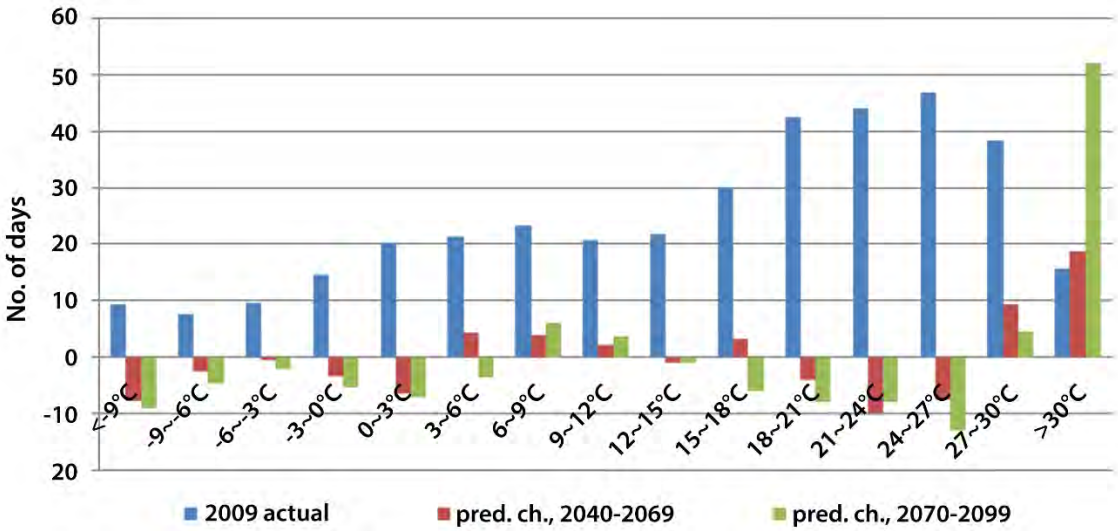

Figure 11. Distribution of annual daily mean temperatures in 2009 and predicted changes in distribution (Emissions Scenario A2)

With the predicted climate data and estimated coefficients from Equation (1), we were able to calculate the predicted impacts of climate change on residential electricity consumption for our sampled cities. Table 6 summarizes the main results from the simulations using the weather conditions in 2009 as the baseline. Before calculating the means, we obtained the percentage change in electricity consumption for each city in our sample. Table 6 suggests that, under the low emissions scenario B1, urban households from the 62 cities in the five provinces would increase electricity consumption by 3.75% annually in the period 2040–2069. The number would increase to 10.03% in the period 2070–2099.

Table 6. Simulated growth in electricity consumption (%): Impacts of climate change

Emissions Scenario	Mean	Std.	Min	Max
B1, 2040–2069	3.75	5.20	–6.41	18.88
B1, 2070–2099	10.03	6.78	–4.90	29.38
A2, 2040–2069	7.90	7.15	–6.08	31.27
A2, 2070–2099	20.45	8.36	2.30	43.45

Note: As there was insufficient information on weather predictions for three cities in the original sample, the simulation analysis covered only 62 cities. The base year was 2009. In that year, a representative household consumed 1,766 kWh of electricity, which is about 615 kWh per person.

Under the high-emission scenario (A2), most cities are predicted to have more days with extremely high temperatures. This would cause residential electricity consumption to grow by a large percentage. In the period 2070–2099, consumption would increase by 20.45% annually. Under the four emissions scenarios in Table 6, it is predicted that the highest increase would happen in Zhanjiang City of Guangdong province.

Our simulated results were higher than those in the US. For example, Auffhammer and Aroonruengsawat (2011) provided simulation results that residential electricity consumption in California would increase by 1%–6% by the end of the century relative to the 1961–1990 base period. Deschênesand Greenstone (2011) estimated that climate change would make annual energy consumption increase by 9% by 2009 in the US. In an earlier study, Crowley and Joutz (2003) used data for three US states and found that a 2°C increase in temperature would make energy consumption increase by 3.8% from current levels.

The simulation indicates heterogeneity even for cities from the same province. Table 7 summarizes the simulation results for the five provinces, which reveals some patterns. Based on the results, climate change would have the most significant impact on Guangdong province; many cities will have many more days with mean temperatures higher than 30°C. On average, Shanxi province would experience the least increase in residential demand for electricity. The two neighboring provinces, Anhui and Jiangsu, are forecasted to have similar impacts in terms of mean increases in residential demand for electricity.

Note that the above simulations from Equation (2) assumed that the estimated marginal impacts of weather in Equation (1) were constant over the years. However, this might not be true, as humans will adapt to climate change in the long run. In the simulations, we also assumed that the variables other than the weather variables on the right-hand side of Equation (1) were the same for the later time periods. When forecasting future residential demand, changes in all conditions including the weather variables and socioeconomic characteristics should be considered.

Table 7. Simulated growth in electricity consumption (%): Impacts of climate change by province

Emissions Scenario	Mean	Std	Min	Max
Shanxi province (9 cities)				
B1, 2040–2069	1.67	5.13	–6.41	11.66
B1, 2070–2099	3.99	5.77	–4.90	14.87
A2, 2040–2069	2.35	5.72	–6.08	12.45
A2, 2070–2099	10.77	5.58	2.30	18.42
Liaoning province (14 cities)				
B1, 2040–2069	4.18	3.21	1.01	9.53
B1, 2070–2099	9.55	4.45	2.01	15.06
A2, 2040–2069	7.21	2.75	1.86	11.55
A2, 2070–2099	21.56	5.52	11.05	31.36
Jiangsu province (13 cities)				
B1, 2040–2069	1.73	2.52	–4.72	6.24
B1, 2070–2099	7.28	1.71	3.44	10.11
A2, 2040–2069	5.01	2.95	–2.07	10.48
A2, 2070–2099	16.19	1.45	12.01	17.78
Anhui province (13 cities)				
B1, 2040–2069	2.09	2.29	–0.73	6.34
B1, 2070–2099	7.83	3.05	3.80	12.01
A2, 2040–2069	5.25	2.77	1.94	9.22
A2, 2070–2099	18.59	4.31	9.13	25.77
Guangdong province (13 cities)				
B1, 2040–2069	8.41	7.94	–3.41	18.88
B1, 2070–2099	19.69	5.98	13.60	29.38
A2, 2040–2069	18.03	7.88	5.61	31.27
A2, 2070–2099	32.10	6.25	25.75	43.45

5.2 The Impacts of Socioeconomic Factors

In the earlier section, the regression results indicated that the price elasticity of electricity consumption was about –0.37 in the short run. In theory, the long-run price elasticity may become larger in absolute value. Retail electricity prices change due to many factors beyond the demand and supply shocks in China. If the social costs of carbon dioxide and other pollutant emissions are considered, then price has much room to increase. If it increases by 100% by the end of the century, then demand could decrease by 23%. This will offset the consumption increase induced by climate change. If the long-run price elasticity becomes significantly higher than –0.37, then the impacts from price increases would be larger.

We estimated that the income elasticity of electricity consumption was about 0.26. It is expected that China's household income has great potential to rise in the near future, which would lead to significant electricity growth by the end of the century. The central government wishes for citizens to double their per capita disposable income by 100% by 2020 from that in 2010. This increase will make electricity consumption increase by about 20%. If the estimated income elasticity holds in the long run, then income growth would significantly increase electricity consumption by the end of the century even at a very conservative income growth rate.

6.0 CONCLUSIONS AND POLICY IMPLICATIONS

6.1 Conclusions

This project was an empirical investigation into the factors that influence residential demand for electricity. The roles of weather and household income were examined in particular. We estimated an econometric model using a data set for households from 65 cities in five Chinese provinces annually from 1992–2009. It was found that as daily mean temperatures increased from 9°C–12°C, the demand for electricity went up. One more day with temperatures higher than 30°C would make a household consume 0.54% more electricity. This translated to about 7 kWh of electricity for a representative household for the 1993–2009 period. As for other important determinants, the results indicated that the income elasticity of electricity consumption was about 0.26, while price elasticity was about –0.37.

Our simulation analysis revealed that climate change would significantly increase residential consumption of electricity in Chinese cities. For the sampled cities, the mean increase would be 10% under the low-emission scenario and 20% under the high-emission scenario by the end of the century. The results also indicated regional heterogeneity of the impacts of climate change. Generally, the highest increases in electricity consumption would happen in the southern provinces while the northern provinces would have lower increases. Future household income growth would bring more challenges for policy makers to meet the growing demand for electricity.

6.2 Policy Implications

This study provides quantitative results regarding the income, price, and weather elasticities of the demand for electricity. A simulation analysis provides predictions for residential electricity consumption at both regional and national levels. The focus was on the impacts of climate change under different scenarios. The estimates and forecasts are helpful for policy makers and utility providers in several aspects.

The simulation analysis indicates that the cities would have larger temperature increases by the end of the century. This would cause residential electricity consumption to grow by more than 10% or 20% for the low- and high-emission scenarios, respectively. Generally, it suggests that the highest increases in electricity consumption would happen in the southern provinces such as Guangdong, while the lowest increases will take place in the northern province of Shanxin. Our simulation results suggest key regions for future planning for expansions of generation and distribution capacities.

The country usually runs short of electricity in cold winters and hot summers in specific regions. A question for policy makers and utility providers is how to better deliver electricity to meet the increasing demands in the context of climate change. Our analyses suggest regional heterogeneity regarding the impacts of weather shocks on electricity demand. The simulation analysis implies that shortages would be more impactful for Southern China in hot summers as temperatures increase, compared to the northern provinces.

Another important debate is on the reform of electricity supply. The central government is trying to let the market, not the government, be the determining force in setting electricity prices. However, a regulation policy is needed in the power industry, one which fully considers the demand side and consumer behavior. The empirical results of this research will be useful for designing such a regulation policy. For example, regions with increasing demand as a result of

climate change should be provided with more electricity. Regulations could allow prices to fluctuate over a wider range in such regions.

Urbanization and the spatial distribution of population will also have impacts on the demand for electricity. As more migrants from villages move to cities where the electricity consumption per capita is usually higher than that in rural areas, the continuing urbanization process will increase electricity demand. Recent migration trends also show that the population growth rate in Southern China is much larger than that in the northern part of the country. As the residents in the southern provinces usually consume more electricity per person, this migration trend will bring about a net increase in electricity consumption. Thus, the forecasted consumption growth rate will be higher than the simulated mean impact reported in this study. Note that the impact of climate change will be much higher in provinces in Southern China such as Guangdong. Future planning of electricity supply should consider the urbanization process and the regional heterogeneity of income growth and weather conditions.

As household income continues to grow, it will significantly increase residential consumption of electricity. If the retail electricity prices take into account the social costs of emissions of carbon dioxide and pollutants, then this will offset the income impact to some extent.

The estimated effects and simulated impacts of weather in this study have important policy implications:

First, the estimated effects are for the short run. In the future, people may adapt to climate change in a number of different ways. In response to increasingly higher temperatures, residents may adopt alternative building technologies and standards such as better housing insulation and double-paned windows. These would moderate the steady compound growth of electricity consumption. On the other hand, increasing temperatures may stimulate more households to purchase air conditioners. This may increase electricity consumption.

Second, the estimated and simulated effects do not distinguish between intensive and extensive margins. As more households become more able to afford air conditioners, it will increase electricity demand in hot summer days. Climate change has similar effects. For several regions, more air conditioners may be purchased when the number of hot days crosses a certain threshold. The simulated results for climate change can be regarded as short-run responses that combine the intensive and extensive margins of weather impacts.

Third, demand management could offset the impacts of climate change to some extent. For example, there is potential to improve the energy efficiency of air conditioners. The government may also consider providing incentives so that households are willing to install rooftop solar systems and use electricity from these as needed.

LITERATURE CITED

Asadoorian, M.O.; R.S. Eckaus; and C.A. Schlosser. 2008. Modeling climate feedbacks to energy demand: The case of China. Energy Economics. 30: 1577–1602.

Auffhammer, M. 2014. Cooling China: The weather dependence of air conditioner adoption. Frontiers of Economics in China. 9(1): 70–84.

Auffhammer, M. and A. Aroonruengsawat. 2011. Simulating the impacts of climate change, prices, and population on California's residential electricity consumption. Climatic Change. 109(S1): 191–210.

Auffhammer, M. and E.T. Mansur. 2014. Measuring climatic impacts on energy consumption: A review of the empirical literature. Energy Economics. 46: 522–530.

Crowley, C. and F. L. Joutz. 2003. Hourly electricity loads: Temperature elasticities and climate change. Paper presented at the 23rd Annual North American Conference, October 19–21, 2003, Mexico City, Mexico. U.S. Association for Energy Economics, Cleveland, Ohio.

Deressa, T.T.; R.M. Hassan.; C. Ringler; T. Alemu.; and M. Yesuf. 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environmental Change. 19(2): 248–255.

Deschênes, O. and M. Greenstone. 2011. Climate change, mortality, and adaptation: Evidence from annual fluctuations in weather in the US. American Economic Journal: Applied Economics. 3(4): 152–185.

Eskeland, G. S. and T. K. Mideksa. 2010. Electricity demand in a changing climate. Mitigation and Adaptation Strategies for Global Change. 15(8): 877–897.

Espey, J.A. and M. Espey. 2004. Turning on the lights: A meta-analysis of residential electricity demand elasticities. Journal of Agricultural and Applied Economics. 36(1): 65–81.

Fei L.; Dong S.; Xue L.; Liang Q.; and Yang W. 2011. Energy consumption-economic growth relationship and carbon dioxide emissions in China. Energy Policy. 39: 568–574.

NBS (National Bureau of Statistics, Department of Energy Statistics). 2013. China Energy Statistical Yearbook 2013. China Statistical Press, Beijing, China.

Murata A.; Kondou Y.; Mu H.; and Zhou W. 2008. Electricity demand in the Chinese urban household-sector. Applied Energy. 85(12): 1113–1125.

Yao C.; Chen C.; and Li M. 2012. Analysis of rural residential energy consumption and corresponding carbon emissions in China. Energy Policy. 41: 445–450.

Zhao X.; Li N.; and Ma C. 2012. Residential energy consumption in urban China: A decomposition analysis. Energy Policy. 41: 644–653.

Zheng X.; Wei C.; Qin P.; Guo J.; Yu Y.; Song F.; and Chen Z. 2014. Characteristics of residential energy consumption in China: Findings from a household survey. Energy Policy. 75: 126–135.

APPENDIX

Appendix 1. Cities in the Data Sample Set

Anhui province: Hefei, Wuhu, Bengbu, Huainan, Maanshan, Huaibei, Tongling, Anqing, Huangshan, Chuzhou, Fuyang, Bozhou, and Xuancheng.

Guangdong province: Guangzhou, Shaoguan, Shenzhen, Zhuhai, Shantou, Foshan, Jiangmen, Zhanjiang, Maoming, Zhaoqing, Huizhou, Meizhou, Qingyuan, Dongguan, and Jieyang.

Jiangsu province: Nanjing, Wuxi, Xuzhou, Changzhou, Suzhou, Nantong, Lianyungang, Huaian, Yancheng, Yangzhou, Zhenjiang, Taizhou, and Suqian.

Liaoning province: Shenyang, Dalian, Anshan, Fushun, Benxi, Dandong, Jinzhou, Yingkou, Fuxin, Liaoyang, Panjin, Tieling, Chaoyang, and Huludao.

Shanxi province: Taiyuan, Datong, Yangquan, Changzhi, Jincheng, Shuozhou, Jinzhong, Yuncheng, Xinzhou, Linfen, and Lvliang.

Strengthening local capacity in the economic analysis of environmental issues

Recent EEPSEA Research Reports

Natural Resource Dependency and Indigenous People's Behavior toward Biodiversity in Virachey National Park, Cambodia
Cheb Hoeurn and Kong Sopheak
2017-SRG1

Weather Events and Welfare in the Philippine Households
Connie Bayudan-Dacuycuy
2017-SRG2

Households' Perception of Arsenic-Contaminated Water and Determinants of Piped Water Connection in Arsenic-Contaminated Areas in the Red River Delta, Vietnam
Le Ha Thanh, Pham Hong Chuong, Trinh Nam Anh, and Le Thai Ha
2017-RR1

Assessment of Climate Impacts, Vulnerability, and Adaptation Strategies in the Coastal Areas of San Juan, Batangas, Philippines
Shaneil Ramos-Dipasupil, Imelda Delos Reyes, and Frank Ilustrado
2017-RR2

Economic Analysis of Adaptation Options in Honda Bay, Puerto Princesa City, Philippines
Patrick A. Regoniel, Melissa Theodora U. Macasaet, and Nelly I. Mendoza
2017-RR3

Drinking Water Options in the Context of Arsenic Contamination in the Vietnamese Mekong Delta
Vo Thanh Danh, Huynh Viet Khai, Nguyen My Hoa, and Nguyen Van Cong
2017-RR4

How Coral Reef Conservation and Marine Protected Areas Impact Human Well-Being: A Case Study of a Marine Protected Area and Fishing Communities in Central Vietnam
Quach Thi Khanh Ngoc
2017-RR5

Measuring Environmental Sustainability of Coffee Production Using Econometric and Frontier-Based Models: Vietnam as a Case Study
Thong Quoc Ho
2017-RR6

A Typology of Mariculture Production Systems and Their Profitability in Selected Sites in the Philippines
Alice Joan G. Ferrer, Herminia A. Francisco, Canesio D. Predo, Benedict Mark M. Carmelita, and Jinky C. Hopanda
2017-RR7

How Mariculture Operations Affect Local Communities: Insights from Seven Mariculture Areas in the Philippines
Alice Joan G. Ferrer, Herminia A. Francisco, Canesio D. Predo, Benedict Mark M. Carmelita, and Jinky C. Hopanda
2017-RR8

The First 15 Years of Mariculture Park in the Philippines: Challenges and Way Forward
Alice Joan G. Ferrer, Herminia A. Francisco, Canesio D. Predo, Benedict Mark M. Carmelita, and Jinky C. Hopanda
2017-RR9

Flood Insurance Market in Vietnam: Challenging but Potentially Profitable
Phung Thanh Binh , Zhu Xueqin , Rolf Groeneveld, and Ekko van Ierland
2017-RR10

Residential Electricity Consumption in China: The Roles of Weather and Household Income
Wang Chunhua
2017-RR11

Trade-Off Analysis between Ecosystem Services, Habitat Quality, and Development Plans in Order to Propose Suitable Solutions for Pu Mat National Park in Nghe An Province
Nguyen The Chinh, Lai Van Manh, Nguyen Thi Thu Ha, Nguyen Thi Yen, and Phan Thi Truong Giang
2017-RR12

EEPSEA is administered by WorldFish on behalf of its donors, Sida, and IDRC.

WorldFish Sida IDRC CRDI