STUDIECENTRUM VOOR ECONOMISCH EN SOCIAAL ONDERZOEK

VAKGROEP PUBLIEKE ECONOMIE

Estimating the Welfare Implications of In-Kind Government Programs : A General Numerical Approach

Bruno DE BORGER

March 1989

report 89/226

Universitaire Faculteiten St.-Ignatius

Prinsstraat 13 - B 2000 Antwerpen

D/1989/1169/02

ABSTRACT

The purpose of this paper is to present and apply a general methodology to estimate the welfare implications of in-kind government programs on the basis of arbitrary systems of demand equations. The method provides a powerful alternative to more restrictive procedures that previously have been used in the literature, as it allows complete flexibility with respect to the specification of demand functions.

The proposed procedures are applied to estimate the benefits and welfare costs of a Belgian public housing program. The results suggest that the estimated efficiency and equity implications of in-kind programs may be quite sensitive to the specification of demand, which provides additional justification for the use of the proposed methodology.

CONTENTS

1. Introduction

Government programs often combine a price subsidy with constraints on the consumption of the subsidized good. Many in-kind subsidy programs, such as public housing and public schools, offer selected eligible households an all-or-nothing choice to consume given quantities of particular goods at less than the market price. They add one consumption bundle to the budget space. Other programs, such as food stamps and minimum-condition housing allowances lead to kinked budget frontiers.

Economists have often been interested in evaluating the benefits of in-kind transfers. The standard procedure in the literature has been to specify a direct utility function, estimate the derived demand functions, use the structural parameters in the corresponding expenditure function, and evaluate the equivalent variation measure of consumer benefit. Examples of this approach are Clarkson (1976), Cronin (1983), De Salvo (1975) and Olsen and Barton (1983). Obviously, this methodology is quite restrictive because only a few very simple utility functions yield analytical expressions for benefit.[1] Moreover, it forces the analyst to estimate very specific demand functions that may not provide the best fit to the data.

More recently, Schwab (1985) prepared an alternative procedure based on results obtained by Hausman (1981). The latter showed that for some simple demand functions it is possible, using Roy's theorem, to derive a differential equation that yields a closed-form solution for the unknown expenditure function. He illustrates how this technique can be used to evaluate the

change in welfare due to a pure price subsidy. Schwab shows, within a two-good framework, that Hausman's methodology can be modified so as to allow the estimation of the benefits of in-kind government programs that impose a quantity constraint on the subsidized good. His proposed method is clearly an improvement over the earlier procedures because it allows the analyst to consider demand functions (such as linear or loglinear functional forms) for which Hausman's technique works and that often provide a good fit to the data but that cannot, or not easily, be derived from a direct utility function. It is still unduly restrictive, however. It is difficult to generalize to a many-commodity world, and even in a two-good framework it will not always be useful as for many demand functions the corresponding differential equation will not have a closed-form solution.

The purpose of this paper is to suggest and apply a general numerical technique to estimate the benefits of in-kind government programs on the basis of arbitrary systems of demand equations. It is based on Vartia's (1983) algorithm which was designed to numerically evaluate the compensated or equivalent income of a pure price change. The proposed method consists of applying the algorithm using specific starting values, defined in terms of an appropriately chosen set of shadow prices. Unlike the traditional approach and the methodology recently proposed by Schwab, the procedure suggested in this paper provides complete flexibility with respect to the choice of demand specifications. Moreover, it is applicable in a multi-commodity world with a potentially large number of rationed goods. It is easy to apply and computationally cheap.

Organization of the paper is as follows. In order to make the paper accessible to readers unfamiliar with Vartia's algorithm, we begin with a brief review in Section 2. In Section 3 we adapt the algorithm so as to allow

the evaluation of the benefits of in-kind government programs on the basis of arbitrary systems of demand equations. We apply the proposed methodology to evaluate the welfare implications of a public rental housing program in Section 4. Conclusions are summarized in Section 5.

2. The equivalent income of a price change: review of a numerical technique

In this section we review Vartia's algorithm to numerically evaluate the equivalent income of a price change. Suppose an individual initially faces a price vector $\underset{\sim}{p}^o$ and income y, allowing him to attain utility u^o. Now consider a set of price changes from $\underset{\sim}{p}^o$ to $\underset{\sim}{p}^1$. Faced with the new price vector the consumer attains a level of well being u^1. The equivalent variation of the price change is $EV = e(\underset{\sim}{p}^o, u^1) - y$, where e(.) is the expenditure function.[2]

To evaluate EV the analyst needs an estimate of equivalent income $e(\underset{\sim}{p}^o, u^1)$. Suppose the only information he has available is a system of estimated demand functions, $\hat{x}(\underset{\sim}{p},y)$, satisfying standard economic properties.[3] The choice of functional form may have been made on the basis of the economic and statistical properties of the estimates.

The algorithm is designed to approximate $e(\underset{\sim}{p}^o, u^1)$ up to any desired degree of accuracy using only the market information captured by the estimated demand system. It is important for the generalization suggested in the next section to emphasize the economic intuition behind the numerical technique. The first step is to derive, using the properties of expenditure and Hicksian and Marshallian demand functions, a differential equation that describes how expenditures change for small price changes, holding utility constant at u^1. Then, using observed income y (= $e(\underset{\sim}{p}^1, u^1)$) and price vector $\underset{\sim}{p}^1$ as initial values, $e(\underset{\sim}{p}^o, u^1)$ is obtained by numerically evaluating the solution of the equation at $\underset{\sim}{p}^o$. Intuitively, the numerical technique consists of moving in

small steps from $\underset{\sim}{p}^1$ to $\underset{\sim}{p}^o$, sliding along the indifference surface corresponding to u^1.

To apply the algorithm one successively calculates

$$\hat{e}_k = \hat{e}_{k-1} + \frac{1}{2}\,[\hat{x}(\underset{\sim}{p}_k,\ \hat{e}_k) + \hat{x}(\underset{\sim}{p}_{k-1},\ \hat{e}_{k-1})]'\ (\underset{\sim}{p}_k - \underset{\sim}{p}_{k-1}) \tag{1}$$

where $\underset{\sim}{p}_k = \underset{\sim}{p}^1 + \frac{k}{N}(\underset{\sim}{p}^o - \underset{\sim}{p}^1)$, $k = 1, \ldots, N$ is the step number and N is the number of steps. Initial values are $\underset{\sim}{p}_o = \underset{\sim}{p}^1$, $\hat{e}_o = e(\underset{\sim}{p}^1, u^1) = y$. At each of the N steps the implicit equation (1) is solved iteratively for $\hat{e}_k$ using

$$\hat{e}_k^{(m)} = \hat{e}_{k-1} + \frac{1}{2}\,[\hat{x}(\underset{\sim}{p}_k, \hat{e}_k^{(m-1)}) + \hat{x}(\underset{\sim}{p}_{k-1},\ \hat{e}_{k-1})]'\ (\underset{\sim}{p}_k - \underset{\sim}{p}_{k-1}) \tag{2}$$

where $\hat{e}_k^{(o)} = \hat{e}_{k-1}$, $k \geq 1$. Iteration stops when $|\hat{e}_k^{(m)} - \hat{e}_k^{(m-1)}|$ is sufficiently small.

It has been shown that the algorithm for large N converges to $\hat{e}_N = e(\underset{\sim}{p}^o, u^1)$, $\hat{x}(\underset{\sim}{p}_N, \hat{e}_N) = \hat{x}(\underset{\sim}{p}^o,\ e(\underset{\sim}{p}^o, u^1))$. Numerical examples (see, e.g., Vartia (1983)) suggest, however, that even for relatively small values for N very close approximations to equivalent income are obtained.

3. Estimating the benefits of in-kind subsidies: a general numerical procedure

In this section we generalize the algorithm in order to allow the estimation of the benefits of in-kind government programs that combine a price subsidy with constraints on quantity. We focus on programs, such as public housing, that offer participants the opportunity to consume given quantities of particular goods at less than the market price. The methodology can easily be adjusted to deal with other types of in-kind programs that imply kinked budget frontiers.

To fix ideas suppose that in the absence of the program the consumer faces prices $\underset{\sim}{p}^o = (p_1^o,\ldots,p_n^o)$. His optimal consumption bundle is $\underset{\sim}{x}^o = (x_1^o,\ldots,x_n^o)$, yielding utility u^o. Now assume the individual participates in a government program that provides him with quantities $\bar{x}_1^s, \bar{x}_2^s,\ldots, \bar{x}_g^s$ of the first g goods at subsidized unit prices $p_1^s, p_2^s,\ldots,p_g^s$. Following the relevant literature it is assumed that the program does not affect the market prices of the unrationed goods $g + 1,\ldots,\ldots,n$. Under the program the individual consumes the bundle $\underset{\sim}{x}^s = (\bar{x}_1^s,\ldots, \bar{x}_g^s, x_{g+1}^s,\ldots, x_n^s)$ and attains utility u^s. Obviously, the bundle $\underset{\sim}{x}^s$ is generally not the consumer's optimal choice corresponding to the price vector $\underset{\sim}{p}^s = (p_1^s,\ldots, p_g^s, p_{g+1}^o,\ldots, p_n^o)$ due to the quantity restrictions on a subvector of goods.

The equivalent variation measure of consumer benefit for this program is

$$EV = e(\underset{\sim}{p}^o, u^s) - y = e(\underset{\sim}{p}^o, u(\underset{\sim}{x}^s)) - y \tag{3}$$

Our goal is to modify the algorithm discussed in the previous section so that it can be used to estimate $e(\underset{\sim}{p}^o, u^s)$ on the basis of an arbitrary system of demand equations.[4] The procedure we propose consists of using very specific starting values, to be defined in terms of an appropriately chosen set of shadow prices.

To see the intuition, first note that the key to Vartia's algorithm in the case of a pure price change was the availability of an observed set of prices and expenditures that actually allowed the consumer to attain the level of well-being attained under the subsidy program. These prices and expenditures were then used as starting values in the numerical procedure. Unfortunately, in the case of rationing of a subvector of goods there is no observable combination of prices and expenditures such that, had the consumer been allowed to freely choose his most preferred bundle of goods, he would

have attained the level of utility u^s. It is clear, however, that there does exist a vector of shadow prices $\underset{\sim}{p}^*$ and corresponding expenditure $e(\underset{\sim}{p}^*, u^s)$ that would have induced the consumer to freely choose the bundle $\underset{\sim}{x}^s$ observed under the program, yielding level of well-being u^s. Suppose we were able to estimate $\underset{\sim}{p}^*$ and $e(\underset{\sim}{p}^*, u^s)$ on the basis of observable information. Using these estimates as starting values, Vartia's numerical technique allows us to move in small steps from $\underset{\sim}{p}^*$ to p^o, thereby sliding from $e(\underset{\sim}{p}^*, u^s)$ to $e(\underset{\sim}{p}^o, u^s)$ along the indifference surface corresponding to u^s. An estimate of $e(\underset{\sim}{p}^o, u^s)$ is sufficient to evaluate consumer benefit according to equation (3).

The only remaining problem is to obtain estimates of the shadow prices and expenditures on the basis of observable information. To do this it is useful to realize, as shown by Neary and Roberts (1980, pp. 27-29), that the shadow prices for unrationed commodities coincide with actual prices. As only the first g goods were assumed to be rationed, this implies that the shadow price vector can be written as $\underset{\sim}{p}^* = (p_1^*, \ldots, p_g^*, p_{g+1}^o, \ldots p_n^o)$. In order to estimate the unknown components of this vector on the basis of an arbitrary system of demand functions and the observed consumption bundles consumed by program participants, we proceed as follows. By definition of $\underset{\sim}{p}^*$ we can write the observed quantities of rationed goods in terms of the Marshallian demand functions as follows:

$$\bar{x}_i^s = x_i(\underset{\sim}{p}^*, e(\underset{\sim}{p}^*, u^s)) \tag{4}$$

where $i = 1, \ldots, g$. Moreover, using the relation between constrained and unconstrained expenditure functions (Neary and Roberts (1980, p. 30)) we find

$$e(\underset{\sim}{p}^*, u^s) = \tilde{e}(\bar{x}_1^s, \ldots, \bar{x}_g^s; \underset{\sim}{p}^s, u^s) + (\underset{\sim}{p}^* - \underset{\sim}{p}^s)' \underset{\sim}{x}^s \tag{5}$$

where $\tilde{e}(\cdot)$ is the constrained expenditure function. Note, however, that for a family participating in the government program the minimum expenditures necessary to attain utility u^s, given the price vector $\underset{\sim}{p}^s$ and the quantity constraint on the first g goods, is just equal to household income y, i.e.,

$$\tilde{e}(\bar{x}_1^s, \ldots, \bar{x}_g^s; \underset{\sim}{p}^s, u^s) = y \tag{6}$$

Using (5) and (6) in (4) finally yields

$$\bar{x}_i^s = x_i(\underset{\sim}{p}^*, y + (\underset{\sim}{p}^* - \underset{\sim}{p}^s)' \underset{\sim}{x}^s) \qquad i = 1, \ldots, g. \tag{7}$$

Equation system (7) is a set of g relations in g unknowns, viz. the g first components of $\underset{\sim}{p}^*$. Using an estimated demand system and observations on $\bar{x}_i^s$, $\underset{\sim}{p}^s$ and y, standard procedures can be applied to numerically solve for $\underset{\sim}{p}^*$. Substituting the result in

$$e(\underset{\sim}{p}^*, u^s) = y + (\underset{\sim}{p}^* - \underset{\sim}{p}^s)' \underset{\sim}{x}^s \tag{8}$$

obtained by combining (5) and (6), yields the corresponding expenditures.

To summarize, the preceding analysis suggests an alternative to more restrictive methods for estimating the benefits of in-kind programs. The proposed methodology allows us to estimate these benefits on the basis of arbitrary systems of demand equations. It consists of evaluating $\underset{\sim}{p}^*$ and $e(\underset{\sim}{p}^*, u^s)$ for each participating family in the sample, and to use these estimates as initial values in the algorithm discussed in the previous section. Given the availability of standard routines to evaluate the shadow prices and the simplicity of programming the algorithm the computational burden is small. Moreover, unlike the traditional approach (Olsen and Barton

(1983)) and the methodology recently suggested by Schwab (1985), the proposed procedure gives complete flexibility with respect to the choice of demand specifications. In addition, contrary to the technique outlined in Schwab (1985), our method is applicable in a multi-commodity world with more than one rationed good.

4. An empirical illustration

In this section we apply the proposed methodology to evaluate the benefits of a public rental housing program. Although the procedure is applicable in a more general setting our data forced us to assume, as is common in the empirical literature, that all goods can be aggregated in two composite commodities, housing (H) and all other goods (X).[5] In the absence of the program market prices are p_H^o and $p_X^o = 1$, respectively. The unit price of housing services is unobservable, as is housing quantity. What is observable is $p_H^o H$, the market rent.

The program under consideration offers participants the opportunity to live in a particular public unit at a subsidized rent. The market value of the public unit, $p_H^o H^s$, implicitly determines the quantity of housing consumed under the program. The quantity of other goods, X^s, is simply income minus the rent charged by the government. The equivalent variation benefit measure is

$$EV = e(p_H^o, u(H^s, X^s)) - y.$$

The data used for this study were derived from a 1972 survey conducted in the central city of Liège, Belgium. The survey collected information on a set of household characteristics and some data related to families' housing situation. The sample is small: it contains 326 observations, of which

approximately 70% concern private, uncontrolled housing, whereas 30% reported to be a participant in the public program.

To apply the method developed in the previous section one needs to disentangle prices and quantities of housing. Since our data pertain to a single urban area we applied the hedonic equation method previously used in the same context by, among others, Ozanne and Struyk (1976), Weinberg et. al. (1981) and Malpezzi (1987). They suggested to estimate a hedonic relation between rent and housing attributes, using the subsample of private units, and to construct a price index of the Paasche type as follows

$$p_H^o = \frac{R}{\hat{R}},$$

where R is observed rent and $\hat{R}$ is rent predicted by the hedonic. Predicted rent is then interpreted as a quantity index of housing, H, where the hedonic coefficients are used as weights. As noted by Malpezzi (1987, p. 132) the procedure is analogous to the widely used method to construct price and quantity indices over time where the hedonic coefficients are the 'base period' prices. Despite this analogy it is clear that this method to disentangle prices and quantities of housing has some serious shortcoming. It implies, among others, that every family in the sample will normally face a different unit price of housing. Although there undoubtedly exits unobservable price variation over the sample, there is no convincing reason why this would be the case. In addition, the hedonic procedure assumes the absence of unobserved and thus excluded characteristics. It finally assumes that the functional form of the hedonic is the correct one.[6] Note, however, that the goal of the application is to illustrate the usefulness of a methodology. We therefore do not consider these obvious shortcomings to be major obstacles for our purposes. More satisfactory methods to separate

prices and quantities are available for other data sets that relate to many urban areas.

The best fit was obtained when a semi-logarithmic hedonic was estimated using indicators of space, and of structural and sanitary quality as explanatory variables. The corrected R^2 amounted to 0.71. The chosen hedonic was used to construct price and quantity indices of housing.

Three different specifications for the housing demand function were estimated: linear and loglinear functional forms, and a specification containing Box-Cox transformations of income and of housing price and quantity. The following results were obtained (t-statistics between brackets) on the basis of the subsample of families in private housing:

$$H = \underset{(2.44)}{1619.8} - \underset{(-1.95)}{1641.3}\, p_H + \underset{(6.81)}{0.102}\, y + \underset{(3.34)}{353.1}\, (ED1)$$

$$+ \underset{(2.81)}{483.6}\, (ED2) + \underset{(1.73)}{713.8}\, (CH12) + \underset{(3.24)}{981.3}\, (CH34) \quad , R^2 = 0.43$$

$$\ln H = \underset{(3.18)}{1.30} - \underset{(-2.13)}{0.57}\, \ln p_H + \underset{(4.83)}{0.64}\, \ln y + \underset{(2.78)}{0.133}\, ED1$$

$$+ \underset{(2.54)}{0.184}\, ED2 + \underset{(1.52)}{0.268}\, CH12 + \underset{(3.88)}{0.381}\, CH34,$$

R^2 (in original space) = 0.47

$$\frac{H^{0.12} - 1}{0.12} = \underset{(1.90)}{2.19} - \underset{(-1.79)}{1.57} \left(\frac{p_H^{0.12} - 1}{0.12}\right) + \underset{(7.24)}{0.54} \left(\frac{y^{0.12} - 1}{0.12}\right)$$

$$+ \underset{(3.14)}{0.347}\, ED1 + \underset{(2.29)}{0.451}\, ED2 + \underset{(1.91)}{0.704}\, CH12 + \underset{(4.03)}{1.016}\, CH34$$

R^2 (in original space) = 0.49.

where[7] H : housing quantity

p_H: price of housing per unit

y : household income

ED1, ED2: dummy variables describing educational attainment of household head (ED1 = 1 if highest degree is a high school degree, ED2 = 1 if a higher degree, e.g., a university degree, was obtained).

CH12, CH34: dummy variables related to family size (CH12 = 1 if household contains one or two children, CH34 = 1 if household contains three or four children).[8]

The estimated demand functions suggest a positive and significant effect of family size and education on housing demand.[9] The results further imply price elasticities between-0.4 and -0.8 and income elasticities between 0.5 and 0.85. Although these values are within the range of recent estimates (see, e.g. Quigley (1979), Mayo (1981)), they should be cautiously interpreted. There appears to be quite a general agreement in the literature that housing demand is a function of permanent rather than observed income. As our estimates are based on the use of measured income the reported income elasticities are likely to substantially underestimate the effects of permanent income on demand. After a detailed survey of the literature Mayo (1981, p. 101) concluded that estimates that 'rely on current income should be adjusted upward by 16% to 50% to convert them to permanent income elasticities'.

Likelihood-ratio tests rejected both the linear and, although marginally, loglinear specifications at the 5% significance level. This is interesting because the Box-Cox demand function cannot be generated from an explicit direct or indirect utility function. As such it provides an appropriate

example to test the usefulness of the methodology proposed in Section 2.

Using demand parameters estimated for a sample of non-participants to estimate benefits of participating families implies the possibility of selection bias. The data did not allow implementation of an appropriate correction procedure. However, Olsen and Barton (1983, p. 314-315) have argued that the existence of eligibility limits on income and the fact that not all eligible families that are willing to participate are selected to join the program partially invalidates the classical selection bias argument, and that the direction of the bias is unclear. Moreover, Schwab (1985) points out that selection bias is unlikely to be important if the process of choosing among eligible families does not systematically favor high-demand households. As in principle this choice in the Belgian system is made on a first-come-first-served basis I suspect that selection bias is not a major problem for the purpose of this study.

For each household in the subsample of participants we applied the method described in the previous section to estimate program benefits. We first solved, using each of the three estimated demand functions, the equation $H^s = H(p_H^*, y - (p_H^s - p_H^*)H^s)$ for p_H^*, the shadow price of housing. Consistent with the procedure used to disentangle price and quantity of housing the quantity provided under the program, H^s, was obtained by inserting the observed housing characteristics of the public unit in the estimated hedonic rent equation. The subsidized unit price of housing, p_H^s, was found by dividing the rent charged under the program by housing quantity H^s.

We then used p_H^* and $[y - (p_H^s - p_H^*)H^s]$ as starting values in the numerical algorithm to evaluate $e(p_H^o, u^s)$, allowing us to calculate the equivalent variation of benefit.[10] The process was repeated for each household in the

subsample of public tenants for each of the three demand specifications.

Aggregate results are summarized in Table 1. First note that the average estimated market rent of public units was almost 35000 Belgian francs per year. Public housing tenants on average paid only slightly more than 21000 francs, implying an average subsidy of about 13500 francs. Mean benefit is substantially smaller than the cash value of the subsidy. Depending on the chosen demand specification it ranges from less than 7900 to almost 10000 Belgian francs. The difference between the cash value of the subsidy and program benefits can be interpreted as the welfare cost of restricting housing consumption at a suboptimal level. The average welfare cost amounts to between 25% and 41% of the cash value of the subsidy, depending on the specification of demand.

Mean benefits estimated on the basis of the loglinear and Box-Cox demand functions are 20% and 15% smaller, respectively, than the corresponding figure for the linear demand specification. It is hard to judge, however, whether these differences are large in a statistical sense. Given the use of estimated shadow prices as initial values in the algorithm the recently designed procedures to approximate the statistical precision of Vartia's estimator (see Porter - Hudak and Hayes (1986)) are not applicable, and we did not see how to approximate the standard errors of the benefit estimates of individual families. Intuition suggests, however, that even if these errors are substantial the standard deviation of mean benefit (i.e. the mean of a set of random variables) is likely to be small relative to this mean, especially in large samples.

Not only mean benefits but also the estimated distributional implications of the program were found to be quite different for different demand functions. We regressed benefits to a set of socio-economic household traits

including income, family size and the age of the household head. Although we found a positive and significant impact of family size in all three cases, the linear demand specification implied a significant negative effect of income on benefit, whereas the loglinear and Box-Cox demand functions yielded a positive but in-significant income coefficient.[11] Given the interest economists have in evaluating the distributional consequences of government programs an appropriate choice of the demand specification does not seem to be a trivial issue.

The procedures proposed and applied in this paper are easy to use and offer complete flexibility as to demand specification. Given this observation and the potentially important differences in the estimated efficiency and equity implications of government programs based on alternative demand functions, the methodology suggested in this paper may be considered as a powerful alternative to more restrictive methods available in the literature.

5. Summary and Conclusion

In this paper we presented a simple methodology that allows the estimation of the benefits of in-kind government programs on the basis of arbitrary systems of demand equations. The method consists of using specific starting values, defined in terms of appropriately defined shadow prices, in Vartia's well-known algorithm. It is easy to apply and computationally cheap.

The proposed procedures were applied to estimate the benefits of public housing. The results suggested that different specifications of demand may yield potentially important differences in the estimated efficiency and equity implications of government programs. The proposed methodology, which allows complete flexibility with respect to the functional form of demand equations, may therefore be a powerful alternative to more restrictive methods that previously have been used.

Footnotes

1. This is not necessarily a problem. Murray (1975) develops a procedure to approximate benefit using a generalized CES utility function for which no analytical benefit formula exists. His method is less general and totally unrelated to the procedures proposed in this paper.
2. It is assumed for simplicity that the consumer's income is unaffected by the price change.
3. It is assumed that the demand functions are continuously differentiable, that they satisfy the adding-up restriction and that the corresponding Slutsky matrix is symmetric and negative semi-definite. These conditions can in principle be checked for an empirically determined demand system or they can be imposed in the estimation procedure.
4. Obviously, the demand system must satisfy the conditions listed in footnote 3.
5. Our data did not contain information on the consumption of different categories of other goods. Consumption of other goods X was defined as income minus housing expenditures. We did have information on the availability of a set of housing characteristics. However, given that the sample is limited to a single and relatively homogeneous urban area, we did not see a satisfactory way to arrive at the subsidized implicit attribute prices under the program.

6. In particular the method will to some extent translate high values for some unobserved characteristics into a higher unit price of housing. Consider two units with the same observed characteristics so that their predicted rent $\hat{R}$ is equal. Suppose one unit contains more of an unobserved attribute that is positively valued in the market. To the extent that the impact of the unobserved attribute on rent is not captured through its correlation with observed characteristics the procedure will assign a higher unit price p_H^o to this unit.
7. Sample means were $\bar{H} = 2689$, $\bar{p}_H = 1$ (by construction, see before), $\bar{y} = 18492$ (Belgian francs per month), $\overline{ED1} = 0.242$, $\overline{ED2} = 0.194$, $\overline{CH12} = 0.45$, $\overline{CH34} = 0.33$.
8. The sample did not contain families with five or more children.
9. Other variables such as age did not appear to be significant.
10. The number of steps in the algorithm, N, was fixed at 10.
11. In each case the results were consistent with the poor distributional performance of public housing in Belgium. This phenomenon is well-known, see De Borger (1985).

References

Clarkson, Kenneth W., 1976, Welfare benefits of the food stamp program, Southern Economic Journal 43, 864-878.

Cronin, Francis J., 1983, The efficiency of demand-oriented housing programs, Journal of Human Resources 18, 100-125.

De Borger, Bruno, 1985, Aggregation theorems, commodity characteristics and estimation of the welfare implications of in-kind transfers: The case of housing assistance, Unpublished Ph.D. dissertation (University of Antwerp, UFSIA).

De Salvo, Joseph S., 1975, The benefits and costs of New York's middle income housing program, Journal of Political Economy 83, 791-806.

Hausman, Jerry, 1981, Exact consumer's surplus and deadweight loss, American Economic Review, 71, 662-676.

Malpezzi, Stephen J., 1987, Rent control and housing market equilibrium: Theory and evidence from Cairo, Egypt, Unpublished Ph.D. dissertation (George Washington University).

Mayo, Stephen K., 1981, Theory and estimation in the economics of housing demand, Journal of Urban Economics 10, 95-116.

Murray, Michael P., 1975, The distribution of benefits in public housing, Econometrica 43, 771-788.

Neary, J. Peter and K. W. S. Roberts, 1980, The theory of household behavior under rationing, European Economic Review 13, 25-42.

Olsen, Edgar O. and David M. Barton, 1983, The benefits and costs of public housing in New York City, Journal of Public Economics 20, 299-332.

Ozanne, Larry and Raymond Struyk, 1976, Housing from the existing stock (The Urban Institute).

Porter-Hudak, Susan and Kathy Hayes, 1986, The statistical precision of a numerical methods estimator as applied to welfare loss, Economics Letters 20, 255-257.

Quigley, John M., 1979, What have we learned about housing markets, in: P. Mieszkowski and M. R. Straszheim, eds., Recent issues in urban economics (The John Hopkins University Press, Baltimore, MD, 391-421.

Schwab, Robert M., 1985, Benefits of in-kind government programs, Journal of Public Economics 27, 195-210.

Vartia, Yrjö O., 1983, Efficient methods of measuring welfare change and compensated income in terms of ordinary demand functions, Econometrica 51, 79-98.

Weinberg, Daniel, Joseph Friedman and Stephen Mayo, 1981, Intra urban residential mobility: The role of transactions costs, market imperfections, and household disequilibrium, Journal of Urban Economics 9, 332-348.

APPENDIX

Market rent public unit	34477
Public rent	21065
Cash value of the subsidy	13412
Program benefit	
- Linear demand	9892
- Loglinear demand	7879
- Box-Cox demand	8463

Table 1: Aggregate effects of public housing (Figures refer to the mean of the corresponding row over the sample public tenants, in Belgian francs per year).