The Pennsylvania State University

The Graduate School

College of Agricultural Sciences

ESSAYS ON CONSUMER BEHAVIOR AND DEMAND ANALYSIS:

FOOD QUALITY, NON-MARKET GOODS, AND HABIT PERSISTENCE

A Dissertation in

Agricultural, Environmental & Regional Economics and Demography

by

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Submitted in Partial Fulfillment

of the Requirements

for the Degree of

Doctor of Philosophy

May 2009

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Abstract

This dissertation consists of three essays on consumer behavior and demand analysis. The three essays incorporate quality variation, non-market goods and habit-persistence, respectively, into the framework of traditional consumer behavior analysis from a theoretical perspective. The essays also use data from China to empirically analyze the demand for food quality, environmental quality, and alcohol and cigarettes in China.

Essay 1 develops a theoretical framework to calculate the biases in income and price elasticities when unit values are used as prices in demand analysis, because unit values reflect not only prices but also information about product quality. The theory is applied in order to calculate corrected income and price elasticities for the demand for food in rural China, starting with elasticity estimates from the current literature.

Essay 2 develops a four-hurdle model, which is a limited information econometric model, to deal with zero bids and missing responses in open-ended bidding for contingent valuation methods of non-market goods. The model is used to analyze the willingness to pay for blue skies in Beijing through the government's Duststorm Sources Control Project.

Essay 3 constructs a habit-persistence model and uses a panel dataset to apply the model to the study addictive behavior, in particular, the interactions between alcohol and cigarette consumption in rural China.

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ACKNOWLEDGEMENTS

I wish to acknowledge all the people who give me a hand during my dissertation work and my whole student career as well. As the lyrics from the popular song “You Raise Me Up” by Secret Garden read,

You raise me up, so I can stand on mountains;
You raise me up, to walk on stormy seas;
I am strong, when I am on your shoulders;
You raise me up: To more than I can be.

First of all, I would think my adviser, Dr. David Abler, for his careful mentoring and selfless commitment. He spent generous time in advising my research and correcting my poor writing. He taught me how to change an immature idea into a beautiful paper, and also has changed me from a novice to a true scholar in the past four years. I am also very grateful to my other committee members: Dr. Jill Findeis, Dr. Ruilin Zhou, and Dr. Richard Ready, for their fruitful advice and precious encouragements in the process of writing my thesis.

I would also like to thank my former advisers—Prof. Masaru Kagatume and Dr. Jinhu Shen at Kyoto University in Japan and Prof. Yinchu Zeng at Renmin University of China for their continuous support. In particular, I would like to thank Prof. Yinchu Zeng for sharing his precious data which is used in Essay 2. Thanks also go to Prof. John Riew in the Department of Economics at the Penn State University, Prof. Guoqing Zhao in the School of Economics at Renmin University of China, and Prof. Funing Zhong and Prof. Yinheng Zhou in the College of Economics and Management at Nanjing Agricultural University, for their precious suggestions.

I would also like to acknowledge financial support from the Department of Agricultural Economics and Rural Sociology and the Population Research Institute at the Pennsylvania State University.

Finally, I would express my deepest thanks to my family, in particular to my parents. They are small farmers with little education in rural China. Without their strong and continuous support, I could not receive a high education and, of course, would not have had a chance to write this dissertation.

Introduction

This dissertation consists of three essays on consumer behavior and demand analysis. The three essays incorporate quality variation, non-market goods and habit-persistence, respectively, into the framework of traditional consumer behavior analysis from a theoretical perspective. The essays also use data from China to empirically analyze the demand for food quality, environmental quality, and alcohol and cigarettes in China.

Essay 1 incorporates quality variation into consumer behavior economics and empirically analyzes the demand for food quality and its implications for the demand for food quantity in rural China. Most literature on food demand analysis uses unit values as prices, which, however, are endogenous and often reflect quality. This thesis shows that households in rural China tend to consume higher quality food as income increases, with a greater sensitivity for basic foods such as grains than for luxury foods, and that investments in education have had significant crowding-out effects on food quality demand. The theoretical framework indicates that the income elasticity of demand for food quality is likely to be biased upward when unit values are used as prices, while the absolute value of own-price elasticity is likely to be biased upward for a normal good and downward for an inferior good. Using the method suggested in this thesis, the correct values of the income and price elasticities of demand can be recovered starting with estimates of these elasticities from the literature. This thesis finds that the absolute value of the own-price elasticity and the income elasticity of demand for grains in the literature are, respectively, overstated by more than 45% and 30%, once the demand for quality is taken into account. Smaller but still significant biases are also found for vegetables and seafood.

Essay 2 incorporates non-market goods into consumer behavior economics and analyzes willingness to pay (WTP) for air quality in Beijing. Based on microeconomic theory, this essay suggests a four-hurdle model to deal with zero and missing responses in the contingent valuation method with open-ended bidding. The bidding behavior of the respondents is disaggregated into four steps: (1) zero-protest bids; (2) bids that constitute valid zeroes; (3) in cases where the respondent has a positive WTP, whether the respondent can indicate a specific number for WTP; and (4) the willingness-to-pay decision in cases where WTP is positive and known. Each step is conditional on the last step. This method is used for analyzing the willingness to pay for blue skies in Beijing where air pollution is known to be very serious. The mean and the median of the predicted willingness to pay for blue skies per household are, respectively, 120 *yuan* and 129 *yuan*, less than 0.2% of the per capita annual disposal income in Beijing. This is very low compared to results from studies of other countries. The empirical results also find that the four-hurdle model is superior to the Tobit model.

Essay 3 incorporates habit persistence into consumer behavior economics and analyzes interdependencies between cigarette and alcohol consumption in rural China. The essay estimates a habit-persistence model using panel data for 10 years (1994-2003) for rural areas of 26 Chinese provinces. There have been many studies of cigarette and alcohol consumption considered separately but few to date for China on interactions between the consumption of these two products. Taxes are often recommended as a tool to reduce alcohol and cigarette consumption. If cigarettes and alcohol are complements, taxing one will reduce the consumption of both and thus achieve a double public health dividend. However, if they are substitutes, taxing one will induce consumers to increase consumption of the other, offsetting the public health benefits of the tax. The results indicate that the demands for both cigarettes and alcohol are very sensitive to the price of alcohol, but not to the price of cigarettes or to income. This suggests that taxes on alcohol can have a double dividend. On the other hand, an increase in cigarette taxes may not be effective in curbing cigarette or alcohol consumption in rural China.

Essay 1
The Demand for Food Quality in Rural China

1.1 Introduction

Rapid economic growth usually leads to significant structural changes in food demand, with China being a good case in point. Since China launched market-oriented economic reforms in 1978, its economic growth rate has averaged 7-8% per year. Engel's Law predicts that the share of food in total expenditure should decrease as income increases, and China is no exception. In rural China, the share of food in total expenditure has fallen significantly in recent years, from about 59% in 1994 to about 46% in 2003, as shown in Table 1-1. The decline in urban areas in China was also significant during this period, from about 50% to about 37%. Furthermore, as incomes increase, consumers in developing countries tend to shift from less expensive foods such as grains to more expensive foods such as meat and dairy products. Sahn (1988) found this type of shift in Sri Lanka, as did Ye and Taylor (1995) in rural areas of northern China. Statistics for rural China as a whole indicate that the share of grain in total food expenditures fell from about 36% in 1994, to about 23% in 2003, while the share of meat in total food expenditures increased from about 17% to about 21% during this period (Table 1-1).

A number of empirical studies for rural and urban China have analyzed changes in recent years in food demand (e.g., Fan, Wailes and Cramer 1995; Gao, Wailes and Cramer 1996; Huang and Rozelle 1998; Shen 2001; Ma, Rae, Huang and Rozelle 2004; Gould and Dong 2004; Yen, Fang and Su 2004; Wan 2005). However, a common point in most of the studies for rural China is that the price data are not actual prices but unit values, obtained by dividing expenditures by the quantity consumed. Relying on unit values can bias empirical analyses because they are not exogenous market prices; they instead reflect household food quality choices within each food product category (Deaton 1988; Nelson 1991). For example, within the category of "meat" there is considerable scope for household choice with respect to the type of meat, cut, appearance, texture, tenderness, flavor, nutrient content, freshness and ease of preparation.

Regressions of quantities demanded on unit values and income may produce biased estimates of income and price elasticities of demand. As this essay shows, the income elasticity is likely to be biased upward, while the absolute value of own-price elasticity is likely to be biased upward for a normal good and downward for an inferior good. The magnitudes of biases can vary, but projections of future food and agricultural consumption based on elasticities that do not account for quality could be subject to significant error. In the case of India, Subramanian and Deaton (1996) found that the elasticity of caloric intake with respect to income is about one-half the income elasticity of total food consumption, due largely to consumer shifts toward more expensive food groups (such as meat) as income increases but also to shifts toward more expensive foods within each group. The potential for bias has been known for several decades, as echoed in seminal work by Houthakker (1952), Theil (1952), Prais and Houthakker (1971) and Cramer (1973).

Gale and Huang (2007) analyzed the impact of changes in income on the demand for food quality for several food groups in China using the Prais and Houthakker (1971) methodology and found significant impacts in several cases, including seafood, fruits and vegetables. This methodology starts with the identity: $e \equiv pq$, where e represents expenditures on some food group, q the physical quantity demanded of that food group and p the unit price, which is an indicator of quality. Since $p = e/q$, the effect of income on the demand for food quality can be measured by the difference between the elasticity of e with respect to income and the elasticity of q with respect to income. Gale and Huang (2007) did not examine the effects of variables other than income on the demand for food quality.

This essay has two objectives. The first is to lay out a theoretical framework for assessing the magnitude of bias in estimates of income and price elasticities of demand from studies using unit values that do not account for household food quality choices and for correcting these biases. The second objective is to estimate the determinants of changes in the quality of food demanded in rural China using panel data for 10 years (1994 through 2003) for rural areas of 26 Chinese provinces.[1] This is a particularly important issue for China, given its large and growing role in global food and agricultural markets and the fact that rural China accounts for nearly 60% of China's total population. This essay analyzes ten food products (grains, fats & edible oils, meat, seafood, fresh vegetables, sugar, alcohol, fruits, dairy products, and cigarettes) that account for more than two-thirds of total food expenditures in rural China.

1.2 Income and the Demand for Quantity and Quality

Household surveys of consumption typically ask respondents to report their consumption quantities and expenditures for groups of items rather than specific individual items. In some surveys there are a small number of broadly defined groups (e.g. "meat"); in other surveys there are a larger number of more narrowly defined groups (e.g. "beef," "pork," "poultry," etc.). Even when groups are narrowly defined in the survey, as is the case for rural China, statistical authorities may limit the public release of data to more broadly defined groups. Whether broad or narrow, the survey data present us with goods assigned to pre-defined groups and typically do

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[1] A parallel study for urban China would be highly valuable, but data availability and quality are limitations. The China National Statistics Bureau (CNSB) does not publish data on unit values for urban China. Also, dining out expenditures, which are significantly greater in urban areas than in rural areas, are not captured well by CNSB data.

not provide data on prices of specific items within each group. Instead, one often has only unit values for each group to use as "prices" in an econometric study of demand. The challenge is to analyze the data as it is compiled in a way that makes sense given the economics of the underlying consumer choices with respect to individual items.

Following Deaton (1988), consider a food group i composed of a number of items, such as different types of meat or different varieties of grain. Let $\underset{\sim}{p}_{ij}$ denote the vector of prices for the items in this food group in some region denoted by j. Assume that these prices can be written as the product of a common (or average) vector of prices for all regions ($\underset{\sim}{p}_i^*$) and a term reflecting differences between regions in prices (λ_{ij}):

$$\underset{\sim}{p}_{ij} = \lambda_{ij} \underset{\sim}{p}_i^* . \tag{1}$$

Inter-regional differences in prices could arise due to transportation costs or perhaps in some countries, government price, tax, or distribution policies. The difference factor λ_{ij} is typically assumed in models of this type to be exogenous to household consumption decisions, and that assumption is generally maintained here.

The aggregate quantity of food group i consumed in region j (Q_{ij}) as typically measured in household surveys is simply the total number of kilograms or pounds of all the items within that food group:

$$Q_{ij} = \underset{\sim}{\theta}_i ' \underset{\sim}{q}_{ij} , \tag{2}$$

where $\underset{\sim}{q}_{ij}$ is a vector of consumption quantities (measured by weight) for the items within this food group, and $\underset{\sim}{\theta}_i$ is a vector of ones.[2] For other purposes such as nutritional studies, $\underset{\sim}{\theta}_i$ might contain information on the caloric, protein or other nutrient content of food items. Expenditures on food group i in region j (E_{ij}) are:

$$E_{ij} = \underset{\sim}{p}_{ij}'\underset{\sim}{q}_{ij}. \tag{3}$$

Given this notation, the unit value of food group i in region j (V_{ij}) is:

$$V_{ij} = \frac{E_{ij}}{Q_{ij}} = \frac{\underset{\sim}{p}_{ij}'\underset{\sim}{q}_{ij}}{\underset{\sim}{\theta}_i'\underset{\sim}{q}_{ij}} = \lambda_{ij}\left(\frac{\underset{\sim}{p}_i^{*}'\underset{\sim}{q}_{ij}}{\underset{\sim}{\theta}_i'\underset{\sim}{q}_{ij}}\right) = \lambda_{ij}\upsilon_{ij}, \tag{4}$$

where $\upsilon_{ij} = \underset{\sim}{p}_i^{*}'\underset{\sim}{q}_{ij} \big/ \underset{\sim}{\theta}_i'\underset{\sim}{q}_{ij}$ is a measure of quality. Thus, υ_{ij} is the average cost of food items within group i consumed in region j, controlling for inter-regional differences in prices. It is endogenous because it depends on household food consumption choices, which in turn depend on income, prices and household characteristics. Equation (4) implies:

$$\ln V_{ij} = \ln \lambda_{ij} + \ln \upsilon_{ij}, \tag{5}$$

which can be viewed as a hedonic model of unit values for food groups.

Following Deaton (1988) and Deaton and Muellbauer (1980), assume that the demand for food group i is weakly separable from all other food and non-food groups, so that we have a two-stage budgeting problem where consumers in the first stage choose how much to spend on each group and in the second stage decide how to allocate expenditures for each group among the goods in that group. The utility function in a two-stage budgeting problem can be written as:

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[2] Q_{ij} is an accounting measure of the quantity consumed of a food group as commonly found in household surveys and should not be confused with the group quantity in a multistage demand system (e.g. Deaton and Muellbauer 1980; Moschini 2001).

$u_j = u_j\left(a_{1j}, a_{2j}, \ldots, a_{nj}\right)$, where $a_{ij} = a_{ij}\left(\underset{\sim}{q}_{ij}\right)$ is an aggregate of goods within the i th group in region j, and n is the total number of groups. The utility maximization process in a two-stage budgeting problem yields a vector of group price indices ($\underset{\sim}{\pi}_j$), with π_{ij} equal to the marginal cost of a_{ij}. The group price indices are endogenous shadow prices.[3]

Optimal expenditures on group i at the first stage of the two-stage budgeting problem are in general functions of prices of all goods in all groups (denoted by the vector $\underset{\sim}{P}_j$), total income (Y_j) and a vector of other household characteristics affecting consumption ($\underset{\sim}{Z}_j$):

$$E_{ij} = g_{ij}\left(\underset{\sim}{P}_j, Y_j, \underset{\sim}{Z}_j\right). \tag{6}$$

At the second stage optimal demands within food group i are a function of prices of goods within that group, group expenditures and household characteristics:

$$\underset{\sim}{q}_{ij} = \underset{\sim}{f}_{ij}\left(\underset{\sim}{p}_{ij}, E_{ij}, \underset{\sim}{Z}_j\right) = \underset{\sim}{f}_{ij}\left(\underset{\sim}{p}_i^*, E_{ij}/\lambda_{ij}, \underset{\sim}{Z}_j\right). \tag{7}$$

The second equality in (7) follows from the fact that the demand functions are homogenous of degree zero in group expenditures and prices. Equations (2), (6) and (7) imply that the demand for the aggregate quantity of food group i is:

$$Q_{ij} = \underset{\sim}{\theta}_i{}' \underset{\sim}{f}_{ij}\left(\underset{\sim}{p}_{ij}, E_{ij}, \underset{\sim}{Z}_j\right) = \underset{\sim}{\theta}_i{}' \underset{\sim}{f}_{ij}\left(\underset{\sim}{p}_{ij}, g_{ij}\left(\underset{\sim}{P}_j, Y_j, \underset{\sim}{Z}_j\right), \underset{\sim}{Z}_j\right) = h_{ij}\left(\underset{\sim}{p}_{ij}, g_{ij}\left(\underset{\sim}{P}_j, Y_j, \underset{\sim}{Z}_j\right), \underset{\sim}{Z}_j\right), \tag{8}$$

where the group-level function $h_{ij}(\cdot)$ aggregates the information from the vector of product-specific functions $\underset{\sim}{f}_{ij}(\cdot)$ within that group.

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[3] An alternative type of separability is indirect weak separability in which the indirect utility function depends on indices for each group. Each group index depends on prices of goods within that group and total expenditure (Moschini 2001).

However, equation (8) often cannot be empirically estimated because data on prices of individual items are unavailable, as is the case for rural China. Instead researchers typically replace the vector of prices $\underset{\sim}{p}_{ij}$ by the unit value V_{ij} and the vector of all prices $\underset{\sim}{P}_j$ by the corresponding vector of unit values $\underset{\sim}{V}_j$ to obtain an equation that can be estimated:

$$Q_{ij} \approx h_{ij}\left(V_{ij}, g_{ij}\left(\underset{\sim}{V}_j, Y_j, \underset{\sim}{Z}_j\right), \underset{\sim}{Z}_j\right). \tag{9}$$

Note that $V_{ij} = \pi_{ij}$ only if the aggregator for group i in the utility function is identical to equation (2): $a_{ij}\left(\underset{\sim}{q}_{ij}\right) = Q_{ij} = \underset{\sim}{\theta}_i{}'\underset{\sim}{q}_{ij}$. If the vector $\underset{\sim}{\theta}_i$ consists of ones, so that food items are aggregated by weight, this would imply that consumers have no interest in quality differences within a food group. In this case consumers would purchase only the least expensive item within each group and spend nothing on the other items, leaving V_{ij} equal to the lowest price in the vector of prices $\underset{\sim}{p}_{ij}$. This is the only situation in which the replacement of $\underset{\sim}{p}_{ij}$ by V_{ij} and the replacement of $\underset{\sim}{P}_j$ by $\underset{\sim}{V}_j$ can be justified theoretically because the only price in each group that affects consumer decision-making is the lowest price.[4]

In econometric work estimating the parameters of equation (9) to examine the effects of a change in income on expenditures and in turn Q_{ij} implicitly involves holding V_{ij} constant as Y_j changes. However, unit values cannot stay constant when income changes unless income has no

[4] This holds for small changes in prices within a food group. Large changes in prices could cause a switch in which item is the least expensive within a group, leading to a movement from one corner solution to another.

impact on the quality of goods purchased within each group (υ_{ij}), or there is an offsetting change in the inter-regional price factors (λ_{ij}) that leaves unit values unchanged.

Let $\gamma_{ij} = \left(\partial \ln Q_{ij} / \partial \ln E_{ij}\right)\left(d \ln g_{ij} / d \ln Y_j\right)$ denote the income elasticity of demand for food group i as obtained from equation (9), and let $\eta_{ij} = d \ln \upsilon_{ij} / d \ln Y_j$ denote the elasticity of demand for quality within group i with respect to income, which one would typically presume is positive. Consider what happens if there is an offsetting change in λ_{ij} that leaves V_{ij} unchanged, so that $d \ln \lambda_{ij} / d \ln Y_j = -\eta_{ij}$. In an econometric analysis this would be tantamount to relying on inter-regional price variability to reduce collinearity between Y_j and V_{ij} to the point where equation (9) could be reliably estimated. Let $\varepsilon_{ij} = -d \ln Q_{ij} / d \ln \lambda_{ij}$ be minus one multiplied by the elasticity of food consumption with respect to the inter-regional price factor. One would typically presume a downward-sloping demand curve for food ($\varepsilon_{ij} > 0$). Utilizing equation (9):

$$\tilde{\gamma}_{ij} = \left.\frac{d \ln Q_{ij}}{d \ln Y_j}\right|_{\lambda_{ij}\text{ offsetting}} = \left.\frac{d \ln Q_{ij}}{d \ln Y_j}\right|_{\lambda_{ij}\text{ constant}} + \frac{d \ln Q_{ij}}{d \ln \lambda_{ij}} \frac{d \ln \lambda_{ij}}{d \ln Y_j} = \gamma_{ij} + \varepsilon_{ij}\eta_{ij}\,. \tag{10}$$

If $\eta_{ij} > 0$ and $\varepsilon_{ij} > 0$, equation (10) implies the elasticity of food consumption with respect to income is greater with an offsetting change in λ_{ij} than when λ_{ij} is constant ($\tilde{\gamma}_{ij} > \gamma_{ij}$).

Assuming that unit values are exogenous, as is typically the case, estimation of equation (9) will overstate the responsiveness of consumption to income by the amount $\varepsilon_{ij}\eta_{ij}$. If food group i is normal ($\gamma_{ij} > 0$), γ_{ij} will be closer to 0 than $\tilde{\gamma}_{ij}$. If it is inferior ($\gamma_{ij} < 0$), γ_{ij} will be further away from 0 (more negative) than $\tilde{\gamma}_{ij}$. This is a type of simultaneous equation bias that occurs in estimation because unit values are in fact endogenous. The larger the income elasticity of demand for food quality is, the greater is the magnitude of the bias.

Deaton (1988) indicates that estimation of equation (9) will also tend to overstate the responsiveness of consumption to changes in price, assuming that the product in question is a normal good. Consider a change in prices due to a change in the inter-regional price factor λ_{ij}. The correct value of the own-price elasticity of demand is $-\varepsilon_{ij}$. As Deaton demonstrates, mistakenly measuring the price elasticity by the relationship between quantity and unit value yields a different elasticity ($\tilde{\varepsilon}_{ij}$):

$$\tilde{\varepsilon}_{ij} = -\frac{d \ln Q_{ij}}{d \ln V_{ij}} = \frac{\varepsilon_{ij}}{1-\varepsilon_{ij}\eta_{ij}/\gamma_{ij}}. \tag{11}$$

If food group i is normal ($\gamma_{ij} > 0$) and if $0 < 1-\varepsilon_{ij}\eta_{ij}/\gamma_{ij} < 1$, the absolute value of the own-price elasticity of demand will be overstated ($\tilde{\varepsilon}_{ij} > \varepsilon_{ij}$).[5] The larger the income elasticity of demand for food quality (η_{ij}) is, the smaller is the denominator in equation (11) and the greater the degree of overestimation. The overestimation occurs because an increase in the inter-regional price factor λ_{ij} has a negative income effect in this situation on the demand for food quality, causing V_{ij} to rise by less in percentage terms than λ_{ij}. This makes it appear as if consumption is more responsive to price when looking at the ratio $d \ln Q_{ij} / d \ln V_{ij}$ than is actually the case.

On the other hand if food group i is inferior ($\gamma_{ij} < 0$), then $1-\varepsilon_{ij}\eta_{ij}/\gamma_{ij} > 1$ and the absolute value of the own-price elasticity of demand will be understated ($\tilde{\varepsilon}_{ij} < \varepsilon_{ij}$). The larger

[5] As Deaton (1988) indicates, one would expect $\varepsilon_{ij}\eta_{ij} < |\gamma_{ij}|$, so that $0 < 1-\varepsilon_{ij}\eta_{ij}/\gamma_{ij} < 1$ when $\gamma_{ij} > 0$ and $1 < 1-\varepsilon_{ij}\eta_{ij}/\gamma_{ij} < 2$ when $\gamma_{ij} < 0$.

the income elasticity of demand for food quality (η_{ij}) is, the larger is the denominator in equation (11) and the greater is the degree of underestimation of the absolute value of the own-price elasticity. This occurs because an increase the inter-regional price factor λ_{ij} has a positive income effect in this situation on the demand for food quality, causing V_{ij} to rise by more in percentage terms than λ_{ij} and making it appear as if consumption is less responsive to price when looking at the ratio $d\ln Q_{ij}/d\ln V_{ij}$ than is actually the case.

Equations (10) and (11) predict that the distortions in estimates of income and own-price elasticities of demand from estimation of equation (9) will depend on the correct value of the own-price elasticity. The larger the value of ε_{ij} is, the greater is the degree of overestimation of the income elasticity and the greater is the degree of either overestimation or underestimation of the absolute value of the own-price elasticity, depending on whether the product is normal or inferior.

Given values for η_{ij}, $\tilde{\varepsilon}_{ij}$ and $\tilde{\gamma}_{ij}$, equations (10)-(11) can be viewed as a system of two equations in two unknowns, the correct values for the price and income elasticities of demand for quantity (ε_{ij} and γ_{ij}). Viewing the equations in this way is useful because estimates of $\tilde{\varepsilon}_{ij}$ and $\tilde{\gamma}_{ij}$ are available from existing studies of food demand that do not correct for quality, and this essay, in addition to other studies, provides estimates of η_{ij}. Letting $b_{ij} = \tilde{\gamma}_{ij} - 2\tilde{\varepsilon}_{ij}\eta_{ij}$ and $c_{ij} = \tilde{\varepsilon}_{ij}\eta_{ij}\tilde{\gamma}_{ij}$, the solution for γ_{ij} is:

$$\gamma_{ij} = \frac{b_{ij} + \sqrt{b_{ij}^2 + 4c_{ij}}}{2} \text{ if } \tilde{\gamma}_{ij} > 0, \qquad (12a)$$

$$\gamma_{ij} = \frac{b_{ij} - \sqrt{b_{ij}^2 + 4c_{ij}}}{2} \text{ if } \tilde{\gamma}_{ij} < 0 . \tag{12b}$$

With this solution in hand, ε_{ij} can be obtained using equation (10):

$$\varepsilon_{ij} = \frac{\tilde{\gamma}_{ij} - \gamma_{ij}}{\eta_{ij}} . \tag{13}$$

If $\tilde{\gamma}_{ij} = 0$, it can be shown that equations (10)-(11) degenerate to the solution $\varepsilon_{ij} = \gamma_{ij} = 0$.

The solutions for ε_{ij} and γ_{ij} when $\tilde{\gamma}_{ij} > 0$ are illustrated in figure 1, while the solutions when $\tilde{\gamma}_{ij} < 0$ are shown in figure 2. Equation (10) in figure 1 is a downward-sloping straight line between $\tilde{\gamma}_{ij}$ on the *y*-axis and $\tilde{\gamma}_{ij}/\eta_{ij}$ on the *x*-axis, while equation (11) is an increasing function that starts at the origin and has an asymptote at $\tilde{\varepsilon}_{ij}$. In figure 2 equation (10) is a downward-sloping straight line beginning at $\tilde{\gamma}_{ij}$ on the *y*-axis, while equation (11) is an increasing function that has an asymptote at $\tilde{\varepsilon}_{ij}$ from below and 0 from above. Estimates of ε_{ij} and γ_{ij} from equations (12a) or (12b) and (13) can be compared to values of $\tilde{\varepsilon}_{ij}$ and $\tilde{\gamma}_{ij}$ to gauge the degree to which regressions of quantities demanded on unit values and income bias price and income elasticities of demand, and to correct for these biases.

1.3 Econometric Model and Data

The econometric model specified here follows in the footsteps of Cox and Wohlgenant (1986) and Deaton (1988), who used cross-sectional data to estimate the determinants of food quality choices in the U.S. and Côte d'Ivoire, respectively. However, in contrast to their cross-sectional analyses, this essay uses panel data at the provincial level for rural China. Panel data analysis can overcome the difficulty of unobservable variables affecting consumer choices such as spatial factors and can improve the efficiency of a regression (Hsiao 2003).

Adding a subscript t to denote time, and assuming that the inter-regional price factors (λ_{ij}) are time-invariant, the empirical counterpart to the hedonic model in equation (5) is:

$$\ln V_{ijt} = \ln \lambda_{ij} + \ln \upsilon_{ijt} . \tag{14}$$

Deaton and Muellbauer (1980) developed a panel data model to estimate quality choice along the following lines:

$$\ln \upsilon_{ijt} = \ln p_{it}^{*} + h\left(Y_{jt}, \underset{\sim}{Z}_{jt}\right), \tag{15}$$

where p_{it}^{*} is a common reference price for food group i for all regions, and similar to the theoretical model above, Y_{jt} is income and $\underset{\sim}{Z}_{jt}$ is a vector of household characteristics.

In the empirical literature on food demand, household characteristics found to be important include household size, place of residence, and the age, gender, education, race, ethnicity and employment of household members (Cox and Wohlgenant 1986; Behrman and Deolalikar 1987; Deaton 1988; Dong, Shonkwiler and Capps 1998; Gould and Dong 2004; Ye and Taylor 1995). Household size squared is sometimes also included to test for nonlinearities with respect to this variable (e.g., scale economies at small household sizes and scale diseconomies at large sizes).

Let us combine equations (14)-(15) and assume that the function $h(\cdot)$ is log-linear. The log-linear form can be viewed as a first-order Taylor series approximation to the true but unknown function and is frequently adopted in empirical hedonic model studies (Deaton and Muellbauer 1980). Then, assuming for simplicity that $\ln p_{it}^{*}$ can be proxied by a time trend (t), the hedonic model that this essay estimates is:

$$\ln V_{ijt} = \beta_{i0} + \beta_{i1} \ln PCI_{it} + \beta_{i2} \ln HHSIZE_{it} + \beta_{i3}(\ln HHSIZE_{it})^2 + \beta_{i4} \ln LABOR_{it} \\ + \beta_{i5} \ln HOUSE_{it} + \beta_{i6} \ln LAND_{it} + \beta_{i7} \ln EDEXP_{it} + \beta_{i8} \ln EDLEVEL_{it} + \gamma_i t + \mu_{ij} + e_{ijt}, \quad (16)$$

where PCI_{it} is per capita income, $HHSIZE_{it}$ is average household size, $LABOR_{it}$ is the average number of members of each household who participate in the labor force, $HOUSE_{it}$ is the average house area (in square meters) per capita, $LAND_{it}$ is average cropland area (in *mu*) per capita, $EDEXP_{it}$ is expenditures on education per capita, $EDLEVEL_{it}$ is the fraction of the adult population with more than a primary school education, μ_{ij} $(= \ln \lambda_{ij})$ is a term reflecting regional differences and e_{ijt} is an independently and identically distributed error term.[6]

Equation (16) is a typical panel data model. The model can be estimated by either fixed effects or random effects. If μ_{ij} is a random variable, so that there are no systematic differences between regions, a random effects model is preferred because it is more efficient than a fixed effects model. Otherwise, a fixed effects model is superior. Hausman's (1978) specification test between fixed and random effects models can be used to analyze whether there are systematic differences among regions.

The panel dataset consists of data for 10 years (1994 through 2003) for rural areas of 26 Chinese provinces, with data being at the provincial level. This essay analyzes ten food products (grains, fats & edible oils, meat, seafood, fresh vegetables, sugar, alcohol, fruits, dairy products, and cigarettes) that account for more than two-thirds of total food expenditures in rural China. Data are from the China National Statistics Bureau (CNSB). The dataset begins in 1994, in order to avoid prior years in which prices were significantly distorted by government regulations.

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[6] A *mu* is a traditional Chinese measure of land area, with 15 *mu* equal to one hectare.

Even though China began food policy reforms in the late 1970s, price regulations were not abandoned until 1993 (Ma et al. 2004).

Unit values for 1994 are derived from *Rural Household Survey Statistics* (RHSS), a CNSB publication, dividing total expenditure in each food group by the total quantity consumed. Starting with the 1994 unit values, this essay uses the provincial-level consumer price index (CPI) for each food group for 1995 through 2003, in order to compute unit values for each food group for those years. Provincial-level CPIs are obtained from the *China Statistical Yearbook of Prices and Urban Household Survey* (various editions), published by CNSB. Data for the right-hand side variables in equation (16) are from RHSS (various editions). RHSS covers 27 provinces, of which Tibet is excluded from the analyses because of missing data, leaving 26 provinces. Nominal values are converted to real terms using the overall rural China CPI, with all prices expressed in 1994 Yuan.

1.4 Hausman Test Results for Spatial Differences

The null hypotheses of the Hausman tests are that there are no systematic differences in unit values and quantity demand among the cross-sectional cohorts—the 26 provinces in this essay. Hausman test results are reported in Table 1-2. The null hypothesis of no systematic differences in demand for quality among regions can be rejected at the 5% significance level for grains, meat, sugar and alcohol. For these food groups a fixed effects model is preferred. Grains, meat and alcohol are products in which until the 1990s, there was little inter-provincial or even inter-farm trade in rural China (Huang and Rozelle 1998). Markets for grains have become much more integrated across space since then (Huang and Rozelle 2006). However, rates of commercialization for grains, defined as the ratio of grains purchased to all grains consumed (purchased plus produced by the household), remain relatively low, which could help explain the Hausman test results for that food group. Rural China differs from urban China in this regard. With respect to sugar, there are significant differences in product composition across Chinese provinces that may account for the Hausman test results.

One cannot reject the null hypothesis of no systematic inter-provincial differences in demand for quality for fats & edible oils, vegetables, seafood and fruits. These products are highly commercialized and now largely standardized throughout China owing to economic reforms and market development since 1978. Quality differences among provinces are small, so the random effects model is preferred for these products.

The Hausman tests for dairy products and cigarettes are negative, implying that the data fail to satisfy the asymptotic assumptions of the test. However, the parameter estimates of the random and fixed effects models are very similar to each other. In the following discussion the fixed effects results are used for dairy and cigarettes.

1.5 Hedonic Model Results and Discussion

The hedonic model results are shown in Table 1-2. Overall, the results are good, with reasonable R^2 values for most food groups (vegetables being the exception) and with most explanatory variables statistically significant.

Income

The results indicate that per capita income is statistically significant for five food groups: grains (estimated elasticity of 0.31), fats & oils (0.19), seafood (0.17), vegetables (0.35) and dairy products (0.18). The estimated income elasticities of demand for quality for the two of these products generally viewed as necessities—grains and vegetables—are larger than those for fats

& oils, seafood and dairy products, which are generally viewed as luxuries in the case of rural China. As incomes increase, it appears that consumers in rural China make greater adjustments regarding the quality of necessities they consume than to the quality of luxuries.

Estimates of own-price and income elasticities of demand from the literature for rural China that do not correct for quality (e.g., Huang and Rozelle 1998; Shen 2001; Ma et al. 2004) can be used in conjunction with the results here and equations (12a), (12b) and (13) to obtain estimates of the quality-corrected price and income elasticities of demand. The corrected results are shown in table 1-3 for grains, vegetables, seafood and fats & oils. These are the four food groups for which we have both: (1) a statistically significant income elasticity of demand for quality in this study, and (2) available estimates from the literature of price and income elasticities of demand for quantity for rural China. In the case of grains, the results indicate that the income (expenditure) elasticity of demand for grains in the literature is overstated by more than 30% once the demand for quality is taken into account, and the own-price elasticity of demand for grains is overstated in absolute value by more than 40%.[7] Smaller though still significant biases are found for vegetables and seafood.

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[7] To illustrate the calculations involved in arriving at the corrected price and income elasticities of demand, consider the case of grains and drop the subscripts i and j for ease of exposition. Huang and Rozelle (1998) find that $\tilde{\gamma} = 0.510$ and $\tilde{\varepsilon} = 0.570$ for grains, and our results indicate that $\eta = 0.306$. Then, the b and c terms in equation (12a) are $b = 0.510 - 2(0.570)(0.306) = 0.161$ and $c = (0.570)(0.306)(0.510) = 0.089$. Using equation (12a), $\gamma = \left(0.161 + \sqrt{(0.161)^2 + 4(0.089)}\right)\Big/2 = 0.389$. Using equation (13), $\varepsilon = \left(0.510 - 0.389\right)\big/0.306 = 0.395$.

Household Size and Labor Force Participation

The estimated coefficients for both the log of household size and the square of this variable are statistically significant for grains, seafood, alcohol and fruits. The relationship between demand for quality and household size for grains (a necessity) is dome-shaped, implying that as household size increases, the demand for grain quality increases at first and then decreases, with a peak at a household size of about 4.6. However, the relationship for seafood, alcohol and fruits (mainly luxury products) are U-shaped, implying that as household size increases, the demand for quality decreases at first and then increases; the minima are at household sizes of approximately 5.4, 7.4 and 7.2 respectively. Considering that the average household size in rural China is 4.45, these results generally imply that there are scale diseconomies with respect to household size in the choice of food quality for luxuries.

In a study for urban China using household survey data, Gould and Dong (2004) found a positive relationship between household size and the demand for quality for pork, seafood and vegetables, a negative relationship for fats & oils and other food products, and no statistically significant relationship for beef, poultry, fruits, rice, other grains, dairy products or eggs. Their model did not allow for the possibility of a dome-shaped or U-shaped relationship between household size and demand for quality. The results here differ from hedonic studies of durable goods prices, which generally find scale economies in household size, perhaps in part because food (unlike most durables) is a rival good within the household.

The labor force participation variable is positive and statistically significant for five of the ten products—fats & oils, alcohol, fruits, dairy products, and cigarettes. It is not statistically significant for the other five products. A higher rate of labor force participation implies greater current income and also greater permanent income, suggesting that the effects of income on the demand for food quality are not fully captured by the per capita income variable. Perhaps there is some remaining income effect that is being captured by the labor force participation variable.

House Area and Cropland Area

The estimated coefficients for house area are negative and statistically significant for two products: seafood and dairy products. Housing can represent a large share of total household expenditures and as such may crowd out food expenditures.

The estimated coefficients for cropland area for grains, sugar, seafood and dairy products are statistically significant, and among these four products all are positive except for seafood. As cropland area increases, households have greater current income and permanent income. As with labor force participation, there may be some remaining effect here of income on the demand for food quality that is not being captured by the per capita income variable.

Education

The estimated coefficients for the educational expenditure variable are negative and statistically significant for five products: grains, meat, vegetables, sugar, and dairy products. The estimated coefficients for the level-of-education variable are negative and statistically significant for grains, positive and statistically significant for sugar and cigarettes, and not statistically significant for the other products.

Households in rural China have made significant investments in education in recent years, and the level of education in rural China has increased rapidly. The percentage of the adult population with more than a primary school education increased from 28% in 1983 to 63% in 2003. The share of total household expenditures devoted to education in rural China has risen even more quickly, from 1.8% in 1983 to 9.0% in 2003. Returns to education are significant but can take many years to materialize. In such a situation households may sacrifice short-run interests such as food quality in order to achieve higher incomes in the future through education. In particular grains represent a large share of total household expenditures (about 10% in 2003), so it makes sense that education has crowding-out effects on grain quality.

In contrast to the results here, Gould and Dong's (2004) study for urban China finds a generally positive relationship between education and the demand for food quality. Unlike the present study, the authors did not include income as an explanatory variable in their unit value regressions. Education and income are positively correlated, so their results for education may reflect the influence of income.

Households choose educational expenditures contemporaneously with food expenditures, so it is possible that the educational expenditures variable in this essay is endogenous. Results of the Hausman test for endogeneity (Hausman 1978), using educational expenditures lagged one year as an instrumental variable for current educational expenditures, fail to reject the null hypothesis of exogeneity except in one case, namely the random effects model for fats & oils. And in that case the educational expenditures variable is not statistically significant in either the model reported in Table 1-2 or in the instrumental variable model.

Changes in Real Food Prices over Time

The time trend variable is negative and statistically significant for nine of the ten products, the only exception being vegetables, where it is not statistically significant. Other things held constant, the results suggest that real unit values have been falling over time. China's transition from a planned economy to a market economy has stimulated much productivity-increasing technical change and significantly reduced transaction costs (Huang and Rozelle 1998; Huang and Rozelle 2006), which may help explain these results. Also, some commodities were significantly protected from international competition in the 1990s, particularly wheat and soybeans. Protection for these commodities has been declining, causing domestic prices to move toward world prices (Huang et al. 2007).

1.7 Conclusions

The objectives of this essay were to develop a theoretical framework for assessing bias in estimates of income and price elasticities of demand in studies using unit values that do not account for household food quality choices; and then to estimate the determinants of changes in the quality of food demanded in rural China, using panel data for 10 years (1994 through 2003) for rural areas of 26 Chinese provinces. This essay analyzed ten food products (grain, fats & edible oils, meat, seafood, fresh vegetables, sugar, alcohol, fruits, dairy products, and cigarettes) that account for more than two-thirds of total food expenditures in rural China.

The theoretical framework here indicates that the income elasticity is likely to be biased upward, while the absolute value of own-price elasticity is likely to be biased upward for a normal good and downward for an inferior good. The larger the income elasticity of demand for food quality is, the greater is the degree of bias in both the income and own-price elasticities. The framework here also provides a means for recovering the correct values of the income and price elasticities of demand using estimates of these elasticities from studies of food demand that do not correct for quality and estimates of the income elasticity of demand for food quality.

This framework is needed because household surveys almost always present us with data in which individual goods have been assigned to pre-defined groups and typically lack data on prices of specific items within each group. Instead, we often have only unit values for each group. The challenge is to analyze the data as it is presented in a way that makes sense given the economics of the underlying consumer choices with respect to individual items. An ideal dataset would not group any items but would provide the price and quantity for every single item consumed. Some type of grouping would probably still be necessary after the fact by the econometrician to make the analysis tractable, but it would be possible to have group demand functions that are consistent with theory on multistage demand systems, estimable without resorting to unit values and free from the biases in price and income elasticities of demand found here.

The econometric results indicate that households in rural China tend to consume higher quality food as income increases, with a greater sensitivity to income for basic foods such as grains than for luxury foods. These results suggest that existing studies of food demand for rural China that do not correct for food quality are biased because as income increases, households switch from lower-quality food to higher-quality food. For grains the results suggest that the income elasticity of demand for grains in the literature is overstated by more than 30% once the demand for quality is taken into account, and the own-price elasticity of demand for grains is overstated in absolute value by more than 45%. Smaller but still significant biases are also found for vegetables and seafood.

The results indicate that there are systematic price differences among provinces mainly for self- and locally-sufficient foods, such as grains and meat, but no systematic price differences for highly commercialized products such as seafood and dairy products. The results also indicate that the pursuit of additional education in rural China has had significant crowding-out effects on the demand for food quality, in particular for grains. Households tend to sacrifice short-run interests by consuming lower-quality grain in order to pursue additional education and achieve higher incomes in the future. In addition because of productivity-enhancing technical change and a reduction in transaction costs resulting from economic reforms, real food prices in China have fallen in recent years.

Considering the rapid rate of China's economic growth and the importance of China to global food and agricultural markets, projections of future food demand for China should take into account the growing demand for food quality. Failing to do so could lead to overestimates of future growth in the quantity of food consumed in China, missing a shift from simply more food to better quality food.

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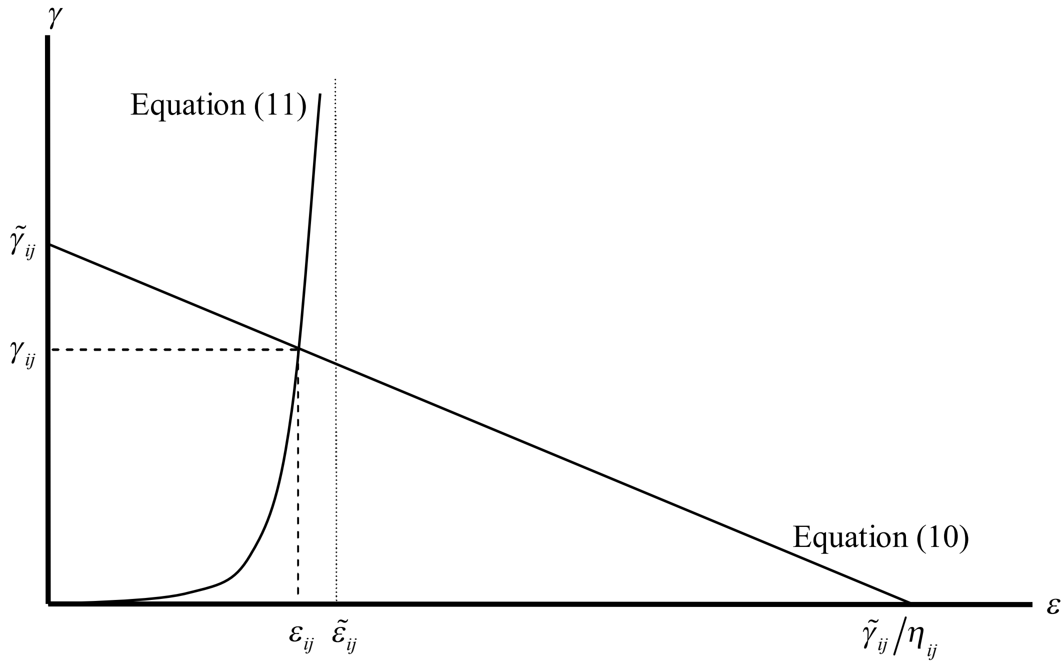

Figure 1-1. Solutions for income and price elasticities (normal good case)

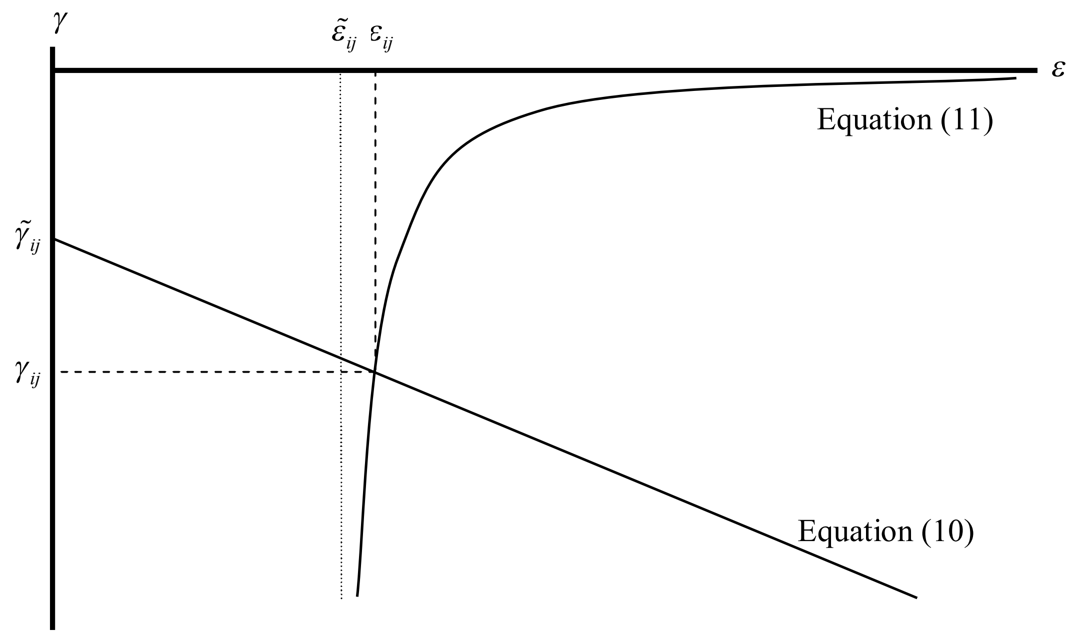

Figure 1-2. Solutions for income and price elasticities (inferior good case)

Table 1-1. Food Expenditures in Rural China

Year	Expenditures (Yuan, current prices)		Engel Index	Shares in Total Food Expenditure (%)											
	(A) Total	(B) Food	(B)/(A)	Food	Grains	Fats & Oils	Meat	Seafood	Vegetables	Sugar	Alcohol	Fruits	Dairy Products	Cigarettes	Other Food Products
1994	1016.81	598.47	0.589	100.00	35.99	6.68	16.75	2.92	9.19	0.80	3.02	2.40	0.25	4.26	17.74
1995	1310.36	768.19	0.586	100.00	39.01	6.35	17.19	2.95	9.07	0.97	2.01	2.37	0.23	3.83	16.01
1996	1572.08	885.49	0.563	100.00	35.29	5.33	17.83	2.94	9.65	0.92	2.01	2.65	0.27	3.20	19.90
1997	1617.15	890.28	0.551	100.00	30.84	5.49	19.11	3.00	9.65	0.87	2.05	3.66	0.33	3.01	21.98
1998	1590.33	849.64	0.534	100.00	31.14	5.61	18.55	2.86	10.39	0.89	2.08	3.17	0.33	3.05	21.93
1999	1577.42	829.02	0.526	100.00	30.76	5.43	18.27	2.83	10.91	0.88	2.10	3.18	0.34	3.13	22.16
2000	1670.13	820.52	0.491	100.00	27.70	5.52	18.51	2.96	11.93	0.65	2.11	2.97	0.38	3.01	24.26
2001	1741.09	830.72	0.477	100.00	26.02	5.04	19.43	3.00	11.51	0.76	2.09	3.22	0.43	2.90	25.60
2002	1834.31	848.35	0.462	100.00	24.79	5.19	19.30	2.98	11.28	0.81	2.15	3.00	0.40	2.76	27.33
2003	1943.30	886.00	0.456	100.00	22.65	4.72	20.63	3.04	11.90	0.54	2.11	2.79	0.55	2.58	28.50

Note: Other food products include seasonings, beans, eggs, cakes, candies, food service and dining out expenditures.

Source: Based on RHSS (various editions).

Table 1-2. Hedonic Model Results

		Grains		Fats & Oils		Meat		Seafood		Vegetables		Sugar		Alcohol		Fruits		Dairy Products		Cigarettes	
		FE	RE	FE	RE	FE	RE	FE	RE	FE	RE	FE	RE	FE	RE	FE	RE	FE	RE	FE	RE
ln(*PCI*)	Estimate	0.306	0.264	0.252	0.188	0.084	0.206	0.172	0.173	-0.076	0.352	-0.116	0.038	-0.007	0.009	-0.183	-0.110	0.182	0.190	-0.121	0.007
	t-ratio	3.52**	3.44**	2.75**	2.55**	1.17	3.77**	2.94**	3.08**	-0.31	2.19*	-1.55	0.82	-0.15	0.21	-2.52**	-1.60	3.50**	3.61**	-1.56	0.09
ln(*HHSIZE*)	Estimate	6.490	6.334	-1.070	0.785	0.641	0.820	-8.217	-7.871	3.064	4.606	-0.871	-1.834	-3.745	-3.740	-3.630	-3.761	-1.495	-1.482	-3.36	-2.66
	t-ratio	3.63**	3.76**	-0.57	0.45	0.44	0.61	-6.85**	-6.73**	0.62	1.07	-0.57	-1.43	-4.00**	-3.99**	-2.43*	-2.58**	-1.40	-1.36	-2.10*	-1.62
ln(*HHSIZE*^{2})	Estimate	-2.113	-2.019	0.078	-0.271	-0.132	-0.109	2.396	2.323	-1.524	-1.364	0.296	0.561	0.938	0.925	0.881	0.952	0.033	0.033	0.701	0.611
	t-ratio	-3.96**	-3.89**	0.14	-0.50	-0.30	-0.26	6.68**	6.60**	-1.03	-1.00	0.64	1.37	3.35**	3.28**	1.97*	2.15*	0.10	0.10	1.47	1.23
ln(*LABOR*)	Estimate	0.349	0.286	0.867	0.581	0.191	0.200	0.082	0.049	0.966	0.976	0.133	0.256	0.527	0.552	0.928	0.985	0.652	0.666	0.71	0.74
	t-ratio	1.63	1.44	3.84**	2.87**	1.09	1.27	0.57	0.35	1.63	1.93	0.73	1.68	4.71**	4.95**	5.19**	5.72**	5.12**	5.13**	3.69**	3.81**
ln(*LAND*)	Estimate	0.142	0.102	0.006	-0.004	0.075	0.049	-0.070	-0.064	0.179	-0.066	0.118	0.110	0.017	0.016	-0.039	-0.05	0.056	0.046	-0.005	-0.016
	t-ratio	2.94**	2.50**	0.12	-0.09	1.89	1.73	-2.14*	-2.07*	1.33	-0.80	2.84**	4.62**	0.66	0.63	-0.95	-1.47	1.95*	1.57	-0.12	-0.39
ln(*HOUSE*)	Estimate	-0.045	-0.044	0.037	0.036	0.065	0.116	-0.164	-0.164	-0.043	0.154	0.049	0.045	0.035	0.038	0.062	0.076	-0.114	-0.107	-0.07	-0.05
	t-ratio	-0.61	-0.62	0.47	0.48	1.08	1.96*	-3.33**	-3.38**	-0.21	0.81	0.77	0.80	0.91	0.99	1.01	1.24	-2.59**	-2.39*	-1.07	-0.69
ln(*EDEXP*)	Estimate	-0.045	-0.046	0.014	0.012	-0.016	-0.007	0.003	0.003	-0.067	-0.058	-0.031	-0.023	0.006	0.007	0.002	0.004	-0.030	-0.029	0.042	0.046
	t-ratio	-4.68**	-4.86**	1.41	1.17	-1.98*	-0.86	0.49	0.50	-2.52**	-2.25*	-3.81**	-2.93**	1.11	1.31	0.25	0.53	-5.17**	-5.00**	4.91**	5.07**
EDLEVEL	Estimate	-0.656	-0.377	-0.715	-0.310	-0.310	0.064	-0.235	-0.226	0.517	0.470	0.476	0.339	-0.084	-0.064	-0.200	-0.299	0.172	0.191	1.06	0.83
	t-ratio	-2.26*	-1.45	-2.33*	-1.25	-1.30	0.35	-1.20	-1.20	0.64	0.88	1.90	2.18*	-0.55	-0.42	-0.82	-1.29	0.99	1.08	4.06**	3.21**
t	Estimate	-0.026	-0.027	-0.059	-0.053	-0.013	-0.026	-0.048	-0.047	0.017	0.007	-0.015	-0.024	-0.019	-0.021	-0.013	-0.015	-0.019	-0.020	-0.045	-0.044
	t-ratio	-3.86**	-5.14**	-8.43**	-11.16**	-2.37**	-7.42**	-10.84**	-11.22**	0.90	0.76	-2.64**	-8.38**	-5.57**	-6.30**	-2.32*	-3.03**	-4.70**	-4.92**	-7.62**	-8.02**
Intercept	Estimate	-7.055	-6.776	0.947	-0.498	0.581	-0.957	7.993	7.652	-2.186	-8.388	2.306	1.996	3.619	3.480	3.844	3.309	2.196	2.082	3.13	1.35
	t-ratio	-4.25**	-4.30**	0.54	-0.31	0.43	-0.77	7.17**	7.01**	-0.47	-2.16*	1.62	1.73	4.16**	3.98**	2.77**	2.43*	2.22*	2.05*	2.11*	0.89
R^2		0.726	0.724	0.809	0.804	0.536	0.512	0.842	0.842	0.157	0.106	0.548	0.538	0.504	0.503	0.476	0.472	0.393	0.392	0.550	0.538
Hausman Test		33.65		14.22		24.46		2.73		13.24		25.59		19.27		10.98		-45.83		-131.01	
p-value		0.0001		0.1146		0.0036		0.9742		0.1521		0.0024		0.0230		0.2774		N.A.		N.A.	

Note: FE = fixed effects model, RE = random effects model. NA signifies not applicable because the results for dairy products fail to satisfy the asymptotic assumptions of the Hausman test (the test statistic is negative). All R^2 values are within-group results.

** Significant at 1% level. * Significant at 5% level.

Table 1-3. Elasticity Corrections for Recent Demand Studies

	Grain		Vegetables		Seafood		Fats & Oils
	Huang and Rozelle (1998)	Shen (2001)	Huang and Rozelle (1998)	Shen (2001)	Ma et al. (2004)	Shen (2001)	Shen (2001)
Study Estimates							
Income Elasticity	0.510	0.105	1.400	0.598	1.280	1.638	0.851
Price Elasticity	-0.570	-0.147	-0.820	-0.154	-0.521	-0.925	-0.130
After Correction							
Income Elasticity	0.389	0.077	1.169	0.549	1.197	1.493	0.827
Price Elasticity	-0.395	-0.093	-0.658	-0.140	-0.485	-0.835	-0.126
Overestimation (%)							
Income Elasticity	31	37	20	9	7	10	3
Absolute Value of Price Elasticity	44	59	25	10	8	11	3

Essay 2
Incorporating Zero and Missing Responses into CVM with Open-Ended Bidding: Willingness to Pay for Blue Skies in Beijing

2.1 Introduction

Air pollution can have serious health consequences. Case studies in Beijing have revealed that air pollution is linked with an increase in the mortality rate (Gao 1993; Xu et al. 1994, Chang et al. 2003), an increase in visits to physicians (Xu et al. 1995), and low birth weight (Wang et al. 1997). Though the Chinese government initiated a very large environmental improvement project in 2000—the Duststorm Sources Control Project (DSCP), planting trees in Beijing and neighboring provinces to prevent duststorms and ease other sources of pollution —pollution is still very serious. Blue skies in Beijing are a rarity, mainly due to rapid growth in the city's population, large-scale expansion of manufacturing and construction industries, and a large increase in the number of automobiles (Fu et al. 2001, He et al. 2002, Benjamin et al. 2007).

There are two main methods to measure the economic value of air quality. One uses hedonic techniques to estimate impacts of pollution on housing prices, based on revealed preference methods (Smith and Huang 1995, Zabel and Kiel 2000, Chay and Greenstone 2004). The other is the contingent valuation method (CVM), based on stated preference methods. Current research on valuation of air quality with CVM has examined countries such as Canada (Leger 2001), Bulgaria (Wang and Whittington 2000), India (Kumar and Rao 2006), South Korea (Kwak, Yoo and Kim 2001, Yoo, Kwak and Kim 2001), and Germany and France (Rozan 2004). A comprehensive review of revealed preference methods and stated preference methods can be found in Bockstael and Freeman (2005).

CVM has been widely used for assessing the benefits of environmental and other non-market goods, and usually includes the continuous method and the discrete method (Ready, Buzby and Hu 1996). The continuous method includes the open-ended bidding approach and the payment card approach. The discrete method is also called dichotomous format, and includes single-bounded and double-bounded formats. Ready, Buzby and Hu (1996) point out that a continuous format generates a lower estimated willingness to pay (WTP) than a dichotomous choice (DC) format due to more yes-saying among DC respondents. A good review of the CVM literature, including theories and applications, as well as current developments and debates, can be found in Carson and Hanemann (2005).

Following the seminal work of Hanemann (1984) and Hanemann, Loomis and Kanninen (1991), most practitioners including an NOAA expert panel (Arrow et al. 1993) prefer the discrete method to the continuous method. A difficult problem for the continuous method is that the data may have a peculiar distribution with a large number of zero responses. Some research just uses the positive observations (Rozan, 2004), and other research takes the logarithm of the positive observations after simply dropping the zero responses or adding a very small number to the zeros which, then, are included in the regressions in order to prevent negative predicted WTPs (Bateman *et al.* 1995, Langford et al. 1997). Some research assumes that the true distribution of WTP bidding is censored at zero, and hence, Tobit regression is used (Halstead *et al*. 1991). Other methods for dealing with zero responses include the Spike Model (Kriström 1997, Reiser and Shechter 1999), symmetrically-trimmed least squares estimation (Kwak, Lee and Russell 1997), and least absolute deviations estimation (Yoo, Kwak and Kim, 2000).

However, the literature is not always clear on the causes of zero responses, which can represent two different scenarios: protest zeros and true zeros. Protest zeros are those who give zero WTPs but their marginal utility of environment quality is not zero, perhaps because they think other agents such as the government or polluters, rather than themselves, should pay for improvements in environmental quality, or they feel the survey is a waste of time. Valid zeros are those who actually have a zero marginal utility of environmental quality.

Besides zero responses, there are missing responses, where respondents do not answer due to a lack of knowledge or the perceived complexity of the open-ended question. For instance, some respondents may only have limited information about their own WTPs. They may know that they have a positive WTP but cannot give a specific number. Such missing respondents, viewed as incomplete samples, are often dropped in the literature. However, it may cause sample selection bias because they are not missing at random.

Zero observations are a very common phenomenon in demand analysis. Cragg (1971) suggested a double-hurdle model in which consumption behavior consists of two decisions: a participation decision which is a binary choice Probit model, and a consumption decision which is a standard Tobit model. The two equations are assumed to be independent. Cragg's model is used by Goodwin et al. (1993) in an analysis of open-ended WTP. However, the assumption of independence between the two decisions causes the same problem as the standard Tobit model, in that latent variables representing cases of zero responses might be greater than zero.

In contrast to Cragg's model, Jones (1989) argues that the participation decision may dominate consumption decision in a study of cigarette consumption in UK. For example, only after a person decides to participate in smoking will a positive consumption of cigarettes be observed. Hence, only positive observations are included in the consumption equation. Jones' model (1989) can avoid the problem of the standard Tobit model where the latent values of the zero responses might be greater than zero. The double-hurdle model has been applied in open-ended CVM analysis, such as Alvarez-Farizo et al. (1999) and Martinez-Espineira (2006). However, the current literature does not pay much attention to the difference between protest zeros and valid zeros, or missing respondents. Following the logic of double-hurdle model, we can incorporate zero respondents and missing respondents into the decision procedure for open-ended bids.

The consistency between CVM estimates and actual behaviors is a critical challenge for CVM in policy making (Carson and Hanemann 2005). Some cognitive psychologists are participating in CVM studies and try to explain CVM from different angles. Fischhoff (2005) has a good review of the current literature on this issue. He points out that there are two lines in this field: behavioral decision-making and decision analysis. The research of behavioral decision-making directly tests people's adherence to the axioms, characterize the cognitive skills that facilitate (and constrain) rationality, or identify behaviorally realistic approaches to decision-making. Decision analysis tries to elicit individuals' probabilities and utilities for possible consequences of their action options. The success of the decision depends on participants' ability to express their beliefs and values in the required form, probabilities and utilities.

Based on decision theory, we can assume there are four steps required to reach a positive and specific WTP for a participant in a survey. That is, the bidding behavior of the respondents is disaggregated into four steps: (1) zero-protest bids; (2) bids that constitute valid zeros; (3) in cases where the respondent has a positive WTP, whether the respondent can indicate a specific number for WTP; and (4) the willingness-to-pay decision in cases where WTP is positive and known. We also assume each step is conditional on the last step. This four-hurdle model is used in this essay to analyze the willingness to pay for air quality in Beijing city with open-ended bidding. Note that, as Fischhoff (2005) points out, elicitation is a reactive measurement procedure. It can change participants, as they reflect on their beliefs and values. Therefore we believe that the order of decision-making that we assume in the four-hurdle model is reasonable. It is also discussed in the following analysis.

2.2 Zero Responses and CVM with Open-Ended Bidding

- **Protest zeros**

Following the logic of the double-hurdle model suggested by Jones (1989), when a respondent faces a question of open-ended bidding for willingness to pay for some environmental goods, she has two choices: protest or non-protest. Only if she decides not to protest might her bid value be observed.

Suppose the indirect utility function for a respondent is $V(p, q^*, m)$, given income m, environmental quality q^* and an exogenous price vector p. If she decides not to protest and participate in bidding, and she is willing to pay some money t ($t \geq 0$) for improving environmental quality by e, the indirect utility function becomes $V(p, q^* + e, m - t)$. On the other hand, if the respondent decides to protest, we assume her utility becomes Z. We can then give the condition for protest zeros:

$$Z \geq V(p, q^* + e, m - t) \tag{1}$$

There are four possible cases for protest as follows.

(1) The respondent may think that the government and polluters rather than individuals should pay for improving environmental quality. In this case, the cost of improving environmental quality will be transferred to the price vector because taxes or pollution control costs will affect the prices that consumers pay for goods and services. Then utility is

$$Z_1 = V(p - \Delta p, q^* + e, m), \tag{2.a}$$

where Δp is the change in price vector due to taxes or costs to polluters of improving environmental quality.

(2) The respondent may think government will not use the money they pay for improving environmental quality. In this case, even if the respondent pays the money,

she does not believe that environmental quality can be improved, so that utility is

$$Z_2 = V(p, q^*, m - t) \tag{2.b}$$

(3) The respondent may believe that environmental quality cannot be improved through any project. Similar with the case (2), then utility is

$$Z_3 = V(p, q^*, m - t) \tag{2.c}$$

(4) The respondent may view the survey as a waste of time. Then utility is

$$Z_4 = V(p, q^*, m) - \omega \tag{2.d}$$

where ω is the loss of utility due to time wasted on participating in the survey. It is possible that richer individuals may be more likely to protest, because the opportunity cost of time for a richer person might be higher.

If we assume the probability of non-protesting is $h_1 \in [0,1]$, we have the utility function for the respondent at the first hurdle:

$$\underset{h_1, t}{Max}. \quad U_1 = h_1 V(p, q^* + e, m - t) + (1 - h_1) Z_i, i = 1,2,3 \text{ or } 4. \tag{3}$$

When $h_1 = 1$ implies that the consumer decides not to protest, and $h_1 = 0$ implies protest.

- **Valid Zero WTPs**

Even though the respondent might pass the first hurdle, and decide not to protest, she may actually have a zero WTP. The utility of the respondent if she has a zero WTP is her reservation utility $V(p, q^*, m)$. Then the utility for the respondent in the second hurdle U_2, conditional on $h_1 = 1$, is

$$\underset{h_2, t}{Max}. \quad U_2 = h_2 V(p, q^* + e, m - t) + (1 - h_2) V(p, q^*, m), \ h_2 \in [0,1] \tag{4}$$

where h_2 is the probability of bidding a positive WTP. $h_2 = 1$ implies that the respondent bids a positive number and believes that environmental quality can be improved by e, and

$h_2 = 0$ implies that the respondent bids a valid zero. Using first-order Taylor expansion to approximate $V(p,q^* + e, m - t)$, we have

$$V(p,q^* + e, m - t) \approx V(p,q^*,m) + \frac{\partial V(p,q^*,m)}{\partial q^*} e - \frac{\partial V(p,q^*,m)}{\partial m} t \,. \tag{5}$$

Substituting (5) into (4) gives

$$U_2 = h_2 \left(\frac{\partial V(p,q^*,m)}{\partial q^*} e - \frac{\partial V(p,q^*,m)}{\partial m} t \right) + V(p,q^*,m) \,. \tag{6}$$

The condition of bidding a positive WTP ($h_2 = 1$) is that $U_2 \geq V(p,q^*,m)$, and $V(p,q^*,m)$ is the reservation utility, so that

$$\frac{\partial V(p,q^*,m)}{\partial q^*} e - \frac{\partial V(p,q^*,m)}{\partial m} t \geq 0 \,. \tag{7}$$

$\partial V(p,q^*,m)/\partial m$ can be defined as the marginal utility of money, and $\partial V(p,q^*,m)/\partial q^*$ can be defined as the marginal utility of environmental quality for the respondent. We can assume $\partial V(p,q^*,m)/\partial m > 0$ and can rewrite equation (7):

$$t \leq \frac{\partial V(p,q^*,m)/\partial q^*}{\partial V(p,q^*,m)/\partial m} e \tag{8}$$

It happens that the willingness to pay (WTP) for improving environmental quality by e is the maximum value of t. Therefore, the WTP can be given as,

$$WTP = Max.t = \frac{\partial V(p,q^*,m)/\partial q^*}{\partial V(p,q^*,m)/\partial m} e \tag{9}$$

Equation (9) indicates that WTP may be zero for some person when her marginal utility of environmental quality $\partial V(p,q^*,m)/\partial q^*$ is zero, or when the marginal utility of money $\partial V(p,q^*,m)/\partial m$ tends to infinity. We can give the following proposition.

Proposition 1: *Those who have a zero marginal utility of environmental quality implying that they do not care about environmental quality, or those who have very large* *marginal utility of money implying that they are relatively very poor, would bid a zero WTP, which are valid zeros.*

Thus the second hurdle for observing a positive WTP is whether the respondent has a zero marginal utility of environmental quality or a relatively very large marginal utility of money.

Leaving aside the valid zero responses, we can take the logarithm of both sides of equation (9) for all positive WTPs:

$$\ln WTP = \ln \frac{\partial V(p, q^*, m)}{\partial q^*} - \ln \frac{\partial V(p, q^*, m)}{\partial m} + \ln e . \tag{10}$$

Furthermore, suppose the indirect utility function $V(p, q^*, m)$ has a constant-elasticity-of–substitution (CES) form, that is

$$V = (q^{*\rho} + m^{\rho})^{1/\rho}, \rho \leq 1, \tag{11}$$

where ρ is a constant. Substituting equation (11) into equation (10), we have the following equation for the observed WTP that can be estimated:

$$\ln WTP = (\rho - 1)\ln q^* + \ln e + (1 - \rho)\ln m \ . \tag{12}$$

Suppose current environmental quality q^* and the anticipated improvement in environmental quality e are both given. Let $\alpha^* \equiv (\rho - 1)\ln q^* + \ln e$, with α^* then being a constant. Rewriting equation (12), we have the econometric model which can estimate the relationship between WTP and income:

$$\ln WTP = \alpha^* + \beta^* \ln m , \tag{13}$$

where $\beta^* = 1 - \rho$. In the CES function, the elasticity of substitution between environmental quality and money is $\sigma = \dfrac{1}{1-\rho}$, so that we can calculate the substitution elasticity $\sigma = \dfrac{1}{\beta^*}$ from equation (13).

Proposition 2: *If the utility function for the consumer is of the CES form, the income (expenditure) elasticity of WTP is the inverse of the substitution elasticity between environmental quality and money.*

Surprisingly, the elasticity of WTP with respect to expenditure (income) has not been well discussed in the literature, except for a study for Bulgaria by Wang and Whittington (2000), in which the estimated income elasticity of WTP for air quality is 0.27.

- **Positive but Unknown WTP**

When using equation (13) in practice, the difficulty of unknown positive WTPs arises, because some respondents may have limited information about their own WTP. They may know they have a positive WTP, but they cannot give a specific number due to the ambiguity of open-ended bidding.

If we simply drop these missing responses as some of the current literature does, it may cause sample selection bias. Hence, before using equation (13), a third hurdle for the missing responses should be added. The current literature does not pay much attention to these responses but they are a valid response to the WTP question.

From the above analysis, as illustrated in Figure 2-1, we find that there are three hurdles before the final hurdle of a positive WTP can be observed. In the next section, a four-hurdle econometric model is developed for analyzing the willingness to pay for blue skies in Beijing.

[Insert Figure 2-1]

2.3 Econometric Model

Following the aforementioned theory, a four-hurdle econometric model involving socioeconomic and demographic variables can be developed.

- **Zero-Protest Equation**

$$h_{1i} = 1\{W_{1i} = x_{1i}\beta_1 + v_{1i} \geq 0\}, \tag{14}$$

where $W_{1i} = x_{1i}\beta_1 + v_{1i}$ is a random utility function determining the choice of zero-protesting behavior for respondent i. x_{1_i} is a vector of observed independent variables and β_1 is a vector of corresponding coefficients. v_{1_i} is the error term with a standard normal distribution $N(0,1)$. When $W_{1i} > 0$, $h_{1_i} = 1$, indicating that the respondent decides not to protest and participates in the bidding; otherwise she has a protest zero.

- **Valid Zero-Bidding Equation**

$$h_{2i} = 1\{W_{2i} = x_{2i}\beta_2 + v_{2i} \geq 0, h_{1_i} = 1\}, \tag{15}$$

where $W_{2i} = x_{2i}\beta_2 + v_{2i}$ is a random utility function determining the choice of valid zero-bidding behavior for respondent i conditional on $h_{1i} = 1$, which indicates that all the respondents facing the second hurdle should pass the first hurdle. x_{2_i} is a vector of observed independent variables and β_2 is a vector of corresponding coefficients. v_{2_i} is the error term with a standard normal distribution $N(0,1)$. When $W_{2i} > 0$, $h_{2_i} = 1$, indicating that the WTP for the respondent is positive; otherwise, her WTP is a valid zero.

- **Positive but Unknown WTP**

$$h_{3_i} = 1\{W_{3i} = x_{3i}\beta_3 + v_{3_i} \geq 0, h_{2_i} = 1\}, \tag{16}$$

where $W_3 = x_{3_i}\beta_3 + v_{3_i}$ is a random utility function determining if the respondent i can give a specific WTP after she passes the second hurdle and knows she has a positive WTP. x_{3_i} is a vector of observed independent variables and β_3 is a vector of corresponding coefficients . v_{3i} is the error term with a standard normal distribution $N(0,1)$. When $W_3 > 0$, $h_{3_i} = 1$, indicating that the respondent can give a specific figure for her WTP. Otherwise, she only has limited information about her WTP; she knows that her WTP is greater than zero but cannot give a specific number.

- **Willingness-to-Pay Equation**

$$\ln t_i = \alpha^* + \beta^* \ln m_i + z_i\gamma + v_{4i}; \text{ if } h_{3i} = 1, \tag{17}$$

where z_i is a vector of the demographic variables except for income or expenditure. Equation (17) determines the WTP for respondent i who can give a specific positive number for her WTP. v_{4i} is an error term with a distribution $N(0,\sigma^2)$.

Obviously, equations (14), (15), (16) and (17) constitute a very complicated system which combines sequential binary choices and sample selectivity. If there are no restrictions on the coefficients and error terms, the model cannot be identified (Jones 1989, Waelbroeck 2005).

We assume that v_{ki} is only correlated with the error $v_{k-1,i}$ in the previous hurdle, $k = 2,3,4$, but not others. That is, v_{4i} is only correlated with v_{3i}; v_{3i} is only correlated with v_{2i}; and v_{2i} is only correlated with v_{1i}. Such an assumption implies that each hurdle is only conditional on the last hurdle, but cannot be affected by the next hurdle. This assumption seems to be a reasonable way of identifying the model.

With this assumption, the four-hurdle model reduces to three sample selection problems: two Probit models with sample selection which are equations (14) and (15), and equations (15) and (16), and one ordinary linear equation subject to sample selection, which is equations (16) and (17).

- **Probit Models with Sample Selection**

Probit models with sample selection have been used in the study of the choice of deductibles in insurance (van de Ven and van Praag 1981), loan defaults (Boyes, Hoffman and Low 1989, Greene, 1992), health status selection and health behavior (Mcquestion 2000), and the study of consumer adoption of computer banking technology (Lee, Lee and Eastwood, 2003). Except for van de Van and van Praag (1981), which used the Heckman two step estimation procedure, all models were estimated by maximum likelihood methods because they are more efficient (Greene 2008). However, using maximum likelihood method may give two estimators for hurdle 2 and hurdle 3, because maximum likelihood methods fits the hurdle with the last hurdle and the next hurdle, which violates our assumption that each hurdle is only conditional on the last hurdle.

Following van de Ven and van Praag (1981), we suggest a recursive method to estimate the system of equations. After estimating equation (14) by ordinary maximum likelihood methods, we have

$$E(W_{2i} \mid x_{2i}, W_{1i} \geq 0) = x_{2i}\beta_2 + E(v_{2i} \mid x_{2i}, W_{1i} \geq 0) \tag{18}$$

Assuming that the correlation coefficient between v_{1i} and v_{2i} is ρ_{12}, we have

$$E(v_{2i} \mid x_{2i}, W_{1i} \geq 0) = \rho_{12}\lambda_{1i}$$

where $\lambda_{1i} = \dfrac{\phi(-x_{1i}\beta_1)}{\Phi(x_{1i}\beta_1)}$, and $\phi(*)$ and $\Phi(*)$ are the standard normal pdf and cdf, respectively. By Heckman(1979),

$$W_{2i} = x_{2i}\beta_2 + \rho_{12}\lambda_{1i} + \tilde{v}_{2i} \tag{19}$$

where

$$E(\tilde{v}_{2i} \mid W_{1i} \geq 0) = 0 \text{ and } E(\tilde{v}_{2i}^{\,2} \mid W_{1i} \geq 0) = \tau_{1i}^{\,2}$$

with

$$\tau_{1i}^{\,2} = 1 - \rho_{12}^{\,2}\lambda_{1i}[(x_{1i}\beta_1) + \lambda_{1i}]. \tag{20}$$

Let $\hat{v}_{2i} = \tilde{v}_{2i} / \tau_{1i}$. If both sides of equation (19) are divided by τ_{1i}, for $\tau_{1i} > 0$, equation (15) becomes

$$h_{2i} = 0 \quad \text{if } W_{2i}/\tau_{1i} = (x_{2i}/\tau_{1i})\beta_2 + \rho_{12}(\lambda_{1i}/\tau_{1i}) + \hat{v}_{2i} < 0 \tag{21}$$

$$h_{2i} = 1 \quad \text{if } W_{2i}/\tau_{1i} = (x_{2i}/\tau_{1i})\beta_2 + \rho_{12}(\lambda_{1i}/\tau_{1i}) + \hat{v}_{2i} \geq 0$$

with $E(\hat{v}_{2i}) = 0$ and $E(\hat{v}_{2i}^{\,2} \mid h_{1i} = 1) = 1$.

We can replace λ_{1i} and τ_{1i} with consistent estimates $\hat{\lambda}_{1i}$ and $\hat{\tau}_{1i}$. $\hat{\lambda}_{1i}$ and $\hat{\tau}_{1i}$ can be estimated based on the Probit model of equation (14) and a consistent OLS estimate ρ_{12} from the linear probability function for equation (19), because the OLS estimate of the linear probability function is consistent. However, the disadvantages of OLS are (1) the predicted probabilities may fall out of the interval [0, 1] and (2) inefficiency due to heteroscedasticity (van de Ven and van Praag 1981). Also, a robust estimator $\tilde{\tilde{\rho}}_{12}$ can be obtained by iteratively substituting the consistent estimator $\widehat{\rho}_{12}$ in equation (20) until it converges to $\tilde{\tilde{\rho}}_{12}$.

In equation (21), we can test $\rho_{12} = 0$ by looking at the t-ratio. If $\rho_{12} = 0$ cannot be rejected, which indicates the hypothesis of non-correlation between the error terms in the two equations cannot be rejected, we can estimate both equations independently, which can yield computational advantages.

We can repeat the above procedure to consistently estimate equation (16) following the estimation of equation (15). However, note that equation (17) is a linear equation, so that we can use the usual two-step procedure suggested by Heckman(1979), after estimating equation (16).

2.4 Willingness to Pay

Another important issue in the current literature is calculating the mean or the median of the values of willingness to pay, which has important policy implications. As aforementioned, if the hypothesis of independence between v_{4i} and v_{3i} cannot be rejected, we can simply drop the samples of positive but unknown WTPs to estimate WTP, because positive but unknown WTPs can be viewed as randomly drawn from the samples with positive WTPs. However, if we reject the hypothesis of independence between v_{4i} and v_{3i}, those positive but unknown WTPs cannot be ignored in estimating WTP; otherwise, sample selection bias will occur, as analyzed above. When the independence between v_{4i} and v_{3i} can be rejected, we propose an approach to calculate the mean and the median of the WTPs as follows.

Following Heckman (1979), the expected value of WTP with the problem of sample selectivity can be given as

$$
\begin{aligned}
E[\ln t_i \mid h_{3i} = 1] &= E[\ln t_i \mid x_{3i}\beta_3 + v_{3i} \geq 0] \\
&= E[\ln t_i \mid v_{3i} \geq -x_{3i}\beta_3] \\
&= \alpha^* + \beta^* \ln m_i + z_i\gamma + E[v_{4i} \mid v_{3i} \geq -x_{3i}\beta_3] \\
&= \alpha^* + \beta^* \ln m_i + z_i\gamma + \rho_{34}\sigma\lambda_{3i} \\
&= \alpha^* + \beta^* \ln m_i + z_i\gamma + \eta\lambda_{3i} \qquad (22)
\end{aligned}
$$

where $\lambda_{3i} = \dfrac{\phi(x_{3i}\beta_3)}{\Phi(x_{3i}\beta_3)}$, $\eta = \rho_{34}\sigma$, and ρ_{34} is the correlation coefficient between v_{3i} and v_{4i}. After estimating equation (16) and (17) by the Heckman two-step procedure, we obtain the estimators $\hat{\alpha}^*$, $\hat{\beta}^*$, $\hat{\gamma}$, and $\hat{\eta}$ for α^*, β^*, γ, η, as well as $\hat{\lambda}_i$ by equation (16), and then we can calculate the expected value of the dependent variable $\ln t_i$ where that value is expected to be unobserved, $E(\ln t_i \mid h_{3i} = 0)$, conditional on the dependent variable being observed by equation (22). In this way we can derive predicted values for all positive WTPs, whether observed or unobserved.

$$
\ln \hat{t}_i \equiv E(\ln t_i \mid h_{2i} = 1) = \hat{\alpha}^* + \hat{\beta}^* \ln m_i + z_i \hat{\gamma} + \hat{\eta}\, \hat{\lambda}_{3i} \qquad (23)
$$

where $\hat{t}_i$ is the predicted value of every positive WTP. In other words, we can find the missing WTP $\tilde{t}_i$ for those positive but unknown WTPs through equation (23). Then it is easy to give the mean or the median of the predicted WTPs, after including valid zeros. In the next section, this model will be used for analyzing the WTP for blue skies in Beijing City.

Note that the predicted values for valid zero WTPs for the four-hurdle model are still zeros, which is different from Tobit model. The expected values of latent variables for valid zero WTPs in Tobit model may be greater than zero. As the result, the mean and the median of the predicted WTPs for the Tobit model will in general be greater than those in the four-hurdle model.

It is possible that some respondents with valid zero WTPs may have small positive WTPs very close to zero, but they round off their answer to zero. If the real censoring threshold is not zero, the standard Tobit model is not consistent, while Heckman two-step regression is still consistent (Carson 1988, Carson and Sun 2007). In this study, the smallest positive WTP for blue skies in Beijing is 10 *yuan.*

2.5 Data and Estimation Results

The survey of willingness to pay for improving the air quality in Beijing was conducted in March of 2006, by Professor Yinchu Zeng and his students at the School of Agricultural Economics and Rural Development at Renmin University of China, for assessing the environmental benefits of the Duststorm Sources Control Project. They randomly selected 3200 telephone numbers in Beijing. In order to obtain a high response rate, they called in the evenings and on weekends. Except for invalid phone numbers (non-resident numbers and unanswered calls), they obtained 464 numbers for residents, of which 404 respondents answered the survey. All respondents had to be older than 18 years old, and had to have lived in Beijing for at least 3 years. The latter requirement was imposed in order to ensure familiarity on the part of the respondent with dust storms in Beijing.

Descriptions of the variables and descriptive statistics for all respondents and for the 189 respondents with positive and known WTP bids are reported in Table 2-1.

As mentioned earlier, there are three scenarios for the 215 zero and missing responses. There are 78 respondents who know they have a positive WTP but cannot give a specific number. The rest of the 111 respondents gave a zero WTP, which can be divided into protest zeros and valid zeros based on another question on the survey asking the reasons for their WTP bid.

[Insert Table 2-1 and Table 2-2]

As shown in Table 2-2, there are 74 samples which can be viewed as protest zeros. Their reasons for protest zeros include: (1) the government or polluters rather than individuals should be responsible for improving environmental quality; (2) it is not transparent as to how the government will use the money we pay; (3) environmental quality cannot be improved through any project; and (4) do not know how to answer the question. In particular, 64 respondents think that the government rather than individuals should pay for improving air quality in Beijing.

Fifty-five respondents who bid zero cited economic reasons, and one bid zero because he did not care about environmental quality. These 56 samples can be viewed as valid zeros. However, some zero bids have multiple reasons, as shown in Table 2-2. We assume the reasons for protest zeros dominate the respondents' behavior, so that respondents with overlapping reasons between valid zeros and protest zeros are classified as protest zeros in this study. Therefore, only 37 WTPs are valid zeros in this study.

Embedding the different scenarios involving zero responses into the four-hurdle model, we report the estimation results both with and without error correlations in Table 2-3. A robust estimation is also reported for comparison. There are no big differences between robust estimators and non-robust estimators. It implies that the hurdle model with error correlation converges well. The corresponding means and medians of the predicted WTPs are reported in Table 2-4[8].

[Insert Table 2-3 and Table 2-4]

[8] The Predicted medians and means of WTPs for the four-hurdle model are based on the non-robust estimation. However, there are no big differences between the robust and non-robust estimations.

Lin and Schmidt (1984) compared the double-hurdle model and the Tobit model, and find that the estimation results for the Tobit model may mix the different effects for different hurdles that are separated out in the double-hurdle model. For comparison purposes, we also report the estimation results for two Tobit models in Table 2-5. We have to drop the positive but unknown WTPs in the Tobit models. The censored part of Tobit model 1 includes protest zeros and valid zeros. And the censored part of Tobit model 2 only includes valid zeros. The corresponding mean and median values of predicted WTPs are reported in Table 2-6.

[Insert Table 2-5 and Table 2-6]

2.6 Discussion

- **Model Comparison**

As Table 2-3 shows, none of the estimated coefficients for λ in hurdle 2, hurdle 3 and hurdle 4 are statistically significant, which indicates that the null hypothesis of no correlation between error terms cannot be rejected. The differences in the estimation results for the two models are also not significant, except for the coefficient on age in the equation of valid-zero-bidding behavior, the coefficient on family size and the coefficient on the logarithm of monthly expenditure in the WTP equation. The coefficient on age in the equation for valid zeros and the coefficient on family size in the WTP equation are statistically significant in the non-error-correlation model but not in the error-correlation model. While the coefficient for logarithm of monthly expenditure in the WTP equation is marginally significant (10%) in the error-correlation model, it is not significant in the non-error-correlation model.

Economic theory predicts that expenditure (income) should have a significant influence on WTP. Therefore, the following discussion is based on the results of the error-correlation model.

- **Zero-Protest Equation**

The estimated coefficients on gender, student status and the logarithm of expenditure in the zero-protest equation are statistically significant. This indicates that these three variables are important for protest behavior. The estimated coefficient on gender is -0.265, which indicates that probability of zero-protest bids for males is higher than that for females. The coefficient of student is 0.917, which indicates that the probability of zero-protest bids by students is lower than that of other respondents, controlling for other variables. Furthermore, the negative sign of the coefficient of the logarithm of expenditure indicates that rich people are more likely to protest.

- **Valid Zero-Bidding Equation**

The coefficients for education, family size, family size squared, and employment status are statistically significant in the equation of valid zero-bidding behavior. The coefficient on education is 0.09, which implies that one additional year of education reduces the probability of a valid zero bid. The negative sign for the coefficient of family size and positive sign for family size squared indicates that the relation between probability of a non-zero bid and family size is U-shaped. As family size increases, the probability of a non-zero bid first decreases and then increases, with the turning point at about four (3.88) family members.

Economic theory predicts that poor people are more likely to bid zero. Therefore, it is reasonable that the estimated coefficient on unemployment is negative. Because the vast majority of unemployed respondents bid zero in this hurdle, only a few unemployed respondents could enter into the subsequent hurdles. Including the unemployment variable in these hurdles causes multicollinearity problems with the intercept, and so this variable was dropped from those hurdles.

- **Positive but Unknown WTPs**

Only the coefficient for ever having had environment-related work experience is statistically significant in this hurdle. It is -0.63, which indicates that the probability of indicating a positive but unknown WTP for those who ever have had environment-related work experience is higher than others controlling for other variables. A possible explanation is that those who have had environment-related work experience are more aware of their own knowledge limitations and more hesitant to indicate a specific number.

- **Willingness-to-Pay Equation**

In the fourth hurdle (willingness-to-pay), there are three coefficients that are statistically significant: age, family size squared and the logarithm of monthly expenditure. The negative sign of the estimated coefficient for age implies that as age increases, people are willing to pay less for air quality. The positive sign for the coefficient on family size squared implies that the WTP for air quality is also a U-shape, first decreasing in family size and then increasing. Small size households and large size households are willing to pay more for air quality. The turning point is about four-and-a-half (5.01) family members.

The coefficient for the logarithm of monthly expenditure is 0.20, and it is marginally significant. It indicates that the expenditure elasticity of WTP is 0.20, close to the estimated value of 0.27 in the case study of Bulgaria (Wang and Whittington 2000). Following Proposition 2, we can calculate the substitution elasticity between money and environmental quality as

$$\hat{\sigma} = \frac{1}{\hat{\beta}^*} = 4.95.$$

This is a relatively high elasticity of substitution, implying that respondents are readily willing to trade off environmental quality against income and vice versa.

- **Tobit Estimation Results**

Table 2-5 reports the estimation results for two Tobit models. The estimated coefficients for education, family size, family size squared and student status are statistically significant in Tobit model 1 in which the censored part includes protest zeros and valid zeros. The coefficients for age, education, family size, family size squared and logarithm of monthly expenditure are statistically significant in Tobit model 2 in which the censored part only includes valid zeros. The results indicate that Tobit model may mix different effects in different hurdles, consistent with the findings of Lin and Schmidt (1984). For instance, the coefficients on logarithm of monthly expenditure are significant in the zero-protesting equation and the willingness-to-pay equation, but with different signs. The coefficient on logarithm of monthly expenditure in Tobit model 2 is also statistically significant, but not in Tobit model 1. A possible explanation is that the Tobit model coefficient mixes the two effects: protest zeros and willingness to pay.

The estimated coefficient on student status is another example. This variable is important for zero protesting behavior but not for other hurdles, as shown in the four-hurdle model. Though the coefficient on student status in Tobit model 1 is also statistically significant, we do not know from the Tobit results if it is important for zero protesting, valid zero bidding, willingness to pay or all of the above.

Education is also an example. In the four-hurdle model, we know that education is important for valid zero bidding behavior, but not for willingness-to-pay. Even though the estimate coefficient for education in Tobit model 2 is statistically significant, we cannot separate out different effects for different hurdles.

- **Willingness to Pay for Blue Skies in Beijing**

Table 2-4 and Table 2-6 report the mean and the median of willingness to pay for blue skies in Beijing based on the four-hurdle models and the Tobit models, respectively.

The correct mean and median values of WTP can be calculated based on all valid samples in the four-hurdle error-correlation model. Though protest zeros are not included, the information from these respondents can be reflected in the WTP values. The mean and the median WTPs are 120.15 *yuan* and 129.39 *yuan*, respectively. The mean and the median are very close to each other, which indicates that the distribution of WTP values is more-or-less symmetric. They are also very close to those of the predicted values of the four-hurdle model without error correlation. Including the protest zeros, the mean and the median of WTPs for the model of error-correlation are 98.14 *yuan* and 120.60 *yuan*, respectively, which are slightly lower than those without protest zeros, as one would expect because more zeros are included in the calculation.

Table 2-6 reports the mean and the median for predicted WTPs of the Tobit model and for the raw data after dropping the positive but unknown WTPs. The mean and the median of WTPs for Tobit model 2 only including valid zeros are 185.31 *yuan* and 177.12 *yuan*, respectively. Those for Tobit model 1 including valid zeros and protest zeros are 175.22 *yuan* and 169.60 *yuan*, respectively. They are much higher than those of the four-hurdle model. The main reason is that the expected values of the latent variables in the Tobit model for zero observations are greater than zero.

The mean and the median of WTPs for the raw data only including valid zeros are 140.00 *yuan* and 100.00 *yuan*, respectively. Those including protest zeros and valid zeros are 105.47 *yuan* and 100.00 *yuan*, respectively. They are close to the results of the four-hurdle model, but the variances are much greater, because some people may give some abnormal bids since willingness to pay does not mean they will pay.

Using 120.15 *yuan* as the average household WTP, and considering that the per capita annual disposal income of Beijing was 19,978 *yuan*[9] in 2006 and the average household size

[9] Source: Beijing Government: http://www.beijing.gov.cn/zfzx/sjtj/tjgb/t723364.htm

for the whole sample is 3.31, we can calculate that the share of WTP for blue skies in disposable income is only about 0.18%. This is very low compared with the current literature. For instance, Wang and Whittington (2000) find that people in the city of Sofia in Bulgaria would pay 4.2% of their income for air quality improvements.

2.7 Conclusions

How to deal with zero and missing responses is a very difficult problem in the contingent valuation method with open-ended bidding. Based on microeconomic theory, this essay suggests a four-hurdle model in which the bidding behavior of the respondents is disaggregated into to four steps: (1) zero-protest bids; (2) bids that constitute valid zeros; (3) in cases where the respondent has a positive WTP, whether the respondent can indicate a specific number for WTP; and (4) the willingness-to-pay decision in cases where WTP is positive and known. Each step is conditional on the last step. The model is found to be superior to the Tobit model because (a) the Tobit model might be inconsistent if the real censoring point is not zero; (b) the Tobit model often mixes different effects in different hurdles; and (c) the predicted values of the latent variables for zero observations in Tobit model are in general greater than zero, which can make the mean and the median predicted WTPs much higher than in the four-hurdle model. The mean of predicted WTPs for the four-hurdle model is also superior to that from the raw data because the variance is smaller.

The four hurdle model is used for analyzing willingness to pay for blue skies in Beijing where pollution is known to be very serious. The main findings are summarized as follows:

(1) Males, non-students and wealthy individuals are more likely to protest.

(2) Lower educated and unemployed persons are more likely to bid valid zeros. And the relation between family size and the probability of non-zero-bidding behavior is U-shaped. Small-sized households and large-sized households are less likely to bid zero.

(3) Interestingly, those who have had environment-related work experience are less able to give a specific number for WTP even though they know they have a positive WTP. A possible explanation is that those who have had environment-related work experience "know what they don't know," that is they know they do not know their own specific value for air quality in Beijing.

(4) Older people are willing to pay less for improving air quality in Beijing; and the relation between family size and willingness-to-pay is a U-shaped. Small-sized households and large-sized households are likely to pay more for improving air quality in Beijing.

As microeconomic theory shows, if the utility function for a consumer is of the CES form, the expenditure (income) elasticity of WTP is the inverse of the substitution elasticity between environmental quality and money. The estimation results show that the expenditure elasticity of WTP is 0.20, and it is marginally significant; therefore, the substitution elasticity between environmental quality and money is about 4.95. This is a relatively high elasticity of substitution, implying that respondents are readily willing to trade off environmental quality against income and vice versa.

The mean and the median values of predicted willingness to pay for blue skies per household are, respectively, 120.15 *yuan* and 128.60 *yuan*. The per capita WTP for blue skies is less than 0.2% of the per capita annual disposal income in Beijing. Willingness to pay for blue skies is very low in Beijing.

Finally, it is worth mentioning that econometric models with different order for the four hurdles were also tried, though they do not fit the usual decision-making procedure. For instance, zero-protest bids and bids that constitute valid zeros were switched in above hurdle sequence, but the estimation results were not ideal. There were no significant terms in the last hurdle, and the robust estimation did not converge.

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Figure 2-1. Four-Hurdle Model of WTP

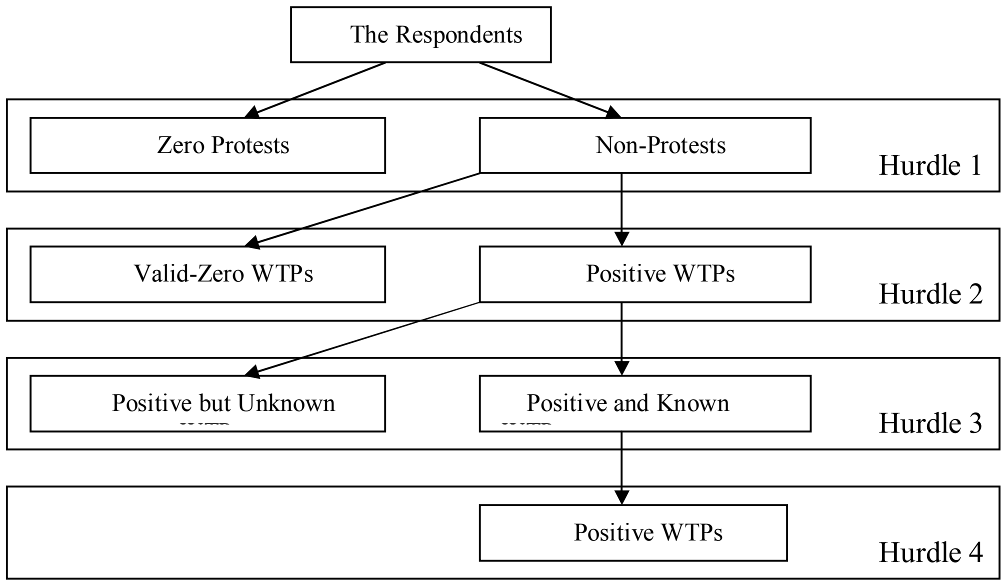

Table 2-1. Descriptive Statistics for the Survey in Beijing

		Whole Samples			Samples of Non-Zero Bidding		
		Mean	Min.	Max.	Mean	Min.	Max.
WTP	The Value of Willingness to Pay	78.317	0	1000	167.407	10	1000
Male	Sex: Female=0; Male=1;	0.507	0	1	0.524	0	1
Age	Age	42.072	18	85	41.603	18	80
EnvironJob	Ever have had environment-related job=1; others=0	0.22	0	1	0.169	0	1
Education	Educational Years	13.334	6	19	13.82	6	19
Family Size	Family size	3.312	1	10	3.402	1	10
Student	Student=1; others=0	0.099	0	1	0.111	0	1
Project-Cognition	Ever Heard Duststorm Sources Control: Project=1; others=0	0.371	0	1	0.392	0	1
Expenditure	Monthly Household Expenditure (yuan)*	2157.339	1106	5062	2209.016	1106	5062
Unemployment	Unemployed=1; others=0	0.082	0	1	0.037	0	1
Sample Size		404			189		

Note :*---- In the survey , the respondents are asked about the monthly expenditure range. In order to fit the theoretical framework, following the lognormal distribution hypothesis of income (Balintfy and Goodman 1973, Lin 2003), we assume household monthly expenditures are lognormal distributed and the data in this study fits it very well. Logarithm of the household monthly expenditure follows a normal distribution with mean 7.542 and standard deviation 0.539 . We use the expenditure at the middle-point of the cumulative distribution as the expenditure for the household falling into that range. That is 1106 for (~ 1500); 1694 for (1500 ~ 2000); 2259 for(2000 ~ 2500); 2877 for (2500~3000); 3327 for (3000~3500); 3745 for (3500~4000); 4069 for (4000~4500); and 5062 for (4500~).

Table 2-2. Reasons for Zero Responses

	Valid Zeros		Protest Zeros			
Reasons	Reason 1	Reason 2	Reason 3	Reason 4	Reason 5	Others
Samples	55	1	64	2	5	3
Percent (%)	50.47	0.93	60.75	1.87	4.67	2.80

Note. 1, Reason 1—Can not offer because of economic reasons;
Reason 2—Do not care about environmental quality.
Reason 3—Environment improvement is the government's duty, not personal.
Reason 4—Do not know how to answer.
Reason 5—It is not transparent for the government in using the money.
Others — One respondent thinks that polluter should pay for the pollution; two respondents do not believe any projects could improve the air quality in Beijing.
2, 111 samples answered the reasons for zero WTPs and some may have multiple reasons. For the overlapped respondents between valid zeros and protest zeros, we think they are protest zeros in the following analysis.

Table 2-3. Estimation Results for the Four-Hurdle Model

	hurdle1		Hurdle2						Hurdle 3						Hurdle 4					
	Probit		Probit		Sample Selection¥		Robust		Probit		Sample Selection¥		Robust		OLS		Sample Selection		Robust	
	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	T	Coef.	t
Lamda					0.306	0.08	0.309	0.08			-0.243	-0.33	-0.238	-0.33			-2.449	-0.85	-2.489	-0.85
Male	-0.265	-1.80*	0.234	1.11	0.203	0.48	0.199	0.47	0.181	1.15	0.169	1.05	0.169	1.05	-0.031	-0.32	-0.266	-0.89	-0.269	-0.89
Age	0.006	1.04	-0.015	-1.68*	-0.014	-1.39	-0.014	-1.37	0.002	0.35	0.003	0.44	0.002	0.43	-0.007	-2.18**	-0.009	-2.18**	-0.009	-2.18**
EnvironJob	0.141	0.77	0.184	0.72	0.200	0.60	0.205	0.62	-0.62	-3.43***	-0.631	-3.43***	-0.630	-3.42***	0.07	0.62	0.941	0.91	0.954	0.91
Education	0.036	1.27	0.086	2.12**	0.089	1.73*	0.090	1.75*	0.029	1.00	0.023	0.67	0.023	0.67	0.016	1.07	-0.022	-0.47	-0.022	-0.48
Family Size	-0.299	-1.38	-1.080	-2.04**	-1.113	-1.77*	-1.110	-1.77*	0.168	0.86	0.196	0.95	0.193	0.93	-0.23	-2.28**	-0.460	-1.57	-0.461	-1.57
(Family Size)^2	0.042	1.59	0.139	1.86*	0.144	1.62	0.143	1.62	-0.011	-0.47	-0.014	-0.60	-0.014	-0.59	0.031	2.99***	0.047	2.12**	0.046	2.12**
Student	0.917	2.47**	-0.157	-0.38	-0.077	-0.07	-0.076	-0.06	-0.196	-0.75	-0.197	-0.75	-0.196	-0.75	-0.012	-0.06	0.257	0.64	0.259	0.64
Project-Cognition	0.237	1.42	0.018	0.08	0.045	0.11	0.041	0.10	-0.042	-0.25	-0.047	-0.27	-0.046	-0.27	-0.068	-0.71	-0.014	-0.13	-0.014	-0.13
Ln(Expenditure)	-0.319	-1.85*	0.451	1.40	0.416	0.90	0.417	0.91	-0.018	-0.10	-0.045	-0.23	-0.044	-0.22	0.169	1.57	0.203	1.79*	0.202	1.78*
Unemployment	0.094	0.35	-0.865	-2.96***	-0.854	-2.59***	-0.853	-2.59***												
Intercept	3.037	2.26**	-0.683	-0.24	-0.546	-0.18	-0.574	-0.19	-0.287	-0.20	-0.015	-0.01	-0.021	-0.01	4.06	4.78***	6.268	2.29**	6.305	2.26**
(Pseudo)R2	0.035		0.206		0.206		0.206		0.044		0.044		0.044		0.107		0.110		0.110	
Samples	404		330						293						189					

Note:¥ the consistent estimator $\widehat{\rho}$ by OLS used in Hurdle 2 model and Hurdle 3 Model are -.02419and -.0933, respectively;

*, ** and *** indicate significant of 10%, 5% and 1%, respectively.

Table 2-4. Mean and Median Values of WTP with the Hurdle Model

		Hurdle Model (Error-Corr.)	OLS (Non-Error-Corr.)
Observed Positive Samples (189 Samples)	Mean	135.72	135.74
	(S.D.)	38.06	39.86
	Median	130.13	129.84
Positive WTP Samples (293 Samples)	Mean	135.32	135.47
	(S.D.)	34.01	34.87
	Median	133.07	131.50
Valid Bidding Samples (330 Samples)	**Mean**	**120.15**	**120.28**
	(S.D.)	**53.43**	**53.96**
	Median	**129.39**	**127.43**
All Samples (404 Samples)	Mean	98.14	98.25
	(S.D.)	67.05	67.43
	Median	120.60	120.10

Table 2-5. Estimation Results for Tobit Models (Dependent variables are WTPs)

	Tobit Model			
	Tobit 1		Tobit 2	
	Coef.	t-ratio	Coef.	t-ratio
Male	-8.925	-0.37	11.282	0.52
Age	-1.130	-1.36	-2.041	-2.72***
EnvironJob	-9.130	-0.29	-3.665	-0.13
Education	11.454	2.56***	9.753	2.43**
Family Size	-87.940	-2.78***	-72.067	-2.55***
$(\text{Family Size})^2$	12.507	3.40***	10.216	3.19***
Student	79.468	1.81*	10.450	0.27
Project-Cognition	-3.507	-0.14	-27.713	-1.17
Ln(Expenditure)	19.409	0.69	56.658	2.25**
Intercept	-62.622	-0.28	-232.464	-1.18
Pseudo R2	0.015		0.022	
Samples	300		226	

Note: *, ** and *** indicate significant of 10%, 5% and 1%, respectively.
Tobit 1: the censored part includes protest zeros and valid zeros;
Tobit 2: the censored part only includes valid zeros.

Table 2-6. Mean and Median Values of WTP with the Tobit Model and Raw Data

		Tobit	Raw Data
Observed Positive Samples (189 Samples)	Mean		167.41
	(S.D.)		151.55
	Median		120.00
Observed Positive Samples and valid zeros (226 Samples)	**Mean**	**185.31**	**140.00**
	(S.D.)	**53.40**	**151.80**
	Median	**177.12**	**100.00**
Observed Positive Samples, protest zeros and valid zeros (300 Samples)	Mean	175.22	105.47
	(S.D.)	40.14	144.90
	Median	169.60	100.00

Essay 3

Interactions between Cigarette and Alcohol Consumption in Rural China

3.1 Introduction

Cigarette and alcohol policies in China face a dilemma (Hu et al. 2006). A large number of studies have shown that cigarette consumption and excessive alcohol consumption are very harmful to health. Cigarettes account for more than 13% of male deaths in China (Liu et al. 1998; Lam et al. 2002). Excessive alcohol consumption has been linked to liver cancer, female choriocarcinoma mortality, increased admission rates to psychiatric hospitals, and traffic accidents in China (Hsing et al. 1991; Le and Xu 1992; Guo et al. 1994; Cochrane et al. 2003). Furthermore, addiction to cigarettes or alcohol can crowd out other household expenditures, having a negative impact on living standards, particularly for low-income households (Hu et al. 2005). Therefore, the Chinese government is trying to adopt policies to reduce alcohol and tobacco consumption, especially the consumption of cigarettes. As shown in Table 1, as per capita income has increased in rural China, the expenditure shares of both cigarettes and alcohol consumption have continuously decreased from 1994 to 2003. The expenditure share of cigarettes dropped from 2.51% in 1993 to 1.18% in 2003, and per capita consumption decreased from 24.6 packs to 21.6 packs though there are some fluctuations during this period. The expenditure share of alcohol decreased from 1.35% in 1994 to 0.97% in 2003; however, per capita consumption increased from 6.5 kg to 7.8 kg.

On the other hand, cigarettes and alcohol are important industries in China. This is particularly true for some less developed regions in China, such as Guizhou Province and Yunnan Province, where they are important income sources for farmers and major revenue sources for the government (Hu and Mao 2002; Hu et al. 2006). In 2004 China collected 210 billion Yuan of taxes from the cigarette industry[10], which represents nearly 8% of the Chinese government's total annual revenue.

A number of studies of the demand for alcohol (Wu 1999; Pan, Fang and Malaga 2006) and the demand for cigarettes (e.g. Hu and Tsai 2000; Lance et al. 2004; Bishop, Liu and Meng 2007) have been conducted for China. However, little attention has been paid to interdependencies between alcohol and cigarette consumption in China, with the exception of Fan, Wailes and Cramer (1995). The objective of this paper is to analyze the interactions between cigarette and alcohol consumption in rural China, using panel data for 10 years (1994-2003) for rural areas of 26 Chinese provinces. In China, most people (59.6% of the total population in 2003) still live in rural areas,[11] although urbanization is rapidly occurring.

The issue of interdependencies has important implications from both econometric and policy perspectives. From an econometric perspective, most existing empirical studies of cigarette demand for China exclude the price of alcohol, and vice versa. If there are interdependencies, the results from these studies are biased (Decker and Schwartz 2000).

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[10] Source: China Cigarette Corporation, http://www.cigarette.gov.cn//ycgk.php. Government revenue includes both local and central government revenues.

[11] Source: *China Statistical Yearbook 2005*.

From a policy perspective, taxes are often recommended as a tool to reduce alcohol and cigarette consumption. Becker and Murphy (1988), using a theory of rational addiction, suggest that taxes may be a very useful tool to reduce harmful addictions, and a number of empirical studies have found that alcohol and cigarette consumption are responsive to price (Levit and Coate 1982; Baltagi and Levin 1986; Chaloupka 1991; Levy et al. 2005; Baltagi and Geishecker 2006; Baltagi and Griffin 2001; Baltagi, Griffin and Xiong 2000; Bishop, Liu and Meng 2007). If cigarettes and alcohol are complements, taxing one will reduce the consumption of both and thus achieve a double public health dividend. However, if they are substitutes, taxing one will induce consumers to increase consumption of the other, offsetting the public health benefits of the tax.

Studies for countries other than China have yielded conflicting results about the relation between cigarettes and alcohol. Goel and Morey (1995) find that cigarettes and liquor are substitutes in consumption using panel data for US states from 1959-1982, while Jones (1989a) finds that cigarettes are a complement to all types of alcoholic beverages using aggregate quarterly expenditure data for the UK from 1964-1983. Decker and Schwartz (2000), using individual-level data for the US from 1985-1993, find an asymmetry in Marshallian cross-price elasticities of demand: higher alcohol prices decrease both alcohol consumption and smoking, while higher cigarette prices tend to decrease smoking but increasing drinking. Busch et al. (2004) reached the same conclusion using individual-level for the US from 1995-2001.

Medical and psychological research indicates that co-occurrence rates of alcohol and cigarette addiction are very high (Batel et al. 1995), which may be partly a result of genetic factors (Madden et al. 2000). In a study of light smokers, King and Epstein (2005) find that alcohol dose-dependency increases the urge to smoke.

With some exceptions (e.g. Goel and Morey 1995), studies to date of the interactions between cigarette and alcohol consumption do not consider the biological and psychological characteristics of addiction, such as dependence, reinforcement and tolerance, which imply that current consumption may be affected by past consumption. This paper constructs a dynamic model of consumption involving a theory of habit persistence in order to account for these factors.

3.2 A Habit Persistence Model

Studies of the demand for cigarettes or alcohol typically begin with a Marshallian demand function that depends on income, prices, and a vector of household characteristics. Advertising is sometimes also included in the demand function (e.g., Baltagi and Levin 1986; Nelson 2003), although we lack data on advertising and thus cannot include it here. For an addictive product such as alcohol or cigarettes, dependence, reinforcement and tolerance are also important factors. Dependence, also known as withdrawal effects, means that consumption of a drug takes precedence over consumption of other goods. Reinforcement means that current consumption of a good increases future consumption of that good, and tolerance means that there is a progressively decreasing response to consumption of a drug (Jones 1999; Thombs 2006).

Dependence, reinforcement and tolerance imply that current consumption of cigarettes and alcohol may depend on the past consumption path, suggesting a habit persistence model of consumption. Following the habit persistence model (Brown 1952; Nerlove 1983), per capita consumption of cigarettes or alcohol in province i of rural China at time t (Y_{it}) is assumed to be determined by past consumption:

$$\ln Y_{it} = \sum_{k=0}^{\infty} \rho_k f\left(P_{it-k}, PCI_{it-k,} Z_{it-k}\right), \tag{1}$$

where P_{it-k} is a vector of prices at time $t-k$, PCI_{it-k} is per capita income, Z_{it-k} is a vector of household characteristics, and the ρ_k are parameters reflecting the impact of the past consumption on current consumption. Suppose ρ_k is geometrically declining, i.e. $\rho_k = (1-\lambda)\lambda^k$, $0 < \lambda < 1$, where $k = 0, 1, 2, \ldots$. Then equation (1) can be rewritten as

$$\ln Y_{it} = \left(1-\lambda\right) \sum_{k=0}^{\infty} \lambda^k f\left(P_{it-k}, PCI_{it-k,} Z_{it-k}\right). \tag{2}$$

Taking a one-period lag of equation (2), multiplying that one-period lag by λ, and substituting the resulting expression into the right-hand side of equation (2) yields

$$\ln Y_{it} = \lambda \ln Y_{it-1} + (1-\lambda) f\left(P_{it}, PCI_{it,} Z_{it}\right), \tag{3}$$

which is a dynamic model of consumption that can be estimated.

Of the current studies on interdependencies between alcohol and cigarette consumption, only Goel and Morey (1995) use a dynamic equation.[12] Other studies do not employ a dynamic model, which for some studies that used individual-level survey data can be explained by the absence of a panel component in those surveys. Since this study uses provincial-level panel data for 26 provinces, a dynamic model is feasible.

In the Becker and Murphy (1988) model of rational addiction, current-period consumption depends on not only lagged consumption but also expected future consumption because rational addicts consider how much they are planning to consume in the future when making current consumption decisions. In our case we have panel data for 10 years (1994-2003). One of those years is used up by the lagged consumption term in equation (3) and another by the GMM estimation procedure we employ (Arellano and Bond 1991; Arellano and Bover 1995; Blundell and Bond 1998). Adding a future consumption variable would use up two additional years (one for the variable itself and one for the GMM estimation procedure), leaving our panel component rather short. We therefore do not include future consumption in the demand equation to be estimated.

[12] There have been studies of cigarette consumption alone (Baltagi and Griffin 2001; Baltagi, Griffin and Xiong 2000; Baltagi and Levin 1986) and studies of alcohol consumption alone (e.g. Baltagi and Geishecker 2006) that have used dynamic models.

3.3 Empirical Model and Data

The price vector P_{it} in the model to be estimated includes prices of cigarettes, alcohol, grains, and meat. The price of grains is included because grains are both an important income source and an important food source in rural China. The price of meat is included for similar reasons—the expenditure share of meat has increased in recent years and now is close to that of grains (Yu and Abler 2009). The vector of household characteristics Z_{it} in the empirical model includes average household size, house area (in square meters) per capita, average cropland area (in *mu*) per capita,[13] and the fraction of the adult population with more than a primary school education[14]. The empirical model also includes a time-trend variables to capture other factors that may be affecting cigarette and alcohol consumption over time.

The function $f\left(P_{it}, PCI_{it,} Z_{it}\right)$ is assumed to be linear in the logs of all its arguments:

$$f\left(P_{it}, PCI_{it,} Z_{it}\right) = \alpha^* + \sum_j \beta_j^* \ln P_{jit} + \eta^* \ln PCI_{it} + \sum_k \gamma_k^* \ln Z_{kit} + \sigma^* t\,, \qquad (4)$$

where . α^*, the β_j^*, η^*, the γ_k^*, and the σ^* are parameters.

Let $\alpha = (1-\lambda)\alpha^*$, $\beta_j = (1-\lambda)\beta_j^*$, $\eta = (1-\lambda)\eta^*$, $\gamma_k = (1-\lambda)\gamma_k^*$, and $\sigma = (1-\lambda)\sigma^*$. Substituting equation (4) into (3), and appending a term to reflect unobserved heterogeneity among provinces (v_i) as well as an error term (ε_{it}), yields the model to be estimated:

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[13] A *mu* is a traditional Chinese measure of land area, with 15 *mu* equal to one hectare.

[14] Someone suggested including a variable to reflect the age structure in each province. However, data on age structure for rural areas at the provincial level are available only once every ten years from the Census. Including this variable from the Census would not change the results because the first-order difference or subtraction of the mean would fully remove the effects of this variable.

$$\ln Y_{it} = \alpha + \lambda \ln Y_{it-1} + \sum_j \beta_j \ln P_{jit} + \eta \ln PCI_{it} + \sum_k \gamma_k \ln Z_{kit} + \sigma_1 t + v_i + \varepsilon_{it} . \quad (5)$$

The unobserved heterogeneity term is assumed to be fixed over time.

Clearly, the error term ε_{it} is correlated with $\ln Y_{it+1}$, $\ln Y_{it+2}$, etc. in equation (5). Therefore, a fixed-effects model, a random-effects model, and the maximum likelihood estimator usually applied to static panel data models are all inconsistent (Anderson and Hsiao 1981; Arellano and Bond 1991). Taking the first difference of equation (5), Anderson and Hsiao (1981) suggest a consistent estimator for this equation using $\Delta \ln Y_{it-2}$ ($= \ln Y_{it-2} - \ln Y_{it-3}$) as an instrumental variable for $\Delta \ln Y_{it-1}$. However, Arellano and Bond (1991) and Judson and Owen (1996) point out that the Anderson-Hsiao estimator is inefficient because it does not take into account all the available moment restrictions, and the performance is very poor when the sample size is small . Arellano and Bond (1991) suggest a GMM estimator which is more efficient because it uses additional instruments whose validity is based on the orthogonality between lagged values of Y_{it} and the error term ε_{it}. This method is further extended by Arellano and Bover (1995) and fully developed by Blundell and Bond (1998). Roodman (2006) provides a pedagogic instruction to the practice of linear GMM with STATA. GMM methods for dynamic panel data are used to estimate the econometric model in this study.

The panel dataset consists of data for 10 years (1994-2003) for rural areas of 26 Chinese provinces, with data being at the provincial level. Data are from the China National

Statistics Bureau (CNSB). The dataset begins in 1994 in order to avoid prior years in which prices were significantly distorted by government regulations. Even though China began food policy reforms in the late 1970s, price regulations were not abandoned until 1993 (Ma et al. 2004). A descriptive statistics of the data can be seen in Table 1.

Prices for 1994 are derived from *Rural Household Survey Statistics* (RHSS), a CNSB publication, dividing total expenditure in each group by the total quantity consumed. Starting with the 1994 unit values, we use the provincial consumer price indices (CPI) for cigarettes, alcohol, grains, and meat for 1995-2003 to compute prices for those years. CPIs are obtained from the *China Statistical Yearbook of Prices and Urban Household Survey* (various editions), published by CNSB. Data on the consumption of alcohol (measured in kilograms per capita, including spirits, beer and wine) and cigarettes (measured as packages per capita), as well as the household characteristic variables in equation (5), are from *Rural Household Survey Statistics* (various editions). *Rural Household Survey Statistics* covers 27 provinces, of which Tibet is excluded from our analyses because of missing data, leaving 26 provinces. Nominal values are converted to real terms using the provincial overall rural CPI, with all prices expressed in 1994 Yuan.

The optimal matrix of instruments in GMM estimation depends on whether the explanatory variables are predetermined or strictly exogenous. We assume that prices and per capita income are predetermined while the household characteristic variables (as well as a time trend) are strictly exogenous.

3.4 Results and Discussion

Table 2 reports the estimation results for cigarette and alcohol demand in rural China, using the fixed-effects model and the first-difference model. The results show that the first-difference model fits the data very poorly. Both the coefficients of lagged consumption for cigarettes and alcohol are negative in the first-difference model, which does not make sense. Though the fixed-effects model is not consistent for a dynamic panel dataset, the results can be used for comparison with GMM methods such as the Arellano-Bond (1991) and Arellano-Bover (1995) methods.

Using GMM, Table 3 shows the estimation results for cigarette and alcohol demand in rural China. We report the estimation results for both the Arellano-Bond method and the Arellano-Bover method. The Arellano-Bover method proposes an orthogonal deviations transformation, subtracting the mean of all available future observations, rather than first-order differences (subtracting the previous observation as in Arellano-Bond method). In this way the lagged observations of a variable do not enter the formula for the transformation; they remain orthogonal to the transformed errors and are valid as instruments (Arellano and Bover 1995). However, like differencing, taking orthogonal deviations still removes fixed effects.

The tests for over-identifying restrictions reject the null hypothesis of over-identifying restrictions for the one-step method for both the alcohol and cigarette equations in both the Arellano-Bond model and the Arellano-Bover model, but do not for the two-step method in the Arellano-Bover model. This implies that there is an identification problem for the one-step GMM methods.

The consistency of GMM estimators hinges heavily upon the assumption that $E[\varepsilon_{it}\varepsilon_{it-2}]=0$ rather than $E[\varepsilon_{it}\varepsilon_{it-1}]=0$ (Arellano and Bond 1991). The Arellano-Bond test of the null hypothesis of no second-order correlation cannot be rejected for any of the GMM models, which indicates that the estimators are consistent.

The over-identification tests cannot reject the null hypothesis of over-identifying restrictions for the two-step Arellano-Bover method; neither can the test of exogeneity of instrumental variables. Furthermore, the estimation results of the two-step Arellano-Bover method are consistent with that of the fixed-effects model. Therefore, the following discussion is based on these results. Arellano and Bond (1991) and Blundell and Bond (1998) point out that though the two step methods is asymptotically more efficient, the reported two-step standard errors tend to be severely downward biased. Windmeijer (2005) developed a finite-sample correction to the two-step covariance matrix, which makes the two-step method more efficient than the one-step method. Table 3 reports both the uncorrected t-ratios and the corrected t-ratios for the two-step Arellano-Bover method. The discussion here is based on the corrected t-ratios.

Dependence, Reinforcement and Tolerance

The lagged terms for both cigarettes and alcohol are statically significant and positive, implying that the effects of dependence, reinforcement and tolerance are important for both products. The coefficients for cigarettes and alcohol are 0.426 and 0.146, respectively. This implies that the consumption of cigarettes has stronger dependence, reinforcement and tolerance effects than alcohol, and current consumption of cigarettes has stronger impacts on future consumption of cigarettes than on alcohol consumption. .

Prices

The most interesting result of this study is that the demands for both alcohol and cigarettes are highly sensitive to the price of alcohol. The estimated own-price elasticity of demand for alcohol is about –1.53 in short run, substantially higher than the estimate of -0.34 in Fan, Wailes and Cramer (1995). Our estimated short-run cross-price elasticity of the demand for cigarettes with respect to the price of alcohol is about -0.62, which indicates that cigarettes are a Marshallian complement to alcohol. This is also substantially larger in absolute value than the estimate of -0.19 in Fan, Wailes and Cramer (1995). Our estimated long-run cross-price elasticity is approximately -1.08.

. Our results imply that taxes on alcohol may be a very effective tool for reducing consumption of both alcohol and cigarettes. Similar results can be found in Decker and Schwartz (2000) and Busch et al. (2004). A possible explanation based on the medical and psychological literature, as mentioned above, is that alcohol dose-dependency increases the urge to smoke, at least among light smokers (King and Epstein 2005).[15]

[15] To our knowledge similar research to King and Epstein (2005) has not been done for heavy smokers.

Interestingly, our results fail to show a statistically significant effect of the price of cigarettes on either cigarette consumption or alcohol consumption. The point estimate of the own-price elasticity of demand for cigarettes is positive and very small (about 0.09 in the short run and 0.16 in the long run). The policy implication is that an increase in cigarette taxes may not be effective in curbing cigarette or alcohol consumption in rural China, although it could be an efficient way of raising government revenue. Similar results concerning the impacts of prices of cigarettes and alcohol can be found in the fixed-effects model.

The estimated short-run cross-price elasticity of demand for alcohol with respect to the price of grains is about 0.64 and statistically significant. The estimated impact of grain prices on cigarette consumption is also positive, but it is not statistically significant. The results for alcohol consumption may be explained by the income effect of an increase in grain price: as grain prices increase, rural incomes increase and hence the demand for alcohol increases. The estimated short-run cross-price elasticities of demand for cigarettes and alcohol with respect to the price of meat are not statistically significant.

Income

The per capita income variable is not statistically significant for either cigarettes or alcohol. The point estimates of the income elasticities are 0.19 and 0.13, respectively. The results imply that demands for alcohol and cigarettes are not sensitive to income. This finding is consistent with some studies on cigarette consumption (Yen 2005; Bishop, Liu and Meng

2007) which argue that income may not play a significant role in the consumption of addictive products due to dependence effects.

Household Size, House Area, and Cropland Area

The estimated impact of average household size on the demand for cigarettes is negative and marginally significant, while the estimated impact on the demand for alcohol is not statistically significant. A possible explanation is that an increase in household size raises the pressure on smokers within the household to quit, because smoking often crowds out expenditures for other goods (Busch et al. 2004). Smoking can also have serious health effects on other members of the household through second-hand smoke, and the number exposed to second-hand smoke increases as household size increases.

House area and cropland area per capita do not have a statistically significant effect on the demand for alcohol. House area also is not statistically significant for cigarette consumption. Cropland area per capita has a negative and statistically significant impact on cigarette consumption, while the estimated impact on the demand for alcohol is not statistically significant. Mullahy and Sindelar (1993) suggest that addictive goods, such as alcohol, are complementary in consumption with leisure. As cropland area per capita increases, there is more farm work to do; hence leisure decreases and in turn the demand for cigarettes decreases.[16]

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[16] For this argument to be valid the market for hired farm labor must be limited in some way or hired labor must be an imperfect substitute for farm household labor in production. Otherwise a farm

Education

Another interesting result of this study is that education in rural China increases cigarette and alcohol consumption. The estimated impacts of an increase in the fraction of the population with more than primary education on consumption of these two goods are positive, and statistically significant for alcohol consumption. In the short run, an increase in this fraction by 1% increases alcohol consumption by about 1.84% .

Wu (1999) and Pan, Fang and Malaga (2006) also find that education is positively associated with consumption of alcoholic products in China, except for the demand for wine coolers (Pan, Fang and Malaga 2006). Hu and Tsai (2000) find that education is positively correlated with consumption of cigarettes.

In rural China, higher education is often associated with more social activities where cigarettes and alcohol are available and consumption is encouraged. Peer pressure (Flay et al. 1983) in these settings may induce more people to consume cigarettes and alcohol, and those already consuming to consume more. The policy implication for reducing the consumption of alcohol and cigarettes is to promote alternative, healthier lifestyles and other types of social activities that do not involve cigarettes or alcohol.

Studies for other countries suggest more ambiguous effects of education on cigarette and alcohol consumption. For the US, Grossman, Chaloupka and Sirtalan (1998) found that education has a positive impact on alcohol consumption. However, another study for the US

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household with more cropland would simply hire more labor to work that land. Because land in rural China is equally divided among peasants at the village level, hired labor is very rare.

by Decker and Schwartz (2000), and a study for Russia by Baltagi and Geishecker (2006), suggest that the relation between education and alcohol consumption might have an inverted U-shape: as education increases, alcohol consumption increases at first, and then decreases, with the peak typically occurring at a high school education level. Testing a U-shaped model for rural China is not really feasible because the percentage of the population in rural China with more than a high school education is still very low, only 1.1% in 2005.[17].

Studies for the UK (Jones 1989b) and US (Decker and Schwartz 2000; Yen 2005) suggest that education is negatively associated with the demand for cigarettes. A possible explanation in these countries is that education may increase the cognitive skill of an individual regarding the health risks of smoking to both the individual and others in the household through second-hand smoke.

Time Trend Variables

The time trend is statistically significant and negative for both cigarettes and alcohol consumption. in rural China. The estimated values of the coefficients are such that, other things equal, the demand for cigarettes and alcohol per capita continuously declined during 1994-2003 period.

[17] Source: *Rural Household Survey Statistics 2006*.

3.5 Conclusions

Using aggregate data for 26 provinces from 1994 to 2003 to estimate a habit persistence model of the demand for cigarettes and alcohol, this paper explored the interactions between cigarette and alcohol consumption in rural China. The main findings are that:

(1) The dependence, reinforcement and tolerance effects are statistically significant both for cigarette consumption and for alcohol consumption, with a stronger effect for cigarettes than alcohol.

(2) The demands for both cigarettes and alcohol are very sensitive to the price of alcohol, but not to the price of cigarettes or to income.

(3) The consumption of alcohol is positively associated with education. In rural China, higher education is often associated with more social activities where alcohol is consumed.

Our results imply that taxes on alcohol can have a double dividend—they may be a very effective tool for reducing consumption of both alcohol and cigarettes. On the other hand, an increase in cigarette taxes may not be effective in curbing cigarette or alcohol consumption in rural China, although it could be an efficient way of raising government revenue. Our results for education suggest the promotion of alternative, healthier lifestyles and other types of social activities that do not involve alcohol. Our results indicate that cigarettes are a Marshallian complement to alcohol, so that reducing alcohol consumption may also reduce consumption of cigarettes.

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Table 3-1. Per Capita Cigarette and Alcohol Consumption in Rural China (1994-2003)

Year	Net Disposable Income (Current Yuan)	Average Household Size (Persons)	House Area per Capita (m^2)	Cropland Area per Capita (mu)	Fraction of Population with > Primary Education (%)	Total Expenditure (Yuan)	Cigarettes				Alcohol			
							Consumption (Packs)	Average Price (Yuan/Pack)	Expenditure (Yuan)	Expenditure Share (%)	Consumptio n (Kg)	Average Price (Yuan/Kg)	Expenditure (Yuan)	Expenditure Share (%)
1994	1220.98	4.73	19.52	2.53	47.4	1016.81	24.60	1.04	25.51	2.51	6.53	2.10	13.74	1.35
1995	1577.74	4.65	20.32	2.54	48.9	1310.36	27.39	1.07	29.43	2.25	7.11	2.36	16.81	1.28
1996	1926.07	4.58	20.59	2.69	51.92	1572.08	25.00	1.13	28.37	1.80	7.13	2.51	17.89	1.14
1997	2090.13	4.52	21.34	2.42	53.42	1617.15	23.64	1.13	26.80	1.66	6.98	2.56	17.84	1.10
1998	2161.98	4.45	22.18	2.40	54.8	1590.33	23.09	1.12	25.94	1.63	6.98	2.53	17.68	1.11
1999	2210.34	4.40	22.96	2.42	56.18	1577.42	23.86	1.09	25.97	1.65	7.02	2.50	17.52	1.11
2000	2253.42	4.34	23.61	2.32	58.49	1670.13	23.28	1.06	24.71	1.48	7.10	2.47	17.52	1.05
2001	2366.40	4.29	24.33	2.33	59.77	1741.09	22.75	1.06	24.07	1.38	7.50	2.45	18.37	1.05
2002	2475.63	4.27	25.11	2.34	60.48	1834.31	22.10	1.06	23.43	1.28	7.70	2.43	18.73	1.02
2003	2622.20	4.23	26.18	2.30	61.38	1943.30	21.60	1.06	22.88	1.18	7.80	2.43	18.94	0.97

Source: *China Statistical Yearbook of Prices and Urban Household Survey* (Various Editions)

Table 3-2. Estimation Results I

	Fixed-Effects Model				First-Difference Model				First-Difference/SURE Model			
	ln(Cigarette Consumption)		ln(Alcohol Consumption)		ln(Cigarette Consumption)		ln(Alcohol Consumption)		ln(Cigarette Consumption)		ln(Alcohol Consumption)	
	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t
ln(Lagged Consumption)	0.215	3.45***	0.121	3.27***	-0.353	-6.63***	-0.055	-1.77*	-0.349	-6.99***	-0.028	-0.96
ln(Cigarette Price)	0.147	1.11	0.043	0.20	-0.105	-0.54	0.255	0.89	-0.105	-0.56	0.198	0.71
ln(Alcohol Price)	-0.743	-3.51***	-0.772	-2.36**	-1.401	-5.57***	-0.329	-0.91	-1.399	-5.72***	-0.308	-0.88
ln(Grain Price)	-0.022	-0.19	0.487	2.66***	-0.049	-0.43	0.266	1.61	-0.048	-0.44	0.298	1.86
ln(Meat Price)	-0.058	-0.47	0.130	0.65	-0.115	-0.95	0.149	0.84	-0.116	-0.98	0.119	0.69
ln(Per Capita Income)	-0.138	-1.07	0.272	1.31	0.347	2.50**	0.002	0.01	0.345	2.56	0.039	0.20
ln(Average Household Size)	-1.806	-3.83***	-1.542	-2.13**	-1.280	-2.22**	-0.075	-0.09	-1.280	-2.28	-0.160	-0.20
Ln(House Area per Capita)	-0.148	-1.44	0.026	0.15	-0.077	-0.70	0.218	1.31	-0.077	-0.71	0.177	1.10
ln(Cropland Area per Capita)	-0.177	-2.56***	0.035	0.33	-0.065	-1.05	0.003	0.03	-0.065	-1.08	0.007	0.08
ln(Fraction of Population with > Primary Education)	0.055	0.20	1.199	2.71***	0.429	1.60	1.140	2.91***	0.431	1.66*	1.216	3.19***
Time	-0.037	-3.87***	-0.022	-1.50	-0.079	-6.13***	-0.004	-0.24	-0.079	-6.29***	-0.007	-0.36
Intercept	7.490	5.50***	2.829	1.34								
Significance Test for the Model	F(11,197)=12.06***		F(11,197)=7.37***		F(10,197)=110.40***		F(10,197) =2.36**		Chi(10)=110.40***		Chi(10) =22.51**	

(1)*** Statistically significant at the 1% level; **Statistically significant at the 5% level; *Statistically significant at the 10% level
(2) In order to improve the efficiency of the First-Difference Model, the seemingly unrelated estimation (SURE) (Zellner 1962) is used.

Table 3-3. Estimation Results II

	ln(Cigarette Consumption)							ln(Alcohol Consumption)						
	Arellano-Bond One-step		Arellano-Bover One-Step		Arellano-Bover Two-Step			Arellano-Bond One-step		Arellano-Bover One-Step		Arellano-Bover Two-Step		
	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Corrected t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Coeff.	t-ratio	Corrected t-ratio
ln(Lagged Consumption)	0.207	2.45**	0.385	3.12***	0.426	8.13***	3.16***	0.054	1.16	0.148	2.74***	0.146	5.31***	1.82*
ln(Cigarette Price)	0.115	0.56	0.093	0.69	0.089	1.32	0.63	0.072	0.28	0.005	0.02	0.049	0.31	0.15
ln(Alcohol Price)	-1.366	-4.38***	-0.590	-2.55***	-0.619	-5.56***	-2.33**	-0.782	-2.29**	-0.728	-2.23**	-1.526	-4.20***	-1.94*
ln(Grain Price)	0.014	0.11	0.016	0.14	0.017	0.27	0.11	0.656	4.24***	0.510	2.81***	0.635	5.83***	3.02***
ln(Meat Price)	-0.159	-1.26	-0.063	-0.52	-0.068	-1.48	-0.65	0.081	0.53	0.095	0.47	-0.029	-0.36	-0.18
ln(Per Capita Income)	-0.008	-0.05	-0.182	-1.40	-0.188	-2.33**	-1.17	0.150	0.78	0.306	1.47	0.125	0.86	0.43
ln(Average Household Size)	-1.670	-2.44**	-1.531	-3.07***	-1.377	-4.80***	-1.93*	-0.473	-0.61	-1.551	-2.20**	-1.203	-2.88***	-1.28
Ln(House Area per Capita)	-0.150	-1.10	-0.139	-1.35	-0.088	-1.25	-0.56	0.018	0.10	-0.003	-0.02	0.161	1.46	0.57
ln(Cropland Area per Capita)	-0.088	-1.03	-0.157	-2.25**	-0.143	-4.51***	-1.96**	-0.105	-1.10	0.032	0.30	0.053	0.82	0.42
ln (Fraction of Population with > Primary Education)	0.086	0.25	0.175	0.61	0.269	1.83*	0.85	1.723	4.32***	1.246	2.86***	1.848	5.69***	2.46**
Time Trend	-0.046	-3.99***	-0.030	-2.94***	-0.032	-8.80***	-3.36***	-0.017	-1.22	-0.023	-1.62	-0.031	-4.29***	-2.23**
Test of Over-Identifying Restrictions														
	chi2(35) = 100.315***		chi2(14) = 44.40***		chi2(14) = 20.51			chi2(35) = 59.736***		chi2(14) = 25.20**		chi2(14) = 17.52		
Tests of Exogeneity of Instrument Subsets														
	-		chi2(10) = 31.65***		chi2(10) = 8.91			-		chi2(10) = 20.63**		chi2(10) = 13.46		
Test of First-Order Non-Autocorrelation among Residuals														
	Z=6.120***		Z=-5.270***		Z=-1.880*			Z=-1.941*		Z=-1.980**		Z=-2.200**		
Test of Second-Order Non-Autocorrelation among Residuals														
	Z=0.835		Z=1.350		Z=1.490			Z=-1.096		Z=-0.750		Z=-0.42		

(1) *** Statistically significant at the 1% level; **Statistically significant at the 5% level; *Statistically significant at the 10% level.
(2) Sargan test of Over-Identification is used for Arellano-Bond estimator, and the Hansen's test used for Arellano-Bover estimator. As the number of instruments increases, the Hansen's test is more robust.
(3) Correction of the variance for two-step estimation suggested by Windmeijer (2005).

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