[*Choice to Make-An Analysis of City Development on Residential Cooking Fuel Transition in China*]

[Han Yan, Rice University , +1-832-875-8643, hy36@rice.edu]

Overview

Transition of developing country households from traditional biomass fuels to clean fuels has recently received growing attention. Indoor air pollution from incomplete burning of biomass fuels has become a major driver of respiratory diseases and child mortality in developing countries. Additionally, the consumption of traditional biomass fuels exacerbates deforestation and climate change. Therefore, the severe environmental and health problem caused by household use of traditional biomass fuels for cooking has drawn attention from both researchers and policy makers. Since the energy consumed for household cooking exceeds energy used to provide other household services, such as heating and lighting, our study focuses on consumer's choice of cooking fuels.

Household characteristics, such as income and education level, are key determinants of residential energy choices. In addition, rapid urbanization in emerging economies also plays an important role in promoting fuel transition in residential energy consumption. China, one of the world's largest economies, has implemented numerous regulations and policies to promote urbanization via internal migration. The consequent expansion in city administrative boundaries and associated infrastructure development has substantially changed the pattern of residential energy demand.

Our proposed research has several goals: the first goal of this study is to model household cooking fuel choice in a way that will allow us conduct counterfactual experiments to predict how energy infrastructure expansion in China is likely to change household cooking fuel choices. A second goal of the study is to investigate how residential energy choice responds to policy-driven natural gas price changes. A third goal of the study is to investigate the effect of reform of the household registration system on residential energy choice. It makes a number of contributions to the substantial body of research studying the determinants of the household cooking fuel choices in developing countries (e.g., Hou et al., (2017); Komatsu et al., (2013); Alem et al., (2016); Paudel et al., (2018)). Most of these studies concentrate on the influences of household demographics or changes in the price of fuel. Furthermore, very few existing studies use a structural model or investigate the effect of urbanization on residential energy demand. This study adopts a structural estimation to facilitate study of counterfatcural situations where the use of reduced form approaches would be subject to the Lucas critique. Compared to the existing literature (e.g., Paudel et al., (2018)), our study also employs a more comprehensive database to account for the pivotal factors of city development (e.g., the length of the natural gas pipeline in each province, and the residential registration status of the households). The ultimate objective of the paper is to answer the following questions: besides the commonly examined determinants (e.g., family size, income level, household education level) of household fuel choices, can we identify some additional explanations for residential energy consumption? How do the policies relate to internal migration and residential energy pricing affect household fuel choices in China?

Methods

Given the discrete nature of household-level demand, we choose a discrete choice demand specification. Index the variables by household $(i = 1, ..., I)$, product $(j = 0, 1, ..., J)$, province $(l = 0, 1, ..., L)$, and time $(t = 1, ..., T)$. Each household i chooses among $J + 1$ different options for their major cooking fuel in time period t. In our empirical study, the choice set includes firewood (A), coal (B), LPG/natural gas/coal gas (C), electricity (D) and outside option. The option 0 is used to indicate the outside option. Define the price for fuel j in province l at time t as p_{mjt}. Note that only the price of the outside option vary across individuals (since it is indexed with household's income level), while the prices of other three alternatives vary over time and province. Use $\boldsymbol{x}_i$ to represent the vector of observed household characteristics (e.g. household size, migration status,...etc). Additionally, the vector of market characteristics $\boldsymbol{k}_{lt}$ includes length of natural gas pipelines as well as the percentage of built-up area in province l during time t. Note that the length of natural gas pipelines (r_{lt}) is treated as exclusion restrictions, since it only affect consumer's choices of category gas.

The indirect utility of household i using cooking fuel j at time t is specified as the following:

$$U_{ijt} = V_{ijt} + \Phi(j|y_{i,t-1}) + (\kappa_i p_{ijt} + \sum_{g=1}^{K} \zeta_g d_{itg}) + e_{ijt} \tag{1}$$

The first term V(.) on the right hand side of the equation is the base line utility that consumer i obtains by choosing product j at time t. The second term $\Phi(j|y_{i,t-1})$ captures the state dependence effect, i.e., the influence of household i's choices in period $t-1$ on the household's choice in period t. The following two terms corresponds to the price effect and the income effect. The mean zero stochastic term e_{ijt} is time specific demand shock for fuel j, which rationalize all remaining variation in fuel choices.

The base utility to household i of consuming fuel j in time t is the following, where $j \in \{0, A, B, C\}$:

$$\begin{cases} V_{i0t} = 0 \\ V_{ijt} = \alpha_j + \boldsymbol{x}_i \boldsymbol{\beta}_j + \boldsymbol{k}_{lt} \boldsymbol{\eta}_j + \boldsymbol{z}_l \boldsymbol{\tau}_j + + \gamma r_l t + \xi_{ij} + v_{it} \end{cases}$$

The model is modified to accommodate the inertia in people's choices such that they tend to stay with the alternatives that they chosen in the past. This behavior is captured by including a lagged dependent variable (i.e. the choice in the previous period) into the model. Since the errors in the logit model are independent over time, the inclusion of the lagged variable will not induce inconsistency in estimation. The state dependence effect $\Phi(j|y_{i,t-1})$ captures this phenomenon and is specified as the following:

$$\Phi(j|y_{i,t-1}) = \phi \mathbb{1}_{y_{i,t-1}=j} \tag{2}$$

Note that here the term $y_{i,t-1}$ represents the type of fuel household i choose in province l during time period $t-1$. If the choice in time t is the same as the last period(i.e. $y_{i,t-1} = y_{i,t} = j$), then the indicator function $\mathbb{1}_{y_{i,t-1}=j}$ would equal to one and zero otherwise.

Assume that the time-constant unobserved consumer attributes ξ_i follows a dimensional multivariate normal distribution. In addition, we assume the time specific unobservable v_{it} follows univariate normal distribution with zero mean and standard deviation μ, and e_{ijt} is distributed extreme value, independent over i, j and t. The choice probability conditional on parameters θ, distribution of ξ and v_{it} of consumer i choosing the alternative $h \in \{0, A, B, C\}$ that he actually observed to choose $\mathbf{h} = \{h_1, ...h_T\}$ in period t can be expressed as the following:

$$Q_{h_t}(\boldsymbol{x}_i, \boldsymbol{z}_l, \boldsymbol{k}_{lt}, t, v_{it}, \xi_{ij}; \boldsymbol{\theta}) = \frac{exp[V_{ih_t t} + \Phi(h_t|y_{i,t-1}) + (\kappa_i p_{ih_t t} + \sum_{g=1}^{K} \zeta_g d_{itg})]}{\sum_{j \in J} exp[V_{ijt} + \Phi(j|y_{i,t-1}) + (\kappa_i p_{ijt} + \sum_{g=1}^{K} \zeta_g d_{itg}]}. \tag{3}$$

Since e_{ijt} are independent over time, and for a given value of time-constant unobserved consumer attributes ξ_i, we assume v_{it} follows univariate normal distribution with mean zero and variance μ, we can then integrate out time specific unobservable v and obtain the following probability that the household i chooses fuel h_t:

$$P_{h_t}(\boldsymbol{x}_i, \boldsymbol{z}_l, \boldsymbol{k}_{lt}, t; \boldsymbol{\theta}, \xi_i) = \int Q_{h_t}(\boldsymbol{x}_i, \boldsymbol{z}_l, \boldsymbol{k}_{lt}, t, v_{it}, \xi_{ij}; \boldsymbol{\theta}) f(v) dv \tag{4}$$

The log-likelihood function is then

$$LL(\theta) = \sum_{i=1}^{N} ln \int \prod_{t=1}^{T} P_{h_t}(\boldsymbol{x}_i, \boldsymbol{z}_l, \boldsymbol{k}_{lt}, t; \boldsymbol{\theta}, \xi_i) f(\xi) d\xi \tag{5}$$

The parameters θ being estimated are: $\theta = \{\boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\eta}, \boldsymbol{\delta}, \boldsymbol{\tau}, \gamma, \boldsymbol{\sigma}, p, \mu\}$. Simulated maximum likelihood is used for parameter estimation.

Results

Based on our preliminary result, we can see the influence agriculture household registration status (Hukou) and internal migration have on the residential choices. In general, the agriculture Hukou influences the consumer's choice on gas and electricity negatively, while internal migration and natural gas pipeline length influences consumer choice on gas positively. This is consistent with our expectation since people who hold agriculture Hukou usually live in a rural area and are more likely to have access to biomass fuels.

Conclusions

The energy transition from traditional cooking fuels to clean fuels in developing countries is important because of the health and environmental issues associate with household's choices. Urbanization plays a crucial rule in promoting resident's accessibility to clean and modern fuels. In this paper, we focus on understanding the consequences of urbanization and the welfare effect by looking at its impact on the changes in residential cooking fuel choices. The paper employees a framework with an indirect utility function that quantifies the effects of various factors (i.e., price, household demographics, internal migration, and infrastructure expansion) on the outcomes of household cooking fuel choices. Our study adds to the literature by measuring the major factors and welfare implications of urbanization by looking at household's choice in cooking fuels. Unlike previous research, our data on energy pipeline length and built-up area permit us to "quantify" the degree of urbanization across years and conduct counterfactual simulation regarding the degree of city expansion. In addition, the policy simulations also have real world implications-whether the household registration policy is related to residential energy consumption, and how policy intervention to change the natural gas price would affect household's welfare.