MAXIMIZING OR SATISFICING?

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I. Introduction

THE hypothesis that utility maximization underlies human behaviour is perhaps the most widely accepted paradigm among economists. Particularly in the study of consumer behaviour, numerous models have been built upon the hypothesis of utility maximization. Reviews of these models can inter alia be found in Houthakker (1961), Brown and Deaton (1972) and Barten (1977).

The testing of the utility maximization hypothesis (HM) in real life situations appears to be a complicated affair. The main problem is that HM can only be tested conditional upon other assumptions. An individual's utility function[1] is commonly measured via the individual's observed behaviour. We call that *indirect measurement.* But the relationship between an individual's utility function and his behaviour is based on HM itself. Hence, having measured utility functions via HM it becomes difficult to use the measured utility function to test HM.

Therefore, testing HM mostly reduces to testing certain restrictions which have to be satisfied by parameters in a system of demand equations. However, testing these restrictions is not without problems, as testing a certain restriction has to take place conditional upon the validity of other restrictions.[2]

As far as testing has been carried out, results are not very encouraging (cf. Barten, 1977; Wales and Woodland, 1976). But, since many additional assumptions are involved,[3] no firm conclusions can be drawn from these negative outcomes.

Given these problems, several paths are open to the student of consumer behaviour. First he may want to dispense with the utility concept altogether and only hypothesize certain consistency properties of individual choices. This approach was taken by Samuelson (1938). If, however, the assumptions on individual preferences are made sufficiently strong, especially if one adopts the strong axiom of revealed preference, their implications for behaviour are equivalent to the restrictions derived from HM (cf. Houthakker, 1950; Stigum, 1973). Hence, testing the restrictions implied by the strong axiom of revealed preference is equivalent to testing HM. Empirical work in this area (cf. Koo, 1963; Mossin 1972) suggests that for everyday commodities (mainly food) most purchases of individual families are not inconsistent with the strong axiom of revealed preference theory. However, in many cases purchases are such that neither consistency nor inconsistency can be assessed (cf. Koo, 1963). Koo (1974) states that "with few exceptions, almost all families made at least some inconsistent choices" (p. 174). He finds that inconsistencies do not arise very often if purchases are in the neighbourhood of past experience. For less routine-like purchases inconsistencies are more likely to occur.[4]

Parenthetically, it may be mentioned that aggregate demand functions have a tendency to be in agreement with the strong axiom of re-

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[1] Throughout the paper the term "utility function" will be used to denote the general concept, whereas the term "welfare function" will be used for the more narrowly defined concept introduced in section II.

[2] In any case one has to specify functional forms for the demand equations. Even when using flexible forms (e.g., Christensen, Jorgenson, and Lau, 1975) the specification may be expected to affect the result.

[3] For example, it is usually assumed that individuals have identical utility functions, or that an individual's utility parameters are not affected by consumption patterns of other individuals, that utility functions do not shift over time, etc. Moreover, estimation is often based on aggregate data.

[4] The empirical investigations in the present paper are concerned with durables. Extrapolating Koo's findings we would expect HM to be violated relatively often for these expenditure categories, since durables are bought infrequently.

vealed preference even if the individual demand functions are not (Mossin, 1972; Maks, 1977). Therefore the application of HM-based systems of demand functions to aggregate data may be justified although this does not tell us very much about the validity of HM on the individual level.

A second path sometimes taken is to conduct small-scale experiments in which environmental factors are sufficiently under control to allow for conclusive testing. Examples of this approach are the studies by MacCrimmon and Toda (1969) and by Battalio et al. (1973). Both of these studies yield results that are mainly (but not uniformly) consistent with HM.

Unfortunately, conclusions based on relatively simple laboratory settings cannot be readily extended to real-life situations. Indeed, it may be argued that in particular the complexity of real life in connection with the human being's limited capacity to process information and solve problems (cf. Hogarth, 1975) prevents individuals from maximizing utility. This leads to the third path. One may assume that in complex situations individuals are unable to maximize utility but rather resort to simple rules-of-thumb. This may lead to so-called satisficing behaviour. Some aspects of satisficing behaviour are outlined in section IV.

Finally, there is a fourth path, which is the one adopted in the present paper. As we suggested above, testing of HM is difficult because utility functions are usually indirectly measured, i.e., via observations on economic behaviour. It seems worthwhile therefore to investigate the possibility of developing *direct methods of measurement* of utility functions, i.e., without having to rely on observations of economic behaviour. If that can be done, one can test HM in a more straightforward manner.

For direct measurement of utility functions in practice one needs to make more specific assumptions than the usual ones of differentiability and quasi-concavity. In particular we shall assume that measurement on a cardinal scale is possible and their functional form will be specified a priori. This entails the risk of misspecifying the functional form of the utility function and consequently deriving wrong empirical implications. So, when measuring utility functions, both the assumption of cardinality itself and the hypothesized functional shape of the utility function should be severely tested. In section II we briefly outline a particular kind of cardinal utility function. This so-called individual welfare function (IWF) has been measured by simple direct questioning methods and put to test in a number of investigations with quite favourable results.[5] Given these results we adopt the IWF as an adequate description of individual preferences.

Having adopted a particular cardinally measured utility function, most of the problems encountered with indirectly measured utility disappear. Armed with knowledge of an individual's utility function we can, by observing his behaviour, in theory, tell whether any economic action he undertakes will maximize his utility or not.

In section II the concept of utility used throughout the paper is explained and a derivation is given of the behavioural implications of HM. In section III the behavioural implications are confronted with the data. It will appear that, under the assumptions used to derive the behavioural implications, HM does not explain the data. In section IV the alternative hypothesis of satisficing behaviour is investigated heuristically. Section V presents evidence for the appropriateness of the satisficing approach. Section VI concludes the paper by stating a number of qualifications to the general validity of the results obtained. Finally, lines of possible future research are pointed at.

II. Maximization of a Multivariate Lognormal Welfare Function

In this section we specify the utility function, point at some empirical evidence regarding its shape and derive the first order conditions for utility maximization.

A. *The Utility Function*

Our specification of an individual's utility function rests upon the notion of a utility tree. We assume that an individual who must decide how to spend his income on various expenditure categories will adopt a multi-stage procedure. In the first stage he decides upon a preliminary allocation of his income over a limited number, say I, of broad categories. Our analysis will be concerned with the first stage only. Under HM, the

[5] References are given in section II.

allocation of the money amounts y_i ($i = 1, \ldots, I$) to the I categories takes place in such a way that the individual's utility function is maximized.

The I categories will be rather complex composites. That is, in each category a large number of characteristics may be distinguished. By inter alia assuming that an individual is able to evaluate the satisfaction derivable from any set of characteristics on a [0, 1]-scale, Van Praag (1968) establishes an isomorphism between probability theory and utility theory. Making a few additional assumptions he then shows that the evaluation of the vector $Y \equiv (y_1, y_2, \ldots, y_I)'$ of money amounts y_i allocated to various expenditure categories can, under fairly weak conditions, be approximated by

$$W(Y) = (2\pi)^{-I/2} |\Sigma|^{-\frac{1}{2}} \int_0^{y_1} \cdots \int_0^{Y_I} \prod_{i=1}^{I} t_i^{-1} \exp\left[-\tfrac{1}{2}(\ln(t) - \tilde{\mu})' \Sigma^{-1} (\ln(t) - \tilde{\mu})\right] dt_1 \ldots dt_I \tag{1}$$

where

$$\ln(t) \equiv (\ln(t_1), \ln(t_2), \ldots, \ln(t_I))', \tag{2}$$

$$\tilde{\mu} \equiv (\mu_1, \mu_2, \ldots, \mu_I)', \tag{3}$$

$$\Sigma \equiv \begin{bmatrix} \sigma_1^2 & \sigma_{12} & \ldots & \sigma_{1I} \\ \sigma_{21} & \sigma_2^2 & \ldots & \sigma_{2I} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \sigma_{I1} & \sigma_{I2} & \ldots & \sigma_I^2 \end{bmatrix}. \tag{4}$$

We call (1) the individual's *individual welfare function* (IWF). The reader will recognize (1) as the I-variate lognormal distribution function (cf. Aitchison and Brown, 1957). The parameters $\tilde{\mu}$ and Σ may vary over individuals. In the present framework they have a psychological rather than a probabilistic meaning.

We shall not go into the interpretation of $\tilde{\mu}$ and Σ in the present paper but refer to earlier work.[6] Some comments on the empirical validity of (1) are in order, because our subsequent analysis rests upon it.

Two important implications of (1) have been confronted with large bodies of data. First the case $I = 1$ has been considered. That is, all expenditures are lumped into one broad category, "total expenditures." Taking savings as postponed expenditures the category of total expenditures may be equated to income.[7] In this case (1) implies that an individual's evaluation of different income levels will approximately follow a lognormal distribution function, to be written $\Lambda(y;\mu,\sigma)$, which stands for the univariate lognormal distribution function with parameters μ and σ. We call $\Lambda(y;\mu,\sigma)$ the individual's *welfare function of income* (WFI).

An individual's WFI is measured by confronting him with a number of evaluations, like "good," "sufficient," "bad," etc. and asking him which income levels in his opinion correspond to these evaluations. Next the evaluations are translated into numbers that partition the [0,1]-interval into equal subintervals. This translation is based on an information theoretical argument (Van Praag, 1971). Thus we obtain for the individual a number of numerical evaluations $U(z_i)$ and the corresponding income levels z_i, $i = 1, \ldots, n$, where n is the number of evaluations offered to the individual (usually between 5 and 8). If the sequence $\{U(z_i), z_i\}_{i=1}^n$ would be in accordance with Van Praag's theory, there would hold $U(z_i) = N((\ln z_i - \mu)/\sigma; 0,1)$, or $\ln z_i = \mu + \sigma w_i$, where w_i follows from $N(w_i; 0,1) = i/(n+1)$. Allowing for white noise the individual's μ and σ are estimated from the regression

$$\ln z_i = \mu + \sigma w_i + \xi_i \qquad i = 1, \ldots, n. \tag{5}$$

Up until now, WFIs of about 14,000 individuals from nine different European countries have been measured in the way described above.[8] The lognormality of the WFIs has been tested in a number of ways. Non-linearity tests have been applied to (5) (Van Praag and Kapteyn, 1973; Kapteyn, 1977); various alternative functional forms have been compared to the lognormal distribution function (Van Herwaarden and Kapteyn, 1978). The validity of the measurements has been investigated by trying to explain the measured parameters in μ and σ by economically meaningful variables like income and family composition. For a short review, see Van Herwaarden, Kapteyn, Van Praag (1977). None of these tests led to a rejection of the lognormal form. Indeed the comparison with other func-

[6] E.g., Van Praag (1968, 1971), Van Praag and Kapteyn (1973).

[7] In the sequel the word "income" will exclusively denote "after tax disposable income."

[8] Cf. Kapteyn (1977), Van Herwaarden, Kapteyn, and Van Praag (1977), and Goedhart, Kapteyn, and Van Praag (1977).

tional forms indicates that the lognormal function is superior to any alternative distribution function as a description of the shape of the WFI.

The outcomes of the various tests also seem to confirm the cardinality of the WFIs. It is hard to imagine how the consistently good performance of the lognormal WFI in the various tests could obtain if the welfare levels $U(z_i)$ would have no meaning, i.e., if they could be replaced by any monotonically increasing transformation.

A second implication of (1) is that money amounts y_i spent on any of the I categories are evaluated according to a univariate lognormal distribution function, to be written $\Lambda_i(y_i;\mu_i,\sigma_i)$. We call $\Lambda_i(y_i;\mu_i,\sigma_i)$ the *partial welfare function* (PWF) of the expenditure category under consideration. Employing the same measurement technique as with WFIs, Kapteyn, Van Herwaarden, and Van Praag (1977) have measured 9,500 PWFs of about 3,000 individuals pertaining to 33 different expenditure categories. Applying the same tests as applied to WFIs (see above) they found that the lognormality of the PWFs could not be rejected.

Experience with multivariate welfare functions is more limited. On the basis of the theoretical analysis in Goedhart and Kapteyn (1978) these authors are presently involved in the measurement of bivariate welfare functions of income and time. However, hitherto only limited testing of the bivariate lognormal form has been done. Dagenais (1977) reports on the measurement of an average bivariate welfare function of income and air quality for groups of people. Comparison with a quadratic and a bivariate normal specification leads her to adopt the bivariate lognormal specification as the best representation of her data.

In sum: The lognormal specification of WFIs and PWFs has been tested in various studies. The bivariate lognormal specification has been investigated less extensively. Since none of the investigations mentioned has produced counter-evidence for the lognormal form we adopt (1) as the utility function describing individual preferences:[9]

Assumption I. *The functional shape of the individual utility function is given by (1).*

Next we derive first order conditions for maximization of (1) subject to a budget constraint.

B. First Order Conditions for Utility Maximization

Before deriving first order conditions for utility maximization we will have to be more specific with regard to (1): Intuitively, it seems plausible that an individual tries to reduce the complexity of the money allocation problem as far as possible. One way of doing so efficiently (from an informational point of view) is to consider only expenditure categories of which the PWFs are independent. For a more detailed motivation we refer to Van Praag (1968, section 3.4 and p. 120). Therefore we take Σ (cf. equation (4)) to be diagonal:

Assumption II. *Σ is diagonal.*

Some empirical evidence in favour of assumption II is given in section III.

Given assumptions I and II, HM amounts to the solution of the following problem:[10]

$$\max_{y_1,\ldots,y_I} \prod_{i=1}^{I} \Lambda(y_i;\mu_i,\sigma_i) \tag{6}$$

subject to

$$\sum_{i=1}^{I} y_i = y, \tag{7}$$

where y is the individual's income. Shorten $\Lambda(y_i;\mu_i,\sigma_i)$ to $\Lambda_i(y_i)$ and write $\lambda_i(y_i)$ for the derivative of Λ_i with respect to y_i. Then the solution for the maximization problem is

[9] The reader will notice that $W(Y)$ vanishes if one of the elements of Y equals zero, i.e., if an individual does not spend money on some category. This implies that if the individual wants to maximize his utility, he has to spend money on all categories. Note however that the definition of the categories has not been discussed so far. In fact, it is Van Praag's contention that the definition of the expenditure categories will vary with the decision problem at hand (see also below, subsection IIIB). In making purchases individuals consider only a "relevant set" (or as it is called in psychology and marketing research, the "evoked set"). As we shall analyze *how much* individuals spend on certain expenditure categories, taking the decision to spend or not to spend on a category as given, we assume that the choice of expenditure categories is such that no y_i is zero. In section VI we shall moreover pay more attention to the sensitivity of our empirical results to the adopted form of the utility function.

[10] Every individual may choose a different number of expenditure categories, I. This choice is immaterial for the tests to be applied.

$$\lambda_i(y_i)/\Lambda_i(y_i) = \lambda_j(y_j)/\Lambda_j(y_j)$$
$$(j = 2, \ldots, I; i = 1, \ldots, j - i). \quad (8)$$

It can be shown that, when the y_i and y_j satisfy (8), second order conditions for a maximum are also fulfilled (Van Praag, 1968, pp. 133 ff.). In words, (8) states that the relative marginal utility of an additional florin should be the same in all expenditure directions.

Relation (8) becomes slightly more complicated if we allow for the possibility that some expenditure categories pertain to durables.[11] By definition a consumer durable, i, is expected to produce a service flow over a fairly long period, say k_i years. A rational consumer will therefore regard the purchase of a durable good partly as an investment and will therefore maximize utility subject to

$$\sum_i (y_i/k_i) = y, \quad (9)$$

rather than (7).[12] It would also be appropriate to replace the PWFs $\Lambda_i(y_i;\mu_i,\sigma_i)$ by $\Lambda(y_i/k_i;\mu_i - \ln(k_i),\sigma_i)$, but these expressions are identical.

Maximizing (6) subject to (9) leads to

$$\lambda_i(y_i)/\Lambda_i(y_i) = k_j\lambda_j(y_j)/k_i\Lambda_j(y_j). \quad (10)$$

In the next section data are investigated in order to ascertain whether relations like (10) are discernible.

III. Testing for Utility Maximization

The data used are from a written survey conducted in 1971. For details see Van Praag and Kapteyn (1973). The measurement of PWFs and WFIs on the basis of this sample is reported on by Kapteyn et al. (1977).

In addition to the information reported in the aforementioned papers, individuals in the sample were also asked whether they planned to buy certain durables, and if so, how much they expected to spend on them. This information was collected for 31 durables. For a good an individual planned to buy he was asked to answer questions which served to measure his PWF (cf. subsection IIA) of that good. The questionnaire left room for a maximum of four PWFs. This does not seem to have been very restrictive since only 51 respondents out of a total of 1,086 did give four PWFs.

The number of 31 durables has been reduced to 28 by combining two goods (new cars and second-hand cars, since the distinction seems to have been unclear to some respondents) and by dropping two goods (floor covering, since no quantities were specified, which makes the meaning of y_i ambiguous, and gas-rings, since only two observations are available). Thus 1,054 individuals remain in the sample with at least one measured PWF, yielding 1,739 measured PWFs in total.

In testing for utility maximization, we have deliberately used data on purchase plans rather than data on actual purchases. It was felt that if utility maximization is the basic mechanism guiding decisions, it is more likely to show up in purchase plans than in actual purchases where a number of unknown influences may disturb the picture.[13]

A. A Test Based on Multiple Observations

In order to test (10) we impose the following stochastic structure:

$$\frac{\lambda_{it}(y_{it})}{\Lambda_{it}(y_{it})} = \alpha_{ij} + \beta_{ij}\frac{\lambda_{jt}(y_{jt})}{\Lambda_{jt}(y_{jt})} + \epsilon_{ijt},$$
$$(j = 2, \ldots, I; i = 1, \ldots, j - i) \quad (11)$$

where t runs over all individuals with respect to whom information on both the i^{th} and j^{th} expenditure category is available. The errors ϵ_{ijt} are assumed to follow a $N(0,\sigma_{\epsilon ij})$ distribution. If (10) were to hold exactly, estimation of (11) should yield $\alpha_{ij} = 0$, $\beta_{ij} \neq 0$. Presumably, however, the parameters μ_i, σ_i, μ_j, σ_j in λ_i, Λ_i, λ_j, Λ_j suffer from errors of measurement.[14] These measurement errors will tend to bias estimates of β_{ij} downwards and to bias the estimates of α_{ij} upwards. As long as the measurement errors in the parameters are not excessive, however,[15] we ex-

[11] All expenditure categories used in the present study to test HM pertain to durables.

[12] We ignore the role of interest rates, imperfect capital markets, myopia, time preference, etc., since these do not affect the basic argument.

[13] For instance, a refrigerator of a given size and make may be the outcome of the utility maximization process, but due to the influence of the salesman, or due to an accidental supply shortage, the individual may as yet decide to buy a different type of refrigerator.

[14] Cf. subsection IIA.

[15] The results obtained by Kapteyn, Van Herwaarden, and Van Praag (1977) indicate that the errors of measurement are moderate.

pect the corrected coefficient of determination, $\bar{R}^2$, corresponding to (11) to be positive.

Out of the 1,054 individuals in the sample, we were able to measure μ_i, σ_i and y_i of more than one expenditure category for 458 individuals: For 96 (i,j)-combinations (out of a maximum possible number of 378) more than two observations were available. The maximum number of observations in one cell was 14. The pattern of non-empty cells seems to give support to assumption II. The vast majority of the non-empty cells pertain to combinations of durables for which interdependency of PWFs is highly unlikely. As an illustration we mention that the three cells with the largest number of observations pertain to the combinations (washing machine, moped), (automatic washing machine, camera), and (gramophone, film camera).

When running the 96 regressions (11) it appears that 47 $\bar{R}^2$-values are positive and 49 values are negative. The average $\bar{R}^2$, weighted by the number of observations, is 0.12. Sixteen F-values are significant at the 10% level.

It is difficult to draw firm conclusions from these results. For example, in case there is no correlation at all between the variables at the left and right hand side of (11) the expected number of significant F-values is equal to 9.6. The number actually found, 16, is significantly (at the 10% level) in excess of 9.6, but still is not very impressive. The average $\bar{R}^2$ being equal to 0.12 suggests that there is some relationship of the type (11) in the data, but the fact remains that a majority of the regressions yield negative $\bar{R}^2$ values.

This ambiguous picture is caused by the very small number of observations per (i,j)-combination (typically between 3 and 6). That makes the correction for degrees of freedom inherent in $\bar{R}^2$ very important but at the same time these $\bar{R}^2$s are unreliable. Also, the F-tests applied will be sensitive for departures of normality of the ϵ_{ijt} in (11).

Since the above analysis uses observations only on the 458 individuals who supplied at least two PWFs, information on more than half of the individuals in the 1,054-sample has been neglected. Neither have the individuals' incomes and WFIs been used. The ambiguous results obtained so far make it urgent to make a fuller use of the data available. At the cost of two additional assumptions we will be able to employ all the data and, as a consequence, we shall obtain more clearcut results.

B. *A Test Based on All Observations*

The first additional assumption we make is

Assumption III. *When considering the purchase of good i, an individual distinguishes two categories only: good i and "other expenditures."*

As with assumption II, this assumption can be motivated by the supposition that an individual adheres to simple rules. The individual is assumed to minimize the complexity of the money allocation problem by reducing I to its sensible minimum, 2.

Given assumption III the utility maximization problem becomes

$$\max_{y_i, y^i} \Lambda_i(y_i)\Lambda^i(y^i) \tag{12}$$

subject to

$$y_i + y^i = y, \tag{13}$$

where y^i is the money spent on all expenditure categories other than i and Λ^i the corresponding PWF. For the moment we ignore the complication due to differences in durability of the goods.

One of the first order conditions now reads:

$$\lambda_i(y_i)\Lambda^i(y^i) = \eta, \tag{14}$$

where η is the Lagrange multiplier corresponding to the budget constraint. The Lagrange multiplier can be given the usual interpretation of marginal utility of income at equilibrium (cf. Phlips, 1974, p. 21), i.e.,

$$\eta = \left.\frac{\partial U^0(z)}{\partial z}\right|_{z=y} \tag{15}$$

where U^0 is the indirect utility function of income.

Relation (15) will be employed after making a second assumption: It has been observed by Van Praag (1968, p. 132) and by Kapteyn (1977, section 2.6) that in the lognormal framework the indirect utility function of income is approximately lognormal as well. Although the WFI is by genesis not an indirect utility function of income, it seems reasonable to take the WFI, $U(z)$, as an approximation to the indirect utility function, at least in the point $z = y$.[16] We thus make

[16] As indicated in subsection IIA, an individual's WFI is measured by letting him evaluate a number of different

ASSUMPTION IV. $U^0(z) = \Lambda(z;\mu,\sigma)$, *in the neighbourhood of* y.

Hence

$$\left.\frac{\partial U^0(z)}{\partial z}\right|_{z=y} = \lambda(y;\mu,\sigma). \tag{16}$$

It follows from assumption IV, (14), (15), and (16) that

$$\frac{\lambda_i(y_i)}{\Lambda_i(y_i)} = \frac{\lambda(y;\mu,\sigma)}{\Lambda(y;\mu,\sigma)} \equiv \frac{\lambda(y)}{\Lambda(y)}. \tag{17}$$

Thus, (17) states that under HM the relative marginal utility from spending money on category i will be equal to the relative marginal utility of income.

Allowing once more for differences in durability we specify the following regression equation which is estimated for 28 durables.

$$\frac{\lambda_{it}(y_{it})}{\Lambda_{it}(y_{it})} = \alpha_{0i} + \alpha_{1i}\frac{\lambda_t(y_t)}{\Lambda_t(y_t)} + \epsilon_{it},$$
$$(i = 1, \ldots, 28;\ t = 1, \ldots, T_i) \tag{18}$$

where T_i represents the number of observations on the i^{th} expenditure category. The error term ϵ_{it} is assumed to follow a $N(0,w_i)$ distribution.

It turns out that 19 out of 28 $\bar{R}^2$-values are negative. Only 2 F-values are significant at the 5% level, whereas one more F-value is significant at the 10% level. In other words, 3 F-values are significant at the 10% level, which is about the number one would expect under the null-hypothesis of no correlation between the variables at the left and right hand side of (17). The average value of $\bar{R}^2$ over all 28 goods (weighted by the number of observations per good) is equal to -0.00.

Given the reasonable number of observations per good and the consistent picture across the goods, we tend to conclude that our data do not provide any evidence in favour of HM. Before discussing in the concluding section the sensitivity of this outcome for the various assumptions that have been made in the course of the analysis, we first turn to different hypotheses that may fit the data better.

hypothetical income levels. It appears that individuals take their own actual income and the corresponding evaluation as a reference point. Presumably an individual's evaluation of his actual income is mainly a reflection of his indirect utility function of income. Hence we expect $U(y)$ and $U^0(y)$ to be approximately equal.

IV. Satisficing

Utility maximization essentially requires the simultaneous solution of a number of interrelated problems. Even in the simple case where only two expenditure categories are involved (good i and "other expenditures") an individual has to decide simultaneously how much satisfaction he expects to derive from y_i and y^i. Since expenditure categories usually are complex composites of many characteristics, such a task may easily exceed the individual's cognitive capacities.

A possible way to cope with the excessive complexity of decision problems is to make decisions sequentially (cf. Simon, 1955), that is, decision alternatives are identified one by one and an alternative is adopted if it exceeds a certain aspiration level. This type of behaviour is called *satisficing*. Two examples may elucidate the concept.

Example 1: An individual is considering the purchase of a toothbrush, which can be bought at different prices at different stores. Given some prior ideas about the distribution of prices, the individual may adopt the strategy of setting an aspiration level.[17] He will search for brushes until he finds one of which the price does not exceed his aspiration level. Of course the aspiration level may change in the course of the search process.

Example 2: An individual is seeking employment. At irregular intervals he is faced with a job offer. Once he encounters a job offer of which the wage exceeds his aspiration level[18] he will accept it.

Given the sequential nature of the information it can be shown that satisficing is optimal under a variety of conditions (cf. Simon, 1955; Rothschild, 1974; Lippman and McCall, 1976). Even if information is not provided sequentially, it may be supposed that an individual, due to his limited information processing capacity, tries to decompose a decision problem into a number of consecutive stages. After this decomposition, satisficing may be the optimal strategy. If, on the other hand, decision problems are simple, there is no need for a sequential strategy. In that case we expect a type of behaviour that is more consistent with utility maximization.

[17] Also called "reservation price" in this context.
[18] Also called "reservation wage" in this context.

The complexity of a problem introduces uncertainty in the sense that an individual is unable to grasp the structure of the problem due to his "computational inability."[19] In this connection we mention two experiments by Ölander (1975). He finds that in well-defined decision problems utility maximization usually gives a better explanation of behaviour than satisficing. If, however, the information on alternatives decreases, satisficing becomes the more frequently observed strategy.

In sum, we observe that consumption decisions are complex. This complexity, in conjunction with an individual's limited cognitive abilities, leads to uncertainty. A sequential decision strategy which can be described by satisficing is then adopted.

In the next subsection we outline the meaning that can be attached to satisficing behaviour in the framework of the IWF.

A. *Satisficing and Partial Welfare Functions*

Reconsider the amount y_i that an individual intends to spend on the i^{th} category. According to the satisficing hypothesis, y_i has to exceed the individual's aspiration level. We may operationalize the hypothesis in a variety of ways, of which two classes will be considered.

I. The satisficing hypothesis may be interpreted in such a way that the welfare expected from the purchase of the i^{th} good has to exceed a certain level. In terms of PWFs, y_i has to satisfy

$$\Lambda(y_i;\mu_i,\sigma_i) \geqq A_i \tag{19}$$

where A_i stands for the aspiration level with respect to the i^{th} good. From (19) it follows that

$$\ln (y_i) \geqq \mu_i + \alpha'_i\sigma_i, \tag{20}$$

where α'_i follows from

$$N(\alpha'_i;0,1) = A_i. \tag{21}$$

We shall denote (20) as hypothesis H1′. Notice that (19) refers to an aspiration level in welfare terms: the welfare derived from spending an amount y_i (as measured by the i^{th} PWF) has to exceed A_i. It is also conceivable that the individual states his aspiration level in money terms directly. This leads to a second class of operationalizations.

II. If an individual's PWF of the i^{th} expenditure category is located far to the right (on the money axis) he will presumably have to spend a larger amount on the i^{th} category to exceed his aspiration level than somebody whose PWF is located more to the left. In general, we expect an individual's aspiration level to be high when his PWF is located far to the right and to be low when his PWF is located to the left. This suggests that the aspiration level depends on one of the location parameters of the PWF. In particular, we will investigate whether an individual's aspiration level is a multiple of either the *median,* the *mean,* or the *mode* of the PWF. This leads to three competing hypotheses for the explanation of y_i:

$$y_i \geqq \beta'_i \exp(\mu_i) \qquad \text{(H2′: median)} \tag{22}$$

$$y_i \geqq \gamma'_i \exp(\mu_i + \tfrac{1}{2}\sigma_i^2) \qquad \text{(H3′: mean)} \tag{23}$$

$$y_i \geqq \delta'_i \exp(\mu_i - \sigma_i^2) \qquad \text{(H4′: mode)} \tag{24}$$

In the next section a selection process will be described which leads to the adoption of one of these four hypotheses on the basis of the sample.

V. Choosing between Four Hypotheses

The choice between the four hypotheses stated in the previous section will take place in a rather heuristic manner. All four hypotheses were stated as inequalities incorporating a single unknown parameter ($\alpha'_i,\beta'_i,\gamma'_i$, or δ'_i). Evidently, it is possible to choose the unknown parameters such that all four hypotheses hold. We therefore make the additional assumption that individuals plan the amount y_i in such a way that the aspiration level is exceeded by a constant proportion

[19] Cf. Simon (1972) who states "What we refer to as 'uncertainty' in chess or theorem proving, therefore, is uncertainty introduced into a perfectly certain environment by inability—computational inability—to ascertain the structure of that environment. But the result of the uncertainty, whatever its source, is the same: approximation must replace exactness in reaching a decision. In particular, when the uncertainty takes the form of an unwieldy problem space to be explored, the problem solving process must incorporate mechanisms for determining when the search or evaluation will stop and an alternative will be chosen" (p. 170).

which is the same for each individual.[20] On the other hand, we allow for individual differences by specifying a stochastic structure.

The four hypotheses are reformulated as follows:

$$\ln (y_{it}) = \mu_{it} + \alpha_i\sigma_{it} + x_{it} \qquad \text{(H1)} \quad (25)$$

$$\ln (y_{it}) = \beta_i + \mu_{it} + u_{it} \qquad \text{(H2)} \quad (26)$$

$$\ln (y_{it}) = \gamma_i + \mu_{it} + \tfrac{1}{2}\sigma_{it}^2 + v_{it} \qquad \text{(H3)} \quad (27)$$

$$\ln (y_{it}) = \delta_i + \mu_{it} - \sigma_{it}^2 + w_{it}. \qquad \text{(H4)} \quad (28)$$

The errors x_{it},u_{it},v_{it} and w_{it} have, by assumption, variances σ_{xi}^2, σ_{ui}^2, σ_{vi}^2, σ_{wi}^2. Further assumptions on the errors will be made below. The parameters α_i, β_i, γ_i and δ_i can be estimated for each good separately.

Since each of the relationships (25) through (28) has the same dependent variable, a choice between them could be made on the basis of the criterion of minimal residual variance. If one of the four models is correct, this model should, on average, exhibit the lowest residual variance (cf. Theil, 1961, or Theil, 1971). Since each of the equations (25) through (28) is estimated for 28 different goods, it would be a rather safe policy to coin one of the equations ''correct'' if it exhibits the lowest residual variance for a large majority of the 28 goods.

Unfortunately, this line of reasoning does not apply directly: the explanatory variables in (25) through (28) all contain errors of measurement[21] whilst Theil's result is based on non-stochastic explanatory variables.

Below we shall develop a modification of Theil's argument which is applicable to the present situation. Before that, we will be able to discard H4 by a simple argument.

A. *Elimination of H4*

We run regressions of the form

$$\ln (y_{it}) = a_{0i} + a_{1i}\mu_{it} + a_{2i}\sigma_{it}^2 + \epsilon_{it}, \qquad (29)$$

with a_{0i}, a_{1i}, a_{2i} parameters to be estimated and ϵ_{it} an identically and independently distributed (i.i.d.) error term. If (28) would hold, we should find estimates for a_{2i}, $\hat{a}_{2i}$, equal to minus one. Due to the measurement errors in σ_i^2, however, the $\hat{a}_{2i}$ will be biased toward zero. But in any case we should find $\hat{a}_{2i} < 0$.[22] Running regression (29) for each of the 28 goods we find that $\hat{a}_{2i}$ is positive for 25 goods. The three negative estimates are all within one standard error from zero. On the basis of this result, H4 is discarded.

B. *The Choice between H1, H2 and H3*

We call a model *correct* if its error term has zero expectation and is distributed independently of the values of μ_{it} and σ_{it}.

ASSUMPTION V. *One of the hypotheses H1, H2, H3 is correct.*

Let s_{1i}^2, s_{2i}^2, and s_{3i}^2 be the residual variances corresponding to H1, H2 and H3. Definitions are given in the appendix, where also an argument is developed which suggests that the correct hypothesis will be the one exhibiting lowest residual variance for a majority of the 28 expenditure categories. That argument is formalized in

ASSUMPTION VI. *If H2 is correct, $P(s_{2i}^2 > s_{3i}^2) \leqq \frac{1}{2}$,*
If H3 is correct, $P(s_{3i}^2 > s_{1i}^2) \leqq \frac{1}{2}$.

It appears that for 21 out of the 28 goods s_{2i}^2 exceeds s_{3i}^2. If H2 were correct, assumption VI implies $P(s_{2i}^2 > s_{3i}^2) \leqq \frac{1}{2}$ and this outcome would have a probability smaller than 0.005. Hence we reject H2.

Next, it appears that for 18 out of the 28 goods s_{3i}^2 exceeds s_{1i}^2. This leads to a rejection of H3 at the 10% level.

Consequently, we take H1 to be the correct hypothesis.

C. *Comments upon H1*

In table 1 the estimates of α_i, $\hat{\alpha}_i$ are presented, along with standard errors, $\bar{R}^2$-values and values

[20] Below we briefly discuss the more general case where aspiration levels may differ between individuals.

[21] The measurement errors are at least as big as the standard errors of the parameter estimates in model (5). Since $U(z_i)$ provides a partitioning of the [0,1]-interval into equal subintervals, the w_i have mean zero. As a consequence the covariance of the parameter estimates in (5) is zero. We assume therefore that the measurement errors in μ_{it} and σ_{it} are independent.

[22] This remark rests on the formula for the asymptotic bias of regression coefficients when there are errors of measurement (e.g., Johnston, 1972, formula (9-42)), on the assumption that the measurement errors are independent (cf. the previous footnote), and on inspection of the variance-covariance matrices of the observations on μ_{it} and σ_{it}^2 for each i.

TABLE 1.—ESTIMATES WITH RESPECT TO H1

	Name of Good	Number of Observations	$\hat{\alpha}_i$	Standard Error of $\hat{\alpha}_i$[a]	$\bar{R}^{2}$[b]	$N(\hat{\alpha}_i;0,1)$
1	car	166	.59	.04	.54	.72
2	house	57	.41	.13	.76	.66
3	boat	13	.65	.14	.77	.74
4	caravan/country cottage	16	.67	.13	.87	.75
5	automatic dishwasher	64	.78	.06	.56	.78
6	spin dryer	26	.78	.12	.64	.78
7	dryer	28	.97	.10	.79	.83
8	gas ring	29	.78	.08	.82	.78
9	gas fire	28	.89	.10	.81	.81
10	refrigerator	80	.71	.05	.72	.76
11	sewing machine	66	.75	.06	.57	.77
12	vacuum cleaner	64	.75	.07	.39	.77
13	washing machine	7	.85	.22	.53	.80
14	automatic washing machine	115	.81	.04	.37	.79
15	tape recorder	123	.72	.05	.61	.76
16	loudspeaker	54	.68	.11	.37	.75
17	gramophone	125	.77	.06	.35	.78
18	wireless	158	.58	.04	.48	.72
19	television (black & white)	80	.64	.06	.22	.74
20	television (colour)	57	.70	.09	−.69	.76
21	electric drill	61	.75	.05	.58	.77
22	slide projector	78	.79	.05	.62	.79
23	film camera	37	.68	.08	.33	.75
24	film projector	19	.52	.11	−.08	.70
25	camera	68	.75	.07	.60	.77
26	moped	21	.80	.08	.67	.79
27	watch	58	.82	.06	.66	.79
28	electric shaver	41	.96	.08	.26	.83

[a] Defined as $(\mathrm{var}\,((\overline{\ln y_i} - \overline{\mu_i})/\overline{\sigma_i}))^{\frac{1}{2}}$. Asymptotically this can be approximated by $(s_{1i}^2/(T_i - 1)\bar{\sigma}_i^2)$ (cf. Cramer, 1969, p. 96).
[b] Defined as $(1 - s_{1i}^2)/\mathrm{var}(\ln(y_i))$.

of $N(\hat{\alpha}_i;0,1)$. The $\bar{R}^2$-values favourably contrast with the $\bar{R}^2$-values obtained with equation (18).[23] H1 appears to be capable of explaining a considerable proportion of the variance of ln (y_i). The strikingly negative $\bar{R}^2$-value for colour TV may be linked to the Dutch consumers' limited experience with colour TV, which was introduced in The Netherlands about a year before the survey was held. This may have hindered the individuals in setting an aspiration level.

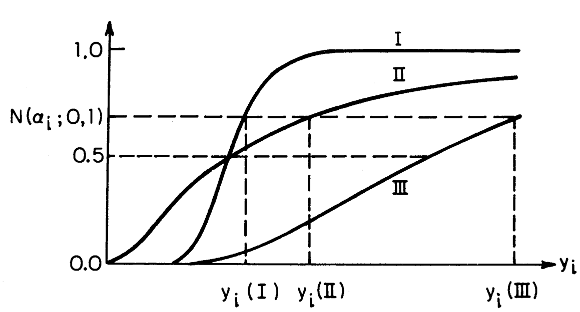
The meaning of the satisficing hypothesis H1 is illustrated, for an arbitrary good i, in figure 1. PWFs of three individuals, I, II and III, are depicted. Given the aspiration level in welfare terms for this good, $N(\alpha_i;0,1)$, the aspiration level in money terms of the three individuals is given by the abscissa-values corresponding to the ordinate-value $N(\alpha_i;0,1)$.

[23] Of course some caution is required in comparing the $\bar{R}^2$-values, since the dependent variables in (18) and (25) are different. Still such a comparison is not entirely meaningless (cf. Granger and Newbold, 1976).

Individuals I and II have the same value of μ_i but different values of σ_i. The larger value of σ_i makes individual II feel that he has to spend more than individual I in order to attain the welfare level $N(\alpha_i;0,1)$. Individual III's μ is larger than the other individuals' μ, and his σ is equal to that of individual II. As a consequence, he feels that he has to spend considerably more than the other two individuals to attain the welfare level $N(\alpha_i;0,1)$.

The values of the aspiration levels $N(\hat{\alpha}_i;0,1)$ shown in table 1 are fairly close to each other.

FIGURE 1.—ILLUSTRATION OF H1



This hints at the possibility that the aspiration level is the same across goods, being about 0.75. However, an approximate F-test for the equality of the α_i shows that the null-hypothesis of equal α_i's for all expenditure categories has to be rejected at the 0.1% level. A superficial glance at table 1 suggests that $N(\alpha_i;0,1)$ is slightly higher for the cheaper goods. This phenomenon requires further research.

The parameters α_i have been assumed to be constant across individuals. This assumption has been made for ease of exposition mainly and may easily be relaxed by adopting a random coefficients framework. The estimated $\hat{\alpha}_i$ are then consistent estimates of the mean α_i in the population. Also the procedure for selecting H1 is not affected. A random coefficients formulation essentially adds a heteroskedastic term to the disturbance term x_{it} in (25). Consequently, s_{1i}^2 overestimates σ_{xi}^2 even more than under the fixed coefficients interpretation. Hence the random coefficients formulation would imply a smaller σ_{xi}^2 and thus reinforce our choice of H1. Notice that for the hypotheses H2, H3, H4, a random coefficients formulation does not make sense as the distributions of the coefficients cannot be distinguished from the error distributions in these models.

D. *Maximizing or Satisficing?*

Now that we have adopted H1 as the adequate operationalization of satisficing behaviour we are able to confront its logical consequences with those of HM.

Let n_i and N_i denote the standard normal density and distribution functions, and define $x_i \equiv (\ln(y_i) - \mu_i)/\sigma_i$, $x \equiv (\ln(y) - \mu)/\sigma$. Then it is immediate that

$$\frac{n_i(x_i)}{N_i(x_i)\sigma_i y_i} \equiv \frac{\lambda_i(y_i)}{\Lambda_i(y_i)} \tag{30}$$

$$\frac{n(x)}{N(x)\sigma y} \equiv \frac{\lambda(y)}{\Lambda(y)}. \tag{31}$$

Neglecting the error term in (25), H1 implies that $n_i(x_i)/N_i(x_i)$ is a constant,[24] whereas HM implies (cf. equation (17)):

$$\frac{n_i(x_i)}{N_i(x_i)} = \frac{\sigma_i y_i}{\sigma y}\,\frac{n(x)}{N(x)}. \tag{32}$$

These two different implications of H1 and HM suggest a simple way of choosing between both hypotheses.

When running the regressions

$$\frac{n_{it}(x_{it})}{N_{it}(x_{it})} = \eta_{0i} + \eta_{1i}\,\frac{\sigma_{it}y_{it}}{\sigma_t y_t}\,\frac{n_t(x_t)}{N_t(x_t)} + \epsilon_{it},$$
$$(i = 1, \ldots, 28;\ t = 1, \ldots, T_i), \tag{33}$$

H1 would imply that the estimates of η_{1i} do not differ significantly from zero, whereas HM would imply that the estimates of η_{0i} do not differ significantly from zero.

It appears that η_{0i} differs significantly from zero at the 5% level for 27 out of 28 goods, whereas no single η_{1i} differs significantly from zero. These outcomes lead us once more to reject HM and to maintain H1.

VI. Concluding Remarks

In this paper directly measured cardinal welfare functions have been employed to compare the utility maximization hypothesis HM with a satisficing hypothesis H1. Given the assumptions made in the course of the analysis, the conclusion seems unambiguous. In making purchase decisions concerning durables, individuals "satisfice" rather than "maximize." In this concluding section we will first discuss briefly the possible sensitivity of the results for the assumptions made and, secondly, hint at some implications for the study of consumer behaviour.

Since the approach in this paper has been to use directly measured welfare functions to investigate whether individuals behave so as to maximize their welfare function, the choice of functional form of the welfare function seems to be crucial to the results. We have assumed that the welfare function is multivariate lognormal (assumption I) and that it is additive, i.e., Σ is diagonal (assumption II). In subsection IIA we have pointed at the various studies that have confirmed lognormality.

Moreover, the results with respect to HM are probably fairly insensitive to the lognormality assumption. The quantities λ_i/Λ_i and λ/Λ that have been used in the analysis are monotonically decreasing functions of $\ln y_i$ and $\ln y$, respectively. It seems unlikely that other monotonous

[24] Both $n_i(x_i)/N_i(x_i)$ and $\Lambda_i(y_i)$ are monotonous functions of $(\ln y_i - \mu_i)/\sigma_i$ only. Since, according to H1, $\Lambda_i(y_i)$ is constant, also $n_i(x_i)/N_i(x_i)$ is constant.

transformations of $\ln y_i$ and $\ln y$ could provide a substantially better fit. For instance if we try to explain $\ln y_i$ by a regression on $\ln y$ we get an average $\bar{R}^2$ (over 28 goods) equal to 0.03 with 11 $\bar{R}^2$s negative. Compared to the $\bar{R}^2$s generated by H1, given in table 1, this is very low. Indeed it is generally found that with individual data income provides a poor explanation of expenditures.[25] The number of transformations of $\ln y_{it}$ that can be tried in the empirical analysis is practically unlimited. If, for example, one would assume that the relevant utility function would be the sum of PWFs rather than their product, the first order conditions for utility maximization would suggest a high correlation between $\lambda_{it}(y_{it})$ and $\lambda_{jt}(y_{jt})$ rather than between the quantities in regression (11). It turns out that out of the 96 correlations that can be computed (cf. subsection IIIA) 47 $\bar{R}^2$-values are negative, with an average equal to 0.10. In fact if we simply correlate $\ln y_{it}$ and $\ln y_{jt}$ we obtain 52 negative $\bar{R}^2$-values with an average equal to 0.04. It is interesting to mention here that the sample distribution of the $\ln y_{it}$ appears to be approximately normal. It is well known that if the distribution of the $\ln y_{it}$ would be normal and the correlation between the $\ln y_{it}$ and $\ln y_{jt}$ $(i \neq j)$ is zero then these quantities are distributed independently. Consequently, transformations of them would also show zero-correlation. Intuitively this would seem to imply that, in view of the low correlation between the $\ln y_{it}$ and $\ln y_{jt}$ we observe, probably transformations of the $\ln y_{jt}$ and $\ln y_{it}$ would always show low correlations.

In favour of the diagonality of Σ we have provided theoretical arguments in subsection IIB and empirical ones in subsection IIIA. The success of H1 suggests, moreover, that the possibility of Σ being non-diagonal cannot save HM, since H1 implies that marginal welfare derived from a good (as measured by the corresponding PWF) is independent of the marginal welfare of income.[26] This is at variance with HM, whether or not Σ is diagonal.

The utility maximization hypothesis may, of course, be maintained by stating that the individual welfare function does not reflect the theoretical notion of a utility function. In particular, the fact that the individual welfare function is measured by direct questioning rather than by observing behaviour may lead one to adopt this conclusion. This would imply, however, that the utility function that is supposed to govern behaviour has nothing to do with the individual's overtly expressed opinions (on income levels and expenditure levels, cf. the description of the measurement method in subsection IIA). Such a position can never be refuted by empirical evidence. The choice of a utility concept has, in other words, to be made on a priori grounds. For reasons of scientific fruitfulness we definitely prefer a concept that allows us to use evidence obtained from verbal statements by individuals.

Comparing the testing of HM carried out in this study to indirect testing based on systems of demand equations a few observations can be made. First, both the direct and indirect methods require the specification of the functional form of the utility function. With the direct method one seems to have more possibilities to test the correctness of the specification.

Second, with the direct method we have not been forced to assume that different individuals have utility functions with identical parameters. The parameters of PWFs and WFIs may, for instance, depend on the existing stock of consumer durables, they may be influenced by the consumption of others, etc. All these effects show up in the measured parameter values per individual and thus are automatically accounted for in the analysis.

Third, contrary to most indirect tests found in the literature, we have used individual data, thus avoiding the cumbersome aggregation problem.

On balance it seems that the direct testing is based on weaker assumptions than the various indirect tests found in the literature. The results of the direct and indirect tests are much the same, however. Also the indirect tests mostly reject HM (cf. Barten, 1977; Christensen, Jorgenson, and Lau, 1975).

Of course the rejection of HM refers to the specific static formulation of the theory (although the investment aspect of the purchase of consumer durables has been taken into account, cf. subsection IIB). There are many ways in which the notion of utility maximization may recur in a more general framework. First of all the satisficing hypothesis has been motivated by an individual's limited computational and information pro-

[25] Since we look only at cross-section data, prices are left out of the analysis (they are assumed identical for all individuals). In the analysis of longitudinal data prices would enter the welfare functions. (Van Praag, 1968, ch. 4).

[26] Below we give an interpretation of this result.

cessing capacity. Taking into account such additional restrictions may easily lead to a broader definition of the concept of utility maximization.[27]

One of the remarkable features of H1 is that the budget constraint does not seem to play a role. It has to be kept in mind, however, that y_i is measured only for individuals who do plan to spend money on a certain expenditure category. In a preliminary process of determining budget shares for major expenditure categories the budget constraint will most likely play a role. Thus the satisficing hypothesis seems to emerge as a sort of screening device: If the budget constraint allows for the allocation of a sufficient amount of money to a particular expenditure category such that the individual's aspiration level is exceeded, he will spend the money. If the amount does not exceed his aspiration level, he will not spend the money in that direction but either save it or allocate it to a different expenditure category. The satisficing hypothesis is thus seen to introduce indivisibilities of consumer goods, beyond their physical indivisibility. Utility maximization then becomes a combinatorial problem, with both the budget constraint and the aspiration levels as restrictions.

These and other hypotheses require further empirical investigation. In the present paper, moreover, the parameters of WFIs and PWFs have been taken as given. On the formation of welfare functions, research is being carried out (e.g., Kapteyn, Wansbeek, and Buyze, 1978). This research yields insight into the dynamic process of the formation of preferences. By combining models of purchase decisions for given preferences and models of the formation of preferences, we may hope to improve upon our understanding of individual consumer behaviour.

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[27] It may for instance be assumed that in some stages of the decision process individuals maximize whereas in other, perhaps less crucial or more complicated stages they satisfice (cf. Leibenstein, 1976, p. 74).

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APPENDIX

Model Selection

In this appendix we motivate assumption VI, while explicitly accounting for measurement errors in the μ_{it} and σ_{it}. The true values of the variables are denoted by asterisks. Thus we rewrite H1, H2, and H3 as

$$\ln(y_{it}) = \mu^*_{it} + \alpha_i\sigma^*_{it} + x_{it} \qquad \text{(H1)} \quad \text{(A.1)}$$

$$\ln(y_{it}) = \beta_i + \mu^*_{it} + u_{it} \qquad \text{(H2)} \quad \text{(A.2)}$$

$$\ln(y_{it}) = \gamma_i + \mu^*_{it} + \tfrac{1}{2}\sigma^{2*}_{it} + v_{it}. \qquad \text{(H3)} \quad \text{(A.3)}$$

By assumption V one of these three models is correct, i.e., its errors follow a distribution that is independent of the values of μ^*_{it} and σ^*_{it} and has zero expectation. We assume finite population means and variances of μ^*_{it}, σ^*_{it}, σ^{2*}_{it} and $\ln(y_{it})$, which are denoted as $\overline{\mu^*_i}$, $\overline{\sigma^*_i}$, $\overline{\sigma^{2*}_i}$, $\overline{\ln(y_i)^*}$ and $V(\mu^*_{it})$, $V(\sigma^*_{it})$, $V(\sigma^{2*}_{it})$, $V(\ln(y_{it}))$, respectively. In general V(.) stands for the population variance of its argument.

The preceding assumptions severely restrict the set of possible assumptions on the incorrect models. The following definitions are consistent with the correctness of any one of the three models.

We define

$$\alpha_i \equiv \frac{\overline{\ln y^*_i} - \overline{\mu^*_i}}{\overline{\sigma^*_i}} \qquad \text{(A.4)}$$

$$\sigma_{xi}^2 \equiv V(\ln(y_{it}) - \mu^*_{it} - \alpha_i\sigma^*_{it}) \qquad \text{(A.5)}$$

$$\beta_i \equiv \overline{\ln(y^*_i)} - \overline{\mu^*_i} \qquad \text{(A.6)}$$

$$\sigma_{ui}^2 \equiv V(\ln(y_{it}) - \mu^*_{it} - \beta_i) \qquad \text{(A.7)}$$

$$\gamma_i \equiv \overline{\ln(y^*_i)} - \overline{\mu^*_i} - \overline{\tfrac{1}{2}\sigma^{2*}_i} \qquad \text{(A.8)}$$

$$\sigma_{vi}^2 \equiv V(\ln(y_{it}) - \mu^*_{it} - \tfrac{1}{2}\sigma^{2*}_{it} - \gamma_i). \qquad \text{(A.9)}$$

These definitions imply that the population means of x_{it}, u_{it} and v_{it} are zero. Notice moreover that for the correct model the definitions are tautological, and hence harmless.

In order to motivate assumption VI, we first consider the error variances σ_{xi}^2, σ_{ui}^2 and σ_{vi}^2 and then turn to residual variances. It is easily seen that the correct model has lowest error variance. One example suffices to show why.

Suppose for a moment that H2 is correct. Then, using (A.9) and H2, we have for σ_{vi}^2

$$\begin{aligned}\sigma_{vi}^2 &= V(\beta_i + \mu^*_{it} + u_{it} - \mu^*_{it} - \tfrac{1}{2}\sigma^{*2}_{it} - \gamma_i) \\ &= V(\beta_i - \tfrac{1}{2}\sigma^{*2}_{it} - \gamma_i) + \sigma_{ui}^2.\end{aligned} \qquad \text{(A.10)}$$

Hence σ_{vi}^2 exceeds σ_{ui}^2 if H2 is correct. Now suppose H3 is correct. Then, using (A.7) and H3, we have

$$\sigma_{ui}^2 = V(\gamma_i + \tfrac{1}{2}\sigma^{*2}_{it} - \beta_i) + \sigma_{vi}^2. \qquad \text{(A.11)}$$

One sees that if H3 is correct, σ_{ui}^2 exceeds σ_{vi}^2 by the same quantity as σ_{vi}^2 exceeds σ_{ui}^2 in case H2 is correct. Similar results are obtained for the case that H1 is correct.

Next we introduce the quantities $s^2(\mu_i)$, $s^2(\sigma_i)$, $s^2(\sigma_i^2)$ which are by definition the variances of the measurement errors in μ_{it}, σ_{it}, σ_{it}^2. The quantities $\overline{\ln(y_i)}$, $\overline{\mu_i}$, $\overline{\sigma_i}$, $\overline{\sigma_i^2}$ stand for the sample averages of the T_i observations $\ln(y_{it})$, μ_{it}, σ_{it}, σ_{it}^2. The measurement errors in μ_{it} and σ_{it} are assumed to have zero expectations and to be mutually independent and independent of x_{it}, u_{it}, v_{it}, $\ln(y_{it})$, μ^*_{it}, σ^*_{it}.

Given these assumptions we can define the following consistent estimators $\hat{\alpha}_i$, $\hat{\beta}_i$, and $\hat{\gamma}_i$ of α_i, β_i and γ_i:

$$\hat{\alpha}_i \equiv \frac{\overline{\ln(y_i)} - \overline{\mu_i}}{\overline{\sigma_i}} \qquad \text{(A.12)}$$

$$\hat{\beta}_i \equiv \overline{\ln(y_i)} - \overline{\mu_i} \qquad \text{(A.13)}$$

$$\hat{\gamma}_i \equiv \overline{\ln(y_i)} - \overline{\mu_i} - \overline{\tfrac{1}{2}\sigma_i^2}. \qquad \text{(A.14)}$$

The last two estimators are unbiased.

Residual variances s_{1i}^2, s_{2i}^2, and s_{3i}^2 are defined by

$$s_{1i}^2 \equiv \frac{1}{T_i - 1} \sum_{t=1}^{T_i} [\ln(y_{it}) - \mu_{it} - \hat{\alpha}_i\mu_{it}]^2 \qquad \text{(A.15)}$$

$$s_{2i}^2 \equiv \frac{1}{T_i - 1} \sum_{t=1}^{T_i} [\ln(y_{it}) - \hat{\beta}_i - \mu_{it}]^2 \qquad \text{(A.16)}$$

$$s_{3i}^2 \equiv \frac{1}{T_i - 1} \sum_{t=1}^{T_i} [\ln(y_{it}) - \hat{\gamma}_i - \mu_{it} - \tfrac{1}{2}\sigma_{it}^2]^2. \qquad \text{(A.17)}$$

Under very weak conditions s_{1i}^2 is a consistent estimator of $[s^2(\mu_i) + \alpha_i^2 s^2(\sigma_i) + \sigma_{xi}^2]$; s_{2i}^2 is an unbiased and consistent estimator of $[s^2(\mu_i) + \sigma_{ui}^2]$; s_{3i}^2 is an unbiased and consistent estimator of $[s^2(\mu_i) + \tfrac{1}{4}s^2(\sigma_i^2) + \sigma_{vi}^2]$.

Let us now turn to the motivation of assumption VI. We start with the case that H2 is the correct hypothesis. In that case $\sigma_{vi}^2 > \sigma_{ui}^2$. The expectation of s_{3i}^3 exceeds the expectation of s_{2i}^2 by $[\frac{1}{4}s^2(\sigma_i^2) + \sigma_{vi}^2 - \sigma_{ui}^2]$, which is clearly positive. If the number of observations is sufficiently large this will imply the first part of assumption VI.

The case where H2 is supposed to be correct requires some more elaboration. First we observe that in this case $\sigma_{xi}^2 > \sigma_{vi}^2$. Second we will argue that probably $\alpha_i^2 s^2(\sigma_i)$ exceeds $\frac{1}{4}s^2(\sigma_i^2)$. To that end we use the asymptotic approximation $s^2(\sigma_i^2) \approx 4(\bar{\sigma}_i)^2 s^2(\sigma_i)$. Since it appears that $\hat{\alpha}_i > \bar{\sigma}_i$ for 24 out of 28 goods we take α_i to exceed $\bar{\sigma}_i$ and hence $\alpha_i^2 s^2(\sigma_i)$ to exceed $\frac{1}{4}s^2(\sigma_i^2)$ $(\approx (\bar{\sigma}_i)^2 s^2(\sigma_i))$. So, if H3 is correct, s_{3i}^2 is a consistent estimator of a quantity which is $[\alpha_i^2 s^2(\sigma_i) - \frac{1}{4}s^2(\sigma_i^2) + \sigma_{xi}^2 - \sigma_{vi}^2]$ larger than the quantity that is consistently estimated by s_{1i}^2. If the number of observations is sufficiently large this implies the last part of assumption VI.

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[Footnotes]

[2] **Transcendental Logarithmic Utility Functions**
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