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Siqi Zheng
Rui Wang
Edward L. Glaeser
Matthew E. Kahn

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ABSTRACT

China urbanization is associated with both increases in per-capita income and greenhouse gas emissions. This paper uses micro data to rank 74 major Chinese cities with respect to their household carbon footprint. We find that the "greenest" cities based on this criterion are Huaian and Suqian while the "dirtiest" cities are Daqing and Mudanjiang. Even in the dirtiest city (Daqing), a standardized household produces only one-fifth of that in America's greenest city (San Diego). We find that the average January temperature is strongly negatively correlated with a city's household carbon footprint, which suggests that current regional economic development policies that bolster the growth of China's northeastern cities are likely to increase emissions. We use our city specific income elasticity estimates to predict the growth of carbon emissions in China's cities.

Siqi Zheng
Institute of Real Estate Studies
He Shanheng Building, Tsinghua University
Beijing 100084, P. R. China
zhengsiqi@tsinghua.edu.cn

Rui Wang
3250 School of Public Affairs Building
UCLA Department of Urban Planning
Los Angeles, CA 90095-1656
ruiwang@ucla.edu

Edward L. Glaeser
Department of Economics
315A Littauer Center
Harvard University
Cambridge, MA 02138
and NBER
eglaeser@harvard.edu

Matthew E. Kahn
UCLA Institute of the Environment
Department of Economics
Department of Public Policy
Box 951496
La Kretz Hall, Suite 300
Los Angeles, CA 90095-1496
and NBER
mkahn@ioe.ucla.edu

I. Introduction

Today, per capita carbon emissions in the United States are about five times per capita emissions in China, which implies that if China's per capita greenhouse gas emissions rose to U.S. levels, then global carbon emissions would increase by more than 50 percent. While forty percent of U.S. emissions are associated with residential and personal transportation, a much smaller share of Chinese emissions come from these sectors, which suggests that Chinese household carbon emissions could rise dramatically China's urban population has grown by 300 million since 1990, and China is investing in the infrastructure needed for hundreds of millions of future urbanites. China's urban development policies could have large potential impacts on global carbon emissions.

Knowing a nation's per-capita income and total population size is not sufficient for judging its household sector's greenhouse gas production. The spatial distribution of this population across diverse cities is key determinant of the size of the aggregate emissions. In this paper, we estimate the carbon emissions associated with the development of different Chinese cities. The more dramatic these differences are, the larger the impact that urban policy can have on Chinese and global carbon emissions.

Using U.S. data, Glaeser and Kahn (2010) found that places with moderate temperatures, like coastal California, have significantly lower emissions than places with extreme temperatures, like Texas: a standardized household's carbon emissions are 78 percent higher in Memphis than in San Diego. Denser places have lower carbon emissions than sprawling car-oriented locales. If these relationships hold in China as well, denser development in the more temperate locales of that country will lead to lower carbon emissions.

In this paper, we calculate household carbon emissions using several data sources including the Chinese Urban Household Survey. This survey provides information on energy usage for 25,000 households across 74 cities. Relative to U.S households, transportation represents a smaller share of Chinese urban household emissions and household heating represents a much larger share. A poorer country can do without air conditioning and cars, but not without winter warmth.

As in Glaeser and Kahn (2010), we are not attempting to estimate an average carbon "footprint," but rather the marginal emissions associated with the movement of a typical new family to a particular locale. For that reason, we calculate a predicted level of carbon emissions in different places for a standardized household with a fixed size and level of income. We do not follow Glaeser and Kahn (2010) and look at disproportionately newer housing to get a better sense of the impact of the latest housing. But given how new most Chinese cities are, an average home in Shanghai is far more likely to be relatively new than an average home in Detroit.

Even though we attempt to hold individual income constant, we find that richer cities have significantly higher household carbon emissions, which was not true in the U.S. One possible explanation for this fact is that richer cities may have invested more in infrastructure that complements energy use. In China, carbon emissions are particularly high in places with cold Januarys, because of centralized home heating. For example, Shanghai (without centralized home heating) is much greener than Beijing (with centralized home heating). The prominent role played by central production of heat indicates that carbon emissions could fall significantly if greener sources of energy were used by the government for that purpose, as argued by Almond et al. (2009).

China currently has three significant regional policies, which support growth in the Northeast, the Western hinterland and the Beijing-Tianjin-Bohai Sea region. Relative to the average city household, carbon emissions are 69 percent higher in the Northeast, 40 percent higher in the Beijing-Tianjin-Bohai Sea region and 17 percent lower in the West. These findings suggest that regional development policies that favor growth in the Northeast and in the greater Beijing areas are likely to increase China's overall carbon emissions.

The range of emissions across China's cities today does not capture the diversity of possible long run outcomes. We use our cross-sectional estimates to predict the increase in Chinese household emissions by 2026 if Chinese incomes increase by 200 percent. We find that the increases predicted by current cross-sectional relationships are quite modest, relative to the current gap between the U.S. and China. Yet to us, this only serves to illustrate the range of possibilities for Chinese emissions.

If Chinese households in 2026 behave like richer versions of Chinese households today, then emissions will grow only modestly. New energy efficiency policy initiatives, such as China's recent announcement of its intent to reduce its carbon intensity (CO_2/GNP) by 40 percent by the year 2020, can offset some of the pollution consequences of growth.[1] But if China invests in infrastructure and changes its urban forms so that China looks more like the United States, then emissions of both China and the world will increase dramatically. Some of the most important environmental decisions in the 21st century may concern the development patterns of Chinese cities and it surely worth better understanding the environmental consequences of those decisions.

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[1] http://www.nytimes.com/reuters/2009/11/26/world/international-uk-climate-china-copenhagen.html.

II. Household Carbon Production and Urban Development in a Developing Country

Urban infrastructure is long lived, and decisions made decades ago still shape older cities like London and New York. In declining areas, like Detroit, where there is little new construction, history is even more important. Today, China is making choices over investments in roads, public transit, electricity generation and housing that will have implications for resource consumption and greenhouse gas production for decades. The combination of irreversibility of investment, and China's vast size, makes its current development decisions relevant for long-term global carbon emissions.

No nation, including China, has a unilateral incentive to tax carbon emissions so that actions internalize global consequences of greenhouse gases. As Glaeser and Kahn (2010) note, in the absence of an appropriate carbon tax, there will be lower social costs created when urban activity locates in a low emissions place rather than a high emissions place. There may also be distortions that come from other public policies, like subsidizing highways or homeownership, that encourage energy intensive lifestyles.

The size of the externality associated with a household locating in place A rather than place B equals the increase in carbon emissions in place A minus the decrease in emissions in place B times the social cost of carbon emissions minus the current carbon tax. We will provide new estimates of these externality costs for 74 major Chinese cities. These estimates will allow us to evaluate the unintended environmental consequences of China's current regional development policies.[2]

Throughout this paper, we will focus solely on carbon dioxide emissions as our measure of city "greenness." In recent work (see Zheng, Kahn and Liu 2010), we have examined how ambient particulate levels and sulfur dioxide levels vary across 35 major Chinese cities as a function of city per-capita income and FDI. Unlike carbon emissions, these other forms of pollution typically decline with income after a certain point, known as the peak of the Environmental Kuznets Curve turning point. For that reason, we expect that further increases in Chinese per-capita income will be associated with local pollution reductions. For example, China is now phasing in Euro IV new vehicle emissions standards in Beijing, which seems likely to reduce smog, because of improved transit service and more effective travel demand management.

In this paper, we focus on household energy consumption. In the U.S., the household carbon emissions account for 40 percent of total carbon emissions, while in China this share is less than twenty percent. However, the household's share of total per-capita carbon emissions will surely grow as China transitions from being a manufacturing economy to being a service economy. As domestic households become richer they will consume more electricity and the demand for

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[2] Assessing the size of the environmental externality from migration requires us to know the marginal impact of an extra household on carbon emission, but we will only be able to measure average emissions. Marginal and average emissions may differ because of increasing or decreasing returns in the production of energy. We have no way of addressing this problem and cannot even be sure of the direction of the bias. Average and marginal emissions may also diverge because new households are more likely to live in larger or more energy-efficient homes or homes on the urban edge.

private transportation services will increase.[3] The industrial sector is a major consumer of energy in China. Several studies have examined the industrial sector using decomposition techniques to study the role of industrial scale, composition and technique effects in explaining trends over time (see Huang 1993, Sinton and Levine 1994, Sinton and Fridley 2000, Shi and Polenske 2006).

III. Measuring Household Greenhouse Gas Emissions in China's Major Cities

We estimate how much carbon dioxide emissions a standardized Chinese household produces per year if it resides within one of China's 74 cities, including all the 35 major cities (all municipalities directly under the federal government, provincial capital cities, and quasi-provincial capital cities) plus some cities that have enough sample observations. We focus on four major household sources of carbon dioxide emissions; transportation, residential electricity consumption, residential heating and domestic fuel. The following equation provides an accounting framework for organizing our empirical work.

$$\text{Emissions} = \gamma_1 * \text{Transportation} + \gamma_2 * \text{Electricity} + \gamma_3 * \text{Heating} + \gamma_4 * \text{Domestic Fuel} \qquad (1)$$

Our main goal is to estimate equation (1) for each Chinese major city for a standardized household. In this equation, transportation represents energy use from a vector of activities including liters of annual gasoline consumed for households that own a car. Transportation also includes miles traveled on cabs, and the energy use of buses and subways. All forms of energy

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[3] Our study will focus on transportation, and household consumption of energy to provide heating and cooling services. We recognize that households consume other products (such as what they eat) that have carbon consequences.

use are multiplied by an emissions factor vector defined as γ_1. For example, each liter of # 93 gasoline consumed produces 2.226 Kg of carbon dioxide.

The second term in this equation represents carbon dioxide emissions from residential electricity consumption. In the U.S., Glaeser and Kahn (2010) found a tight link between electricity consumption and hot summers, presumably because of extensive use of air conditioning. To convert electricity usage into carbon emissions, we must use the regional area power plants' average emissions factor, denoted by γ_2, defined as carbon dioxide emissions per megawatt hour of power generated. Coal fired power plants have a higher emissions factor than natural gas fired power plants or power plants that run on renewable power such as wind, hydro, or solar power.

Major Chinese cities differ with respect to their geography and available natural resources that can be used for energy. For instance, some are located in regions that receive more of their power from power plants with a lower emissions factor. In our calculations we report below, we will use recent regional emissions factors for power plants as an input in ranking cities with respect to household carbon emissions based on equation (1). It is important to note that today's average emissions factor may not be an accurate estimate of future regional emissions factors if China were to sign a global carbon reduction treaty.

China's cities differ greatly with respect to their winter temperatures. Northern cities are much colder than southern cities. In northern Chinese cities, heat is provided publicly through a system that provides a fixed amount of heating between November 15 and March 15. Prior to the 1980s, heating was considered a basic right and the government provided free heating (which is called the “centralized heating system”) for homes and offices, either directly or through state-owned enterprises. The legacy of this system remains today.

The cities north of the Huai River and Qinling Mountains continue to receive subsidized heating in winter months, while the southern cities are not entitled to centralized heating. Individual households are unable to control the indoor temperature when centralized heating is provided. Given these points, we assume that energy usage for heating is proportional to the floor area of the home. This sector creates high level of emissions because heating’s main energy source is coal (Almond et. al., 2009).

The fourth term in the equation is emissions from domestic fuels, which are also used, in some cases, to heat homes. This term includes three components; coal, liquefied petroleum gas (LPG), and coal gas. Coal is inexpensive, but it is carbon intensive. A byproduct of using it is elevated ambient air pollution level such as sulfur dioxide, and particulates. LPG and coal gas are extracted from petroleum oil and coal, and are much cleaner and less carbon intensive.

Data Description

Our first source of data is the Chinese Urban Household Survey (UHS) in the year 2006. This survey is conducted annually by the Urban Survey Department of the State Statistic Bureau of China. The survey targets households living in cities and towns for more than half a year. The data collected from the survey is primarily used for estimating the urban consumer expenditure component in GDP and CPI. The annual UHS that we use in this paper includes approximately 25,300 observations across the 74 cities. We compute the carbon emissions from electricity use, private car, taxi, and three domestic fuels based on this micro data set. The survey also provides information on city economic and demographic variables such as per household income, household size, and age of household head. Since many households in northern cities still receive free heating services, there is no record of heating expenditure in the UHS.

Given the current relatively low private vehicle ownership level in China, it is important to measure public transportation's contribution to the average household's carbon emissions. The China Urban Statistic Yearbooks provide us with city level information, such as energy consumption information on buses and subways. We have the electricity consumption in 2006 for each of the ten cities with a subway system. In the case of buses, converting fuel use into carbon emissions is straightforward. For electricity-powered subways, the conversion of energy use into carbon requires additional information about power production.

To construct common units measured in tons of carbon dioxide, we need access to carbon emissions factors associated with both electricity production and public home heating. The data for these items comes from various sources. The carbon emission factors of regional power grid, γ_2, come from the Department of Climate Change of the National Development Research Center of the State Council. The energy consumption involved in centralized heating comes from the Department of Environmental Engineering and Department of Building Science in Tsinghua University.

Table One lists the names, definitions, means and standard deviations of our key variables. Table Two reports the summary statistics. The average household in our sample has an annual income of 40 thousand Yuan, or 5.7 thousand dollars. It consumes 1,700 kWh of electricity and spends 130 Yuan on taxis in 2006. Across our 74 city sample, 16.4% of the 25,300 households own cars. Auto ownership in Chinese cities is growing rapidly as incomes escalate. Between 2002 and 2007, the number of private cars in Beijing increased from 1.5 to 3 million.

Pooled Cross-City Regressions Results

To estimate the components of equation (1), we will estimate separate city specific regressions for relevant carbon producing activities such as electricity and gasoline consumption. These city specific regressions allow us to predict energy consumption for a standardized household in each of the 74 cities. This procedure generates an unwieldy number of regression coefficients, but generally these regression coefficients are similar in magnitude across places.

We first use the household micro data to estimate the determinants of Chinese household energy use. We regress travel behavior, household electricity use, heating consumption and domestic fuel consumption on city fixed effects and basic demographics. In the case of household electricity consumption, we estimate:

$$\text{Log}(\textit{Electricity}) = \textit{City Fixed Effects} + b_1 * \text{Log}(\textit{Income}) + b_2 * \textit{Household Size} + b_3 * \textit{Age of Household Head} + U \qquad (2)$$

The unit of analysis is household *j* in city *k*. Note that the regression coefficients do not have city specific subscripts. In the results reported in Table Three, we include city specific fixed effects but impose the constraint that household demographics have the same marginal effects on energy consumption across cities. Our final estimates relax this assumption, but since this produces an enormous number of coefficients, we report the more consolidated estimates.

With the exception of electricity consumption and taxi gas consumption, we estimate the other energy consumption regressions using a Heckman two-step procedure. Many households in our sample have literally zero consumption of a specific fuel. For example, in Beijing, we estimate the car ownership rate to be 23 percent. Thus, in this relatively wealthy city 77 percent of households are consuming zero gasoline and the remaining 23 percent are consuming a positive quantity of gasoline. In Shanghai, the vehicle ownership rate is even lower (16.4 percent) due to higher population density and a license plate quota policy. The same issue arises for household consumption of three domestic fuels (coal, coal gas and LPG), where many households consume none of particular fuel.

In implementing the Heckman two-step estimator for each of these categories of energy consumption, we use a first stage probit of the form:

$Prob(consume\ fuel\ j) = f(\ b_1*\mathrm{Log}(Income) + b_2*Household\ Size + b_3*Age\ of\ Household\ Head)$ (3)

In the second stage, we estimate $\mathrm{Log}(consumption|\ \mathrm{consumption}>0) = c_1*\mathrm{Log}(Income) + e$ (4)

We have no theoretical reasons for including variables in the participation equation but not the consumption equation, but small sample sizes led us to exclude age and household size from the second stage regression. Our sample sizes conditional on positive energy consumption (especially when we stratify by city) are small so age and household size effects were extremely imprecisely measured. This procedure therefore corrects for the tendency of places with differently aged or larger households to have more cars or more strictly positive amounts of LPG consumption, but it does not correct for any connection between age or household size and consumption, conditional upon consumption being positive.

The results in Table 3 indicate that taxi use is a luxury good with an income elasticity greater than one. Car ownership and gasoline consumed have high income elasticities. The income elasticity of electricity consumption is 0.29. Richer urban Chinese households are moving up the energy ladder by substituting away from dirty home heating fuels such as coal and increasing consumption of cleaner fuels such as electricity and coal gas. These urban China results are in accord with past household Environmental Kuznets Curve (EKC) work by Pfaff et. al. (2004). Richer people consume cleaner energy sources and this can reduce local air pollution despite a rising quantity of consumption. Coal and LPG are both inferior goods, whose use declines with income (but if a household uses coal, the coal consumption rises with income), while the use of coal gas, the cleanest of these energy sources, increases with income. Coal gas is transmitted through pipes directly into households, while LPG is less convenient and coal is far dirtier.

City-Specific Income Elasticities

We use the UHS data to estimate city specific regressions for household consumption of gasoline, electricity, coal, LPG and coal gas that allow the coefficients to vary by city. Each of these regressions has the same form as those reported in Table Three but in this case, we now have 222 (74 cities and three explanatory variables) separate coefficient estimates for income, household size and age. We report only the income coefficients in Table Four. Economic growth will surely continue in China; these income coefficients suggest which cities may be particularly likely to increase energy consumption over time.

There are sizable differences in the relationship between household income and energy consumption across cities. The table highlights the cross-city heterogeneity with regards to income effects. Shanghai's income elasticity of private car fuel consumption (conditioning on ownership) is two times larger than the income elasticity in Beijing. The income elasticity of electricity consumption is 0.163 in Beijing, 0.171 in Shanghai and 0.445 in Zibo. Assuming that these year 2006 cross-sectional income elasticities do not change over time, we use the estimates reported in Table Four to forecast how ongoing urban growth will affect energy consumption in different Chinese cities. For example, economic development in Zibo will lead to greater electricity consumption than in Beijing.

IV. Measuring Household Carbon Emissions across Chinese Cities

To measure the carbon emissions of our 74 Chinese cities based on carbon dioxide emissions, we use the estimated city-specific energy consumptions for seven energy types for a standardized household and then convert that energy use into carbon dioxide emissions. The standardized household is defined as a household with an annual income of 40,000 Yuan or 5,714 dollars, 3 members and a household head of 45 years old, which are the means of these three variables of the whole sample. By predicting the carbon dioxide emission of a standardized household, we are able to answer; "if a household moved from city I to city j, would aggregate carbon emissions rise or fall?"

In estimating the regression equations (2, 3,4), we control for demographics but not for housing characteristics. After all, we are not attempting to estimate emissions assuming that people in Beijing live in Huaian's "Southern-Huai -River" small town style homes. If households live in smaller homes in more expensive areas, then the resulting reduction in carbon emissions should be attributed to that location.

Household Electricity

Based on equation (2), we estimate 74 city specific electricity consumption regressions. To provide one salient example, in equation (5) we report our estimates based on the Shanghai sample of 1,018 households.

$$\text{Log}(\textit{Electricity Use}) = \underset{(0.29)}{3.58} + \underset{(0.03)}{0.33}*\text{Log}(\textit{Income}) + \underset{(0.02)}{0.10}*\textit{Household Size} - \underset{(0.001)}{0.0005}*\textit{Age} \qquad (5)$$

Standard errors are reported in parentheses. In this regression, the R-squared is 0.199. We take these regression coefficients and predict the annual electricity consumption for a household living in Shanghai, with an income of 40,000 Yuan, 3 members and a household head of 45 years old. The result is 1494.9 kilowatt hours (kWh). We then multiply this number by the electricity conversion factor in Shanghai (0.8154 tCO_2/mWh), which is γ_2 in Equation (1). This yields a prediction for the standardized household equal to 1.219 tons of carbon dioxide emissions. These steps yield an estimate of γ_2*Electricity (see equation 1) for each city.

The electricity conversion factor (power plant emission factor, γ_2) is a key parameter that varies by region across China. Seven electricity grids (six regional grids on the Mainland plus one on the Hainan Island) support most of China's power consumption. The baseline emission factors (at both operating margin and build margin) for regional power grids are estimated for recent years by the Office of National Coordination Committee on Climate Change, a department within the National Development and Reform Commission.

Car and Taxi Usage

For private cars, we use the city-specific two-stage Heckman model to predict a standardized household's fuel consumption (fuel consumption taken to be 0 when unobserved). In the case of car usage in Beijing, for example, the selection equation is:

$$\mathit{Prob(Owning\ a\ car)} =$$

$$f\,(-8.84 + 0.81*\text{Log}(\mathit{Income}) - 0.003*\mathit{Household\ Size} - 0.015*\mathit{Age\ of\ household\ head}) \quad (6)$$

(0.861) (0.079) (0.051) (0.003)

Standard errors are in parentheses. The consumption equation, given the household owns a car, is:

$$\text{Log}(\ \mathit{Car\ Fuel\ Use} \mid \mathit{Car\ ownership} = 1) = 4.52 + 0.27*\text{Log}(\mathit{Income}) \quad (7)$$

(6.599) (0.519)

Standard errors are in parentheses. In the above Heckman two-step estimation, there are 2,081 observations. From the first step regression we predict that the standardized household has a 18.4% probability of owning a car. Using both equations, we predict that the standardized household's expected fuel consumption is 292.2 liters per year. We then convert fuel consumption into carbon emissions using standard gas conversion measures. We employ a similar procedure to predict a standardized household's emissions from taxi use in each of the 74 cities.

Bus and Subway Emissions

The UHS expenditure data do not provide us with reliable estimates of the mileage and energy consumed by households using public transit. To overcome this problem, we use aggregate data in China Urban Statistic Yearbooks and additional sources.[4] The Yearbooks provide data on the total numbers of standard buses, LPG buses and CNG buses. We assume that the bus operating rate is 90 percent, and every bus travels approximately 150 kilometers per day. The fuel consumption of a standard bus is 25 liters per 100 km. A LPG (or CNG) bus consumes three-fourths of the fuel that a conventional bus consumes for an equal distance. We then calculate each city's total bus fuel consumption and divide by the total number of households in the city. Standard conversion factors transform per household fuel consumption to per household carbon emission.

There are only 10 Chinese cities that have subway lines: Beijing, Shanghai, Guangzhou, Shenzhen, Tianjin, Dalian, Changchun, Nanjing, Wuhan, and Chongqing. There is no public data available on the electricity usage of subways, so we must rely on private governmental data. We follow the same procedure as we followed for estimating bus emissions by city. For each city, we calculate total electricity consumption by the subway system and then divide this by the city's household count. This yields an estimate of a city's per-household average electricity consumption from subway use. We then use region-specific conversion factors to estimate the carbon emissions associated with subway electricity usage in each city. The total carbon emission from transportation sector is the sum of the above four sub-categories: private car, taxi, bus, and subway.

Fuel and Heating Emissions

We apply the Heckman two-stage procedure (see equations 4 and 5) to predict a standardized household's carbon emissions from home fuel use. For three types of fuel, coal,

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[4] Glaeser and Kahn (2010) follow the same strategy in their United States study ranking cities with respect to their household carbon footprint.

LPG and coal gas, we first estimate the probability the standardized household uses this fuel type, and then predict the consumption quantity conditional upon using the fuel. We calculate expected fuel consumption for each source and then multiply this by standard conversion factors to predict total carbon emissions.

Since many households in northern cities still receive free heating services, there is no record of heating expenditure in the UHS, beyond the three fuel types discussed above. In markets where there is centralized heating, there is no heating meter since heat is provided by the state for free in fixed quantities. The best predictor of energy usage in such households, that we know of, is floor area. Tsinghua University's Department of Building Science and Department of Environmental Engineering provided us with conversion factors that indicate how much carbon dioxide is emitted when heating a square meter of living space in each province for a given outside temperature .

We then multiply this conversion factor times the predicted amount of floor space for an average household. Using UHS information on each household's housing unit size, we estimate a city specific regression (similar to equation 2) where home unit size is regressed on income and demographics. Using this regression, we predict expected square footage for a standardized house and then multiply this by the province-specific home heating conversion factors to predict total carbon emissions in each of our 74 cities.

China's Greenest Cities Based on the Household CO_2 Metric

Combining the components in equation (1) then enables us to rank China's 74 major cities with respect to total carbon emission per standardized household. The results are shown in

Table Five. Table Five's first 9 columns report our sectoral estimates for this standardized household in each of the 74 cities. The units are tons of CO_2.

China's major cities' household carbon emissions are dramatically lower than in the U.S. Glaeser and Kahn (2010) report that in the cleanest cities (San Diego and San Francisco), a standardized household emits around 26 tons of CO_2 per year.[5] Shanghai's standardized household produces 1.8 tons of carbon and Beijing's standardized household produces 4.0 tons. Even in China's brownest city, Daqing, a standardized household emits only one-fifth of the carbon produced by a standardized household in America's greenest cities. Table Five presents our ranking in order from Greenest to Brownest. The top ten cities are: Huanian, Suqian, Haikou, Nantong, Nanchang, Taizhou, Zhengjian, Shaoxing, Xining, and Xuzhou. The bottom ten sorted from worst to relatively cleaner are; Daqing, Mudanjiang, Beijing, Qiqihaer, Yingchuan, Shenyang, Haerbin, Dalian, Baotou, and Liaoyang.

Figure 1 shows the per household carbon dioxide emissions in each of the 74 cities on a GIS map. High levels of carbon emissions are particularly common in the north, which reflects the cold temperatures and government heating policy. Coastal cities also have higher emissions, perhaps because they are somewhat more developed. Eight of the ten greenest cities in our sample are located just south of the centralized heating border in the coastal provinces. These cities are not entitled to winter heating services and their summers are not exceptionally hot. Daqing, China's oil capital, has dramatically higher carbon emissions than any other city.

The Chinese heating system is coal-based and highly-subsidized. Most of the heat is derived from coal-fired heat-only boilers or combined heat and power generators, which are

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[5] Glaeser and Kahn's standardized U.S urban household has an income of \$62,500. Obviously, this is a much higher income level than for the standardized Chinese urban household.

inefficient in energy usage compared to electric, gas and oil heating systems in industrial countries (T.J. Wang et al., 2000; Yi Jiang, 2007). If China's home heating system were to be dramatically changed, perhaps using far less carbon intensive energy sources, then this could certainly change the rankings of cities.

The results reported in Table Five are measured in tons of carbon dioxide per household. We use an estimate of \$35 per ton as the marginal social cost of one ton of carbon dioxide. This is a conservative estimate relative to the Stern report (2008), which suggests a cost of carbon dioxide that is twice this amount. This value lies in the middle of the range reported by Metcalf (2007).[6]

Given our estimates of the spatial differences in household carbon emissions across, China's cities we find that moving the average household from the greenest city to the brownest would cause a social externality of \$136.5 (35*(5.1-1.2)) per year. This is roughly 2.5 percent of a year's income. If the northern cities substitute away from coal for home heating, or if the richer cities invest more in subways or other forms of transit, this gap could narrow.[7] Conversely, increases in income could cause some of the differences in consumption to widen. We will explore these possibilities in Section VI.

A city's carbon emissions is just one indicator of its "greenness," but it the component of greenness that seems most likely to have an impact outside the city and country of residence. Zheng, Kahn and Liu (2009) use hedonic methods to rank China's major 35 cities. A major

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[6] It is relevant to note that carbon tax policy proposals have suggested taxes per ton of carbon dioxide roughly in this range. Metcalf (2007) proposes a bundled carbon tax and a labor tax decrease. As shown in his Figure Six, he proposes that the carbon tax start at \$15 per ton (in year 2005 dollars) now and rise by 4% a year. Under this proposal, the carbon tax per ton of carbon dioxide would equal \$60 per ton (in year 2005 dollars) by 2050.

[7] Northern cities should be aware of the local ambient pollution problems caused by household coal use. After the horrific deaths in the great 1952 London Fog, the city banned home coal use. While households have little incentive to curb their greenhouse gas emissions, the cost of local pollution (caused by coal burning) provides a direct incentive to consider encouraging substitution to cleaner fuels.

component in their quality of life index calculation is city air quality, measured by small particulate matter, PM_{10}. We calculate the correlation between the 35 cities' PM_{10} levels and our per-household carbon emission. These two sets of rankings have a positive correlation coefficient of 0.33. In the colder northern cities, people burn coal to produce home and office heating creating both particulates and carbon dioxide emissions.

Understanding Cross-City Differences in Carbon Emissions

Table Six reports the correlation between our carbon emissions estimates and city-level attributes including population, population growth, income, temperature and urban form. Population is positively correlated with emissions from use of taxis, buses and electricity. Unsurprisingly, larger cities tend to be more transit oriented and less dependent on cars. Population density is associated with lower levels of emissions from taxi use and buses. An increase of 1,000 people per square km (about 19% of the sample standard deviation) on average is associated with a reduction of carbon dioxide emissions per household of 0.424 ton from use of taxis and 0.837 ton from the use of buses. This may indicate shorter average travel distance or much more effective urban public transportation. Just as in the U.S., compact development leads to lower carbon emissions.

There is a positive correlation between city-level income and carbon emissions, even holding individual income constant. Higher income cities have higher emissions from electricity, driving, and subways but lower emissions from taxis. One explanation for the link between city-level income and emissions for a standardized household is that there is mismeasurement in individual income and that city-level income is correlated with unobserved household prosperity. A second explanation is that there is a social multiplier in certain types of energy use. A third explanation is that higher income cities have built infrastructure that is complementary with greater use of energy. When we form our projected energy use in a richer China, we will combine both the income effects suggested by the individual regressions and the city-level income elasticities.

Figure 2 shows the strong correlation between January temperature and carbon emissions, which reflects both the natural tendency of colder places to require more heat and the home heating rules that provide heat only to northern cities. A one standard deviation increase in January temperature (8.66 degrees) is associated with a 0.29 ton decrease in carbon dioxide emissions. The temperature effect of January comes primarily from its impact on household heating emissions – one degree higher in January temperature corresponds to 0.111 ton less CO_2 emissions from heating. There are offsetting effects from the other energy sources.

V. **The Environmental Consequences of China's Regional Development Policy**

Unlike the United States, China's government is pursuing a well defined set of regional growth policies. If successful, these policies will impact China's overall carbon emissions. In China, there are at least three significant programs that are intended to bolster the growth of particular regions. The Western Development Program launched in 1999 gives infrastructure aid and support for industrial adjustment to western and inland provinces. The program attempts to help heavy and defense industries convert to consumer goods production (Chow (2002: 174)). China's Northeast once benefited from the emphasis on heavy industry during the Mao years (Liaoning, Jilin and Heilongjiang). Since then, like the American Rustbelt, the Chinese northeast has struggled with high unemployment, aging industry and infrastructure, and social welfare bills

(Saich 2001: 149). While the Western Development Program targets both urban and rural areas, the Northeast Revitalization Program focuses on reinventing the declined cities.

A third program is targeted at the development of Beijing-Tianjin- Bohai Sea region. This program intends to expedite the development of this northern mega-region to catch up the Yangtze and Pearl River Deltas in the south. The 2008 Olympics caused a massive public investment in infrastructure and environmental improvement. Centralized political power will surely continue to attract physical and human capital to the region (Ades and Glaeser, 1995). [8]

To assess the carbon production consequences of these programs would require a detailed model of how each of these programs will influence the spatial distribution of Chinese urban growth. To begin to address this topic, we calculate the regional household carbon emissions factor by taking population weighted averages of our household carbon production measures reported in Table Five. The weighted average of residential emissions in the Western region is 1.9 tons per household relative to 2.3 tons in the rest of the country. The weighted average residential emissions in the cities impacted by northeastern regional development are 3.5 tons per household. Emissions are 2.0 tons per household outside that region. Finally, the weighted average emissions in the cities inside the Beijing-Tianjin-Bohai Sea region are 2.9 tons per household, as opposed to 2.1 tons outside that region. The Northeast Revitalization Program and the development program of Beijing-Tianjin- Bohai Sea region seem to be trying to bolster growth in areas that have particularly high levels of carbon emissions. The Western Development Program is encouraging the developments in the areas with slightly low levels of carbon emissions.

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[8] There is the fourth regional development program called "Rise of Central China", aiming to support the development of central provinces. However, very few real policies came out since the launch of this program.

These results highlight how the environmental costs of regional policies can be incorporated into a type of "green accounting" for estimating the full consequences of spatial policies. Such externalities need to be put in the context of other policy objectives. Our estimates just suggest that there are environmental consequences of regional policy.[9]

VI. Future Carbon Emissions

China is changing so rapidly that current Chinese emissions only offer the vaguest sense of what emissions will be like 20 years in the future. In this admittedly speculative section, we use our income elasticity estimates to project household carbon emissions across Chinese cities 20 years in the future. We make the same assumptions about incomes and population levels in 2026. The assumptions are from authoritative research institutes in China: (1) Chinese urban per capita incomes will increase 200 percent over 20 years, which would occur if urban incomes grew at a 5.6 percent annual real rate. (source: Institute of Quantitative & Technical Economics, Chinese Academy of Social Sciences); (2) Chinese urbanization rate will increase from 43.9% in 2006 to 62% in 2026, thus urban population growth is about 40 percent over 20 years. (source: China Academy of Science)

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[9] Such hidden cost may be further increased if urbanization leads to more reliance on local and regional energy sources. Fossil fuels are predominantly in the north, which has 90% of the oil and 80% of the coal reserves. Hydropower remains the vast majority of renewable power (roughly 17% of the total electricity) generated in China. Roughly two thirds of the hydropower is located in the south west region of China. In contrast to the distribution of fossil and hydro energy, the east and south coastal areas have very little energy resources. Of course, the northern part of the country has some potential in increasing its small but increasing share of renewable energy. Wind power is concentrated in the northern provinces and the east and south coasts. The seasonal fluctuation of wind power is complementary to hydropower, but the geographical distribution of land areas with rich wind power potential is to a large extent different from that of the demand for power. In addition, international energy trade may help reduce the northern cities' carbon footprint. If the northern cities can import natural gas from Russia to substitute their coal use to a significant level, the geography of urban carbon foot print will be different.

We then use our China-specific data to estimate emissions for 2026. To do this, we create a composite regression that includes our predicted emissions for every household in the UHS, including emissions from fuel, subways, cars and so forth. We then perform the following regression:

$$\textit{Emissions}=a_i*\text{Log}(\textit{Income})+b_i*\textit{Household Size}+c_i*\textit{Age}+d*\text{Log}(\textit{City Population})+e*\textit{January Temperature} \qquad (8)$$

Coefficients a_i, b_i and c_i all differ by city. We first use this equation to predict the standardized household's carbon emissions in each of the 74 cities in 2006. We then predict for each city in 2026, the predicted emissions for a household with three members earning 120,000 Yuan, or 17,500 dollars in today's currency (a 200% increase from 40,000 Yuan), assuming that the city's population has also risen in the manner discussed above. The predicted 2026 per-household carbon emissions are listed in Column (3) in Table Seven. They essentially predict household energy use assuming that China in 20 years looks essentially like a richer and more urbanized version of China today. All cities have higher emission levels in 2026. On average, per household carbon emission grows by 26% from 2006 to 2026. This extremely modest change suggests that a richer China will have only a modest impact on global emissions.

But there are good reasons to be skeptical about that optimistic projection, which essentially assumes that China in 2026 will look like a richer version of China today, not a poorer version of the United States. Glaeser and Kahn (2010) calculated the emissions for a household that earns 62,500 dollars, which is about 10.66 times richer than the Chinese household investigated in this study. The median city in their United States sample had household carbon emissions that are 20 times higher than the median city found here in China.

To explain this difference with income alone, the income elasticity of carbon emissions would have to be 1.3, which is far higher than any of our estimates within China, or Glaeser and Kahn's estimates within the United States.

In other words, a comparison of the United States and China suggests that increases in national income may be associated with far greater increases in carbon emissions increases in income across country. Presumably, this greater cross-national difference adopts infrastructure choices that are made at the city, region or national level and that would cause the aggregate effects of income to be higher than the individual effects of income. Such effects may explain why there was a correlation between emissions and city-income in China, holding individual income constant.

If China's middle class in the future starts uses energy like China's wealthiest citizens today, then China will have a modest impact on global emissions. If China's middle class in the future starts to use energy like the poorer Americans today, then global emissions will rise quite significantly. The wide range between those alternatives suggests the large impact that different investments in Chinese infrastructure will have on the world's carbon emissions.

VI. Conclusion

China's economic growth has profound environmental implications. Past research has examined the greenhouse gas implications of this growth using an Environmental Kuznets Curve framework either using national panel data (see Schmalensee, Stoker and Judson 1998) or using regional aggregate data. Auffhammer and Carson (2008) create a panel data set for 30 Chinese provinces covering the years 1985 to 2004. They also find that the relationship between greenhouse gas emissions and per-capita income is increasing and concave.

In this paper, we find that some of the patterns of carbon emissions within China replicate findings that hold in the United States and elsewhere. If economic growth takes place in compact, public transit friendly, cool summer, warm winter cities, then the aggregate carbon emissions will increase less than if economic growth takes place in "car dependent" cities featuring hot summers and cold winters and where electricity is produced using coal fired power plants.

Recognizing that diverse cities differ with respect to these characteristics, we have used individual and institutional data to measure household carbon emissions across a sample of 74 Chinese cities. We have found that the "greenest" cities based on this criterion are Huaian and Taizhou while the "dirtiest" cities are Daqing and Mudanjiang. However, even in China's brownest city, Daqing, a standardized household emits only one-fifth of the carbon produced by a standardized household in America's greenest city (San Diego).

The cross city differential in the carbon externality is "large". At $35 per ton of damage from carbon dioxide, moving a standardized household from Daqing to Huaian would reduce the externality by roughly $136.5 per year, which is reasonably high relative to household per capita income of 40,000 Yuan, or about 5800 dollars. This differential is mainly generated by cross city differences in climate, centralized heating policy, regional electric utility emissions factors, and urban form. Unlike the United States, China is pursuing major regional growth initiatives. Our results highlight the presumably unintended adverse carbon consequence of encouraging growth in the North.

Our study relies on cross-sectional data, and changes over time may not resemble differences at a point in time. New technologies may radically reduce the carbon emissions associated with certain types of energy production. Alternatively, China may invest more in infrastructure, like highways, that complement heavy energy use. China will surely grow richer, and the country is likely to use more energy. But the actual impact on carbon emissions, which may be either modest or large, will depend on infrastructure and new technologies.

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Table One: Summary Statistics and Definitions

Variable Name	Definition	Unit	Mean	Std.dev.
Household level variables				
ELECQ	Household's electricity consumption in 2006	kWh	1,699	1,089
CAR_USE	Binary: 1=own a car, 0=otherwise. In 2006.		0.164	0.370
CARQ	Household's fuel consumption by driving car in 2006	Liter	178.8	202.9
TAXIQ	Household's fuel consumption by taking taxi in 2006	Liter	13.2	21.2
COAL_USE	Binary: 1=use coal as domestic fuel, 0=otherwise. In 2006.		0.092	0.289
COALQ	Household's coal consumption in 2006	kg	760.4	654.7
LPG_USE	Binary: 1=use LPG (liquefied petroleum gas) as domestic fuel, 0=otherwise. In 2006.		0.419	0.493
LPGQ	Household's LPG consumption in 2006	kg	82.9	55.4
COALGAS_USE	Binary: 1=use coal gas as domestic fuel, 0=otherwise. In 2006.		0.582	0.493
COALGASQ	Household's coal gas consumption in 2006	m^3	252.9	189.5
HHSIZE	Household size	person	2.9	0.8
AGE	Household head's age	year	50.5	11.9
INCOME	Annual household income	yuan/household	39,639	23,056
HSIZE	Housing unit size	square meter	74.271	33.789
City-level variables				
CINCOME	City average household income	yuan	37977	10273
POP	City population	1000 persons	2,556	2,652
DENSITY	City population density	1000 persons/km^2	13.4	5.3
JAN_TEMP	Average temperature in January	℃	0.46	8.66
JULY_TEMP	Average temperature in July	℃	27.21	2.65

Table Two: City Level Summary Statistics for Year 2006

City	Obs	Avg. income (Yuan)	Avg. electricity use (kWh)	Car ownership (%)	Avg. gas use (L)	Avg. taxi expenditure (Yuan)	Std. bus mileage (1e3 km)	LPG/ CNG bus mileage (1e3 km)	Rail electricity use (1e3 kWh)	Heated floor space (m^2)	coal use rate (%)	Avg. coal use (kg)	LPG use rate (%)	Avg. LPG use (kg)	Coal gas use rate (%)	Coal gas use (m^3)	House unit Size (m^2)
All	*25330*	*40,058*	*1699.0*	*16.4*	*178.8*	*130*	*99,926*				*9.2*	*760.4*	*41.9*	*82.9*	*58.3*	*252.9*	*64.9*
Beijing	2081	55,718	2286.2	23.0	309.3	255	758,835	174,926	244,907	222,180	7.4	1159.9	22.1	97.2	74.8	233.6	65.8
Tianjin	1554	40,441	2151.4	11.0	204.1	176	356,505	2,119	54,741	109,680	8.8	808.2	7.9	73.9	90.9	148.5	76.1
Shijiazhuang	301	32,201	1470.7	7.3	126.5	120	75,785	29,466		38,280	5.3	1150.6	53.2	85.4	53.2	340.0	68.4
Tangshan	200	37,647	1137.7	16.0	199.4	165	117,915			21,640	0.0	0.0	0.0		100.0	406.6	68.9
Qinhuangdao	200	29,472	1132.1	23.5	141.5	103	39,075			9,120	4.5	1411.1	65.0	76.2	39.0	368.3	73.4
Handan	200	28,633	1121.4	12.0	88.3	75	63,023			10,030	9.5	396.4	10.0	28.8	95.0	361.8	93.0
Cangzhou	150	30,080	1152.5	18.0	69.8	134	19,217			5,830	4.0	1200.0	92.0	83.1	38.0	112.0	70.4
Taiyuan	310	32,039	1293.2	8.1	159.7	102	99,683			37,850	3.2	528.0	7.1	83.8	92.9	447.6	85.3
Shuozhou	150	31,747	853.6	26.0	74.4	95	4,977			2,470	22.0	1597.0	48.7	60.2	57.3	131.1	72.9
Huhehaote	400	37,383	1293.2	11.8	188.8	189	10,200	44,200		12,030	9.0	1377.0	45.8	72.4	53.0	247.3	75.5
Baotou	400	40,109	1361.4	19.0	111.9	209	39,962	13,945		23,680	10.8	1215.0	37.5	67.2	42.5	242.3	85.9
Wuhai	150	34,596	1162.8	65.3	64.4	135	20,548			2,600	31.3	1567.9	27.3	54.4	13.3	214.8	75.9
Chifeng	200	26,572	1141.7	16.5	59.2	103	16,803	1,183		12,210	8.5	1386.5	89.0	46.5	1.5	42.7	72.9
Tongliao	150	28,275	1680.5	26.7	75.7	193	7,983			4,660	8.7	1923.8	78.0	85.1	5.3	60.8	65.8
Shenyang	502	31,190	1343.2	4.0	241.7	180	196,410	54,695		117,776	0.4	175.0	5.8	69.3	95.6	175.7	68.8
Dalian	508	37,514	1242.8	3.0	147.2	239	207,842		17,987	60,350	0.2	1275.0	11.4	56.9	94.1	344.0	71.2
Liaoyang	200	27,259	1182.8	5.5	60.7	124	18,774			12,630	3.5	62.7	56.0	102.7	63.0	87.6	77.5
Changchun	322	33,444	1224.8	6.8	206.8	210	86,823	100,028	14,680	49,480	5.3	1517.6	5.6	58.4	92.5	236.8	78.7
Jilin	300	29,074	1366.9	3.0	196.4	226	289,195	138,364		21,610	0.7	177.0	88.0	92.6	17.7	159.8	65.7
Haerbin	541	31,125	1571.0	3.9	132.7	162	124,666	102,837		55,750	1.3	426.9	16.5	108.2	88.5	403.5	64.8
Qiqihaer	300	22,989	1012.3	7.7	62.1	108	46,466			20,300	1.0	1666.7	18.3	106.1	90.3	198.8	86.1
Daqing	200	37,427	1708.0	4.0	72.1	228	91,011			29,610	0.0	0.0	74.0	133.9	7.5	80.2	64.6
Mudanjiang	200	22,349	1254.9	6.5	100.3	165	6,701	15,226		13,590	6.0	1612.5	74.0	48.9	3.5	104.1	61.1
Shanghai	1018	56,717	1778.3	16.4	183.6	242	818,852	13,846	427,302		0.0	0.0	3.4	64.1	97.0	403.6	69.9

Nanjing	821	47,448	1960.7	15.1	197.9	116	207,349	45,234	67,180		1.3	462.7	54.8	77.6	50.5	204.0	75.2
Wuxi	301	48,705	2057.3	18.9	194.8	127	130,283	8,968			2.7	259.4	35.2	76.0	65.4	350.0	66.0
Xuzhou	301	35,331	1278.4	9.6	93.1	82	84,162				28.6	583.8	33.2	66.9	61.1	288.4	81.0
Changzhou	301	42,536	1746.6	42.5	142.8	104	65,240	13,994			7.0	458.8	52.8	81.4	59.8	161.6	83.1
Suzhou	300	49,096	1960.2	22.3	173.6	117	101,309				4.0	581.3	32.7	86.1	69.3	231.9	82.3
Nantong	205	38,890	1524.7	5.4	179.0	61	37,498				3.4	284.0	29.3	81.4	82.4	311.7	79.6
Huaian	200	29,379	1289.0	16.0	51.2	60	28,974				42.0	403.5	70.5	56.6	27.0	87.4	91.9
Yangzhou	200	36,080	1655.5	27.5	70.1	71	36,562				10.5	250.5	49.0	64.5	58.0	278.7	81.4
Zhenjiang	200	40,896	1593.5	10.0	52.1	98	36,119				24.0	532.0	40.5	54.2	69.0	149.6	87.9
Taizhou	200	33,580	1468.5	40.5	88.8	49	11,727				22.5	539.0	60.5	62.1	28.0	71.7	117.9
Suqian	207	26,626	1038.6	21.3	54.0	42	16,162				43.5	503.0	87.4	48.3	1.4	26.0	78.4
Hangzhou	614	51,432	2286.5	18.1	243.7	96	234,795				4.6	262.1	66.9	81.1	42.3	128.3	69.2
Ningbo	406	48,805	1768.0	15.0	262.4	90	130,776				2.2	351.7	78.1	112.3	27.6	60.9	87.3
Wenzhou	204	54,042	2836.0	43.1	335.7	195	83,620				0.5	50.0	84.8	115.4	16.2	34.4	76.0
Jiaxing	150	44,866	1716.0	38.0	186.4	87	32,374				5.3	197.3	80.0	98.0	25.3	55.0	80.7
Huzhou	200	42,087	1727.5	21.0	97.4	90	29,910				5.5	456.4	87.0	89.9	18.5	163.5	74.2
Shaoxing	200	49,815	1568.6	9.0	150.6	68	36,119				27.5	224.7	42.5	77.5	71.0	119.5	86.5
Jinhua	153	43,932	1514.1	37.3	137.5	119	33,162				24.2	238.2	85.0	71.7	16.3	37.3	96.4
Quzhou	150	37,848	1415.4	16.7	128.1	88	26,461				10.7	753.4	76.0	101.8	28.7	389.7	104.5
Taizhou	150	52,123	1914.5	39.3	263.3	86	17,591				12.7	88.9	84.0	118.3	18.0	50.8	88.1
Lishui	150	44,803	1881.5	48.7	152.8	50	4,583				14.0	187.5	92.7	90.8	4.0	30.1	71.1
Hefei	410	31,293	1624.5	5.6	106.4	222	96,776	21,927			27.8	417.3	58.8	83.7	48.5	177.6	68.3
Huainan	411	31,410	1255.3	6.3	84.9	232	42,623				28.0	575.4	46.7	51.5	64.7	325.6	82.0
Fuzhou	303	44,596	2804.7	24.8	144.8	76	91,750				0.3	30.0	68.6	117.8	36.3	120.3	87.0
Xiamen	201	52,711	2776.8	25.9	172.1	121	126,883				6.5	584.3	67.7	93.1	34.8	106.3	70.8
Nanchang	300	28,905	1537.2	1.7	50.0	38	108,159				0.3	150.0	75.0	85.4	38.3	250.8	75.6
Jinan	416	43,605	1573.0	31.3	133.2	185	138,561	46,269		23,680	25.7	1140.4	52.9	50.3	39.4	143.8	67.6
Qingdao	407	43,263	1668.9	10.3	236.3	172	177,291	20,646		18,370	20.4	1050.2	48.6	55.9	63.9	222.6	93.9
Zibo	150	38,050	1299.7	42.7	79.6	149	82,339	4,977		18,300	11.3	1205.3	66.7	81.2	29.3	148.9	72.8
Yantai	200	40,448	1248.6	26.0	72.6	184	73,962	296		15,970	8.5	1273.5	55.0	61.4	52.0	205.5	81.0
Rizhao	102	31,736	1412.1	60.8	136.6	139	35,527			5,670	22.5	1163.2	59.8	47.9	8.8	67.3	80.4
Zhengzhou	462	35,124	1508.3	7.4	97.6	52	87,857	70,365		10,610	14.7	991.9	30.3	87.2	79.9	241.4	82.6

Luoyang	307	32,683	1402.5	22.5	87.7	72	40,948			3,200	25.1	612.3	75.9	82.4	22.5	325.2	78.2
Wuhan	531	34,558	2092.8	5.5	222.0	135	201,091	83,225	11,284		7.7	503.4	50.5	109.9	63.8	253.7	79.5
Changsha	409	38,758	1918.3	16.4	207.9	227	131,564	2,562			8.6	604.3	81.4	97.1	31.5	258.3	77.2
Guangzhou	304	59,751	2361.1	27.0	242.3	166	209,271	316,444	185,417		0.7	66.0	69.1	112.6	50.3	260.7	95.5
Shenzhen	101	82,429	2893.5	42.6	466.6	219			100,485		0.0	0.0	53.5	140.4	59.4	79.2	87.8
Zhuhai	101	55,577	2039.5	36.6	295.0	162	57,504				5.0	118.8	97.0	137.3	12.9	48.4	74.2
Nanning	202	32,663	1591.5	39.1	136.2	65	107,567				12.4	319.3	92.6	107.4	6.4	70.0	94.8
Haikou	306	35,693	1580.0	33.7	193.4	64	42,377				4.2	577.3	85.6	97.3	15.0	139.4	75.5
Chongqing	308	35,571	2051.0	3.2	155.7	119	40,504	349,113	26,120		1.0	783.3	2.6	67.9	98.4	341.2	76.4
Chengdu	430	36,138	1821.8	20.9	262.3	116	3,597	32,669			2.1	1596.7	5.1	103.9	94.4	348.4	80.6
Mianyang	200	27,587	1394.5	9.5	188.8	100	2,661	33,556			0.5	150.0	4.5	71.3	97.5	279.6	63.5
Guiyang	316	33,034	2155.4	15.5	128.0	99	77,559				29.1	848.1	19.0	58.7	69.0	292.2	92.4
Kunming	600	30,445	1522.3	14.3	181.1	45	123,582	77,756			10.3	372.8	41.7	74.9	51.3	399.0	62.5
Xi'an	366	31,172	1396.1	6.6	50.2	108	135,309	131,466		18,390	20.8	678.6	38.5	58.2	53.3	247.2	61.9
Lanzhou	321	25,819	911.7	3.1	47.4	74	4,139	91,159		22,140	6.5	667.2	44.9	61.6	59.5	166.5	73.8
Xining	300	27,781	1507.6	4.7	111.8	113		86,379		130	17.0	1273.6	14.3	63.7	5.0	392.7	72.0
Yinchuan	314	27,870	1334.8	15.3	71.7	191	40,455	12,713		21,230	10.5	467.9	66.2	42.7	20.7	233.5	69.4
Wulumuqi	402	29,294	1053.5	4.0	37.4	136	12,812	196,755		29,000	0.7	500.0	26.9	54.1	61.7	233.5	64.9

Table Three: Energy Consumption Regressions Using 2006 Micro Data

			Heckman Two Step		Heckman Two Step		Heckman Two Step		Heckman Two Step		
Dependent variable	log(*ELECQ*)	log(*TAXIQ*)	*CAR_USE*	log(*CARQ* |*CAR_USE=1*)	*COAL_USE*	log(*COALQ* |COAL_USE=1)	*LPG_USE*	log(*LPGQ* |LPG_USE =1)	*COALGAS_USE*	log(*COALGASQ* |*COALGAS_USE =1*)	log(HSIZE)[c]
Model	OLS[a]	OLS[a]	Probit[b]	[a]	Probit[b]	[a]	Probit[b]	[a]	Probit[b]	[a]	OLS[a]
log(*INCOME*)	0.289 (39.21***)	1.929 (54.95***)	0.630 (34.16***)	0.768 (9.40***)	-0.448 (-23.83***)	0.169 (2.17**)	-0.240 (-17.46***)	-0.082 (-2.08**)	0.354 (25.46***)	-0.070 (-0.59)	0.265 (61.36***)
HHSIZE	0.06 (11.77***)	-0.287 (-11.83***)	0.044 (3.39***)		0.153 (11.23***)		0.039 (3.82)		-0.030 (-2.91)		0.025 (8.26***)
AGE	0.0009 (2.62***)	-0.018 (-11.37***)	-0.021 (-23.90***)		0.011 (11.69***)		-0.004 (-6.14**)		0.008 (11.48***)		0.0003 (1.53)
constant	3.988 (51.1***)	-13.642 (-36.75***)	-6.702 (-34.90***)	-2.689 (-2.59**)	2.288 (11.71***)	5.283 (9.39***)	2.389 (16.33***)	3.829 (16.44***)	-3.789 (-25.54***)	5.184 (3.01***)	1.367 (29.83***)
City fixed effects	yes	yes	--		--		--		--		yes
Obs	25328	25328	25328		25328		25328		25328		25328
Significance	R^2: 0.22	R^2: 0.234	rho: -0.558 sigma: 1.764 lambda: -0.984		rho: -0.398 sigma: 1.330 lambda: -0.529		rho: 0.961 sigma: 1.314 lambda: 1.262		rho: -0.364 sigma: 0.917 lambda: -0.335		R^2: 0.222

[a] t-statistics in parentheses.

[b] z-statistics in parentheses.

[c] for estimating heating. * indicates significance at the 10% level, ** at the 5% level and *** at the 1% level.

Table Four: Income Effect Estimates Based on the Household Level Regressions Estimated for Each City

Dependent variable	log(elecq)	log(taxiq)	Car_use	log(carq)	log(hsize)	coal_use	log(coalq)	lpg_use	log(lpgq)	coalgas_use	log(coalgasq)
Model	OLS	OLS	Heckman		OLS	Heckman		Heckman		Heckman	
Beijing	0.163 (3.631***)	1.432 (10.230***)	1.463 (8.213***)	0.269 (0.518)	0.218 (11.158***)	-0.344 (-1.806)	-0.037 (-0.180)	-0.447 (-3.679***)	0.705 (0.897)	0.514 (4.415***)	0.068 (0.650)
Tianjin	0.402 (9.811***)	1.499 (8.470***)	1.526 (6.044***)	0.160 (0.281)	0.416 (19.992***)	-1.427 (-7.558**)	0.519 (0.840)	-0.959 (-5.155***)	-0.080 (-0.358)	0.516 (3.018***)	0.058 (0.461)
Shijiazhuang	0.321 (2.605**)	-0.493 (-1.011)	1.894 (3.155***)	1.197 (0.796)	0.312 (6.087***)	-1.361 (-2.523**)	0.028 (0.015)	-0.387 (-1.424)	-1.889 (-0.161)	0.552 (1.996)	-0.097 (-0.313)
Tangshan	0.197 (2.147**)	2.227 (4.043***)	1.53 (2.915***)	-0.053 (0.00)	0.328 (6.456***)						
Qinhuangdao	0.138 (1.59)	0.532 (1.542)	1.174 (2.396)	0.753 (1.446)	0.137 (4.175***)			-1.095 (-3.385***)	-0.492 (-1.506)	1.023 (3.296***)	-0.833 (-0.887)
Handan	0.144 (0.944)	-0.657 (-0.986)	1.792 (1.486)	1.184 (1.077)	0.356 (6.546***)	-0.3 (-0.42)	-1.202 (-1.093)	-1.192 (-1.692*)	0.501 (0.668)	-0.109 (-0.129)	0.146 (0.521)
Cangzhou	0.333 (2.734***)	1.013 (1.820*)	0.567 (0.879)	0.341 (0.605)	0.162 (3.139***)			-0.444 (-0.632)	0.160 (0.338)	0.335 (0.882)	-0.141 (-0.233)
Taiyuan	0.08 (1.221)	1.681 (3.365***)	1.194 (1.929*)	0.984 (0.745)	0.110 (4.948***)			-0.225 (-1.108)	-0.366 (-1.000)	0.093 (0.361)	-0.011 (-0.212)
Shuozhou	0.312 (1.857*)	0.476 (1.195)	1.054 (2.398**)	0.756 (1.472)	0.038 (0.706)	-1.816 (-4.031***)	-0.102 (-0.203)	-0.934 (-2.630***)	0.154 (0.269)	1.646 (4.030***)	0.478 (1.577)
Huhehaote	0.163 (1.636)	1.173 (3.398***)	2.521 (4.780***)	2.647 (2.708***)	0.221 (7.348***)	-0.978 (-2.986***)	0.448 (0.744)	-0.223 (-1.164)	0.177 (1.164)	0.235 (1.236)	-0.118 (-0.183)
Baotou	0.167 (1.488)	1.215 (3.253***)	0.574 (1.218)	-0.374 (-0.535)	0.191 (5.684***)	-0.51 (-1.421)	-0.204 (-0.666)	-0.105 (-0.442)	0.007 (0.041)	0.98 (3.788***)	-0.372 (-1.247)
Wuhai	0.507 (1.835*)	0.411 (0.804)	0.719 (1.712*)	0.594 (1.292)	0.487 (6.074***)	-0.963 (-1.803)	-0.026 (-0.075)	1.593 (2.498**)	0.427 (1.093)	1.604 (1.923)	-0.339 (-0.361)
Chifeng	0.243 (1.487)	1.354 (2.375**)	2.023 (3.581***)	1.889 (2.703***)	0.247 (4.507***)	-0.88 (-1.456)	-0.881 (-0.431)	-0.619 (-1.016)	-0.234 (-0.472)		
Tongliao	0.427 (3.540***)	0.696 (2.089**)	1.172 (3.082***)	1.915 (1.377)	0.325 (8.107***)	-1.846 (-3.529***)	-0.207 (-1.097)	0.276 (0.85)	0.102 (0.928)		
Shenyang	0.242 (3.925***)	2.004 (3.945***)			0.322 (10.696***)			-0.733 (-1.834*)	0.072 (0.067)		
Dalian	0.344 (6.375***)	1.571 (2.905***)			0.264 (8.803***)			-0.525 (-1.775*)	0.348 (0.866)	0.744 (1.89)	-0.136 (-0.361)
Liaoyang	0.041 (0.512)	1.675 (2.132**)	1.908 (1.551)	0.790 (0.488)	0.247 (5.762***)			0.811 (2.381**)	0.116 (0.314)	-0.803 (-2.288)	0.231 (0.538)
Changchun	0.274 (2.814***)	2.026 (3.938***)	1.454 (2.830***)	2.268 (3.058***)	0.135 (3.718***)	-3.219 (-4.001***)	4.182 (0.825)	-1.463 (-2.386**)	-0.095 (-0.121)	-0.406 (-0.876)	0.271 (2.299***)
Jilin	0.239 (3.641***)				0.127 (5.168***)			0.007 (0.031)	0.017 (0.012)	0.216 (0.682)	-0.056 (-0.072)
Haerbin	0.373 (4.859***)	0.269 (0.648)			0.358 (12.992***)			-0.213 (-0.977)	-0.139 (-0.865)	0.51 (2.002)	0.231 (1.719*)
Qiqihaer	0.119 (2.471**)	1.14 (2.385**)	-0.105 (-0.127)	1.270 (0.715)	0.123 (5.649***)			0.1 (0.406)	0.166 (0.817)	-0.317 (-0.811)	0.074 (0.690)

Daqing	0.219 (1.379)				0.097 (3.881***)			-0.454 (-1.453)	0.407 (0.403)	0.769 (1.323)	0.299 (1.013)
Mudanjiang	0.346 (3.151***)	0.823 (1.697*)	1.253 (2.245**)	0.677 (0.619)	0.193 (5.898***)	-0.879 (-1.721)	0.635 (1.077)	-0.142 (-0.533)	0.095 (0.885)		
Shanghai	0.171 (4.932***)	1.34 (6.738***)	1.983 (8.036***)	0.850 (1.152)	0.485 (15.975***)						
Nanjing	0.242 (5.548***)	1.388 (6.707***)	0.839 (2.810***)	-0.201 (-0.242)	0.282 (16.963***)			-1.143 (-8.306***)	0.569 (1.610*)	1.368 (9.538***)	0.548 (2.322***)
Wuxi	0.279 (4.084***)	1.382 (4.137***)	2.328 (4.884***)	1.618 (2.191***)	0.304 (7.811***)			-1.332 (-5.051***)	1.577 (0.552)	1.435 (5.319***)	-0.838 (-0.771)
Xuzhou	0.251 (3.674***)	1.182 (3.339***)	-0.31 (-0.473)	-0.695 (-0.251)	0.264 (7.468***)	-1.174 (-4.481***)	0.137 (0.578)	-0.836 (-3.809***)	0.406 (2.308***)	1.149 (5.090***)	0.126 (0.682)
Changzhou	0.376 (4.943***)	0.597 (2.466**)	0.321 (1.306)	0.201 (0.679)	0.191 (4.728***)	-0.819 (-1.551)	0.701 (1.184)	-0.045 (-0.2)	0.081 (0.668)	0.113 (0.5)	0.249 (2.240***)
Suzhou	0.32 (4.264***)	0.927 (3.089***)	0.968 (2.899***)	0.179 (0.245)	0.416 (9.257***)			-1.057 (-3.905***)	0.945 (0.671)	0.861 (3.221***)	-0.935 (-0.707)
Nantong	0.213 (2.156**)	1.291 (2.053**)	3.545 (2.282**)	6.984 (0.617)	0.214 (5.536***)			-1.124 (-3.401***)	-0.059 (-0.105)	1.741 (3.996***)	0.689 (1.749*)
Huaian	0.127 (1.159)	0.869 (2.392**)	1.269 (2.181**)	0.608 (0.597)	0.242 (5.290***)	-1.206 (-4.156***)	0.408 (1.172)	-0.614 (-2.212**)	-0.010 (-0.062)	1.281 (3.913***)	-0.585 (-0.884)
Yangzhou	0.355 (3.224***)	1.342 (3.468***)	0.642 (1.302)	-0.139 (-0.198)	0.284 (5.234***)	-0.601 (-1.202)	-0.203 (-0.456)	-0.044 (-0.149)	-0.107 (-0.627)	0.522 (1.696)	0.221 (1.288)
Zhenjiang	0.375 (3.895***)	1.438 (2.750***)	-0.007 (-0.008)	-0.668 (-0.595)	0.396 (9.079***)	-2.182 (-4.894***)	-0.153 (-0.292)	-0.935 (-3.089***)	-0.153 (-0.510)	1.923 (4.942***)	0.162 (0.590)
Taizhou	0.29 (2.835***)	0.431 (1.551)	0.928 (3.182***)	0.763 (2.263)	0.254 (4.479***)	-1.017 (-2.912***)	0.462 (1.529*)	-0.416 (-1.609)	0.306 (1.192)	1.356 (4.090***)	0.350 (0.880)
Suqian	0.238 (2.071**)	1.473 (4.453***)	0.22 (0.458)	-2.082 (-0.578)	0.093 (2.006**)	-0.43 (-1.836)	0.232 (1.504*)	0.436 (1.305)	0.019 (0.018)		
Hangzhou	0.336 (7.124***)	1.228 (5.246***)	1.122 (3.579***)	-0.453 (-0.417)	0.285 (10.060***)			-0.512 (-3.047***)	0.123 (1.217)	0.563 (3.530***)	0.357 (1.786*)
Ningbo	0.13 (2.942***)	1.231 (4.391***)	0.678 (2.368**)	0.490 (0.852)	0.217 (8.958***)			-0.233 (-1.168)	0.085 (0.532)	0.617 (3.119***)	0.027 (0.181)
Wenzhou	0.241 (2.984***)	1.362 (4.383***)	0.853 (5.133***)	-0.081 (-0.127)	0.340 (5.679***)			-1.692 (-3.741***)	0.211 (1.034)	2.086 (4.302***)	1.613 (0.389)
Jiaxing	0.222 (2.463**)	1.381 (3.214***)	0.383 (1.056)	-0.317 (-0.521)	0.227 (4.645***)			-1.222 (-2.580**)	0.483 (0.926)	0.466 (1.102)	0.349 (1.243)
Huzhou	0.232 (2.726***)	1.313 (3.412***)	1.121 (2.991***)	0.954 (1.966***)	0.321 (7.426***)	-0.992 (-1.725)	0.675 (0.732)	-1 (-2.366**)	0.511 (0.644)	1.318 (3.440***)	-2.622 (-0.430)
Shaoxing	0.348 (3.754***)	1.445 (2.435**)	0.684 (0.471)	1.711 (0.607)	0.326 (6.775***)	-1.319 (-3.346***)	0.341 (0.688)	-1.258 (-3.664***)	-0.184 (-0.300)	1.61 (4.102***)	-0.032 (-0.050)
Jinhua	0.276 (3.316***)	1.133 (2.998***)	0.128 (0.351)	-0.438 (-0.962)	0.256 (4.802***)	-1.34 (-3.299***)	-0.395 (-1.284)	-0.935 (-1.981**)	0.077 (0.693)	1.285 (2.686***)	0.282 (0.201)
Quzhou	0.2 (2.214**)	0.165 (0.422)	1.323 (3.180***)	1.477 (3.254***)	-0.043 (-0.620)	-2.381 (-3.706***)	-0.525 (-0.433)	-0.198 (-0.589)	0.197 (1.668)	0.507 (1.562)	0.085 (0.233)
Taizhou	0.326 (3.100***)	0.992 (2.519**)	1.028 (2.783***)	0.922 (2.234***)	0.242 (3.676***)	-1.281 (-2.207**)	0.631 (0.833)	-2.094 (-3.520***)	0.406 (1.172)	1.695 (3.186***)	2.347 (0.485)
Lishui	0.235 (2.536**)	1.676 (4.326***)	1.03 (3.196***)	0.725 (1.859**)	0.202 (4.431***)	-0.054 (-0.138)	-0.734 (-1.657)	-0.276 (-0.525)	-0.029 (-0.133)		

Hefei	0.097 (1.308)	2.597 (4.425***)	0.439 (0.42)	2.800 (1.010)	0.225 (6.235***)	-1.16 (-3.776***)	-0.050 (-0.189)	-0.693 (-2.737***)	-0.369 (-1.488)	1.081 (4.151***)	0.701 (1.341)
Huainan	0.221 (2.425**)	0.922 (1.598)	0.75 (0.686)	-0.230 (-0.185)	0.245 (5.470***)	-0.922 (-2.872***)	-0.328 (-1.224)	0.363 (1.322)	-0.042 (-0.171)	0.305 (1.062)	-0.431 (-1.534*)
Fuzhou	0.151 (2.390**)	1.275 (3.781***)	0.645 (1.511)	0.237 (0.411)	0.250 (6.845***)			-0.594 (-2.112**)	0.174 (0.838)	0.877 (3.148***)	0.362 (1.439)
Xiamen	0.161 (2.415**)	0.538 (1.623)	1.638 (3.406***)	1.348 (1.443)	0.328 (5.836***)	-2.627 (-4.191***)	5.956 (0.422)	-0.575 (-1.871*)	0.105 (0.507)	1.162 (3.509***)	0.483 (1.108)
Nanchang	0.022 (0.197)				0.205 (5.044***)			-0.397 (-1.297)	-0.082 (-0.524)	0.367 (1.29)	0.118 (0.501)
Jinan	0.122 (1.433)	0.894 (4.157***)	1.494 (5.489***)	1.165 (2.757***)	0.303 (8.586***)	-1.398 (-5.927***)	0.353 (1.715*)	-0.865 (-4.379***)	0.244 (2.045***)	0.954 (4.666***)	-1.139 (-0.766)
Qingdao	0.374 (4.117***)	2.168 (4.960***)	1.56 (2.666***)	-1.863 (-0.943)	0.275 (8.525***)	-1.023 (-4.018***)	0.224 (0.900)	-0.262 (-1.295)	-0.138 (-0.990)	0.528 (2.486)	-0.054 (-0.246)
Zibo	0.445 (2.112**)	0.062 (0.14)	0.521 (0.842)	0.500 (0.774)	0.302 (4.871***)	-2.06 (-3.002***)	1.612 (0.710)	-1.163 (-2.509**)	1.160 (1.083)	0.879 (1.892)	0.155 (0.047)
Yantai	0.563 (4.053***)	-0.135 (-0.28)	1.549 (2.338**)	1.603 (2.731***)	0.198 (4.663***)	-1.97 (-2.470**)	0.903 (0.487)	-0.685 (-1.662*)	-0.436 (-0.369)	0.789 (1.884)	-0.089 (-0.162)
Rizhao	0.403 (2.511**)	0.951 (2.236**)	1.578 (4.102***)	1.113 (2.039***)	0.190 (5.014***)	-1.598 (-3.044***)	-1.235 (-1.766*)	-0.587 (-1.519)	0.662 (0.591)		
Zhengzhou	0.259 (3.951***)	0.975 (2.391**)	0.457 (0.742)	-1.476 (-0.770)	0.219 (6.540***)	-0.876 (-3.072***)	0.192 (0.769)	-0.298 (-1.363)	0.207 (1.230)	0.055 (0.221)	0.171 (2.007***)
Luoyang	0.127 (1.314)	1.268 (3.527***)	1.28 (2.845***)	1.201 (2.305***)	0.315 (6.934***)	-0.945 (-3.033***)	0.704 (2.240***)	-0.554 (-1.727*)	0.089 (0.450)	0.747 (2.237)	1.318 (0.471)
Wuhan	0.246 (5.273***)	2.823 (5.385***)	1.779 (2.882***)	0.628 (0.380)	0.269 (8.347***)	-1.425 (-4.245***)	-0.106 (-0.143)	-0.39 (-2.158**)	0.051 (0.320)	0.91 (4.638)	-0.685 (-0.951)
Changsha	0.345 (5.948***)	1.206 (4.120***)	1.226 (3.336***)	0.215 (0.346)	0.322 (10.448***)	-1.538 (-4.916***)	0.805 (1.003)	-0.98 (-3.860***)	-0.088 (-0.577)	1.06 (5.001***)	0.718 (2.167***)
Guangzhou	0.185 (2.213**)	1.853 (4.645***)	0.935 (1.963**)	0.511 (0.584)	0.333 (6.615***)			-1.357 (-3.870***)	0.922 (0.679)	1.007 (3.298***)	0.476 (0.915)
Shenzhen	0.275 (4.076***)	1.581 (2.691***)	0.144 (0.682)	0.078 (0.147)	0.158 (3.364***)			-1.275 (-2.439**)	0.515 (0.781)	2.16 (3.567***)	0.064 (0.196)
Zhuhai	0.098 (1.001)	1.711 (3.263***)	1.416 (3.761***)	1.860 (1.750**)	0.085 (1.747*)			1.839 (1.585)	0.098 (0.494)	-0.341 (-0.518)	-0.570 (-1.342)
Nanning	0.167 (2.916***)	0.829 (3.300***)	0.653 (2.232**)	0.492 (1.097)	0.316 (9.342***)	-1.796 (-3.884***)	2.628 (1.044)	-1.292 (-2.712***)	-0.085 (-0.350)	2.161 (3.491***)	-0.822 (-0.380)
Haikou	0.256 (3.917***)	1.388 (5.474***)	1.145 (4.332***)	-0.391 (-0.437)	0.294 (5.875***)			-0.546 (-1.842*)	0.134 (0.931)	1.456 (4.305***)	0.486 (1.845**)
Chongqing	0.229 (4.134***)	1.255 (1.705*)			0.336 (7.458***)						
Chengdu	0.291 (8.148***)	1.635 (6.881***)	1.915 (6.694***)	2.726 (1.300)	0.340 (12.646***)			-1.5 (-3.574***)	0.147 (0.302)	1.442 (3.612***)	0.156 (2.412***)
Mianyang	0.287 (3.775***)	2.458 (3.610***)	2.837 (2.349**)	1.288 (0.998)	0.296 (6.634***)						
Guiyang	0.203 (3.138***)	1.868 (5.220***)	1.344 (3.588***)	0.276 (0.090)	0.358 (10.284***)	-0.859 (-3.374***)	0.314 (0.984)	-0.813 (-2.896***)	0.162 ()0.371	0.909 (3.707***)	0.454 (1.140)
Kunming	0.307 (5.270***)	1.077 (4.538***)	0.599 (2.531**)	-0.144 (-0.322)	0.315 (8.327***)	-0.025 (-0.105)	-0.113 (-0.334)	-0.576 (-3.668***)	0.176 (1.674*)	0.355 (2.343)	0.027 (0.354)

Xi'an	0.395 (5.133***)	1.238 (2.894***)	1.134 (1.677*)	-0.222 (-0.094)	0.300 (8.616***)	-1.659 (-5.612***)	0.075 (0.136)	-1.651 (-6.504***)	0.924 (1.918***)	1.706 (6.720***)	0.069 (0.307)
Lanzhou	0.249 (3.051***)	0.322 (0.553***)			0.218 (6.831***)	-1.116 (-2.581**)	-0.208 (-0.279)	-0.382 (-1.855*)	-0.182 (-1.066)	0.127 (0.62)	0.006 (0.031)
Xining	0.285 (2.423**)	1.419 (2.323**)			0.140 (5.254***)	-1.281 (-4.680***)	0.873 (1.008)	0.24 (0.796)	0.073 (0.165)	1.664 (2.687***)	-2.106 (0.265)
Yinchuan	0.167 (2.045**)	0.473 (1.641)	0.804 (2.019**)	0.341 (0.625)	0.137 (6.053***)	-0.334 (-1.298)	-0.206 (-0.448)	-0.652 (-2.973***)	0.641 (0.997)	0.703 (2.605)	0.225 (0.445)
Wulumuqi	0.349 (3.068***)	0.965 (1.684*)			0.136 (5.441***)			-0.002 (-0.007)	-0.340 (-1.398)	0.494 (2.196)	-0.200 (-1.187)

Notes: When estimating city-level regressions for car use, coal, LPG and coal gas, we did not employ Heckman two-step estimations when the use rate of the corresponding energy type is less than 5% or larger than 95% in a city. For the former case, we set the corresponding energy use in that city to be zero; for the latter case, we use OLS estimations. T-statistics are reported in parentheses.

Table Five: Overall 2006 Green City Ranking

Rank	City	Electricity	Coal	LPG	Coal gas	Car	Taxi	Bus	Rail	Heating	Total CO_2	Standard error
1	Huaian	0.879	0.098	0.082	0.016	0.120	0.011	0.023			1.230	0.090
2	Suqian	0.865	0.218	0.117		0.000	0.006	0.026			1.231	0.073
3	Haikou	0.983	0.007	0.176	0.015	0.000	0.006	0.065			1.252	0.124
4	Nantong	1.062		0.036	0.164	0.000	0.007	0.012			1.281	0.080
5	Nanchang	0.978		0.141	0.048	0.000	0.007	0.130			1.305	0.138
6	Taizhou	1.069	0.041	0.076	0.016	0.094	0.006	0.005			1.307	0.142
7	Zhenjiang	1.098	0.067	0.036	0.064	0.030	0.009	0.027			1.331	0.118
8	Shaoxing	1.170	0.048	0.066	0.052	0.002	0.006	0.021			1.365	0.115
9	Xining	0.878	0.250	0.020	0.012	0.000	0.019	0.175		0.016	1.371	0.198
10	Xuzhou	0.946	0.070	0.046	0.112	0.172	0.010	0.040		0.006	1.401	0.172
11	Shuozhou	0.594	0.255	0.046	0.060	0.083	0.016	0.015		0.357	1.426	0.113
12	Yangzhou	1.123	0.033	0.063	0.083	0.113	0.009	0.019			1.443	0.325
13	Quzhou	1.115	0.030	0.189	0.068	0.006	0.007	0.037			1.452	0.278
14	Luoyang	0.905	0.155	0.127	0.027	0.040	0.010	0.038		0.189	1.491	0.169
15	Chengdu	1.243	0.016	0.005	0.232	0.007	0.012	0.007			1.522	0.097
16	Nanning	1.079	0.001	0.220	0.002	0.117	0.009	0.097			1.524	0.073
17	Mianyang	1.157		0.001	0.209	0.153	0.012	0.027			1.558	0.135
18	Changzhou	1.224	0.009	0.106	0.053	0.131	0.010	0.041			1.574	0.100
19	Jinhua	1.154	0.046	0.167	0.002	0.233	0.008	0.016			1.626	0.094
20	Huzhou	1.330	0.014	0.194	0.008	0.026	0.007	0.059			1.638	0.100
21	Lishui	1.308	0.018	0.197		0.110	0.005	0.013			1.651	0.108
22	Ningbo	1.328	0.004	0.213	0.011	0.058	0.006	0.050			1.670	0.142
23	Chongqing	1.396			0.229	0.000	0.014	0.039	0.004		1.681	0.342
24	Zhuhai	1.197		0.345	0.002	0.026	0.010	0.148			1.726	0.027
25	Wuxi	1.461		0.071	0.123	0.023	0.010	0.060			1.748	0.044
26	Zhengzhou	0.984	0.185	0.053	0.109	0.000	0.006	0.057		0.363	1.757	0.071
27	Taizhou	1.359	0.008	0.256	0.004	0.117	0.007	0.009			1.761	0.157
28	Hefei	1.360	0.069	0.101	0.064	0.000	0.044	0.138			1.776	0.064
29	Lanzhou	0.573	0.029	0.047	0.067	0.000	0.016	0.077		0.976	1.785	0.081
30	Shanghai	1.219		0.007	0.235	0.130	0.014	0.118	0.074		1.796	0.066
31	Guangzhou	1.315		0.213	0.052	0.056	0.008	0.127	0.055		1.827	0.138
32	Rizhao	1.060	0.092	0.065		0.222	0.013	0.060		0.318	1.831	0.102
33	Zibo	0.998	0.169	0.119	0.024	0.034	0.021	0.062		0.441	1.870	0.120
34	Jiaxing	1.286		0.187	0.009	0.373	0.007	0.028			1.890	0.088
35	Huainan	1.008	0.144	0.056	0.085	0.480	0.063	0.058			1.895	0.091
36	Nanjing	1.293	0.003	0.097	0.051	0.318	0.009	0.096	0.032		1.899	0.045
37	Hangzhou	1.650	0.006	0.132	0.026	0.000	0.006	0.087			1.907	0.045
38	Wuhan	1.526	0.016	0.133	0.092	0.065	0.011	0.069	0.003		1.915	0.100

39	Yantai	0.969	0.142	0.069	0.067	0.017	0.019	0.022		0.629	1.934	0.066
40	Wulumuqi	0.509		0.027	0.086	0.000	0.024	0.177		1.128	1.951	0.091
41	Handan	0.998	0.029	0.008	0.222	0.004	0.013	0.068		0.633	1.974	0.215
42	Guiyang	1.433	0.201	0.016	0.118	0.141	0.010	0.073			1.993	0.076
43	Qingdao	1.205	0.248	0.060	0.067	0.000	0.020	0.053		0.388	2.041	0.123
44	Xi'an	0.871	0.072	0.037	0.101	0.605	0.018	0.104		0.246	2.055	0.101
45	Changsha	1.204	0.028	0.193	0.044	0.505	0.021	0.088			2.083	0.095
46	Shenzhen	1.491		0.261	0.012	0.263	0.010		0.112		2.149	1.601
47	Kunming	1.003	0.033	0.068	0.106	0.814	0.005	0.138			2.167	0.133
48	Jinan	1.099	0.373	0.062	0.030	0.084	0.017	0.085		0.436	2.185	0.060
49	Tangshan	0.865			0.232	0.405	0.017	0.058		0.625	2.203	0.076
50	Cangzhou	0.868		0.185	0.020	0.023	0.029	0.014		1.087	2.226	0.080
51	Suzhou	1.424	0.016	0.068	0.077	0.718	0.008	0.033			2.344	0.167
52	Wenzhou	2.057		0.286	0.001	0.000	0.015	0.051			2.410	0.090
53	Wuhai	0.536	0.632	0.045	0.017	0.089	0.014	0.093		1.008	2.435	0.155
54	Qinhuangdao	0.841	0.096	0.076	0.089	0.253	0.017	0.096		0.977	2.447	0.157
55	Taiyuan	0.939	0.027	0.012	0.237	0.027	0.013	0.086		1.107	2.449	0.171
56	Fuzhou	2.124		0.201	0.025	0.060	0.006	0.054			2.470	0.076
57	Huhehaote	0.747	0.105	0.066	0.073	0.014	0.034	0.077		1.468	2.584	0.115
58	Xiamen	2.035	0.001	0.152	0.021	0.326	0.007	0.171			2.713	0.069
59	Tongliao	1.448	0.063	0.162		0.000	0.058	0.019		0.972	2.722	0.073
60	Shijiazhuang	1.110	0.044	0.091	0.099	0.000	0.019	0.048		1.313	2.724	0.069
61	Jilin	0.983		0.198	0.016	0.000	0.030	0.204		1.512	2.944	0.126
62	Chifeng	0.873	0.161	0.085		0.025	0.020	0.031		1.802	2.998	0.089
63	Tianjin	1.551	0.063	0.014	0.070	0.553	0.018	0.087	0.017	0.690	3.063	0.071
64	Changchun	0.914	0.010	0.003	0.126	0.004	0.024	0.056	0.006	1.938	3.080	0.069
65	Liaoyang	0.962		0.139	0.024	0.173	0.026	0.028		1.885	3.237	0.052
66	Baotou	0.698	0.102	0.054	0.053	0.174	0.021	0.072		2.134	3.309	0.084
67	Dalian	0.904		0.015	0.191	0.000	0.040	0.071	0.007	2.143	3.371	0.068
68	Haerbin	1.157		0.027	0.236	0.000	0.021	0.057		2.009	3.508	0.285
69	Shenyang	0.974		0.009	0.099	0.000	0.028	0.082		2.337	3.528	0.060
70	Yinchuan	0.675	0.019	0.059	0.036	0.338	0.034	0.095		2.287	3.543	0.146
71	Qiqihaer	0.765		0.054	0.115	0.000	0.018	0.041		2.620	3.614	0.085
72	Beijing	1.558	0.145	0.049	0.084	0.650	0.018	0.138	0.049	1.306	3.997	0.192
73	Mudanjiang	1.047	0.136	0.081		0.353	0.040	0.017		3.154	4.827	0.107
74	Daqing	0.998		0.233	0.003	0.000	0.026	0.137		3.719	5.115	0.056
	Mean	*1.122*	*0.093*	*0.102*	*0.077*	*0.135*	*0.016*	*0.067*	*0.036*	*1.228*	*2.177*	*0.134*

The units are tons of carbon dioxide per household per year.

Table Six: Explaining Cross-City Variation in the Standardized Household's Carbon Production

	Electricity	Heating	Car	Taxi	Rail	Bus	TOTAL
Log(*CINCOME*)	0.439 (3.40***)	1.065 (1.08)	1.420 (1.88*)	-1.377 (-4.96***)	3.188 (2.00*)	-0.455 (-1.22)	0.440 (3.24***)
Log(*POP*)	0.067 (1.95*)	-0.028 (-0.13)	-0.083 (-0.36)	0.153 (1.79*)	0.535 (1.08)	0.491 (4.47***)	0.054 (1.46)
JAN_TEMP		-0.111 (-4.41***)					-0.033 (-8.8***)
JULY_TEMP	0.031 (2.64***)						
DENSITY			0.257 (0.61)	-0.424 (-2.75***)	-0.66 (-0.7)	-0.837 (-4.01***)	
constant	-5.898 (-5.06***)	-11.72 (-1.22)	-17.822 (-2.21**)	10.085 (3.41***)	-41.273 (-2.58**)	0.238 (0.06)	-4.291 (-3.08***)
obs	74	35	74	74	10	73	74
R2	0.436	0.394	0.05	0.27	0.91	0.317	0.598

* The dependent variable is measured in tons of carbon dioxide emission of standardized household. The unit of analysis is one of the 74 cities. T-statistics are reported in parentheses.

* indicates significance at the 10% level, ** at the 5% level and *** at the 1% level.

Table Seven: Predictions of CO_2 emissions per Standard Household in the Year 2026

City	CO2 emission in 2026 (tons)	City	CO2 emission in 2026 (tons)	City	CO2 emission in 2026 (tons)
Beijing	5.250	Wuxi	2.425	Jinan	4.931
Tianjin	5.272	Xuzhou	1.601	Qingdao	4.720
Shijiazhuang	5.282	Changzhou	2.083	Zibo	5.234
Tangshan	4.439	Suzhou	2.250	Yantai	4.103
Qinhuangdao	5.018	Nantong	1.574	Rizhao	5.331
Handan	5.473	Huaian	1.595	Zhengzhou	5.851
Cangzhou	5.776	Yangzhou	1.808	Luoyang	6.110
Taiyuan	4.496	Zhenjiang	1.634	Wuhan	2.921
Shuozhou	4.701	Taizhou	1.555	Changsha	2.656
Huhehaote	6.526	Suqian	1.461	Guangzhou	2.711
Baotou	6.681	Hangzhou	2.738	Shenzhen	3.062
Wuhai	8.136	Ningbo	2.263	Zhuhai	2.546
Chifeng	7.361	Wenzhou	3.708	Nanning	2.289
Tongliao	8.050	Jiaxing	2.267	Haikou	2.171
Shenyang	4.249	Huzhou	2.260	Chongqing	2.629
Dalian	4.461	Shaoxing	1.899	Chengdu	2.367
Liaoyang	4.694	Jinhua	2.040	Mianyang	1.853
Changchun	5.863	Quzhou	1.907	Guiyang	2.542
Jilin	6.184	Taizhou	2.474	Kunming	2.056
Haerbin	6.672	Lishui	2.292	Xi'an	4.123
Qiqihaer	5.976	Hefei	2.381	Lanzhou	3.705
Daqing	7.973	Huainan	1.841	Xining	6.627
Mudanjiang	6.474	Fuzhou	3.572	Yinchuan	4.702
Shanghai	2.361	Xiamen	3.592	Wulumuqi	3.429
Nanjing	2.238	Nanchang	1.946		

Figure 1: Carbon Dioxide Emissions per Household in 74 Chinese Cities

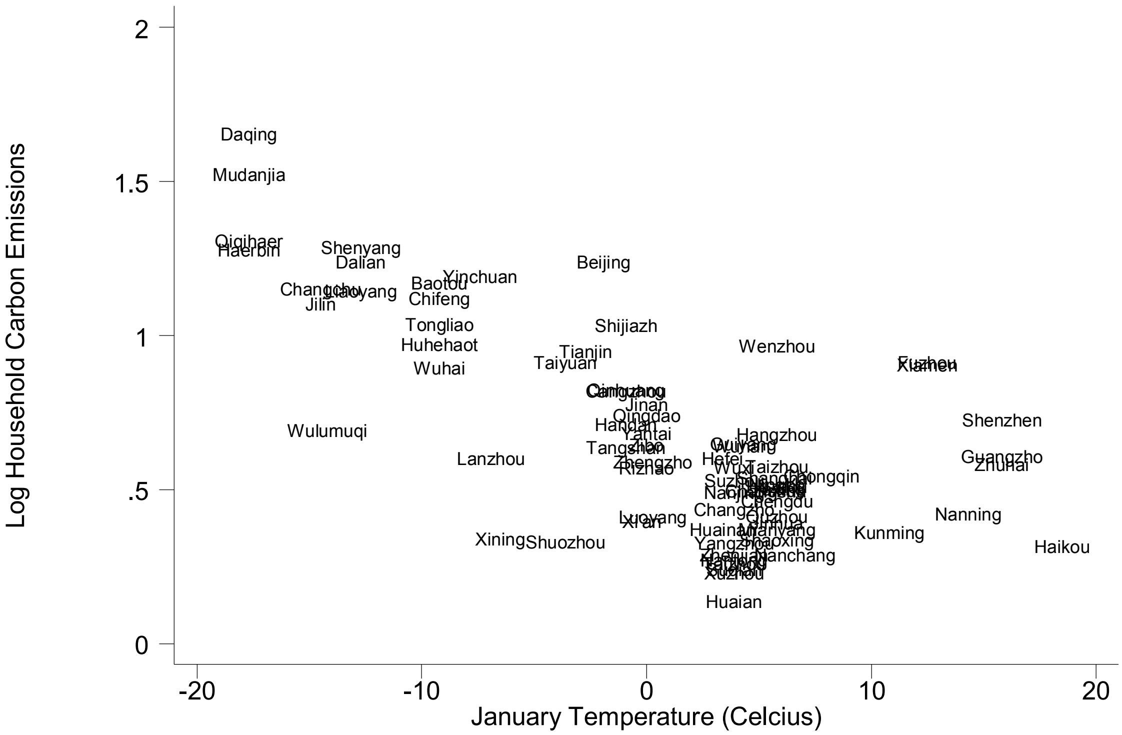

Figure 2: The Cross-City Relationship between Winter Temperature and Household Carbon Emissions