The Gap Between Macro and Micro Economic Statistics: Estimation of the Misreporting Model using Micro-data Sets Derived from the Consumer Expenditure Survey*

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Abstract

In many countries we observe a gap between macroeconomic and microeconomic statistics. In order to explain the underreporting observed in microeconomic statistics, the present paper tests the misreporting hypothesis through the double hurdle model. This model enables us to correct for over-reporting of zero expenditure households in the micro data. The data used for estimation involves thirteen clusters of consumer durables from the Consumer Expenditure Survey compiled by the Bureau of Labor Statistics. The empirical results are satisfactory in supporting the conclusion that misreporting plays an important role in the underreporting in microeconomic statistics compared with macroeconomic statistics.

JEL classification: C4, D1
Keywords: misreporting hypothesis, double hurdle model, underreporting

January 2004

*) We thank Hendrik Houthakker, Dale Jorgenson, Michael Smith, Murray Smith, Alan Woodland and the seminar participants at the University of Sydney for their comments and suggestions. The first author is grateful for the financial support of the Social Science Research Council's Abe Fellowship program in 2001.

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1. Introduction

In many countries there is a gap between macroeconomic and microeconomic statistics. The tendency of underestimation for microeconomic statistics compared with macroeconomic statistics is called underreporting. For example, aggregating data for commodities and services from microeconomic statistics such as family expenditure surveys tends to underestimate the value obtained for such categories of consumption based on macroeconomic data such as national income statistics. (1)

According to a seminal paper by Deaton and Irish (1984), the expenditure on alcoholic beverages or tobacco obtained from the micro-data reported in the *Family Expenditure Survey* in the U.K. is less than that reported in the macroeconomic statistics. Based on this finding, they proposed the misreporting hypothesis to explain the underreporting in microeconomic statistics. Based on the work of Deaton and Irish (1984), Maki and Nishiyama (1996) tested the validity of the misreporting hypothesis by focusing on consumer durables using Japanese data sets. Though the idea of the misreporting hypothesis is similar to Deaton and Irish (1984), Maki and Nishiyama (1996) replaced the p-tobit model proposed by Deaton and Irish (1984) with a p_i-tobit model that was originally proposed by Cragg (1971) who called it the double hurdle model. (2) The difference between the p-tobit and p_i-tobit models is that the latter assumes that the misreporting probability of each household is different according to household characteristics.

In this paper, the probability of underreporting and that of misreporting are estimated by using an econometric model for thirteen clusters of U.S. consumer durables. The misreporting hypothesis concerning consumer durables focuses on ‘zero expenditure

households' in the Survey. The misreporting hypothesis is based on some key assumptions; it is assumed that there are two categories of 'zero expenditure households' in the Survey - one category involves households that did not purchase consumer durables during the survey period and reported zero expenditure correctly on the Survey while the other category of 'zero expenditure households' involves households that, although they purchased consumer durables during the survey period, reported zero expenditure on the Survey. This is the source of misreporting. We also assume that there are 'positive expenditure households' for consumer durables in the Survey. These positive expenditure households for consumer durables are assumed, in the misreporting hypothesis, to have reported correctly their expenditures on consumer durables in the Survey.

Section 2 introduces the model used for this estimation. This analysis tests the misreporting hypothesis using the p_i-tobit model with the *1994 Consumer Expenditure Survey* (CE) in the U.S. compiled by the Bureau of Labor Statistics (BLS). There is a different definition of misreporting between the present model and the BLS. Section 3 explains the difference of the definition for misreporting between the present analysis and the BLS. Then, we explain the applicability of our misreporting hypothesis to the CE micro-data sets. This section also explains the data generating design for the estimations derived from the quarterly series of micro-data sets of CE and introduces the thirteen clusters of consumer durables used for the estimation.

Section 4 denotes the estimation method, reports the results of the empirical analysis and estimates the probability of underreporting and that of misreporting. Finally, section 5 presents some conclusions.

2. The model

The present econometric model called the p_i-tobit model is:

$$y_i^* = X_{1i}'\beta + u_i,\ u_i \sim N(0,\sigma^2) \quad (1)$$

$$z_i^* = X_{2i}'\gamma + v_i,\ v_i \sim N(0,1) \quad (2)$$

$$z_i = 1, \text{ if } z_i^* > 0$$

$$= 0, \text{ if } z_i^* \leq 0, \quad (3)$$

$$y_i = y_i^* \text{ if } y_i^* > 0 \text{ and } z_i = 1$$

$$= 0, \text{ otherwise.} \quad (4)$$

The error terms, u_i and v_i, are assumed to be independent from each other. The first equation in the model is a tobit-type demand function for consumer durables. The latent variable, y_i^*, in (1) is a function of socio-economic factors. The second equation in the model is a probit function to determine whether or not a household misreported an entry of expenditure for consumer durables. The latent variable, z_i^*, is assumed to be a function of household characteristics such as type of household, age and education. The probability of reporting zero expenditure is:

$$\Phi(-X_{1i}'\beta/\sigma) + \Phi(-X_{2i}'\gamma)\Phi(X_{1i}'\beta/\sigma). \quad (5)$$

The first term of (5) corresponds to the probability of the household that did not purchase consumer durables, and the second term corresponds to the probability of the household that purchased consumer durables, but did not report the amount on the Survey. The probability density of reporting positive expenditure is:

$$\Phi(X_{2i}'\gamma)\sigma^{-1}\varphi((y_i - X_{1i}'\beta)/\sigma). \quad (6)$$

The log-likelihood function of the p_i-tobit model is:

$$\ln L = \sum_0 \ln\{1 - \Phi(X_{2i}'\gamma)\Phi(X_{1i}'\beta/\sigma)\}$$

$$- n_+ \ln\sigma + \sum_+ \ln\Phi(X_{2i}'\gamma) + \sum_+ \ln\varphi\{(y_i - X_{1i}'\beta)/\sigma\}. \qquad (7)$$

When $\Phi(X_{2i}'\gamma) = p_i = p$, it is called the p-tobit model proposed by Deaton and Irish (1984), and when $p_i = p$, the p_i-tobit model proposed by Maki and Nishiyama (1996) is mathematically identical to the p-tobit model. In contrast to the assumption by Deaton and Irish (1984) that p is a constant derived from the estimation, Maki and Nishiyama (1996) assumed p_i is a variable specified by $\Phi(X_{2i}'\gamma)$. [(3)]

Here, we clarify the difference between underreporting and misreporting for a household derived from the model in the following two equations. The first denotes the probability of misreporting for a household and the second denotes the probability of underreporting for a household:

(a) Probability of misreporting for a household:

$$\text{Prob}^1 = \Pr(y_i^*>0,\ z_i^*\le 0) = \Phi(-X_{2i}'\gamma)\Phi(X_{1i}'\beta/\sigma). \qquad (8)$$

(b) Probability of underreporting for a household:

$$\text{Prob}^2 = (0\cdot\Pr(y_i^*\le 0) + 0\cdot\Pr(y_i^*>0, z_i^*\le 0)\ ) + x\Pr(y_i^*>0, z_i^*>0))$$

$$/(\ 0\cdot\Pr(y_i^*\le 0) + x\cdot\Pr(y_i^*>0))$$

$$= \Pr(y_i^*>0, z_i^*>0) / \Pr(y_i^*>0) = \Pr(z_i^*>0 \mid y_i^*>0)$$

$$= \Phi(X_{2i}'\gamma)\Phi(X_{1i}'\beta/\sigma)/\Phi(X_{1i}'\beta/\sigma) = \Phi(X_{2i}'\gamma) \qquad (9)$$

where x in the formula is the amount of expenditure.

In a subsequent section, we use the probability of underreporting across households and the underreporting rate in relation to the probability of misreporting across households. The definitions of the three concepts are as follows:

(1) Probability of underreporting across households as indicated in Table 6:

$$Prob^3=(1/n)\sum_i Pr(z_i^*>0 \mid y_i^*>0) = (1/n)\sum_i \Phi(X_{2i}'\gamma) \qquad (10)$$

(2) Underreporting rate (CE-PCE rate) as indicated in Table 7:

$Prob^4$: from external information by the Bureau of Labor Statistics

(3) Probability of misreporting across households as indicated in Table 8:

$$Prob^5 = (1/n)\sum_i Pr(y_i^*>0, z_i^*\leq 0) = (1/n)\sum_i \Phi(-X_{2i}'\gamma)\Phi(X_{1i}'\beta/\sigma). \qquad (11)$$

The gap between microeconomic and macroeconomic statistics is obtained by comparing $Prob^3$ with $Prob^4$. When both are the same as unity, there is no misreporting and no difference between the microeconomic and macroeconomic statistics. On the other hand, when both are the same but not at unity, there is a gap between microeconomic and macroeconomic statistics and it is explained fully by the misreporting hypothesis. Finally, when both are different and not at unity, the gap may be explained by other factors in addition to the misreporting hypothesis. (4)

3. The data used for estimation

The data used for the estimation is drawn from the *1994 Consumer Expenditure Survey* compiled by the Bureau of Labor Statistics, US Department of Labor. This includes many clusters of household expenditures and includes household characteristics and other kinds of socio-economic factors for four quarters in 1994. During the four quarters in 1994, some households had one interview, some had two interviews, some had three interviews, and some had four interviews according to the beginning date of inclusion in the Survey of CE. All the households can be identified by the CU's in the

data-sets in every quarter and all the households can be classified into seven streams of households. (5)

Regarding the issue of misreporting in the CE, there is a different definition of misreporting in the BLS from the present analysis. With regard to responses about expenditures by a household respondent in the CE, there are basically five options, not three as in the present model denoted in section 1.

In the sample survey, consumer units are asked two questions about almost all items of expenditures: one is a screener on whether or not there was a purchase and the other is a question on the amount that a respondent paid for an item. There are two types of screener questions; one involves straightforward questions about particular items, for example, "Did you buy any magazines?" The other type of screener question covers broad categories of items such as Appliances and household equipment. In this type of screener, the respondent picks items purchased from the 'laundry list' indicated in the Appliances and household equipment category covering forty items ranging from small electric kitchen appliances to telephones and accessories.

For example, if the respondent had an expense, say, for a toaster, then a screener record is created in the category of small electric kitchen appliances in which the toaster is included. And if the respondent had no purchase, say, for telephone accessories in the sample period, no screener record is created for the category of telephones and accessories.

If the answer to the screener is "Don't Know or Refusal" (the latter meaning no answer on the survey), then the screener record is specified as 'Don't Know or Refusal' and the amount in the expenditure field for the item is specified as 'valid blank' in the

Survey. In cases of "No", "blank" or "Don't Know or Refusal", the observed value in the CE is recorded as zero and the household is classified as a "zero expenditure household" for the category. There is no misreporting on zero expenditure according to the BLS definition of misreporting.

If a respondent answered "Yes" to the purchase screener but answered "Don't Know or Refusal" regarding the amount, then the amount is imputed by the BLS office. This estimation is one of the potential sources of misreporting by the BLS. The other potential source of misreporting by the BLS consists in misreporting the amount purchased by a positive expenditure household. In this way, misreporting for positive expenditure households occurs in the BLS.

We have five options given the above responses used in the CE survey. The five options are introduced in Table 1. As we have seen, in the BLS estimations, misreporting takes place in cases in which the respondent answers Yes to the screener question and fails to specify the amount of the purchase (in case (5) in Table 1) or fails to report the amount purchased correctly (in case (4) in Table 1). On the other hand, misreporting according to our approach takes place in the case of zero expenditure households, as in cases (1), (2) and (3) explained in section 1. The comparison between our approach to calculating misreporting and the BLS is also indicated in Table 1.

(Table 1)

Though our definition of misreporting is completely different from that of the BLS as indicated in Table 1, there are several reasons to use our misreporting hypothesis

in econometric analysis. The first reason for using our misreporting hypothesis stems from the comparison of microeconomic and macroeconomic statistics. As we have mentioned in section 1, there is a tendency of underreporting in microeconomic statistics compared with macroeconomic statistics. If the underreporting of some item in microeconomic statistics is, say, 67% (That is, the ratio of the amount for micro- to macro-data is two to three), the price of the item becomes 1.5 times (namely the rate of three to two) higher than the price reported in the CE for positive expenditure households in order to adjust for underreporting based on the BLS definition. According to the misreporting hypothesis in our model, this statistical gap can be adjusted by assessing zero expenditure households to determine if some are in fact positive expenditure households. With our method, there is no modification of consumer prices.

The second reason is that we focus on consumer durables in the analysis. Consumer durables are characterized by a low purchase frequency. Because of the low frequency of purchasing consumer durables, some respondents may forget to report such purchases of relatively inexpensive consumer durables such as sports equipment or inexpensive watches. This is classified as misreporting in our model. On the other hand, because some consumer durables such as new automobiles are expensive, respondents who wanted to report the purchase of consumer durables are more likely to accurately describe the amount paid by checking their credit card receipt or checkbook when they respond to the Survey. In this situation, the amount is correctly reported in the Survey. For these reasons we concentrate on zero expenditure households applying the misreporting hypothesis. [(6)]

The first panel of Table 2 shows the rearrangement of households from the first to the seventh stream by using the CU's.

(Table 2)

Here, the case of stream 1 indicated in Table 2 (a) is explained. The households included in stream 1 had the final or fifth interview in the first quarter of 1994, and they were excluded from the Survey after the second quarter of 1994. They reported their expenditure behavior in the final three quarters in 1993 and the first quarter of 1994. The number of households classified in stream 1 is 1,172 as indicated in Table 2 (b). In the case of stream 4, the households had a second interview in the first quarter of 1994, a third interview in the second quarter of 1994, a fourth interview in the third quarter of 1994, and the fifth and final interview in the fourth quarter of 1994. The number of households included in stream 4 is 891. Finally, in the case of stream 7, households had the second interview in the fourth quarter of 1994 and continued to have consecutive interviews in the first three quarters of 1995. (7)

In Table 2, the total number of households used for estimating the model is 7,108; there are seven streams according to the number and the timing of interviews in 1994, and the beginning date of the interviews.

This paper concentrates on the purchasing behavior for consumer durables in order to test the misreporting hypothesis specified in section 2. The data suggests a high percentage of zero-expenditure households for consumer durables (cf. Table 4 in this section), and thus an application of the tobit-type qualitative response model is

reasonable for analyzing demand behavior for consumer durables. In contrast, say for total food expenditure, there are few zero-expenditure households in the Survey and thus we cannot specify equations (5) and (6) to test the misreporting hypothesis by using data for total food expenditure.

In case of stream 1 in Table 2 (a), household expenditure is observed in only one quarter. It might seem reasonable to quadruple expenditures on consumer durables in one quarter in order to estimate an annual amount. The present analysis did not make such an estimate because of the characteristics of consumer durables. The definition of consumer durables is that they can be used for over one year because of their durability. So it is erroneous to assume the replacement of consumer durables every quarter and therefore we didn't make such an estimate. (8)

Consumer durables are divided into thirteen clusters of items defined by the *National Income and Product Accounts* (NIPA). These clusters are: Jewelry and watches (item 18), Furniture, including mattresses and bed springs (item 29), Kitchen and other household appliances (item 30), China, glassware, tableware and utensils (item 31), Other durable house furnishings (item 32), Ophthalmic products and orthopedic appliances (item 46), New autos (item 70), Net purchases of used autos (item 71), Other motor vehicles (item 72), Tires, tubes, accessories and other parts (item 73), Books and maps (item 87), Wheel goods, sports and photographic equipment, pleasure boats and aircraft (item 90), and Video and studio products, computing equipment, and musical instruments (item 91).

Table 3 shows a set of independent variables. Eleven categories in the CE are selected as options for independent variables.

(Table 3)

Table 3 identifies two types of variables such as X and D. The X's indicate continuous or discrete variables and the D's indicate dummy variables. Table 3 also depicts the mean, standard deviation, minimum and maximum of the variables. In the Appendix of the paper, the contents of the dummy variables are explained in detail. Table 4 presents statistics regarding dependent variables and the number of zero expenditure households for thirteen clusters of items. We find that the rate of zero expenditure households for various items ranges from 50 percent up to 98 percent.

(Table 4)

4. The estimation results

The estimation equation of the p_i-tobit model for the item is:

$$\ln L = \sum_0 \ln\{1 - \Phi(X_{2i}'\gamma)\Phi(X_{1i}'\beta/\sigma)\}$$

$$- n_+ \ln\sigma + \sum_+ \ln\Phi(X_{2i}'\gamma) + \sum_+ \ln\varphi\{(y_i - X_{1i}'\beta)/\sigma\} \qquad (12)$$

where y_i is the amount of expenditure, X_{1i} and X_{2i} are the matrix of independent variables, respectively. The β's, γ's, and σ are parameters to be estimated.

In equation (1), socio-economic variables for determining the purchasing behavior of consumer durables are selected such as housing tenure, pre-tax income, number of family members, family type, number of weeks worked and number of rooms. In

equation (2), variables concerning household characteristics are selected such as age, urban/rural, education, employer status and total expenditure last quarter.

The maximum likelihood estimators are obtained, and are indicated in Table 5 for Jewelry and watches (item 18), New autos (item 70), Other motor vehicles (item 72) and Wheel goods, sports and photographic equipment, pleasure boats and aircraft (item 90). Except for Furniture, including mattresses and bed springs (item 29), Kitchen and other household appliances (item 30), Other durable house furnishings (item 32), Tires, tubes, accessories and other parts (item 73), all the sets of independent variables are common. (9)

(Table 5)

Before explaining several findings for the estimation results, it is important to denote the identification problem of the present econometric model. In the complex non-linear likelihood function of (12), there is always discussion concerning the identification problem of the model. In the present analysis we confirmed that the model is identifiable in the following two ways; first by estimating the parameters by using a part of the total sample size, and second by changing the income variable in the same item. (10) Based on these results, we confirmed that the model is identifiable.

There are several findings based on the estimation results. At first, we focus on the tobit-type demand function of equation (1) for each item. Regarding housing tenure, there are several categories whose demand behavior is different between owner housing tenure (D51) and rental housing tenure (D52). The owner housing tenure (D51) is set as a benchmark in the estimation. The parameter of rental housing tenure is negative and

statistically significant in four clusters of items such as Kitchen and other household appliances (item 30), Other durable house furnishings (item 32), Ophthalmic products and orthopedic appliances (item 46) and New autos (item 70). This indicates, other conditions being equal, that demand for such items is less among consumers of rental housing tenure compared to that for owner housing tenure.

We included two variables regarding income variable, namely X11 and the square of X11 in equation (1). The parameter of X11 is positive and significant for all items, while that of the square of X11 is negative and significant for all items.

The effect of the number of family members, X8, is significant in Furniture, including mattresses and bed springs (item 29), China, glassware, tableware and utensils (31), New autos (item 70), Tires, tubes, accessories and other parts (item 73), and Books and maps (item 87). In the case of New autos (item 70), the parameter is negative, indicating that an increase in family members decreases demand for New autos (item 70). On the other hand, the parameter is positive in Furniture, including mattresses and bed springs (item 29), China, glassware, tableware and utensils (31), Tires, tubes, accessories and other parts (item 73) and Books and maps (item 87), indicating that demand for the four items increases with an increase in family members.

Regarding household purchasing behavior for consumer durables, family type appears to be an important factor to decide the level of demand. We classified family type in six categories: namely, (i) husband-and-wife only (D91), (ii) husband-and-wife with children (D92), (iii) all other cases of households with husband-and-wife (D93), (iv) one parent households (D94), (v) single-person households (D95), and (vi) others (D96). In

the present model, households with husband-and-wife only serve as a benchmark in the estimation.

The demand behavior of husband-and-wife only households and those of husband-and-wife with children (in cases of D92 or D93 being unity) is different in the categories of: Jewelry and watches (item 18); Net purchases of used autos (item 71), and Video and studio products, computing equipment, and musical instruments (item 91). For these three categories the parameters of D92 and/or D93 are positive and significant, indicating that the husband-and-wife with children households purchase far more consumer durables from the three categories than the husband-and-wife only households.

There is a big difference in consumption of durables between husband-and-wife only households and single-person households. This difference is evident because almost all of the dummy variables of D95 are significant and negative for four items, namely, Jewelry and watches (item 18), Ophthalmic products and orthopedic appliances (item 46), New autos (item 70) and Net purchases of used autos (item 71). This indicates that demand for consumer durables is less in single-person households compared to that of husband-and-wife only households. The parameter of D95 in Books and maps (item 87) is positive and significant, indicating that single person households purchase more books and maps than husband-and-wife only households.

For the two categories of Tires, tubes, accessories and other parts (item 73) and Books and maps (item 87), the parameter of X13, 'Number of weeks worked', is positive and significant.

Space is one of the important factors when considering purchasing consumer durables. In the set of independent variables, the 'Number of rooms' variable (X17) is a

proxy variable for ‘space’. The parameter of X17 is significant for items of Jewelry and watches (item 18), Furniture, including mattresses and bed springs (item 29), Kitchen and other household appliances (item 30), China, glassware, tableware and utensils (item 31), Other durable house furnishings (item 32) and Video and studio products, computing equipment, and musical instruments (item 91). On the other hand, the parameter of X17 is insignificant for items related to automobiles such as New autos (item 70), Net purchases of used autos (item 71), Other motor vehicles (item 72), and Tires, tubes, accessories and other parts (item 73).

We then consider the parameters of the probit functions, γ, related to the probability of misreporting indicated by $\Phi(-X_{2i}'\gamma)\Phi(X_{1i}'\beta/\sigma)$. The parameter of age, X2, is negative and significant for all clusters of items except Kitchen and other household appliances (item 30) and Books and maps (item 87), indicating that the probability of misreporting increases according to the increase in age under the condition $\Phi(X_{1i}'\beta/\sigma)$ being equal. The parameter of age is positive and significant for Ophthalmic products and orthopedic appliances (item 46), indicating that the probability of misreporting decreases according to the increase in age, other conditions being equal.

When the parameter of the rural dummy, D32, is negative, we can conclude that the probability of misreporting for rural households is high compared to urban households, other conditions being equal, and vice versa. The parameter of the rural dummy is significant in Net purchases of used autos (item 71), Other motor vehicles (item 72), and, Tires, tubes, accessories and other parts (item 73). Regarding the above three auto-related categories, the rural dummy is positive, indicating that the probability

of misreporting for these items is lower in rural households than in urban households when $\Phi(X_{1i}'\beta/\sigma)$ is the same.

Education affects the probability of misreporting for households. The education dummy is classified into four categories, namely: (i) less than high school graduate (D71); (ii) less than college graduate (D72); (iii) college graduate (D73); and (iv) graduate school graduate (D74). The base dummy in the estimation is the category (i) of 'less than high school graduate' (D71). Almost all the education dummies of D72, D73 and D74 are positive and significant, indicating that the probability of misreporting becomes less with increases in the level of education. Moreover, all the education dummies are significant and positive for Ophthalmic products and orthopedic appliances (item 46), New autos (item 70), Books and maps (item 87), and Video and studio products, computing equipment, and musical instruments (item 91). The above results indicate an inverse correlation between educational attainment and the probability of misreporting.

Regarding employer status, the parameters on Net purchases of used autos (item 71) are positive and significant, indicating that the probability of misreporting is less for employed households compared to unemployed households. We consider the variable of 'total expenditure last quarter' (X19) as a proxy for psychological comfort and a way of determining the accuracy of reporting expenditures. When a household faces pecuniary difficulties, it is less likely to spend enough time to report the details of expenditures to the Survey. The parameter of X19 is positive and significant for all the categories except for the Net purchase of used autos (item 71).

Now we look at the probability of underreporting by categories defined by $Prob^3$ indicated in Table 6.

(Table 6)

Regarding the probability of underreporting by $Prob^3$, there are five clusters of items in which the gap, that is defined by the magnitude of 1 minus the probability of underreporting, between microeconomic and macroeconomic statistics is less than ten percent: 7.2 percent in Jewelry and watches (item 18); 8.8 percent in Furniture, including mattresses and bed springs (item 29); 7.0 percent in Kitchen and other household appliances (item 30); 9.1 percent in China, glassware, tableware and utensils (item 31), and; 3.6 percent in Other durable household furnishings (item 32). There are five clusters in which the gap is between ten and twenty percent: 19.3 percent in Ophthalmic products and orthopedic appliances (item 46); 12.6 percent in Tires, tubes, accessories and other parts (item 73); 16.2 percent in Books and maps (item 87); 10.9 percent in Wheel goods, sports and photographic equipment, pleasure boats and aircraft (item 90), and; 11.0 percent in Video and studio products, computing equipment, and musical instruments (item 91).

There are two clusters in which the gap is extremely high, namely 70.9 percent in New autos (item 70), and 57.8 percent in Other motor vehicles (item 72). The estimation results for these two categories are not credible due to misspecification by excluding some important variables to determine demand for such items. The age, number and condition of automobiles owned by a household is not reported in the CE. Such

information is important in assessing the probability of automobile purchases since a household that purchased an automobile last year, and has maintained it in good condition, has little probability of purchasing another automobile this year. The estimation results are thus poor because information on households' existing autos is one of the most important factors in determining auto demand and is absent from the CE.

Including such variables as vintage and conditions if they exist in the data set of New Auto (item 70), the $Pr(y_i^* \leq 0)$, namely $\Phi(-X_{1i}'\beta/\sigma)$, would increase, while the $Pr(y_i^* > 0)$, namely $\Phi(X_{1i}'\beta/\sigma)$, would decrease and the $Pr(y_i^* > 0, z_i^* \leq 0)$, namely $\Phi(-X_{2i}'\gamma)\Phi(X_{1i}'\beta/\sigma)$ would also decrease. This is the same for Other motor vehicles (item 72). As a result, we exclude the categories of New auto (item 70) and Other motor vehicles (item 72) for further analysis because data is insufficient to get stable demand function for the items.

The numbers in Table 6 excluding New auto (item 70) and Other motor vehicles (item 72) are directly compared with those of consumer durables derived from macroeconomic statistics. The comparison of CE (corresponded to microeconomic statistics) to PCE (corresponded to macroeconomic statistics) is reported in the *Consumer Expenditure Survey, 1996-97* compiled by the BLS. The Survey reported that 'The ratios (of CE to PCE) indicate that the Consumer Expenditure Survey estimates for the major categories of consumption are lower than the PCE.' Table 7 shows the estimates for consumer durables entitled 'Comparisons with Other Data Sources' indicated in the *Consumer Expenditure Survey, 1996-97*.

(Table 7)

There is a significant problem in the comparison of underreporting based on CE-PCE ratios in CE publications. The CE-PCE comparisons that are presented in the CE publications are based on the assumption that annual expenditures for categories of items can be determined by multiplying quarterly expenditures by four. We cannot follow this procedure as we base our model on individual, rather than aggregate, consumer unit expenditures and characteristics. Thus, any comparison to the PCE must be carefully treated as a first approximation and requires modification if we wish to make a reliable comparison in the future.

Though it is difficult to compare the numbers directly because the method of aggregation differs, we can draw some conclusions from Tables 6 and 7. From Table 7, the CE is underestimated compared to the PCE by 34 percent in Household furnishings and equipment. Examining consumer durables related to Household furnishings and equipment in Table 5, the categories of Furniture, including mattresses and bed springs (item 29), Kitchen and other household appliances (item 30), China, glassware, tableware and utensils (item 31) and, Other durable house furnishings (item 32) correspond to the category of Household furnishings and equipment. For these four categories, the gap is less than 10 percent, indicating that about 30 percent of the gap between CE and PCE can be explained by the misreporting hypothesis.

The category of Television, radios and sound equipment in Table 7 corresponds to that of Video and studio products, computing equipment, and musical instruments (item 91). The gap between the CE and PCE is 40 percent and the gap obtained from the

present model is 11 percent, indicating that 30 percent of the gap between CE and PCE can be covered by the misreporting hypothesis. (11)

Finally, the probability of misreporting for the item is calculated in Table 8. The probability of misreporting is obtained by $(1/n)\sum_i \Phi(-X_{2i}'\gamma)\Phi(X_{1i}'\beta/\sigma)$.

(Table 8)

The probability of misreporting is between 1 and 4 percent for all items except Net purchases of used autos (item 71), indicating that the number of households that purchased consumer durables but did not report such expenditures was about 70 to 280 households among the sample households, depending on the items. The probability of misreporting is less than 2 percent for six items, namely Jewelry and watches (item 18), Furniture, including mattresses and bed springs (item 29), Kitchen and other household appliances (item 30), China, glassware, tableware and utensils (item 31), Other durable household furnishings (item 32) and Wheel goods, sports and photographic equipment, pleasure boats and aircraft (item 90). The probability of misreporting is between 2 and 3 percent for the items of Tires, tubes, accessories and other parts (item 73) and Books and maps (item 87). It is between 3 to 4 percent for the items of Ophthalmic products and orthopedic appliances (item 46), and Video and studio products, computing equipment, and musical instruments (item 91). And it is 4.8 percent for the item of Net purchases of used autos (item 71).

5. Conclusion

This paper tests the misreporting hypothesis through the p_i-tobit model. The data used for the estimation involves thirteen clusters of consumer durables classified by the *National Income and Product Accounts* in the U.S. The theory and the specification of the misreporting hypothesis are simple and useful in considering the gap between microeconomic and macroeconomic statistics.

For ten consumer durables out of eleven excluding New autos (item 70) and Other motor vehicles (item 72), the probability of underreporting is less than 20 percent for all households. For the remaining category of consumer durables, Net purchases of used autos (item 71), the probability of underreporting is 20.6 percent.

Compared to the results of the CE-PCE comparison by the BLS, the misreporting hypothesis plays a significant role in the underreporting observed in the micro-data sets. The present results do not contradict Slesnick (1992), who found that the microeconomic data of the CE is underreported compared to the macroeconomic data of NIPA by 35 percent in 1989. Based on the CE-PCE comparison conducted by the BLS, Slesnick and the present authors, it is clear that we have to analyze the gap between macroeconomic and microeconomic statistics numerically and develop a better experimental design for collecting data. After we determine the estimates of the underreporting rate between CE and PCE on the same aggregation design, we can compare the probability of underreporting with the underreporting rate more accurately.

Finally, although the number of households that purchased consumer durables but did not report such expenditures on the Survey is small, ranging from 1 to 4 percent of households, this factor strongly influences the degree of underreporting.

Notes

(1) Houthakker and Taylor (1970) are the first to investigate the gap between macro- and micro-data sets in the U.S. They report that the cross-section total, namely the *Consumer Expenditure Survey* (CE) micro-data set, is only 93 percent of the comparable time series total, namely the *National Income and Product Accounts in the U.S.* (NIPA*)* macro-data set. Slesnick (1992) reports that a comparison of the estimates of aggregate expenditure by the NIPA and the CE reveals that the difference between the two data sets has been growing over time. The gap in 1961 was only 5 percent, in 1981 32 percent, and in 1989 it rose to 35 percent. Maki and Nishiyama (1993), using the micro-data sets of the *Family Income and Expenditure Survey* (FIES) and the *National Survey on Family Income and Expenditure* (NSFIE) compiled by the Statistics Bureau, suggest that the total consumption estimated by the FIES and the NSFIE is underestimated by 20 percent compared to the macro-control totals of the *System of National Accounts* (SNA) compiled by the Economic Planning Agency. For consumer durables, consumption aggregates obtained from the FIES and the NSFIE are 30 percent lower than the SNA. Papers presented at the 1991 Stockholm Workshop on Methodological Problems in Household Expenditure Surveys and Other Types of Daily Surveys report that total consumption is underestimated by 20 percent in Australia, 15 percent in Finland, 8 percent in England, and 15 percent in Sweden.

(2) The economic implications of Maki and Nishiyama (1996) and Cragg (1971) are different from each other, but the econometric specification is the same. Cragg (1971) called his model the double-hurdle model.

(3) The p_i-tobit model is better than the p-tobit model in assessing the consistency of the model. This is because even though the theoretical value of p ranges between zero and unity, the estimated value of p in the p-tobit model sometimes exceeds unity, while that of p_i obtained from p_i-tobit model ranges from zero to unity due to the specification.

(4) The underreporting rate indicated in Table 7 in section 4 is obtained in a different manner from the present experimental design. In section 4 we explain this in detail.

(5) The CU is a code number of the household and it is the same for all quarters for a sample household.

(6) Considering the possibility of misreporting on the imputed amount and the amount that the respondent reported in the Survey, we have to develop a more complex model than the present one.

(7) In the first interview of the Survey, households don't report their expenditure.

(8) Regarding the data used for estimation of thirteen clusters of consumer durables, we aggregate original quarterly data of expenditures into an annual base. In the aggregation process, we sometimes found out that a household purchased consumer durables of the same category, say Video and studio products, computing equipment, and musical instruments

(item 91), several times in the four quarters in 1994. Examining such expenditures carefully, we found out that the broad categories obscure significant differences in purchasing behavior. For example, there are households that purchased a PC in one of the four quarters in 1994 and at the same purchased a DVD player in the same or another quarter. The PC and the DVD player are different consumer durables, but both are classified into the same category in the thirteen clusters of items in the present analysis. There are other cases when households purchased a PC in one of the four quarters and purchased another PC in the same or another quarter. We understand that these situations create aggregation problems. In the present experimental design we assume the annual base of thirteen clusters of consumer durables as the thirteen elementary commodities. This is the essential assumption to compare the present results with macroeconomic statistics.

(9) In this paper we showed the estimation result only in the case of Jewelry and watches (item 18) in Table 5 because of space limitations. In the case of Tires, tubes, accessories and other parts (item 73), convergent parameters of the model could not be obtained from the common set of independent variables. In item 73, 'Family type' is excluded from equation (1) and 'Employer status' from equation (2).

(10) We used three kinds of income variables, namely a series of observed income before tax, imputed income before tax in the second interview, and imputed income before tax in the fifth interview. The latter two income series are experimentally calculated by the BLS. Comparing the estimated parameters, the parameter of income is stable and almost all parameters in the model are also stable.

(11) There is a puzzle for the CE-PCE comparison for Vehicle purchases, namely the ratio between CE and PCE exceeds unity, indicating over-reporting. The ratio between CE and PCE is 1.14. Though the explanatory remark accompanying the Table in *Consumer Expenditure Survey, 1996-97* explained that 'contents of PCE for consumer durables is not matched to those of CE', it is still a puzzle why it shows over-reporting. One of the reasons is that CE uses a family expenditure survey method focusing on households, while PCE uses a commodity-flow method mainly focusing on retail statistics. In the footnote of the Table in *Consumer Expenditure Survey*, the BLS explains the difference between the family expenditure survey method and the commodity flow method regarding Vehicle purchases as follows: PCE estimates are derived, using estimates of dealer margin (a concept which cannot be matched to CE) and wholesale value of net transactions between persons and government, foreigners, and non-dealer businesses. CE data on vehicle purchases and trade-ins were combined to approximate the total value of new vehicle purchases. CE data on used vehicle purchases, trade-ins, sales and losses were combined to approximate the values of net transactions of used vehicles. The most difficult issue in interpreting retail statistics is to separate automobile purchases between a household's family and business uses.

References

Cragg, J.G. (1971), "Some statistical models for limited dependent variables with application to the demand for durable goods," *Econometrica* 39, 829-844

Deaton, A. and M. Irish (1984), "Statistical models for zero expenditures in household budgets," *Journal of Public Economics* 23, 59-80

Houthakker, H.S. and L.D. Taylor (1970), *Consumer Demand in the United States: Analysis and Projections*, Harvard University Press, Cambridge Mass, 2nd edition.

Maki, A. and S. Nishiyama (1993), "Consistency between macro- and micro-data sets in the Japanese household sector," *Review of Income and Wealth*, 39, 195-207

Maki, A. and S. Nishiyama (1996), "An analysis of under-reporting for micro-data sets: The misreporting or double-hurdle model," *Economics Letters*, 52, 211-220

Slesnick, D.T. (1992), "Aggregate consumption and saving in the postwar United States," *Review of Economics and Statistics*, 74, 585-597

Table 1. The different definition for misreporting between the BLS and the present model

	Screener	Amount	Observed value	Possibility of misreporting CE	Ours
(1)	No	0	0	NO	YES
(2)	Blank	Blank (valid)	0	NO	YES
(3)	Don't Know or Refusal	Blank (valid)	0	NO	YES
(4)	Yes	positive amount	positive amount	YES	NO
(5)	Yes	Don't Know (positive amount imputed by CE office)	positive amount	YES	NO

Table 2. Rearrangement of households

(a) Seven streams

Quarter\interview	2nd	3rd	4th	5th
Q1	stream 4	stream 3	stream 2	stream 1
Q2	stream 5	stream 4	stream 3	stream 2
Q3	stream 6	stream 5	stream 4	stream 3
Q4	stream 7	stream 6	stream 5	stream 4

(b) Number of households in the seven streams

Stream	No of samples	Period
Stream 1	1,172	1994 Q1
Stream 2	1,073	1994 Q1,Q2
Stream 3	953	1994 Q1,Q2,Q3
Stream 4	891	1994 Q1,Q2,Q3,Q4
Stream 5	944	1994 Q2,Q3,Q4
Stream 6	991	1994 Q3,Q4
Stream 7	1,084	1994 Q4
total	7,108	

Table 3. Statistics of the independent variables

	Mean	Std dev	minimum	maximum
Age				
X2	48.74	17.25	16	90
Urban and rural				
urban (D31)	.888	.316	0	1
rural (D32)	.112	.316	0	1
Housing tenure				
owner (D51)	.669	.470	0	1
rented (D52)	.310	.462	0	1
other (D53)	.021	.142	0	1
Education				
less than high (D71)	.194	.395	0	1
high school (D72)	.552	.497	0	1
college (D73)	.140	.346	0	1
graduate (D74)	.114	.317	0	1
Number of members				
X8	2.62	1.51	1	13
Family type				
hus and wife (D91)	.207	.405	0	1
H/W own chld (D92)	.297	.456	0	1
others (D93)	.044	.204	0	1
one parent (D94)	.062	.242	0	1
single (D95)	.265	.441	0	1
other (D96)	.125	.330	0	1
Income before tax				
X11	35968.0	30900.0	2	293000.0
Employer status				
no employment (D121)	.253	.434	0	1
private (D122)	.535	.498	0	1
federal (D123)	.130	.336	0	1
self-employed (D124)	.082	.274	0	1
Number of weeks worked				
X13	16.8	23.3	0	52
Number of rooms				
X17	5.76	1.96	1	18
Total expenditure last quarter				
X19	17864.2	14664.5	716.6	184354.0

Table 4. Statistics of dependent variables

	Mean	Std dev	min	max	No of zero expenditure
Jewelry and watches DEP18	76.6	357.0	0	10500.0	4646 (65.3%)
Furniture, including mattresses and bedsprings DEP29	181.1	652.0	0	17700.0	5015 (70.5%)
Kitchen and other household appliances DEP30	74.3	247.1	0	5322.0	4769 (66.9%)
China, glassware, tableware and utensils DEP31	20.1	77.9	0	1902.0	5383 (75.7%)
Other durable household furnishings DEP32	115.6	369.6	0	10073.0	3817 (53.7%)
Ophthalmic products and orthopedic appliances DEP46	31.4	89.4	0	1512.0	5776 (81.2%)
New autos DEP70	4621.2	14122.0	0	225000.0	6064 (85.3%)
Net purchases of used autos DEP71	2984.1	8997.4	0	209040.0	5438 (76.5%)
Other motor vehicles DEP72	110.7	1388.4	0	37186.0	6999 (98.4%)
Tires, tubes accessories and other parts DEP73	35.4	143.7	0	5150.0	5285 (74.3%)
Books and maps DEP87	15.9	59.5	0	1500.0	5722 (80.5%)
Wheel goods, sports and photographic equipment,					

boats, and pleasure aircraft DEP90	489.9	6266.5	0	419626.0	4846 (68.1%)
Video and audio products, computing equipment, and musical instruments DEP91	137.3	359.9	0	6000.0	4076 (57.3%)

Table 5. Maximum Likelihood Estimator: Jewelry and watches (item 18), New autos (item 70), Other motor vehicles (item 72), and Wheel goods, sports and photographic equipment, pleasure boats and aircraft (item 90)

(1) β variables	item 18	item 70	item 72	item 90
constant (β_0)	-638.8 (11.6)	4739.8 (0.6)	-41333.4 (6.1)	-14114.3 (10.1)
Housing tenure				
rented D52 (β_1)	-12.3 (0.4)	-13073.4 (4.3)	-102.6 (0.0)	-556.4 (0.8)
other D53 (β_2)	-212.1 (2.1)	-21382.8 (2.5)	3127.2 (0.5)	1125.2 (0.8)
Income before tax				
X11 (β_{10})	.0057 (9.6)	.503 (6.1)	.252 (3.1)	.133 (7.4)
Squared of x11(10^{-8}) (β_3)	-.622 (2.4)	-104.9 (2.4)	-117.4 (2.2)	-49.7 (4.8)
Number of members				
X8 (β_4)	-6.03 (0.5)	-12005.6 (2.8)	-138.8 (0.1)	260.2 (0.8)
Family type				
own chid D92 (β_5)	36.7 (1.0)	2075.1 (0.5)	977.0 (0.2)	392.1 (0.4)
other D93 (β_6)	115.7 (2.5)	12824.9 (1.7)	-4883.4 (0.6)	-2031.6 (1.2)
1 parent D94 (β_7)	-28.9 (0.4)	-10871.9 (1.9)	-1383.5 (0.2)	-508.1 (0.3)
single D95 (β_8)	-91.0 (2.3)	-12005.6 (2.8)	4577.9 (1.1)	-1010.4 (1.0)
other D96 (β_9)	-21.0 (0.5)	67.4 (0.0)	1812.4 (0.4)	-1151.4 (1.1)
No. of weeks worked				
X13 (β_{11})	-.530 (0.9)	1.841 (0.0)	11.6 (0.1)	27.9 (1.9)
No. of rooms				
X17 (β_{12})	21.4 (4.0)	542.4 (0.8)	-181.0 (0.3)	255.7 (1.7)
σ	653.2 (241.9)	34793.5 (31.8)	18772.0 (11.5)	11454.0 (571.4)

(2) γ

variables	item 18	item 70	item 72	item 90
constant (γ_0)	1.613 (1.4)	-.685 (3.4)	1.53 (1.1)	3.55 (3.1)
Age				
X2 (γ_1)	-.039 (2.4)	-.0076 (3.3)	-.057 (2.4)	-.067 (4.2)
Urban/Rural				
rural D32 (γ_2)	-.592 (1.9)	-.086 (1.0)	2.43 (2.2)	.423 (1.0)
Education				
high schoolD72 (γ_3)	.827 (2.7)	.249 (3.0)	.369 (0.6)	.873 (3.2)
collegeD73 (γ_4)	.684 (1.0)	.364 (3.7)	-.385 (0.7)	1.02 (1.9)
graduateD74 (γ_5)	1.39 (1.0)	.248 (2.4)	-.822 (1.2)	2.70 (0.7)
Employer				
privateD122 (γ_6)	.463 (0.9)	.130 (1.3)	-.149 (0.2)	.106 (0.2)
federalD123 (γ_7)	.312 (0.4)	.268 (2.5)	.226 (0.3)	-.851 (1.4)
self-emp.D124 (γ_8)	.589 (0.6)	.118 (1.0)	1.16 (1.4)	-.128 (0.2)
Total expenditure last quarter				
X19 (γ_9)	.00015 (3.4)	.000009 (5.4)	.000032 (2.2)	.000099 (3.0)
Prob[3]	0.926	0.291	0.422	0.891
Prob[5]	0.015	0.339	0.020	0.018

Note: The figures in parentheses denote asymptotic t-ratio.

Table 6. Probability of under-reporting by the model ($Prob^3$) and the magnitude of gap (1-$Prob^3$)

	Probability of under-reporting	the gap
Jewelry and watches (item 18)	0.928	0.072
Furniture, including mattresses and bed springs (item 29)	0.912	0.088
Kitchen and other household appliances (item 30)	0.930	0.070
China, glassware, tableware and utensils (item 31)	0.909	0.091
Other durable house furnishings (item 32)	0.964	0.036
Ophthalmic products and orthopedic appliances (item 46)	0.807	0.193
New autos (item 70)	0.291	0.709
Net purchases of used auto (item 71)	0.794	0.206
Other motor vehicles (item 72)	0.422	0.578
Tires, tubes, accessories and other parts (item 73)	0.874	0.126
Books and maps (item 87)	0.838	0.162
Wheel goods, sports and photographic equipment, pleasure boats and aircraft (item 90)	0.891	0.109
Video and studio products, computing equipment, and musical instruments (item 91)	0.890	0.110

Table 7. Underreporting Rate (Ratio of CE to PCE) in *Consumer Expenditure Survey, 1996-97* ($Prob^4$) and the magnitude of gap ($1- Prob^4$)

1994	Ratio of CE to PCE	the magnitude of gap ($1- Prob^4$)
Household furnishings and equipment	.66	.34
Television, radios and sound equipment	.60	.40

Table 8. Probability of misreporting: Prob[5]

	Probability of misreporting: Prob[5]
Jewelry and watches (item 18)	0.015
Furniture, including mattresses and bed springs (item 29)	0.019
Kitchen and other household appliances (item 30)	0.018
China, glassware, tableware and utensils (item 31)	0.016
Other durable house furnishings (item 32)	0.010
Ophthalmic products and orthopedic appliances (item 46)	0.034
Net purchases of used autos (item 71)	0.048
Tires, tubes, accessories and other parts (item 73)	0.025
Books and maps (item 87)	0.025
Wheel goods, sports and photographic equipment, pleasure boats and aircraft (item 90)	0.018
Video and studio products, computing equipment, and musical instruments (item 91)	0.034

Appendix: Variable name

Age: X2

Urban and rural

- D31: urban
- D32: rural

Housing tenure

- D51: owner with mortgage, owner without mortgage, and owner mortgage not reported
- D52: rented
- D53: occupied without payment of cash rent, and student housing

Education

- D71: elementary, and high school, less than high school graduate, and never attended school
- D72: high school graduate, and college, less than college graduate
- D73: college graduate
- D74: graduate school

Number of members: X8

Family type

- D91: husband and wife only
- D92: H/W, own children only, oldest child less than 6, H/W, own children only, oldest child between 6 and 17, and H/W, own children only, oldest greater than 17
- D93: all other H/W CU's
- D94: one parent, male, own children only, and one parent, female, own children only
- D95: single persons
- D96: other CU's

Income before tax

- X11
- X11(I2): imputed income
- X11(I5): imputed income

Employer status

- D121: no employment
- D122: private company, business or individual
- D123: Federal government, State government, and Local government
- D124: self-employed in own business, professional, and family business or farm

Number of weeks worked: X13

Number of rooms: X17

Market value of stocks: X18

Total expenditure last quarter: X19
