Usefulness of Incomplete Demand Model in Censored Demand System Estimation [1]

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Abstract

The popularity of AIDS may not easily extend to censored demand systems. We propose an incomplete demand system that has relatively few restrictions on the parameter space, but preserves its theoretical consistency and apply this model to Indonesian data that have significant proportion of censored observations.

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1. Introduction

The increasing use of cross-section household survey data in applied demand analysis presents both opportunities and difficulties. On the one hand, the detailed information that a household survey provides opens opportunities for examination of impacts of demographic variables on consumption behavior. However, serious methodological challenges are presented by the many zero observations common in household survey data. Whereas, single-equation demand estimation is well established even with zero observations, development of its counterpart in a system of equations framework has been slowed down by the difficulty of evaluating multiple integrals in the likelihood function.

The bias in the parameter estimates resulting from the use of only positive consumption values when there are many zero observations is a common result. Several approaches have been used for dealing with the zero values. For example, in the past, zero consumption was avoided by employing a representative household as a unit of observation, with the expectation that averaging[2] would eliminate observations with zero consumption. Recently, two fundamental approaches have emerged for dealing with zero consumption in a system of equation. The first is an economic approach, which uses a Kuhn-Tucker model (Wales and Woodland [1983], Lee and and Pitt [1986]) that treats zero consumption as a corner solution of a consumer's utility maximization problem. The second is a statistical approach, which proceeds by assuming all interior solution but uses a truncated distribution for the random disturbance to correct for any zero consumption. With the difficulty of evaluating multiple integrals in the likelihood function, maximum likelihood estimation in the second approach is not widely used. Instead, a two-step

[2] For example, an average of a Primary Sampling Unit is used.

procedure is commonly used. Heien and Wessels (HW 1990) proposed a two-step procedure where the estimating model is augmented with a "Mills ratio" regressor to account for the bias in the estimates. HW used an augmented AIDS model. However, Shonkwiler and Yen (SY 1999) showed that the HW model lacks proper interaction of the censoring rule and the mean of the latent variable. Moreover, in a Monte Carlo experiment, SY reported tendencies of attenuation and inflation of parameters with the procedure suggested by HW. Su and Yen (Su-Y 2000) applied the SY approach in estimating a censored system of cigarette and alcohol consumption. In both SY and Su-Y a simple system of equations is used, without imposing any theoretical demand restrictions. In fact, it is an additional challenge to impose these theoretical demand restrictions in censored demand systems.

This paper approaches the issue of zero observation with a treatment regimen rather than a piece meal treatment approach. We start with the choice of a demand system specification. It turns out that many of the methodological challenges can be avoided at this stage. SY and Su-Y cannot provide any guidance since both did not use a theoretically consistent demand system.[3] It is no surprise that many demand applications use AIDS because of its flexibility, theoretical consistency, and ease in estimation. But the choice of AIDS, for example, by HW, presents methodological issues that can be avoided in other specifications without compromising its preferred properties. First, by construction, AIDS require imposing all theoretical demand restrictions in the parameter space of the model. In particular, both the adding-up restriction and singularity problem with expenditure shares as dependent variable require dropping one equation in the system. The parameters of the dropped equation are derived using the restrictions implied by the theoretical demand model. Second, the use of predicted prices to substitute prices in

[3] Moreover, Su-Y did not have price as an explanatory variable, removing the issue of treating zero prices in the demand system, and the need to impose the theoretical restrictions (e.g., symmetry).

observations with zero expenditure may induce multicollinearity with other prices and or to the group expenditure.

The treatment regimen we propose starts with choosing a theoretically consistent demand system with the least theoretical restrictions imposed on the parameter space. The best candidate is the LinQuad incomplete demand system. There are several advantages of LinQuad over AIDS in a censored system. Although both systems are integrable, thereby allowing welfare analysis, the similarity ends here. First, with LinQuad, homogeneity is imposed by using real prices and income in the model. The same can be done in AIDS but it is possible that the numeraire chosen for the deflator can be zero if the goods examined are highly disaggregated. Also, others have shown that the use of Stone Price Index can cause potential bias.[4] In contrast, the LinQuad, uses a deflator which is an aggregate price index for the products that are not of interest. Since this is a bigger set of products compared to the set of goods of interest, we can reasonably expect that the aggregate price index will be positive for all observations.[5]

Second, all equations are estimated in LinQuad since there is no need to impose adding-up because the total expenditure on the goods of interest is always lower than total income. Imposing adding-up is important in an AIDS because expenditure shares are in the dependent variable. Each share must be $0 \leq w_i \leq 1$ and $\sum w_i = 1$. Unlike AIDS which uses expenditure share as dependent variable, LinQuad can use quantity of consumption. Third, direct unconditional elasticities are estimated because total income is used as a regressor, making the elasticities directly useful for policy analysis as compared to unconditional elasticities from AIDS.[6] Also, the use of total income reduces the likelihood of encountering multicollinearity problems with prices compared to the use of total expenditure for the products of interest.

[4] SPI is also not invariant to scale (Moschini, 1995).
[5] Zero (or not) prices are often addressed first either by using a regression equation to estimate missing prices.
[6] Welfare measures can also be biased with the use of a conditional demand system.

The primary objective of this study is to estimate a theoretically consistent censored demand system using the LinQuad incomplete demand system. We then disaggregate the elasticity estimate into an elasticity from the structural demand equation and an elasticity from the probability of consumption equation.

2. Model

The model is developed in two steps. First, we specify the latent variables and censoring mechanism. Then we specify the structural component of the model using LinQuad. Following the representation used by SY and Su-Y, we model the zero consumption using latent variables with a selection mechanism in [1], i.e.,

[1] $$x_i^* = h(p,q,y) + \mu_i, \qquad d_i^* = z_i^{'}\lambda_i + \upsilon_i$$

$$d_i = \begin{cases} 1 & if \quad d_i^* > 0 \\ 0 & if \quad d_i^* \le 0 \end{cases}$$

$$x_i = d_i x_i^*$$

where x and d are observed values of the latent variables; p and q are prices, y is income, and z is a vector of regressors in the censoring equation that may include prices, income, and demographic variables; and μ and υ are error terms.

As derived by SY, the correct unconditional expected value of the system in [1] is

[2] $$x_i = \Phi h(p,q,y) + \kappa_i \phi + \varepsilon_i$$

where ϕ and Φ are the standard normal density and cumulative density function, and ε is an error term.

For this paper, the structural component of the model in [2] is specified as a LinQuad. Let x be a vector of goods of interest and o be a vector of the remaining commodities in the consumption bundle of a consumer with their respective prices given as p and q. The consumer's utility maximization problem is

[3]
$$\max_{x,o} \quad U = U(x,o)$$
$$s.t. \quad px + oq \leq y$$

where U is the utility function. The solution to [3] gives demand functions for the goods of interest of the form,

[4] $$x_i = h(p,q,y)\cdot$$

This demand function is well-behaved and has the following properties:

<u>Positive valued</u>

[5] $$x_i = h(p,q,y) \geq 0$$

<u>Homogeous of degree zero in prices and income</u>

[6] $$h(p,q,y) = h(tp,tq,ty) \quad \forall \quad t \geq 0$$

<u>Income greater than total expenditures of goods of interest</u>

[7] $$ph(p,q,y) \leq y$$

Also, the compensated substitution effects for the goods of interest are symmetric and negative semidefinite.

Integrability conditions for [4] give an expenditure function consistent with the LinQuad demand system in [4], i.e.,

[8] $$E(p,q,\theta) = p'\alpha + p'Ar + 0.5p'Bp + \delta(r) + \theta(q,u,r)e^{\gamma p}$$

where θ is the constant of integration, r is a vector of demographic variables, and α, γ, and B are conformable matrix of parameters. The specific Marshallian demand is derived from the expenditure function in [8] through Shephard's lemma and substituting income (y) for expenditure. The estimating demand equation is of the form,

[9] $$x_i = \alpha_i + A_i r + B_i p + \gamma_i (y - p'\alpha - p' Ar - 0.5 p' Bp)$$

Equation [9] is augmented with demographic variables to examine their impacts on consumption. Homogeneity is imposed by using real prices and income with $\pi(q)$ as the deflator; symmetry is imposed in the B matrix with each element $B_{ij}=B_{ji}$; and adding-up is always satisfied with property [7] of the incomplete demand system.

The standard Marshallian, income, and Hicksian elasticity formula for the LinQuad are:

[10] $$\varepsilon_{ij}^{s} = \left(\beta_{ij} - \gamma_i(\alpha_j + A_j z + B_j p\right)\frac{p_j}{x_i}$$

[11] $$\varepsilon_i^s = \gamma_i \frac{y}{x_i}$$

[12] $$\varepsilon_{ij}^{s*} = \varepsilon_{ij}^{s} + \varpi_j \varepsilon_i^{s}.$$

Standard elasticity estimates need to be adjusted to account for the influence of the selection mechanism. The HW and SY papers did not address this adjustment directly. HW simply reported elasticity estimates without any mention of how they were generated. One can only assume that the standard elasticity formulas were used. On the other hand, the SY paper focused primarily on the divergence of their parameter estimates with the HW model, not on elasticity estimates. Su-Y reports elasticity estimates without disaggregating their sources.

The adjusted formula of the elasticity of the expected value of quantity consumed with respect to price and expenditure are given in [13] and [14]. Accounting for the probability of consumption, the adjusted elasticity is of the form

[13] $$\varepsilon_{ij}^{a} = \Phi_i \varepsilon_{ij}^{s} + \frac{\phi_i \lambda_{ij} p_j}{x_i} \{x_i - \kappa_i (z\lambda)\}$$, and

[14] $$\varepsilon_{i}^{a} = \Phi_i \varepsilon_{i}^{s} + \frac{\phi_i \lambda_{iy} y}{x_i} \{x_i - \kappa_i (z\lambda)\}.$$

Unlike the neat decomposition in earlier studies (e.g., McDonald and Moffit), several terms do not vanish in our case because of the different functional form used in the unconditional mean (LinQuad) and the selection mechanism (linear). Nevertheless, the interpretation of the formula remains very intuitive. The formulae in [13] and [14] include parameters from the standard LinQuad model (γ_{ij}, β_I, A, and B), parameters from the selection mechanism (λ), and parameters corresponding to the additional regressor in the augmented LinQuad model (κ). The first term in the price elasticity is the standard elasticity formula conditional on $q>0$ and weighted by the probability of a positive consumption Φ (see equation [13]). The second term has two elements. The first element captures the change in the probability of a positive consumption weighted by the mean impact of price on probability. The second element is the change to the original probability density function weighted by the mean impact of price on probability. The first element on the second term enters in the elasticity formula as the weight of the conditional mean in deriving the unconditional mean. The second element enters in the elasticity formula through the adjustment of the expected value of x due to truncation. The same interpretation holds for the adjusted expenditure elasticity. It is clear to check that as the argument of the selection mechanism approaches infinity, that is, $\Phi \to 1$ and $\varphi \to 0$, then the elasticity formula collapses into the standard LinQuad elasticity formulae.

The part of the elasticity estimates that can be attributed to changes in probability of consumption is computed by taking the difference between the adjusted and standard elasticity estimates. The standard errors of the elasticity estimates can be derived using the delta method corrected to account for the two-step procedures used in estimation.

3. Empirical Results

The Bureau of Statistics in Indonesia (BPS) conducts a national socio-economic household survey (SUSENAS) every three years. This study uses the 1996 SUSENAS which had 60,674 households. Nine aggregate major commodities are considered, including cereals, tubers, fish, meat, eggs-milk, vegetables, pulses (legumes), fruits, and oils-fat. Table 1 shows the proportion of positive consumption, average consumption, prices (unit values), and expenditure share of each food group. The data display wide differences in the censoring of consumption of these food groups. Cereals, vegetables, and oils-fat had the highest proportion of positive consumption, approaching 100 percent of all the households in the survey. This is followed by fish with 87 percent positive consumption. Eggs-milk, pulses, and fruits have 76 percent positive consumption each. The food group with the lowest positive consumption reported is tuber at 51 percent and then meat at 43 percent. The level of consumption is estimated as the average of households with positive consumption. Cereals also had the highest level of consumption at 9.53 kilograms per person per month. This is followed by vegetables, fruits, and tubers at 2 to 3 kilograms. Fish consumption is 1.52 kilograms and pulses is 1.48. Eggs-milk and meat had the lowest level of per capita consumption at 1.29 and 1.04 kilograms, respectively. Tubers had the lowest price (rupiah per kilogram) followed by cereals. Meats, eggs-milk, and fish commanded the highest price. In terms of expenditure allocation, cereals accounted for 38 percent, followed by vegetables and fish at 13-14 percent. Tubers had the lowest share at 2 percent, followed by pulses at 5 percent. The share of meat, eggs-milk, fruit, and oils-fat were at 7 percent each.

All estimations were done in SAS version 8.2. The probability for a positive consumption was estimated using a probit model. Predicted values of the probability and cumulative density functions were then used in the second step to estimate the unconditional mean of consumption. All theoretical demand restrictions were imposed. Homogeneity was imposed by using relative prices in the estimation. Adding-up is satisfied by construction of the LinQuad model, and symmetry was imposed on the parameter space. Concavity was checked after estimation and the necessary condition for concavity, that is, negative eigenvalues of the price parameter matrix is met.

Table 2 shows that the own-price and income parameter estimates are all significant. Tables 3 to 5 give the price and income elasticities. It is shown that the Marshallian and Hicksian own-price elasticities have the correct negative sign and income elasticities have the correct positive signs. Table 3 shows that cereals consumption is no longer responsive to changes in income with the lowest elasticity of 0.021. The animal protein sources food groups (eggs-milk, meat, and fish) and fruits have the highest income elasticity. The decomposition of adjusted elasticity into standard and probability uncovers some differential responsiveness of the food groups to changes in income. Consumers' probability to consume is very responsive to changes in income in the case of fruits and eggs-milk, with their income elasticity increasing by 0.584 and 0.468, respectively. Also, a positive response in the probability to consume is shown by pulses, fish, and oils-fat. On the other hand, the probability to consume cereals and vegetables is not very responsive to changes in income. This may be the case because almost 100 percent of the household in the sample already report a positive consumption for both food groups. In the case of meat, it is shown that almost all the responsiveness of consumers to changes in income comes from consumers that are already consuming meat, and very small responsiveness on the probability of consuming meat. This behavior may be largely influenced by religious-cultural factors. A change in income has an inverse impact on consumer's probability to consume tubers.

4. Summary and Conclusion

The increasing use of cross-section household survey data in applied demand analysis presents both opportunities and difficulties. Although detailed analysis on impacts of demographic variables is now possible, the many zero observations common in household survey data present a serious methodological challenge especially for imposing theoretical demand restrictions in a censored demand systems model.

We use an incomplete demand system (LinQuad) that is theoretically consistent but requires less direct restrictions on the parameter space, which is difficult in a censored demand model. Nine food groups are constructed from the 1996 Indonesian national socio-economic household survey. A wide differential in censoring of consumption is displayed in this data. Three groups approach 100 percent positive consumption for the 60,674 households in the survey, and two food groups had very low (43 and 51 percent) proportion of positive consumption.

All theoretical demand restrictions were satisfied. Homogeneity was imposed by using relative prices in the estimation. Adding-up is satisfied by construction of the LinQuad model, and symmetry was imposed on the parameter space. Concavity was checked after estimation and the necessary condition for concavity, that is, negative eigenvalues of the price parameter matrix is met.

Most parameter estimates are significant. Marshallian and Hicksian own-price and income elasticities had the correct signs and reasonable magnitudes. The paper decomposed the responsiveness of consumers to changes in income into the standard response of the quantity demanded and response through changes in the probability of a positive consumption. Differential responsiveness was uncovered. With almost 100 percent of households having positive consumption, the responsiveness of cereals and vegetables was mostly through changes in quantity and very limited response on the probability of a positive consumption. On the other hand, fruits and eggs-milk showed the largest response in the probability of a positive consumption. Although, the response in quantity consumed was already high in meats, somewhat of a surprise is its lack of responsiveness on the probability of positive consumption. This may be driven by the fact that religious and cultural considerations play a major role in the meat consumption pattern of Indonesian consumers.

The problem of reported zero consumption or expenditure is made more evident when analysts have the opportunity to analyze demand decisions at the household level. One challenge, addressed in this paper, is how to meet the empirical difficulties and at the same time retain a model that is theoretically consistent. By using the incomplete demand system with the LinQuad method, we identify an approach that is theoretically consistent and can be used with relative computational ease. These desirable properties and the results in an application to a large household survey suggest a fruitful area for further research.

Table 1. Consumption, prices, and expenditure share in the 1996 SUSENAS

	Positive Use	**Consumption**	**Prices**	**Share**
	Percent	Kg per month	Rupiah per kg	Percent
Cereals	99.64	9.53	962	0.385
Tuber	51.32	2.13	574	0.021
Fish	87.33	1.52	3331	0.132
Meat	42.74	1.04	5857	0.065
Eggs and Milk	76.09	1.29	4094	0.071
Vegetable	98.98	3.28	1563	0.140
Pulses	75.86	1.48	1353	0.051
Fruits	75.93	2.78	1234	0.065
Oils and Fat	98.68	1.15	1737	0.071

Table 2. Parameter estimates 1996 SUSENAS

	Coefficient	Std **Error**
Cereals Equation		
Cereals Price	-2.21E-03	3.80E-05
Food Expenditure	3.34E-07	2.60E-08
Tubers Equation		
Tuber Price	-2.06E-03	3.60E-05
Food Expenditure	3.32E-07	5.01E-08
Fish Equation		
Fish Price	-1.40E-04	1.10E-06
Food Expenditure	4.08E-07	8.54E-09
Meat Equation		
Meat Price	-3.00E-05	2.35E-07
Food Expenditure	1.98E-07	3.55E-09
Eggs and Milk Equation		
Eggs and Milk Price	-5.83E-06	2.87E-07
Food Expenditure	2.52E-07	2.38E-08
Vegetable Equation		
Vegetable Price	-4.50E-04	1.51E-06
Food Expenditure	7.83E-07	1.36E-08
Pulses Equation		
Pulses Price	-2.90E-04	2.13E-06
Food Expenditure	1.81E-07	8.46E-09
Fruit Equation		
Fruits Price	-4.60E-04	9.99E-06
Food Expenditure	5.77E-07	1.76E-08
Oil Equation		
Fruits Price	-2.80E-04	1.99E-06
Food Expenditure	2.64E-07	5.09E-09

Table 3. Standard and adjusted expenditure elasticity SUSENAS 1996

	Standard	**Adjusted**	**Probability**
Cereals	0.021	0.021	0.000
Tubers	0.158	0.123	-0.035
Fish	0.170	0.239	0.069
Meat	0.283	0.285	0.002
Eggs and Milk	0.153	0.621	0.468
Vegetables	0.145	0.144	-0.001
Pulses	0.105	0.209	0.104
Fruits	0.168	0.752	0.584
Oils and Fat	0.142	0.150	0.008

Table 4. Marshallian elasticity SUSENAS 1996

	Cereals	Tubers	Fish	Meat	Egg	Vege	Pulses	Fruits	Oils
Cereals	**-0.43**	-0.02	0.01	0.01	0.00	-0.02	0.02	-0.02	0.02
Tubers	-0.32	**-1.58**	-0.01	-0.14	-0.01	-0.29	-0.03	-0.09	0.01
Fish	0.01	0.00	**-0.59**	-0.02	0.00	0.00	0.00	0.02	-0.01
Meat	0.01	-0.04	-0.03	**-0.77**	-0.01	-0.04	0.00	-0.01	-0.01
Egg	-0.01	0.00	0.00	-0.01	**-0.05**	-0.01	0.00	0.00	0.00
Veg	-0.04	-0.04	0.00	-0.02	-0.01	**-0.37**	0.01	-0.02	0.01
Pulses	0.12	-0.01	0.00	0.00	-0.01	0.02	**-0.75**	0.01	0.05
Fruits	-0.10	-0.03	0.04	-0.01	-0.01	-0.04	0.01	**-0.46**	0.02
Oils	0.11	0.00	-0.03	-0.01	-0.01	0.02	0.04	0.02	**-0.82**

Table 5. Hicksian elasticity SUSENAS 1996

	Cereals	Tubers	Fish	Meat	Egg	Vege	Pulses	Fruits	Oils
Cereals	**-0.42**	-0.02	0.01	0.01	0.00	-0.01	0.02	-0.02	0.03
Tubers	-0.26	**-1.58**	0.01	-0.13	0.01	-0.27	-0.02	-0.08	0.02
Fish	0.08	0.00	**-0.57**	-0.01	0.01	0.03	0.01	0.03	0.00
Meat	0.12	-0.04	0.00	**-0.76**	0.01	0.00	0.01	0.01	0.01
Egg	0.05	0.00	0.02	0.01	**-0.04**	0.02	0.01	0.01	0.01
Veg	0.02	-0.04	0.02	-0.01	0.00	**-0.35**	0.01	-0.01	0.02
Pulses	0.16	-0.01	0.01	0.01	0.00	0.04	**-0.74**	0.02	0.06
Fruits	-0.03	-0.03	0.06	0.00	0.01	-0.02	0.02	**-0.44**	0.03
Oils	0.16	0.01	-0.01	-0.01	0.01	0.04	0.04	0.03	**-0.81**

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