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THE DYNAMICS OF PREFERENCE FORMATION*

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A model is developed and estimated which explains the formation of individual preferences on consumption under the influence of contacts with others (preference interdependence) and own consumption over time (habit formation). The model employs a cardinal utility function which can be measured independently of behavioral assumptions. Since preference interdependence has been analyzed earlier, the paper concentrates on habit formation, the preference interdependence component being imputed from an earlier study. Due to data restrictions and measurement error, special econometric provisions must be made. Preference interdependence appears to explain two thirds of individual preferences and habit formation one third.

1. Introduction

The notion of variable preferences can be found in scattered places in the economic literature from its very beginning. The persistence of concepts like 'conspicuous consumption', 'habit formation', 'snob effects' illustrate this fact. Leibenstein (1950) notices that the notion of conspicuous consumption can even be traced back to the works of Horace. At the same time, however, established economic theory usually takes preferences as exogenous and constant. No doubt, the substantial simplifications achieved through this assumption have greatly contributed to its survival, despite its utter lack of plausibility.

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Mostly, the omission of preference formation aspects from economic theory is defended by a division of labor argument. Psychologists and sociologists study the formation of preferences and economists take them as given in order to study implications for economic behavior [cf. Friedman (1962, p. 13)]. Some take a firmer view, like Stigler and Becker (1977, p. 76) who, in a paper titled *De Gustibus Non Est Disputandum*, state:

> 'Our title seems to us to be capable of another and preferable interpretation: that tastes neither change capriciously nor differ importantly between people. On this interpretation one does not argue over tastes for the same reason that one does not argue over the Rocky Mountains — both are there, will be there next year, too, and are the same to all men.'

In their article they explain a number of cases of apparent taste change, like addiction, advertising and fashion, by assuming that in all these cases an individual's efficiency as a producer of pleasure is affected, but not his preferences.

Stigler and Becker's position is hard to attack. In its general form the assumption of changes in production technology provides a 'protective belt' [see, e.g., Latsis (1976)] which makes it practically impossible to falsify the hypothesis of constant and identical preferences. Indeed, if one is sufficiently non-specific as to the precise nature of the production technology, their hypothesis may be empirically indistinguishable from a preference formation hypothesis. In empirical work however, one has to be specific and, probably, a preference formation hypothesis generates different models than a production technology change hypothesis does. Ultimately, empirical fruitfulness then has to decide which hypothesis is to be preferred.

Thus we can distinguish three main attitudes. First, there are the die-hards who contend that preferences are constant. Second, there is the pragmatic view that economists should leave the study of preference formation to other social sciences. And thirdly, there are various authors who allude to the variability of preferences and, as we shall see below, an increasing number of papers appear which deal with formal models of preference formation.

A position vis-à-vis the first proposition is largely a matter of expected fruitfulness, as suggested before. The second attitude amounts to treating variables (i.e., preferences) as exogenous that may very well be endogenous. This introduces a specification error which may be quite serious. Treating preferences as exogenous is thus not a matter of labor division but a matter of specification. By now there appears to be substantial empirical evidence on the endogeneity of preferences. Below we shall discuss this evidence. The third attitude is adopted by the authors of the present paper.

In the study of the formation of preferences on consumption two types of influences may be distinguished, viz. an individual's own past consumption (*habit formation*) and consumption by others (*preference interdependence*). In particular, preference interdependence has seldomly been incorporated in economic models. The most elaborate studies so far are due to Gaertner (1974) and Pollak (1976a). They both integrate preference interdependence in the Linear Expenditure System by letting the parameters of an individual utility function depend on the consumption by others. Both studies are theoretical. Earlier attempts to account for preference interdependence have been made by Duesenberry (1949) and Leibenstein (1950). The Relative Income Hypothesis can also be interpreted as a model of interdependent preferences. Empirical work on this hypothesis has been done by Brady and Friedman (1947), Duesenberry (1949), Modigliani (1949), among others. A sociological theory of preference interdependence has been developed by Hayakawa and Venieris (1977).

Especially in recent years habit formation has been attracting increasing attention. Some of the early work has been done by Duesenberry (1949, theoretically and empirically), Georgescu-Roegen (1950, theoretically) and Brown (1952, empirically). The more recent work is mostly done in the context of demand systems in which parameters are made dependent upon the consumption history of individuals. Pollak (1978) reviews the literature on the subject. To his references we may add the theoretical contributions by Day (1971), and Benhabib and Day (1979). The theoretical part of the literature emphasizes conditions for stability of the dynamic demand systems and the existence of long-run equilibria. Empirical studies are due to Houthakker and Taylor (1970), Phlips (1972, 1974), Manser (1976), among others.

The implications of interdependent preferences and habit formation for welfare economics have been studied by a number of authors. Most notably among them are Duesenberry (1949), Harsanyi (1954), Von Weizsäcker (1971), Fisher and Shell (1972), Pollak (1976b).

The modern literature on preference formation (mainly habit formation) is firmly embedded in the systems approach to consumer demand theory. Parameters of individual utility functions are made dependent on past consumption or consumption by others. As already observed by Duesenberry (1949, p. 17) this leads to 'double indirect' measurement.

> 'Ordinarily we try to measure preference parameters (or functions of them) by market behavior, since we cannot observe the preferences directly. With shifting parameters we should be carrying indirect measurement a step farther. We would not only have to measure the preference parameters but the parameters of the relation governing shifts in the preferences.'

Thus, in empirical specifications at least three hypotheses are entangled: the specification of the utility function, the hypothesis of utility maximization the part of the consumer and the specification of the preference formation process. For none of these three hypotheses is very specific evidence available to justify them or to aid specification.[1] On top of that, data are often aggregated.

From the viewpoint of scientific progress, the entanglement of hypotheses is very unfortunate. Whenever a demand system gives a less than perfect explanation of consumer behavior, we do not know which hypothesis is to blame and what to do about it. There are simply too many possible explanations, and sifting out a 'correct' explanation empirically promises to be an extremely tedious job, if possible at all. To some extent we may hope for relief by the future availability of better disaggregated data. On the other hand, however, we may expect that the entanglement of hypotheses will only get worse, for instance if we also want to model the influence of expectations.

The increasing complexity of estimating demand models is due to the assumed non-measurability of utility functions. If we could observe preferences independent of behavior, we would be able to study preference formation directly.[2] Thus, various hypotheses could be formulated and tested. These hypotheses would presumably be more specific than the ones used so far in the systems approach. If a more specific hypothesis survives confrontation with the data, then it is to be preferred to a less specific one because it is more informative [see, e.g., Popper (1968, p. 113)].

These two advantages of directly measuring utility functions will be exploited in this paper.[3] In section 2 we briefly describe the utility function which underlies the empirical analysis. In section 3 we review the main elements of a preference formation theory which explains the variation of utility function parameters over individuals. The theory unifies habit formation and preference interdependence in a single model. Since the preference interdependence aspects have been investigated empirically in an earlier paper, the main emphasis of the empirical analysis will be on habit formation aspects.

Since our data are confined to a single cross-section and the model is dynamic, we face an estimation problem. The problem is tackled by the introduction of an auxiliary dynamic relation which, in conjunction with the preference formation model, is used to eliminate the need for longitudinal data. This relation (a simple satisficing model) is introduced in section 4. Sections 5 and 6 give the estimation method and empirical results. Section 7

[1] As to the utility maximization hypotheses we give a brief review of the evidence, in Kapteyn, Wansbeek and Buyze (1979).

[2] Also other hypotheses, like utility maximization could be tested directly. See Kapteyn, Wansbeek and Buyze (1979).

[3] There is a price to be paid, however. In order to measure utility functions directly, we need somewhat stronger assumptions than usual. In particular, we will adopt a certain cardinal utility function. Since, however, this function can be measured directly per individual, the additional assumptions can be tested directly. In the sequel we shall point at the results of these tests as far as required for an appraisal of the empirical analysis.

gives some implications and section 8 concludes. The econometric details have been relegated to three appendices.

2. The individual welfare function

In this section we briefly review the welfare function concept[4] developed by Van Praag (1968). We give an informal motivation and point to empirical evidence. For a complete understanding of the underlying assumptions and the empirical status of the concept the reader should consult the various references given below.

Following Lancaster (1966) and Van Praag (1968), we assume that individuals derive welfare from the characteristics of commodities rather than from commodities themselves. In general, a commodity will possess more than one characteristic, and a characteristic will be shared by more than one commodity. We define a *commodity group* as a set of commodities which, in any combination of quantities, can be described by the same (finite or infinite) set of characteristics.

In this paper we shall not deal with preferences defined on the space of all characteristics, but only with preferences on subspaces of characteristics that represent a certain commodity group. Such a confinement may be justified by suitable separability assumptions. Let the commodity group under consideration be represented by p characteristics, then we suppose that any combination of quantities of the commodities in the group can be represented by a point in $\mathscr{R}^p$.

The preferences on $\mathscr{R}^p$ are assumed to be representable by a cardinal welfare function $W:\mathscr{R}^p\to[0,1]$. In other words, an individual *evaluates* the welfare derived from a certain combination of characteristics on a [0, 1]-scale. We assume moreover that W has all formal properties of a probability distribution function. The latter assumption can, to a large extent, be warranted by a proper definition of the characteristics.

By spending money on a commodity group, an individual acquires a certain combination of characteristics. In this way spending money generates welfare. The resulting welfare level obviously depends on the relation between the amount of money spent and the point in $\mathscr{R}^p$ attained by the corresponding acquisition of commodities. This relation may depend on market conditions and on the shape of the household production function.

We will assume that each money amount to be spent on the commodity group under consideration corresponds with a unique welfare level. Thus, an individual assigns welfare levels to money amounts spent on a certain commodity group, to be denoted by $U:\mathscr{R}^+\to[0,1]$.

[4]Henceforth the words 'welfare function' will be reserved for the concept as explained in this section, whereas 'utility function' will refer to the general concept as it is used in economics.

Just like W, U is also assumed to be formally identical to a probability distribution function. Among other things, this assumption requires that spending more money on a commodity group does not lower the welfare level. In other words: oversatiation is ruled out. We call U the *partial welfare function* (PWF) of the commodity group under consideration.

One way of interpreting $U(y)$ for any amount y spent on the commodity group would be to look upon it as an indirect utility function. Holding prices constant, the consumer maximizes W subject to the constraint that total expenditures on the commodity group do not exceed (and in fact are equal to) y. In the context of a utility tree this would mean that the consumer first allocates money to the commodity groups he distinguishes, such that total utility is maximized and next he allocates money within the commodity groups to maximize welfare.

This idea is illustrated by fig. 1. There a commodity group is represented by two characteristics x_1 and x_2. *DBE* signifies the various combinations of

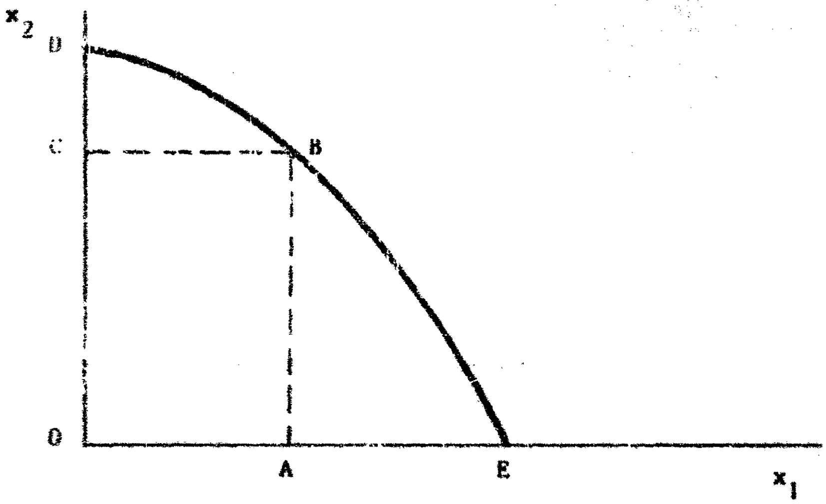

Fig. 1. The iso-price curve in characteristics space.

x_1 and x_2 which can be acquired by spending an amount y on the commodity group. It may be interpreted as a kind of budget constraint, although Van Praag calls it the 'iso-price curve', since it signifies the price paid to acquire certain amounts of a commodity group (or, what amounts to the same, certain bundles of characteristics). Let us assume the combination $x_1 = OA$, $x_2 = OC$ would maximize W with respect to the commodity group. The welfare level attached to the expenditure y would be the indirect utility of y, $U^0(y)$. The value of $U^0(y)$ is the integral of $dW(x_1, x_2)$ over the area OABC.

As a description of a psychological process this is not very appealing. In the preliminary process of deciding how much money should go to the commodity under consideration the individual needs to know $U^0(y)$ for a whole range of relevant y-values. For each of these y-values he has to maximize W in order to find the optimal combination of characteristics. He has to do that, moreover, for each commodity group. Hence, in his mind he has to carry through numerous maximization processes. The calculations involved probably exceed an individual's computational capacity [cf. Day (1971), Simon (1972, 1976)].

Van Praag (1968, ch. 3) assumes that individuals resort to less optimal but more manageable decision rules. He postulates that an individual equates the welfare to be derived from money spent on a commodity group to the integral of dW over the whole area under *DBE*. The motivation is that, before actually spending an amount on the commodity group, each point under *DBE* is attainable. In the *ex ante* evaluation of y, the individual considers all points under *DBE* feasible and hence they all contribute to the evaluation of y. Evidently, the procedure results *ex post* in a disappointment with the welfare level attained. The degree of disappointment depends on the shape of *DBE* and the precise form of W.

The *ex ante* over-estimation of the welfare derived from spending money on a commodity group detracts somewhat from the rationality of the hypothesized procedure. However, assuming imperfect rationality may be perfectly realistic, and ultimate justification of the assumption can, of course, only be gained by testing its empirical consequences. We shall briefly discuss these consequences below.

So far our assumptions have been insufficiently specific to derive the functional form of $U(y)$, except for its formal isomorphism with a probability distribution function. The discussion has brought out, however, that the evaluation of a money amount y, $U(y)$, will depend on the underlying welfare function on characteristics space, W, and on the iso-price curve *DBE* in fig. 1. If for example prices are increasing, the amount of characteristics that can be bought for an amount y decreases and this shows up in a shrinkage of *DBE* towards the origin. So, implicitly, $U(y)$ is conditioned on prices.

The particular hypothesized process that generates $U(y)$ is not the only conceivable one, although we think it to be more plausible than an indirect utility function interpretation. This particular form, however, leads to powerful mathematical results, granted some additional assumptions: Consider a commodity group that possesses a large number of characteristics. We call such a commodity group *broad*. The isomorphism of W and a probability distribution function suggests the application of a central limit theorem: $U(y)$ is *formally* a distribution function of a function of many random variables (i.e., the function that describes the iso-price curve). Depending on the particular assumptions with respect to the properties of that function and the distribution of the underlying random variables, the limiting distribution of y, if the number of random variables goes to infinity, may take a variety of forms, inter alia the normal and the log-normal distribution. Without going into further details we mention that Van Praag has chosen his assumptions in such a way that he could derive for a broad commodity group that $U(y)$ will approximately have the shape of a lognormal distribution function, i.e.,

$$U(y) \approx \frac{1}{\sigma\sqrt{2\pi}} \int_0^y \frac{1}{t} \exp\left\{-\frac{1}{2}\left(\frac{\ln t-\mu}{\sigma}\right)^2\right\} dt \equiv \Lambda(y;\mu,\sigma) \equiv N(\ln y;\mu,\sigma), \tag{1}$$

where $\Lambda(\cdot,\mu,\sigma)$ is the lognormal distribution function with median $\exp(\mu)$ and log-variance σ^2 and $N(\cdot,\mu,\sigma)$ the normal distribution function with mean μ and variance σ^2.

It may be worthwhile to stress once more that (1) has no probabilistic connotation. It stands to reason, however, that in the present framework the introduction of uncertainty can be done in a particularly elegant way [see, e.g., Van Praag (1975)]. Since we have only presented part of the assumptions underlying (1), the reader has no way of judging its plausibility. We shall argue below, however, that empirical evidence strongly supports (1). As we basically only need (1) in the present paper and not the underlying theory, this should be sufficient. Moreover, in the concluding section it will be argued that the main empirical results obtained in this paper would remain valid if $U(y)$ has a somewhat different form than (1).

A psychological interpretation of the parameters μ and σ in (1) will be given in the next section. The parameters vary across individuals and across commodity groups. Measurement of the parameters μ and σ of a particular individual with respect to a particular commodity group takes place by direct questioning methods. In surveys, people are given verbal qualifications like 'excellent', 'good', 'bad', etc. and asked, for a specific commodity group, to state which expenditure levels they feel correspond to these qualifications. By translating the verbal qualifications into numbers between zero and one [see, e.g., Van Praag (1971) or Van Praag and Kapteyn (1973)], this method gives us a number of observations on the individual's PWF under consideration. The parameters μ and σ are next estimated per individual by simple regression.

A particularly interesting PWF arises if we look at the broadest conceivable commodity group, i.e. total expenditures or, taking savings as postponed expenditures, total after tax income. The ensuing welfare function is called the *individual welfare function of income* (WFI).

Since the PWF and WFI concepts were developed, extensive measurement has been carried out in some 10 different European countries. The lognormal form of about 25 000 PWF's and WFI's has been compared to a number of alternative functional forms [Van Herwaarden and Kapteyn (1979)] and specification analysis has been invoked [Kapteyn (1977, ch. 3)]. The evidence in these and other papers indicates that, whatever the true shape of a PWF or WFI, it will be very close to a lognormal function. We shall not try to summarize the evidence here but refer to the following papers, each of which also describes the measurement method: Van Praag (1971), Van Praag and Kapteyn (1973), Kapteyn, Van Herwaarden and Van Praag (1977), Van Praag, Kapteyn and Van Herwaarden (1978). For our present purpose it is important to stress the fact that the PWF's of an individual describe his preferences with respect to the various commodity groups. A theory of preference formation should therefore be capable of explaining differences in PWF's between individuals. In the next section we describe such a theory.

3. Preference formation

The PWF and WFI concepts have been developed in terms of characteristics. The preference formation theory we want to put to test in this paper was developed in terms of characteristics as well.[5] That is, the theory explains the formation of W. Via the process that generates $U(y)$ for each commodity group, we can next derive the implications for the formation for PWF's or WFI. Since the empirical analysis will be concerned with the PWF of one particular commodity group ('holiday expenditures'), we economize on the exposition of the theory by stating it directly in terms of expenditures on a commodity group.

Most existing theories of habit formation or preference interdependence specify some parameters of an individual's utility function as linear combinations of his consumption levels in the past or of consumption by others.[6] The isomorphism of a PWF and a probability distribution function suggests particular forms for these linear combinations. In order to bring about the basic idea we introduce some notation.

Let there be N individuals in society. *Time* is measured in years, $t=-\infty,\ldots,0$, where $t=0$ represents the present.[7] At each moment of time an individual n $(n=1,\ldots,N)$ is assumed to assign non-negative *reference weights* $w_{kn}(t)$ to any other individual k in society $(k=1,\ldots,N)$, $\sum_{k=1}^{N} w_{kn}(t)=1$. The reference weights indicate the importance that individual n attaches to the consumption by individual k at time t. Obviously, quite a few of the $w_{kn}(t)$ will be zero. On the other hand, $w_{nn}(t)$, i.e., the weight that individual n attaches to his own consumption at time t, may be substantial. The set $(w_{1n}(t),\ldots,w_{n-1,n}(t),\ w_{n+1,n}(t),\ldots,w_{Nn}(t))$ will sometimes be referred to as individual n's *social reference group* at time t.

[5]The theory was developed and partly tested in Kapteyn (1977). It was spawned by the empirical results obtained in earlier papers: Van Praag (1971), Van Praag and Kapteyn (1973), Kapteyn and Van Praag (1976), Kapteyn, Van Praag and Van Herwaarden (1976).

[6]For an elaboration of the dynamic consequences of nonlinear dependence, see Benhabib and Day (1979).

[7]A formulation of the theory in continuous time is slightly more elegant. Here we stick to discrete time in view of the empirical analysis.

Moreover, let $y_n(t)$ be the money amount spent on the commodity group under consideration by individual n at time t. The reference weights now allow for the definition of a *perceived distribution function of expenditures on the commodity group at time t*. Denote this distribution by $F_n(y|t)$, then its definition is

$$F_n(y|t) \equiv \sum_{\{k|y_k(t) \leq y\}} w_{kn}(t). \tag{2}$$

The $F_n(y|t)$ for any t can be aggregated to one *presently perceived distribution function of expenditures on the commodity group*, $F_n(y)$. To that end we introduce a *memory function* $a_n(t)$ which describes individual n's weighting of perceived consumption over time,

$$\sum_{t=-\infty}^{0} a_n(t) = 1, \qquad n = 1, \ldots, N. \tag{3}$$

Most likely, a_n is an increasing function of t.

The presently perceived distribution function $F_n(y)$ is then defined by

$$F_n(y) \equiv \sum_{t=-\infty}^{0} a_n(t) F_n(y|t). \tag{4}$$

Since each individual has, in principle, for a given commodity group, a different PWF, we shall index that function as well as its parameters, i.e., we write $U_n(y) = \Lambda(y; \mu_n, \sigma_n)$. What relationship do we expect between $U_n(y)$ and $F_n(y)$? To aid intuition we may look at figs. 2 and 3.

In fig. 2, the PWF's of three individuals with respect to a certain commodity group, say holiday expenditures, are depicted. Individual I will evaluate *ex ante* his holidays by 0.5 if he spends approximately $600 on it. Expenditures amounting to $1200 will yield him a welfare level of approximately 0.85. Individual II on the other hand needs almost $1500 to attain the welfare level 0.5. He will reach the 0.85 level if he spends approximately $2500. One observes that, for a given σ, μ indicates how much money one needs to attain a certain welfare level: e^{μ} is the amount that is evaluated as 0.5. The higher μ is, the more has to be spent on the commodity group to attain a certain welfare level. What do we expect $F_n(y)$ of these individuals to be? $F_I(y)$ will be fairly far to the left, individual I himself and other people he knows probably do not spend very much on holidays. On the other hand we expect $F_{II}(y)$ and $F_{III}(y)$ to be more to the right, since the position of the PWF's of these individuals may be explained by the fact that they are either used to more expensive vacations or that people in their social reference group tend to take rather expensive vacations.

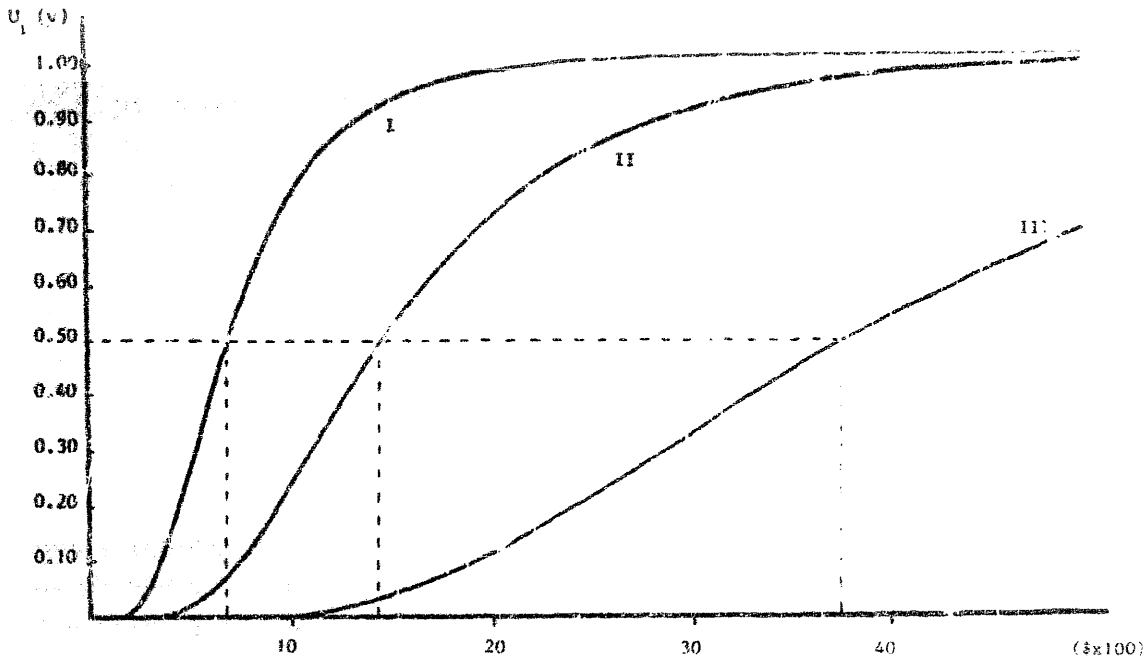

Fig. 2. PWFs of three individuals with different μ and identical σ.

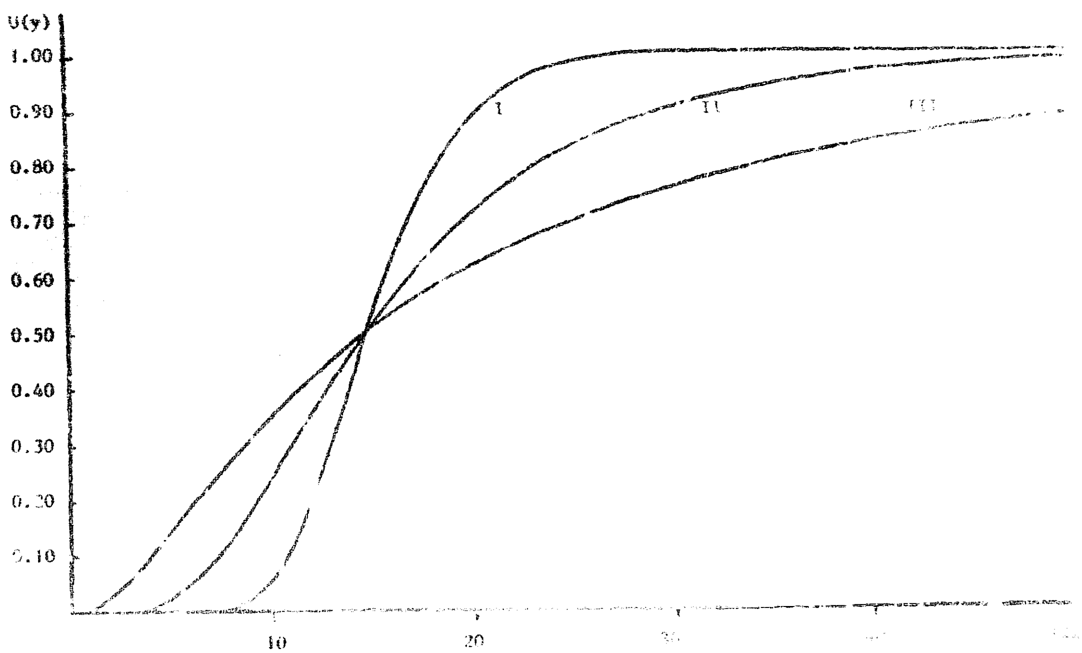

Fig. 3. PWFs of three individuals with different σ and identical μ.

Now look at fig. 3, where PWF's of three other individuals are shown. They have identical μ's but their σ's differ: $\sigma_I < \sigma_{II} < \sigma_{III}$. Individual I's PWF is steep. An expenditure somewhat below $\exp(\mu_I)$ yields a very low welfare level whereas an expenditure somewhat higher than $\exp(\mu_I)$ yields a very high welfare level. What does $F_I(y)$ look like? Probably it is very steep also. Most people individual I knows are likely to spend about the same amount of money on vacation as he does. Therefore he will have a limited experience with vacations that are either very cheap or very expensive. $F_{III}(y)$ on the other hand probably is very flat. Individual III's own expenditures in the past may have increased substantially (e.g., from backpacking to luxurious cruises) or he may have a social reference group wherein some people take very cheap vacations and others very expensive ones. Consequently individual III has a broad gamut of experiences. He knows that also cheap holidays may be fun [so his evaluation does not immediately drop to zero below $\exp(\mu_{III})$] but also is he able to imagine that even if he would spend very large sums on his vacation, it still would be possible to conceive of vacations that are even more enjoyable [thus his evaluation does not immediately go to one above $\exp(\mu_{III})$].

To be sure, an individual's PWF, U_n, and his perceived expenditure distribution, F_n, are two logically distinct concepts. The preceding observations only serve to suggest how F_n influences U_n. Also, in principle, U_n and F_n can be measured separately: U_n is measured by direct questioning as indicated in section 2 and one can also conceive of questions that would serve to measure F_n. In the present paper, though, F_n will not be measured directly but rather indirectly through a model which explains the influence of F_n on U_n.

Secondly, it should be kept in mind that the PWF's sketched in figs. 2 and 3 do not prescribe any behavior. We only observe, for instance, that in fig. 3, individual I *could* reach the evaluation level 0.8 at lower cost than individual III but this does not tell us how much I and III will respectively spend on holidays. In the next section, however, we will be more specific on behavioral aspects.

The remarks made with respect to figs. 2 and 3 suggest that U_n and F_n will similar. In fact we hypothesize that they are equal:

$$U_n(y) = F_n(y), \qquad n = 1, \ldots, N, \quad y \in [0, \infty]. \tag{5}$$

In words (5) states that an individual evaluates an expenditure on a commodity group by 0.7, say, if it is at least as high as 70% of the expenditures in his perceived expenditure distribution, by 0.8 if it exceeds 80% of the expenditures in his perceived distribution. At first sight, (5) may seem unduly restrictive and simple. One might prefer to hypothesize some more general relation between U_n and F_n rather than postulating their equality. Also, one might want to allow for the possibility that at least part of an individual's preferences are purely individual and not subject to habit formation or preference interdependence. Once more referring to Popper's principle of maximal informational content, we prefer to investigate the empirical quality of (5) before retreating to less specific or more complex hypotheses. The empirical research conducted since the formulation of the theory indicates that the hypothesis performs so well that there is no reason to modify or weaken (5). In particular there appears to be very little room for purely individual preferences.

It may be worth stressing once more that the original preference formation theory in Kapteyn (1977) was formulated in terms of characteristics. The advantage is that the various assumptions come out more clearly. In order not to burden the exposition in this paper too much, we have preferred the present simplified exposition.

The explanation of μ_n and σ_n

Because of its lognormality an individual's PWF with respect to some commodity group is completely characterized by μ_n and σ_n^2, since they are the first two log-moments of $U_n(y)$. Denote the first two log-moments of F_n by m_n and s_n^2, i.e.,

$$m_n \equiv \int_0^\infty \ln y \, \mathrm{d}F_n(y), \tag{6}$$

$$s_n^2 \equiv \int_0^\infty (\ln y - m_n)^2 \, \mathrm{d}F_n(y). \tag{7}$$

From (5) it follows that $\mu_n = m_n$ and $\sigma_n = s_n$. So, if we are able to measure m_n and s_n^2 for the same individuals for whom μ_n and σ_n^2 have been measured, we can test (5) by comparing μ_n with m_n and σ_n with s_n. Since we do not have data in which individuals have been questioned directly about their perceived distribution, m_n and s_n are unobservable. To remedy that problem we construct a model which allows for estimation of these quantities from the data at hand. To arrive at such a model we have to make a few additional steps.

First, our data refer to families, rather than to individuals, i.e., the measured PWF's pertain to family heads and are assumed to be representative of their family's PWF. We therefore adapt (5) by reformulating the hypothesis in terms of expenditures per *equivalent adult*. Let $f_n(t)$ be the number of equivalent adults in family n at time t with respect to the commodity group under consideration. The expenditure per equivalent adult is then denoted by

$$\tilde{y}_n(t) \equiv y_n(t)/f_n(t). \tag{8}$$

Replacing $y_n(t)$ and y in (2), (4), (6), (7) by $\tilde{y}_n(t)$ and $\tilde{y}$, we obtain $\tilde{F}_n(\tilde{y})$ with first two log-moments $\tilde{m}_n$ and $\tilde{s}_n^2$.

The notion of equivalent adults serves here as a means for the individual to transform the expenditures he perceives, into quantities that can be compared. The underlying equivalence scale thus represents his personal perception of differences in cost of living associated with differences in family composition. Assuming that each individual uses the same function f_n entails that different individuals' ideas about relative cost differences associated with family composition differences have to be (approximately) identical. Exactly the same assumption underlies the demand systems approach to the measurement of family equivalence scales. In addition, the systems approach also requires a strong assumption on the nature of the household decision-making process. That assumption is avoided here.

The reformulation of $U_n(y)$ in terms of expenditures per equivalent adult can be seen from fig. 2 (or 3). Redefining all amounts in terms of expenditures per equivalent adult amounts to a scale transformation of the horizontal axis; y is replaced by $\tilde{y} \equiv y/f_n$ and e^{μ_n} is replaced by $e^{\tilde{\mu}_n} \equiv e^{\mu_n}/f_n$.[8] So we get

$$U_n(y) = N(\ln y; \mu_n, \sigma_n) = N(\ln y/f_n; \mu_n - \ln f_n, \sigma_n)$$

$$= N(\ln \tilde{y}; \tilde{\mu}_n, \sigma_n) \equiv \tilde{U}_n(\tilde{y}). \tag{9}$$

Thus (5) is reformulated as

$$\tilde{U}_n(\tilde{y}) = \tilde{F}_n(\tilde{y}), \qquad n = 1, \ldots, N, \quad \tilde{y} \in [0, \infty). \tag{10}$$

Once more the equality of the two distribution functions implies the equality of their log-moments,

$$\mu_n = \tilde{m}_n + \ln f_n, \tag{11}$$

$$\sigma_n^2 = \tilde{s}_n^2. \tag{12}$$

Using the definition of $\hat{F}_n$, these formulas can be rewritten,

$$\mu_n = \ln f_n + \sum_{t=-\infty}^{0} a_n(t) \sum_{k=1}^{N} w_{kn}(t) \ln \tilde{y}_k(t)$$

$$= \sum_{t=-\infty}^{0} a_n(t) \sum_{k=1}^{N} w_{kn}(t) \ln y_k(t) + \ln f_n$$

$$- \sum_{t=-\infty}^{0} a_n(t) \sum_{k=1}^{N} w_{kn}(t) \ln f_k(t)$$

$$= m_n + \ln f_n - h_n. \tag{13}$$

[8] For convenience we generally omit arguments equal to zero, so $f_n \equiv f_n(0)$.

where h_n is the last term of the third member. In words (13) says that μ_n is equal to a time and reference weighted average of log-expenditures, plus the logarithm of the number of equivalent adults minus a time and reference weighted average of log-family sizes (defined as the number of equivalent adults in each family).

For σ_n^2 we obtain

$$\begin{aligned}\sigma_n^2 &= \sum_{t=-\infty}^{0} a_n(t) \sum_{k=1}^{N} w_{kn}(t)[\ln \tilde{y}_k(t) - \tilde{m}_n]^2 \\ &= \sum_{t=-\infty}^{0} a_n(t) \sum_{k=1}^{N} w_{kn}(t)[\ln y_k(t) - m_n]^2 \\ &\quad + \sum_{t=-\infty}^{0} a_n(t) \sum_{k=1}^{N} w_{kn}(t)[\ln f_k(t) - h_n]^2 \\ &\quad - 2 \sum_{t=-\infty}^{0} a_n(t) \sum_{k=1}^{N} w_{kn}(t)[\ln y_k(t) - m_n][\ln f_k(t) - h_n] \\ &\equiv s_n^2 + r_n^2 - 2c_n, \end{aligned} \tag{14}$$

where r_n^2 and c_n have been implicitly defined. So σ_n^2 is the sum of the log-variance of the perceived expenditure distribution and the log-variance of the distribution of family size minus twice the covariance between log-expenditure and log-family size.

The second step we make is to introduce a number of simplifying assumptions that will facilitate estimation of the model. Some assumptions are weak, others are stronger and evidently only approximately correct. They are to be justified by the pioneering nature of this study and the data limitations.

We assume that $w_{nn}(t)$ is the same for all individuals and constant over time, i.e., all individuals give themselves the same constant weight. We write $\beta_2 \equiv w_{nn}(t)$ and $\beta_3 \equiv 1 - \beta_2$. The function $\ln f_n$ is specified as $\beta_0 + \beta_1 \ln fs_n$, where fs_n is the number of persons in family n. The function $a_n(t)$ is assumed identical for all families and of the form $(1-a)a^{-t}$. This specification amounts to a stationarity assumption: The ratio of weights given to two periods t_1 and t_0 only depends on $(t_1 - t_0)$.

To formulate further assumptions, some more notation is needed,

$$\bar{m}_n(t) \equiv \frac{1}{\beta_3} \sum_{k \neq n} w_{kn}(t) \ln y_k(t), \tag{15}$$

where $\bar{m}_n(t)$ is the log-mean of expenditures in family n's social reference group at time t. Similarly we define the log-mean of family sizes in n's social reference group at time t by

$$\bar{f}_n(t) \equiv \frac{1}{\beta_3} \sum_{k \neq n} w_{kn}(t) \ln f_k(t). \tag{16}$$

These definitions and the assumptions above allow us to rewrite (13) as

$$\mu_n = \beta_0 + \beta_1 \ln fs_n + (1-a) \sum_{t=-\infty}^{0} a^{-t} \times [\beta_2\{\ln y_n(t) - \beta_1 \ln fs_n(t) - \beta_0\} + \beta_3\{\bar{m}_n(t) - \bar{f}_n(t)\}]. \tag{17}$$

Since no data on $f_n(t)$ are available for $t<0$, we are forced to assume that $f_n(t)$ is constant over time.[9] We moreover assume that $\bar{f}_n(t)$ does not correlate appreciably with the other right-hand side variables in (17), which allows to conveniently relegate $\bar{f}_n(t)$ to an error term without introducing serious specification errors. As a result (17) carries over into

$$\mu_n = \beta_0(1-\beta_2) + \beta_1(1-\beta_2)\ln fs_n + (1-a) \sum_{t=-\infty}^{0} a^{-t}[\beta_2 \ln y_n(t) + \beta_3 \bar{m}_n(t)] + \varepsilon_n, \tag{18}$$

where ε_n is an *i.i.d.* error term. Eq. (14) can be rewritten in a similar way but the resulting expression remains rather complicated. The limited data available call for a number of econometric provisions which make estimation of (18) already complicated. As can be seen from the following sections, estimation of (14) would lead to a non-linear errors in variables model which is very difficult to estimate. Hence we concentrate exclusively on (18) in this paper, taking the implied loss of efficiency for granted.

Eq. (18) is essentially dynamic. Hence longitudinal data seem to be required for estimation. Since our data come from a single cross-section, we need further amend the model. To this end, we introduce, in the next section, a dynamic behavioral relationship which allows for estimation of the dynamic model from cross section data. This relationship is based on the notion of *satisficing*. Due to its intrinsic methodological interest we devote a separate section to it.

[9] The extent to which this introduces a specification error depends on a. The estimate of a we finally come up with is 0.57. This implies that any change in f_n that took place longer than four years, say, gets a weight of 0.10 at most.

4. Satisficing

In section 2 we briefly discussed the result that the PWF of a broad commodity group is approximately lognormal. As a straightforward extension it can be shown that the simultaneous evaluation of spending money amounts $y_1, \ldots, y_I$ on I commodity groups follows approximately a multivariate lognormal distribution function [Van Praag (1968, sect. 3.7)]. This result and the availability of measured PWF's make it possible to test the hypothesis that individuals allocate their income to the I commodity groups such that this multivariate lognormal welfare function is maximized. In Kapteyn, Wansbeek and Buyze (1979) we have tested this hypothesis (to be called HM for short) on the basis of measured PWF's for 28 different commodity groups by investigating whether *purchase plans* are made in accordance with HM. The multistage allocation model inherent in the utility tree model would seem to make purchase plans excellently fit for a test of the model. It turns out, however, that HM is not capable of explaining any variation in purchase plans at all.

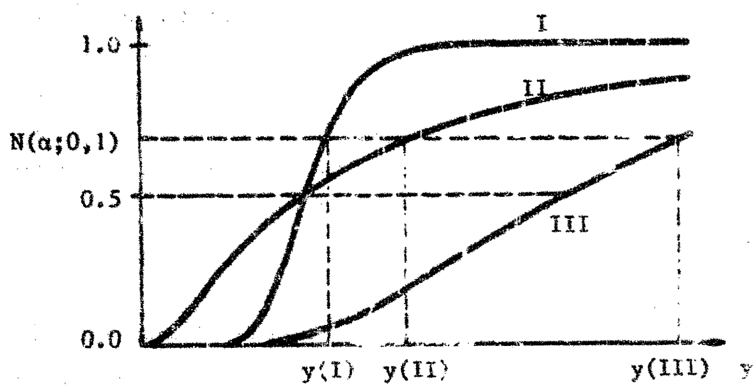

Fig. 4. Satisficing.

There are various ways of explaining this result. For one thing, it might be held that the multivariate lognormal welfare function is an inadequate specification of an individual's utility function. This argument would be strongest if no other behavioral hypotheses were able to explain the purchase plans on the basis of the measured PWFs. To investigate that possibility we have looked into the alternative hypothesis of satisficing.

The notion of satisficing in the present framework is illustrated in fig. 4. For a particular commodity group PWF's are depicted of three different individuals I, II and III. The ordinate value $N(\alpha, 0, 1)$ represents an *aspiration level* which has been taken identical for the three individuals. The satisficing hypothesis states that, if an individual considers spending money on the commodity group, he will spend an amount that just allows him to reach his aspiration level. If he would spend less he would feel that the satisfaction from the purchase would be insufficient.

This kind of behavior is less sophisticated than HM, since in the expenditure decision, with respect to a particular commodity group, the consequences for other commodity groups are largely ignored. The advantage of satisficing as a behavioral rule is that the purchase decision becomes a lot simpler and in fact it may be claimed that satisficing is optimal if a human being's limited problem solving capacity is accounted for. [This is the same motivation as the one underlying the mechanism that supposedly generates $U(y)$, cf. the argument with respect to fig. 1.] For reasons of space we will not discuss the various methodological aspects of satisficing vis-à-vis HM, but rather we refer to our earlier paper. For the present purposes it suffices to state that we have investigated various formulations of the satisficing hypothesis, that each of these formulations turned out to be superior to HM in terms of explaining the data and that the particular formulation illustrated in fig. 4 provided the best fit.

There is, however, one interesting observation which can be made by comparing fig. 4 to fig. 3. Remember that we conjectured that individual I in fig. 3 would have a history of rather stable expenditures whereas individual II would have experienced more variation, either in his own expenditures or in the expenditure by others in his social reference group. The satisficing hypothesis now predicts that individual I will spend an amount on his holidays which is closer to his $\exp(\mu)$ than individual II. Since $\exp(\mu)$ is partly made up of a geometric average of past expenditure [cf. (18)], this suggests that the amount spent by individual I will be rather close to his previous expenditures, whereas the expenditures by individual I are a bit more out of line. Thus the preference formation theory in connection with the satisficing relationship exhibits a reinforcing mechanism in the sense that some people will experiment a lot and feel reinforced doing that, whereas others show a very stable (if not dull) expenditure pattern and feel reinforced to stick to that pattern.

It is easily seen that the satisficing behavior as illustrated in fig. 4 can be formulated mathematically as

$$\ln(y_n) = \mu_n + \alpha\sigma_n + v_n, \tag{19}$$

where y_n is the amount of money individual n plans to spend on the commodity group under consideration, μ_n and σ_n are the parameters of his PWF for this commodity group, α is the parameter depicted in fig. 4 and v_n a random disturbance term. Relation (19) has been estimated for 28 different commodity groups. The parameter α appears to differ significantly between commodity groups. In contrast to HM, (19) is capable of explaining about 50% of the variance in $\ln y_n$. Further direct comparisons between satisficing and HM also appear to support satisficing unambiguously.

Reconsidering fig. 4, one observes that a high value of μ leads to a high aspiration level in money terms [the abscissa-value corresponding to $N(\alpha, 0, 1)$]. For equal μ's the PWF with the highest σ yields the highest aspiration level in money terms.

The main purpose served by eq. (19) for the present study is that it allows estimation of (18) on the basis of the data available.

5. The estimation method

The commodity group which is the subject of the empirical analysis is holiday expenditures. The data come from a survey of members of the Dutch Consumer Union in 1971. A more detailed description of the data is given in Van Praag and Kapteyn (1973). The measurement of the PWF's of the individuals in the sample is described in Kapteyn, Van Herwaarden and Van Praag (1977). Complete observations on the PWF-parameters μ and σ, total holiday expenditures, and the number of family members are available for 2081 families.

We shall first show how the satisficing relation can be used to make (18) amenable to estimation from cross-section data. Next, some further assumptions are introduced.

Remember that the satisficing relation pertained to purchase plans. We shall assume that the holiday expenditure y_n in this year is the result of plans made in the previous year. This allows us to rewrite (19) as

$$\ln y_n = \mu_n(-1) + \alpha\sigma_n(-1) + \zeta_n, \tag{20}$$

where $\mu_n(-1)$ and $\sigma_n(-1)$ are the values of individual n's PWF parameters in the previous period and ζ_n is an $N(\cdot, 0, \sigma_\zeta)$ distributed random disturbance term. This relation allows for the truncation of the infinite sum in (18) after one period: First rewrite (18) as

$$\begin{aligned}\mu_n = {} & (1-a)\{\beta_0(1-\beta_2) + \beta_1(1-\beta_2)\ln fs_n + \beta_2 \ln y_n + \beta_3 \bar{m}_n\} \\ & + a\mu_n(-1) + \varepsilon_n - a\varepsilon_n(-1),\end{aligned} \tag{21}$$

where the convention of omitting arguments equal to zero has been maintained and $\varepsilon_n(-1)$ is the disturbance term of the relation which explains $\mu_n(-1)$ analogous to (18). We assume that ε_n and $\varepsilon_n(-1)$ are mutually independent and that both follow an $N(\cdot; 0, \sigma_\varepsilon)$ distribution. Now solve $\mu_n(-1)$ from (20) and insert it in (21):

$$\begin{aligned}\mu_n = {} & (1-a)\beta_0(1-\beta_2) + (1-a)\beta_1(1-\beta_2)\ln fs_n \\ & + \{(1-a)\beta_2 + a\}\ln y_n + (1-a)\beta_3\bar{m}_n - \alpha a\sigma_n(-1) + u_n \\ \equiv {} & \gamma_0 + \gamma_1 \ln fs_n + \gamma_2 \ln y_n + \gamma_3 \bar{m}_n + \gamma_4 \sigma_n(-1) + u_n,\end{aligned} \tag{22}$$

where the γ's are implicitly defined and

$$u_n \equiv \varepsilon_n - \alpha(\varepsilon_n(-1) + \zeta_n). \tag{23}$$

The unobserved variable left in (22) is $\sigma_n(-1)$. The only way to get rid of $\sigma_n(-1)$ seems to be to assume that $\sigma_n(-1) = \sigma_n$. The plausibility of that assumption can be checked by looking at (14). Some algebraic manipulations show that $\sigma_n(-1)$ and σ_n will be equal if the holiday expenditures of all individuals grow at the same constant rate and if no changes in family size have occurred recently. Although this condition is not fully met, the steady overall growth of holiday expenditures in The Netherlands during the last decades suggests that it may be a reasonable approximation of reality. The assumption allows us to replace (22) by

$$\mu_n = \gamma_0 + \gamma_1 \ln fs_n + \gamma_2 \ln y_n + \gamma_3 \bar{m}_n + \gamma_4 \sigma_n + u_n. \tag{24}$$

In principle (24) can be estimated from a cross section of individuals where μ_n, σ_n, fs_n and y_n is known. The construction of $\bar{m}_n$ per individual requires knowledge of the reference weights w_{kn} [cf. (15)]. These reference weights have been estimated up to a constant of proportionality in an earlier study for the same sample that is used here [Kapteyn, Van Praag and Van Herwaarden (1976)]. Since the specification of the w_{kn} rests upon a complicated model which is costly to estimate we take the w_{kn} from the earlier study rather than re-estimating them. The estimates are subject to measurement error, so the variable $\bar{m}_n$ is also subject to error. This renders the OLS coefficient estimates in (24) inconsistent. In addition $\ln y_n$ correlates with u_n, as shown in appendix (A). This introduces another source of inconsistency. These econometric problems call for some special provisions. The estimation method used is the so-called CALS method developed in Kapteyn and Wansbeek (1979). This method yields consistent estimations of the coefficients. A discussion of the details of the estimation method is relegated to appendix (A).

One of the parameters in (22) is α. It is unidentified, so it cannot be estimated from the data. Neither is it known from the research by Kapteyn, Wansbeek and Buyze (1979) since their research did not pertain to holiday expenditures. We do know however the α's of 28 other commodity groups. This knowledge is used to specify a prior distribution for α. For details we refer to appendices (A) and (B).

6. Results

Table 1 presents the estimation results. The first column contains the estimates of regression coefficients obtained by OLS. The second column

Table 1

Estimation results.[a]

OLS-estimates of γ's (1)	CALS-estimates of γ's (2)	OLS-estimates of original parameters (3)	CALS-estimates of original parameters (4)	Without uncertainty about α (5)
$c_0 = 2.02$ (0.24)	$\hat\gamma_0 = 0.04$ (0.03)	$\tilde\beta_0 = 3.49$	$\hat\beta_0 = 0.14$ (0.09)	$\hat\beta_0 = 0.14$ (0.07)
$c_1 = 0.15$ (0.02)	$\hat\gamma_1 = 0.12$ (0.02)	$\tilde\beta_1 = 0.26$	$\hat\beta_1 = 0.39$ (0.11)	$\hat\beta_1 = 0.39$ (0.07)
$c_2 = 0.42$ (0.01)	$\hat\gamma_2 = 0.71$ (0.05)	$\tilde\beta_2 = -0.93$	$\hat\beta_2 = 0.31$ (0.21)	$\hat\beta_2 = 0.31$ (0.12)
$c_3 = 0.31$ (0.04)	$\hat\gamma_3 = 0.29$ (0.05)	$\tilde\beta_3 = 1.03$	$\hat\beta_3 = 0.69$ (0.21)	$\hat\beta_3 = 0.69$ (0.12)
$c_4 = -0.50$ (0.03)	$\hat\gamma_4 = -0.41$ (0.03)	$\tilde a = 0.70$	$\hat a = 0.57$ (0.08)	$\hat a = 0.57$ (0.04)

Number of observations: 2081 $\hat\sigma_\varepsilon^2 = 0.05$ (0.05), $\hat\sigma_\zeta^2 = 0.34$ (0.02), $\hat\sigma_\delta^2 = 0.07$ (0.01)

OLS $\bar R^2$: 0.49[b]

CALS $\bar R^2$: 0.83[c] (0.17)

[a]Asymptotic standard errors in parentheses. The computation method has been described by Kapteyn and Wansbeek (1979).

[b]The corrected $\bar R^2$ obtained by performing OLS on (24).

[c]This quantity is defined as $1 - \hat\sigma_\varepsilon^2/\mathrm{var}(\mu_n)$, with $\mathrm{var}(\mu_n)$ the sampling variance of μ.

contains estimates of the same coefficients but now based on the consistent CALS method. The third column presents the estimates of β's and a based on the OLS estimates of the regression coefficients. The fourth column presents the same quantities based on the CALS estimates. The meaning of the fifth column will be explained shortly.

A number of observations can be made regarding the econometric aspects of the results.

(1) There appears to be a considerable difference between the OLS-estimates and the CALS-estimates of the regression coefficients [columns (1) and (2)]. Neglecting errors in variables (in our case in $\bar m_n$) and other sources of correlation between explanatory variables and the error term (i.e., between $\ln y_n$ and u_n) leads to estimates that may be wildly misleading. In particular the OLS-estimate of γ_2 is far removed from the CALS-estimate. This conclusion is even strengthened if one computes the β's and a from respectively the OLS and CALS estimates of the regression coefficients [columns (3) and (4)]. Some of the parameter values in column (3) do not make much sense.

(2) The CALS-estimates of the β's and a are reasonably accurate. The standard errors are larger than those of the γ's because $\hat{a}$ and the $\hat{\beta}$'s depend on the $\hat{\gamma}$'s via α. As indicated in the previous section, α is an unknown parameter for which a prior distribution was specified. The uncertainty inherent in the prior distribution amplifies the uncertainty about the β's and a. This is illustrated by column (5) where the standard errors are given under the assumption that α is completely known.

(3) The value of σ_δ^2 (=0.67, with standard error 0.01) indicates that indeed the measurement errors of $\tilde{m}_n$ could not be disregarded without introducing serious specification errors.

(4) The CALS $\bar{R}^2$, as defined in note c of table 1, is an estimate of the percentage of variance of μ which is explained by model (18). The value of 0.83 suggests that only 17% in the variation of an individual's μ remains unexplained by model (18). Its standard error suggests that it does not differ significantly from one. Given that we use disaggregated data this is remarkably high. Part of the 17% can be explained by measurement errors in μ_n and by the specification errors that have been introduced by the simplifying assumptions which allowed us to move from (17) to (18). In particular, assuming f_n to be constant over time and neglecting $\bar{h}_n(t)$ may have depressing effect on $\bar{R}^2$. Furthermore the specification of f_n as $\beta_0+\beta_1 \ln fs_n$ is rather primitive and can be improved upon [cf. Kapteyn and Van Praag (1976, 1980)]. The high $\bar{R}^2$ that has emerged despite these specification errors is encouraging evidence for the validity of the preference hypothesis.

(5) The fairly complex estimation method which had to be used in estimating (18) indicates why we have abstained from simultaneously estimating the relationship explaining σ_n^2. That part of the model gives rise to a non-linear errors in variables model for which no standard estimation method exists. We are currently developing an estimation method for this type of model. Since the equation explaining σ_n^2 contains the same parameters as the relationship explaining μ_n, the model will then allow for tests of overidentifying restrictions and for the abolishment of some of the stronger assumptions. For example, it is then no longer necessary to assume that σ_n^2 is constant between the previous and the present period. Ideally, of course, model (13) and (14) should be estimated from longitudinal data. The estimation from such data would, moreover, be considerably simpler than the methods that had to be invented in this paper. In particular we could have done without the auxiliary satisficing relation.

7. Some implications

In order to aid intuitive appreciation of the results we spell out some implications. We ignore the uncertainty inherent in the statistical estimates.

The parameter a has been estimated at 0.57. This means that the weights attached to years 0, −1, −2, etc. decrease as follows: 0.43, 0.25, 0.14, 0.08, 0.05, 0.03, 0.01, 0.01, 0.00,... The periods beyond year −7 get a weight less than 1%. One observes also that the three most recent years (0, −1, −2) get the bulk of the weights: 82%. This is in agreement with Friedman's three-year horizon [Friedman (1975), Holbrook (1967)].[10]

The parameter β_2 has been estimated at 0.31 and β_3 at 0.69. Apparently, habit formation explains about one third of the variation in individual preferences, whereas preference interdependence explains the remaining two thirds. This is illustrated in fig. 5. There we present the PWF (I) of an individual who spends y_0 on a particular commodity group. He evaluates the result of this expenditure by 0.6. Next he decides to increase his expenditure by a factor $(1+\alpha)$. According to his PWF he expects to evaluate the result of the increasing expenditures by 0.85. Due to habit formation [eq. (18)] his PWF starts shifting to the right however. If we wait long enough, say more than seven years (remember that 99% of the weights is given to the most recent seven years) then the PWF will have reached the new equilibrium position II in fig. 5. In the long run, therefore, the evaluation of the increased expenditure has crept back to 0.7.

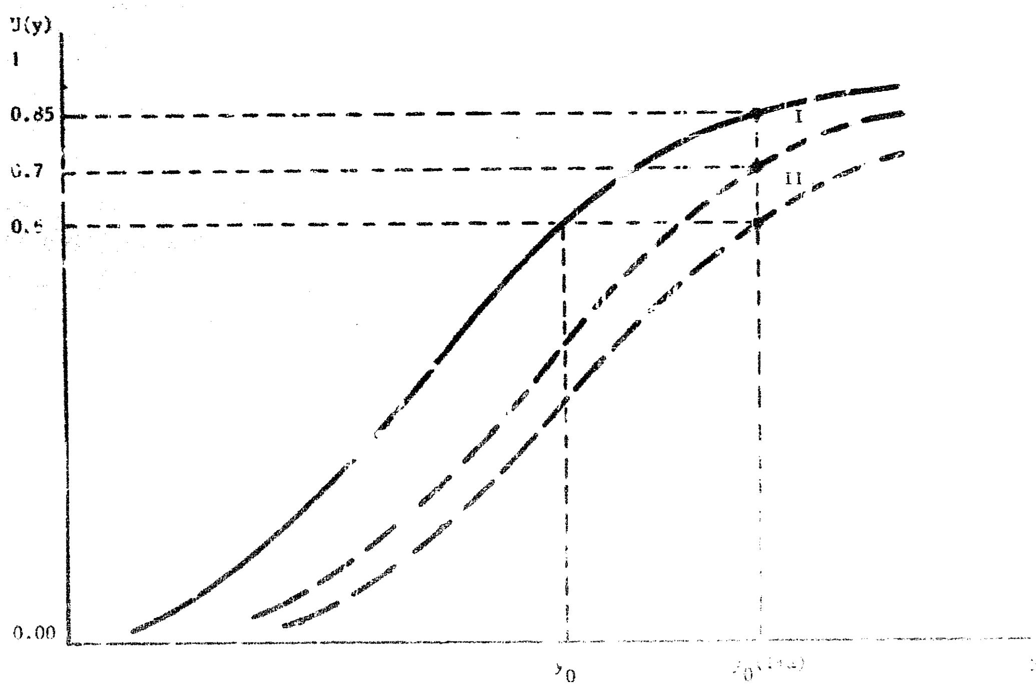

Fig. 5. The long-run influence of an expenditure increase.

[10] Of course Friedman's permanent income hypothesis (PIH) has an entirely different theoretical basis than habit formation, but it is also well-known that in many operationalizations the two are almost indistinguishable. For a close scrutiny of the difference between PIH and habit formation we refer to Singh and Ullah (1976).

Now imagine that everybody in society, or at least everyone to whom individual n attaches a positive reference weight, increases expenditures by the same factor $(1+\alpha)$. Then, according to (18), the PWF shifts further to the right until eventually it reaches position III. In the new equilibrium $y_0(1+\alpha)$ gets the same evaluation as y_0 in the old situation, *viz.* 0.6.

Thus, in the long run, the combined effect of habit formation and preference interdependence annihilates the welfare effect of expenditure increases. Since a WFI is a special case of a PWF we may expect similar outcomes with respect to income increases. It is of interest to re-interpret fig. 5 in terms of income. We see then that an income increase in the short run leads to a higher welfare level. In the longer run habit formation and preference interdependence nullify that effect.

Eq. (5) in fact shows that the *level of average income* in society is irrelevant to the evaluation of income. One's income evaluation is only dependent upon the relative position in the income distribution in one's social reference group and on the movement of incomes over time. The former implication of the theory is in agreement with findings by Easterlin (1974) who observes that self ratings of happiness between countries do not correlate with national income per capita, whereas within countries there is a significant correlation with individual income. To many people the relative nature of well-being is counter-intuitive ('People cannot eat relative income') and particularly in poor countries one would expect that the satisfaction with income does not exclusively derive from its relative position in perceived income distribution. Of course our empirical results refer to a developed country and we do not know to which extent the model would be valid in developing countries. But the presumed objectivity of certain basic needs may be less well-established than one would intuitively think. For example, Kilpatrick (1973) quotes evidence from various sources that subsistence levels of income, as defined by experts in the U.S. in various years between 1903 and 1960, grow roughly proportional with average family income: The growth is a little less than proportional but the assumption of proportionality cannot be rejected. In view of the vast changes in the welfare system during that period a little less than proportionate growth of the subsistence level is something which one would predict even on the basis of an entirely relativistic theory since the amount of subsidies and in-kind income has presumably grown substantially.

The effect of income growth over time is somewhat more complex. In Kapteyn (1977, ch. 8) various cases have been investigated. If, for instance, incomes in society are equal and grow at the same rate, then one can easily show that the welfare evaluation of income is *independent of the growth rate.* The reason for that phenomenon is illustrated in fig. 6. If incomes grow slowly, s_μ^2 will be small and so is σ_μ^2. If incomes grow fast, s_μ^2 is larger and so is σ_μ^2. As one sees from fig. 6, the resulting effect on income evaluation is the same for both cases.

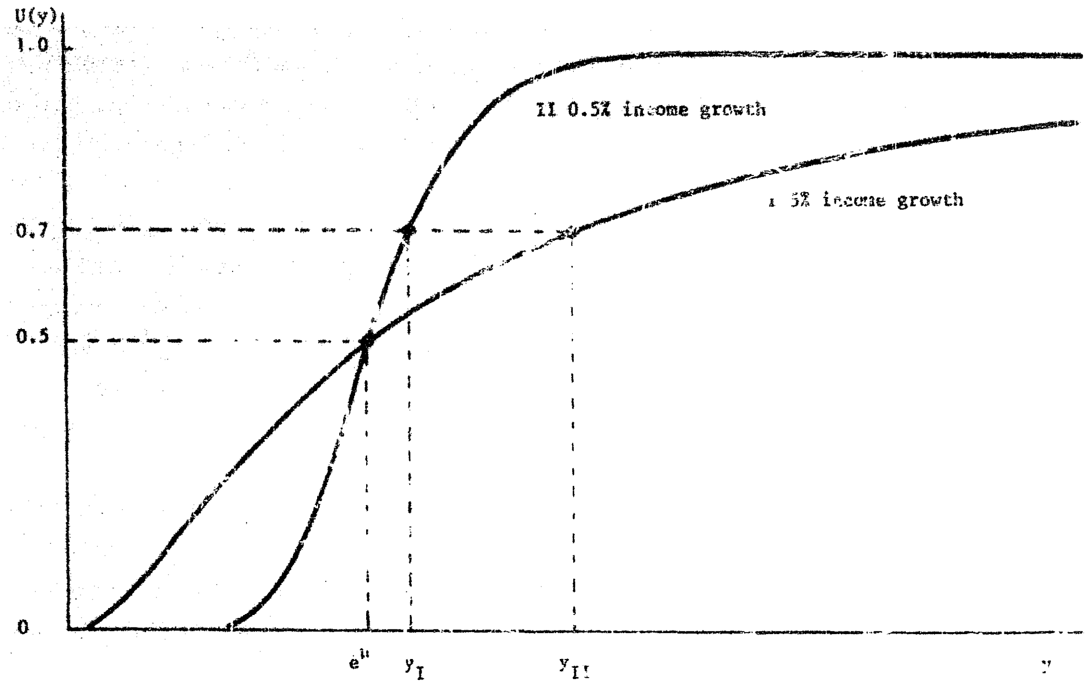

Fig. 6. Equal income evaluation at different growth rates.

8. Concluding remarks

The present paper is a first attempt to assess quantitatively the effects of habit formation and preference interdependence. Since preference interdependence had been quantified before, we have concentrated on habit formation, thereby imputing the reference weights from an earlier study. The empirical analysis is a first attempt in many respects. The data are far from ideal and, in order to avoid excessive econometric complications, simplifying assumptions had to be made.

Given these qualifications, the empirical endeavour seems highly successful. The preference formation theory put forward is specific and consequently vulnerable. It appears, however, to stand up to empirical tests quite well. The specificity of the theory has two distinct advantages. First of all, if the theory is true, its implications are many and hence the theory is informative about reality. Remember for instance the discussion in the preceding section regarding the welfare effects of income distribution and income growth. Secondly the specificity is of help in the construction of the model to be estimated. In section 3 we have introduced quite a few assumptions, not all of which were equally satisfactory. Since the theory is specific, we know fairly well what is wrong with the assumptions and how the model can be improved. The theory thus provides substantially more guidance in empirical specification than is usual in economic research.

In light of economists' traditional preoccupation with interpersonal utility comparisons it may be worthwhile to observe that the preference formation theory quantified here, strictly speaking, does not involve such interpersonal comparisons. Eqs. (13) and (14) explain the individual parameters μ_n and σ_n which have been obtained from verbal expressions of individual n. If words like 'excellent', 'good' etc. (cf. the description of the measurement method at the end of section 2) would have a markedly different meaning for different individuals then the measured parameters μ and σ would presumably exhibit substantial variation between individuals that cannot be explained by objective factors. The successful explanation of variation in μ over individuals by model (13) does suggest that words like 'excellent' and 'good' have largely the same meaning for different individuals. This supports the intersubjective meaning of the welfare parameters μ and σ. Thus, although the preference formation theory does not presuppose the interpersonal comparability of welfare functions, its success in explaining the variation of the parameters between individuals supports the interpersonal comparability of the welfare functions.

Another question of interest is to which extent the results are sensitive to the lognormal specification of the PWF. First of all we have indicated in section 2 that there is substantial evidence to support the lognormal form. Secondly, however, we suspect that if the lognormal specification turned out to be wrong, the empirical results with respect to preference formation would not change much. The parameter μ is the first log-moment of the lognormal distribution function. If preferences have to be described by a different distribution function it would probably still be possible to define the first log-moment and (18) would hold. The parameter μ as measured here would still be an estimate of the first log-moment of the true welfare function. If the true welfare function is not lognormal, however, one can conceivably construct a more efficient estimate of its first log-moment than μ. Thus, if a PWF is not lognormal one would expect some unnecessary measurement error in μ. This lowers the $\bar{R}^2$ corresponding to (18). So, if the lognormal assumption is wrong, we have presumably underestimated the explanatory power of the preference formation theory.

All this takes for granted that a welfare function is isomorphic to a probability distribution function, as presupposed in postulating (5). That supposition has not been tested in the present paper. It is hard to see however how the excellent fit of (18) could come about if the assumption were far off the mark.

In section 4 we have briefly treated a behavioral model which relates expenditures to PWF's. These expenditures influence preferences (of the individual himself and of other people). In turn these preferences influence behavior. In theory, then, we have a full, preference interdependent dynamic model of consumption. A model like that should be of great value for a better understanding of economic processes, like the diffusion of new commodities, changes in demand for old commodities, and the welfare effects of income maintenance programs. Obviously, the present state of knowledge is not sufficient to achieve these goals immediately. Especially on the behavior side there is a considerable amount of work to be done: The satisficing relation (19) only explains the size of planned purchases, not why individuals want to spend money on a commodity group at all. No well-developed theory exists yet, so (19) should perhaps better be viewed as an observed empirical regularity, which needs further explanation.[11] On the preference formation side the main task left seems to be the incorporation of expectations, which have remained outside the picture hitherto.

To improve the situation in the sense mentioned, more theorizing has to be done. But, equally important, better data are needed as well. In particular, longitudinal are of primary importance to estimate a full scale dynamic model like the one aimed at in our research.

Appendix

(*A*) *Details of estimation*

Model (24) has been estimated by means of the so-called CALS-method [Consistent Adjusted Least Squares, see Kapteyn and Wansbeek (1979)]. We briefly describe the method and then show what steps have to be taken in applying it to model (24).

The CALS-method has been developed to estimate the following single equation errors-in-variables (EV) model:

$$y=\tilde{X}\gamma+\varepsilon, \tag{A.1}$$

with y an N-vector of dependent variables, $\tilde{X}$ an $N\times k$-vector of non-stochastic explanatory variables, γ a $k\times 1$-vector of unknown parameters and ε an N-vector of independent $N(\cdot;0,\sigma)$-distributed unobservable random variables. Due to measurement errors one or more columns of $\tilde{X}$ are unobservable. Instead we observe the $N\times k$-matrix X which is assumed to be generated by

$$X=\tilde{X}+V, \tag{A.2}$$

where V is an $N\times k$-matrix of unobservable random variables. Each row of V, v_i', $i=1,\dots,N$, is $N(\cdot;0,\Omega)$ distributed, with Ω of order $k\times k$; $E(v_iv_j')=0$ if $i\neq j$. For those columns of $\tilde{X}$ that are measured without error, the corresponding columns of V are identically equal to zero.

[11] For the subject of the present paper, (19) served a purely auxiliary purpose. If longitudinal data are available, eqs. (13) and (14) can be estimated without involving the satisficing relation.

The model is underidentified and it is well-known that the OLS-estimator $c \equiv (X'X)^{-1}X'y$ is an inconsistent estimator of γ. Also the residual variance estimator of σ^2, s^2, is inconsistent. We assume therefore that a system of, possibly non-exact, identifying restrictions is available,

$$F(\Omega, \gamma, \sigma^2 | \lambda) = 0, \tag{A.3}$$

where λ is an unobservable m-vector of random variables. If λ has a degenerate distribution, then the restrictions are exact.

It is shown in Kapteyn and Wansbeek (1979) that under certain regularity conditions regarding F, the estimators $\hat{\gamma}$, $\hat{\Omega}$ and $\hat{\sigma}^2$ of γ, Ω and σ^2, defined by

$$(I_k - N(X'X)^{-1}\hat{\Omega})\hat{\gamma} - c = 0, \tag{A.4}$$

$$F(\hat{\Omega}, \hat{\gamma}, \hat{\sigma}^2 | \lambda_0) = 0, \tag{A.5}$$

$$\hat{\sigma}^2 + \hat{\gamma}'\hat{\Omega}c - s^2 = 0, \tag{A.6}$$

are consistent, provided that λ_0 is the correct choice for the unobservable λ. Since the asymptotic distribution of c, $N^{-1}X'X$ and s^2 is known, one can for a given distribution of λ derive the asymptotic distribution of the CALS-estimators. An alternative route is to simulate this distribution by drawing from the (asymptotic) distribution of c, s^2, $N^{-1}X'X$ and λ and compute for each drawing $\hat{\gamma}$, $\hat{\Omega}$ and $\hat{\sigma}^2$ from (A.4)–(A.6). The moments of the thus simulated sample of CALS-estimates are consistent estimators of the moments of the asymptotic distribution of the CALS-estimator.

Let us now see how model (24) fits into this framework. We have already seen that $\bar{m}_n$ is measured with error. The measurement error has variance σ_ζ^2. Furthermore, $\ln y_n$ correlates with u_n. We find

$$c_{yu} \equiv \operatorname{cov}(\ln y, u_n) = -a(\sigma_\varepsilon^2 + \sigma_\zeta^2), \tag{A.7}$$

by using (20) and (23) and the fact that $\operatorname{cov}(\mu_n(-1), \varepsilon_n(-1)) = \sigma_\varepsilon^2$.

This covariance can be interpreted as a measurement error in $\ln y_n$ with variance

$$\frac{a}{\gamma_2}(\sigma_\varepsilon^2 + \sigma_\zeta^2) = -\frac{\gamma_4}{\gamma_2 \alpha}(\sigma_\varepsilon^2 + \sigma_\zeta^2). \tag{A.8}$$

Hence there are two variables measured with error. Assuming that the measurement errors are uncorrelated and that the other variables are measured without error we need two identifying restrictions. The first identifying restriction follows from the observation that

$$\gamma_2 + \gamma_3 = 1, \tag{A.9}$$

because $\beta_2 + \beta_3 = 1$.

The second identifying restriction is obtained by noting that the satisficing relation (20) implies

$$\begin{aligned} \operatorname{var}(\ln y_n) = {} & \operatorname{var}(\mu_n(-1)) + \alpha^2 \operatorname{var}(\sigma_n(-1)) \\ & + 2\alpha \operatorname{cov}(\mu_n(-1), \sigma_n(-1)) + \sigma_\zeta^2, \end{aligned} \tag{A.10}$$

where var$(\cdot)$ and cov$(\cdot, \cdot)$ stand for population variances and covariances of the arguments. We assume that the variances and covariances on the right-hand side of (A.10) do not change appreciably between last year and this year, i.e., the development of preferences in society is supposed to be stationary in some sense. This assumption allows us to write

$$\sigma_\zeta^2 = \operatorname{var}(\ln y_n) - \operatorname{var}(\mu_n) - 2\alpha \operatorname{cov}(\mu_n, \sigma_n) - \alpha^2 \operatorname{var}(\sigma_n), \tag{A.11}$$

which yields the second identifying restriction we were looking for.

The quantity σ_ζ^2 is consistently estimated by replacing the population moments on the right-hand side of (A.11) by the corresponding sample moments. We shall call the expression thus obtained $\hat{\sigma}_\zeta^2$. Assuming that $\ln y_n - \mu_n - \alpha\sigma_n$ is normally distributed, the standard error of $\hat{\sigma}_\zeta^2$ is known for a given value of α [see, e.g., Kendall and Stuart (1977)].

Unfortunately, α is unknown, as mentioned in section 5. Therefore we specify a prior distribution for α. In our earlier paper [Kapteyn, Wansbeek and Buyze (1979)] we estimated α for 28 different commodity groups (*not* including holiday expenditures). These estimates range from 0.41 to 0.97, with an average (weighted by the number of observations on which each estimate is based) equal to 0.71. Since the α's appeared to be significantly different from each other, we cannot maintain that α has the same value for all commodity groups. Rather we take α_i (the α of the ith commodity group) to be a drawing from a distribution with mean μ_α and variance σ_α^2. Given the 28 estimates and their standard errors it is possible to estimate μ_α and σ_α^2. This is set out in appendix (B). We take $N(\cdot; \mu_\alpha, \sigma_\alpha)$ to be the prior distribution from which the holiday expenditures α is drawn. In computing the β's and a from the estimates of the γ's we fix α at 0.71, its ML value. When computing standard errors of the β's and a, we take the uncertainty regarding the true value of α into account by imputing a standard error s_α (the estimate of σ_α) to α.

Returning to eq. (A.11), it is obvious that the uncertainty about α contributes to the uncertainty about σ_ζ^2. The simultaneous distribution of and $\hat{\sigma}_\zeta^2$ is derived in appendix (C). Thus, referring to (A.3), the vector λ in the present application consists of α and $\hat{\sigma}_\zeta^2$. The asymptotic standard errors of the CALS-estimators are obtained by the simulation procedure outlined above. The number of drawings is equal to 100. The covariance between c and s^2 on the one hand and α and $\hat{\sigma}_\zeta^2$ on the other hand is assumed to be zero.

(B) Estimation of the moments of α

In this appendix we discuss (asymptotically) unbiased estimators m_α and s_α^2 of μ_α and σ_α^2, the mean and variance of the distribution from which we assume the α_i, $i=1,\ldots,I$, $(I=28)$ to have been randomly drawn. In case the α_i were known with certainty, the problem would be trivial. However, we only have an asymptotically unbiased estimator $\hat{\alpha}_i$ of α_i with estimated variance $\hat{\sigma}_i^2$ for each i; $\hat{\sigma}_i^2$ is an estimator σ_i^2 (the true variance of the estimator) and is asymptotically unbiased as well.[12]

Let n_i be the number of observations on which the estimators $\hat{\alpha}_i$ and $\hat{\sigma}_i^2$ are based, and let $\rho_i \equiv n_i(\sum_{i=1}^{I} n_i)$. Define

$$m_\alpha \equiv \sum_{i=1}^{I} \rho_i \hat{\alpha}_i, \tag{B.1}$$

$$s_\alpha^2 \equiv \left(1 \Big/ \sum_{i=1}^{I} \rho_i(1-\rho_i)\right) \sum_{i=1}^{I} \rho_i((\hat{\alpha}_i - m_\alpha)^2 - (1-\rho_i)\hat{\sigma}_i^2). \tag{B.2}$$

It will be shown that m_α and s_α^2 are asymptotically unbiased estimators of μ_α and σ_α^2, assuming

$$\lim_{n_i \to \infty} \rho_i = \pi_i, \qquad i=1,\ldots,I, \tag{B.3}$$

with $0 < \pi_i < 1$, $i=1,\ldots,I$, and $\sum_{i=1}^{I} \pi_i = 1$.

Asymptotic unbiasedness of (B.1) is trivially established. Regarding (B.2), we observe

$$\begin{aligned} \lim_{n \to \infty} E(\mu_\alpha - m_\alpha)^2 &= \lim_{n \to \infty} E\left(\sum_{i=1}^{I} \rho_i(\hat{\alpha}_i - \mu_\alpha)\right)^2 \\ &= \lim_{n \to \infty} E \sum_{i=1}^{I} \rho_i^2 (\hat{\alpha}_i - \mu_\alpha)^2 = \sum_{i=1}^{I} \pi_i^2 \operatorname{var}(\hat{\alpha}_i) \\ &= \sum_{i=1}^{I} \pi_i^2 (\sigma_i^2 + \sigma_\alpha^2); \end{aligned} \tag{B.4}$$

[12] This follows from Kapteyn, Wansbeek and Buyze (1979, sect. 5 and the appendix).

This result is used to derive

$$\lim_{n\to\infty} E \sum_{i=1}^{I} \rho_i(\hat{\alpha}_i - m_\alpha)^2 = \lim_{n\to\infty} \left\{ \sum_{i=1}^{I} \rho_i E(\hat{\alpha}_i - \mu_\alpha)^2 - E(m_\alpha - \mu_\alpha)^2 \right\}$$

$$= \lim_{n\to\infty} \left\{ \sum_{i=1}^{I} \rho_i \operatorname{var}(\hat{\alpha}_i) - \sum_{i=1}^{I} \rho_i^2 \operatorname{var}(\hat{\alpha}_i) \right\}$$

$$= \sum_{i=1}^{I} \pi_i(1-\pi_i)(\sigma_i^2 + \sigma_\alpha^2). \tag{B.5}$$

In view of the asymptotic unbiasedness of $\hat{\alpha}_i$ and $\hat{\sigma}_i^2$, the asymptotic unbiasedness of s_α^2 in (B.2) follows directly from (B.4) and (B.5). Since $\hat{\alpha}_i$ and $\hat{\sigma}_i^2$ are consistent as well, consistency of m_a and s_α^2 can be established along the same lines.

(C) The simultaneous asymptotic distribution of $\hat{\sigma}_\zeta^2$ and α

Recall (20),

$$\ln y_n = \mu_n(-1) + \alpha\sigma_n(-1) + \zeta_n. \tag{C.1}$$

If α were known, an unbiased estimator of σ_ζ^2 would be

$$\hat{\sigma}_\zeta^2 \equiv \frac{1}{N-1} \sum_{n=1}^{N} [\ln y_n - \mu_n(-1) - \alpha\sigma_n(-1) - \overline{\ln y} - \overline{\mu(-1)} - \overline{\alpha\sigma(-1)}]^2, \tag{C.2}$$

where bars on top of variables indicate sample averages. Now denote the true α by α_*, i.e., in (C.1) α should be replaced by α_*. Furthermore we replace as usual $\sigma_n(-1)$ by σ_n. Then (C.1) and (C.2) imply

$$\hat{\sigma}_\zeta^2 = \frac{1}{N-1} \sum_{n=1}^{N} ((\alpha_* - \alpha)(\sigma_n - \bar{\sigma}) + (\zeta_n - \bar{\zeta}))^2. \tag{C.3}$$

Of course (C.2) and (C.3) have no practical value since they contain unobservables. That is why (A.11) has been employed to obtain an estimate of $\hat{\sigma}_\zeta^2$. We shall employ (C.3) however to derive the simultaneous distribution of α and $\hat{\sigma}_\zeta^2$. We know that α follows an $N(\cdot; \mu_\alpha, \sigma_\alpha)$ distribution, whereas $\hat{\sigma}_\zeta^2$ is also asymptotically normally distributed for a given α. Hence α and $\hat{\sigma}_\zeta^2$ are simultaneously normally distributed. The mean of $\hat{\sigma}_\zeta^2$ is estimated at 0.34. This value is obtained by replacing all moments in (A.11) by their sample counterparts. The derivation of the variance of $\hat{\sigma}_\zeta^2$ and the covariance between $\hat{\sigma}_\zeta^2$ and α is given now.

In the derivation we shall use the following lemma:

Lemma. *Let $\{a_i\}_{i=1}^I$ be a sequence of constants adding up to zero and $\{b_i\}_{i=1}^I$ a sequence of independent $N(0,\sigma)$ distributed random variables. Define $\bar b \equiv (1/I)\sum_{i=1}^I b_i$. Then*

$$\operatorname{var}\left(\sum_{i=1}^I (a_i+b_i-\bar b)^2\right)=2(I-1)\sigma^4+4\sigma^2\sum_{i=1}^I a_i^2. \tag{C.4}$$

Proof. The result can be verified by direct evaluation.

The variance of $\hat\sigma_\zeta^2$ can be decomposed as

$$\operatorname{var}(\hat\sigma_\zeta^2)=\operatorname{var}_\alpha E_\zeta(\hat\sigma_\zeta^2|\alpha)+E_\alpha \operatorname{var}_\zeta(\hat\sigma_\zeta^2|\alpha) \tag{C.5}$$

[see, e.g., Mood, Graybill and Boes (1974)]. Both terms on the right-hand side of (C.5) will be evaluated consecutively.

With respect to the first term on the right-hand side of (C.5) we have

$$\begin{aligned}E_\zeta(\hat\sigma_\zeta^2|\alpha)&=\frac{1}{N-1}\sum_n\{(\alpha_*-\alpha)(\sigma_n-\bar\sigma)\}^2+\frac{1}{N-1}\sum_n E(\zeta_n-\bar\zeta)^2\\&=(\alpha_*-\alpha)^2 m_{\sigma\sigma}+\sigma_\zeta^2,\end{aligned} \tag{C.6}$$

with $m_{\sigma\sigma}$ the sample variance of σ. Hence

$$\begin{aligned}\operatorname{var}_\alpha E_\zeta(\hat\sigma_\zeta^2|\alpha)&=m_{\sigma\sigma}^2\operatorname{var}(\alpha^2-2\alpha\alpha_*)\\&=m_{\sigma\sigma}^2\{2\sigma_\alpha^4+4\mu_\alpha^2\sigma_\alpha^2+4\alpha_*^2\sigma_\alpha^2\}\\&=2m_{\sigma\sigma}^2\{\sigma_\alpha^2+2(\alpha_*^2+\mu_\alpha^2)\}\sigma_\alpha^2.\end{aligned} \tag{C.7}$$

With respect to the second term on the right-hand side of (C.5) we have

$$\begin{aligned}\operatorname{var}_\zeta(\hat\sigma_\zeta^2|\alpha)&=\frac{1}{(N-1)^2}\operatorname{var}_\zeta\left\{\sum_n[(\alpha_*-\alpha)(\sigma_n-\bar\sigma)+\zeta_n-\bar\zeta]^2\right\}\\&=\frac{1}{(N-1)^2}\left[2(N-1)\sigma_\zeta^4+4\sigma_\zeta^2\sum_n(\alpha_*-\alpha)^2(\sigma_n-\bar\sigma)^2\right]\\&=\frac{2}{N-1}[\sigma_\zeta^4+2(\alpha_*-\alpha)^2 m_{\sigma\sigma}\sigma_\zeta^2],\end{aligned} \tag{C.8}$$

where (C.4) has been used. Consequently

$$E_{\alpha}\,\mathrm{var}_{\zeta}(\hat{\sigma}_{\zeta}^{2}|\alpha)=\frac{2}{N-1}\sigma_{\zeta}^{4}+4\{(\alpha_{*}-\mu_{\alpha})^{2}+\sigma_{\alpha}^{2}\}m_{\sigma\sigma}$$

$$=\frac{2}{N-1}\sigma_{\zeta}^{2}[\sigma_{\zeta}^{2}+2\{(\alpha_{*}-\mu_{\alpha})^{2}+\sigma_{\alpha}^{2}\}m_{\sigma\sigma}]. \tag{C.9}$$

Combining (C.5), (C.7) and (C.9) we finally obtain

$$\mathrm{var}(\hat{\sigma}_{\zeta}^{2})=2m_{\sigma\sigma}^{2}\{\sigma_{\alpha}^{2}+2(\alpha_{*}^{2}+\mu_{\alpha}^{2})\}\sigma_{\alpha}^{2}$$

$$+\frac{2}{N-1}\{\sigma_{\zeta}^{4}+2[(\alpha-\mu_{\alpha})^{2}+\sigma_{\alpha}^{2}]\sigma_{\zeta}^{2}m_{\sigma\sigma}\}. \tag{C.10}$$

Since α_{*} is unknown we replace it by m_{α} [cf. appendix (B)]. Similarly the other parameters are replaced by estimates to obtain

$$\mathrm{var}(\hat{\sigma}_{\zeta}^{2})=2m_{\sigma\sigma}^{2}\{s_{\alpha}^{4}+4m_{\alpha}^{2}s_{\alpha}^{2}\}+\frac{2}{N-1}\{\hat{\sigma}_{\zeta}^{4}+2s_{\alpha}^{2}s_{\zeta}^{2}m_{\sigma\sigma}\}. \tag{C.11}$$

The value of the right-hand side of (C.11) is used as the variance of the normal distribution from which $\hat{\sigma}_{\zeta}^{2}$ is drawn in the simulation.

Finally the covariance between α and $\hat{\sigma}_{\zeta}^{2}$ has to be calculated,

$$\mathrm{cov}(\alpha,\sigma_{\zeta}^{2})=E(\hat{\sigma}_{\zeta}^{2}(\alpha-\mu_{\alpha}))$$

$$=\frac{1}{N-1}E\left\{(\alpha_{*}-\alpha)^{2}(\alpha-\mu_{\alpha})\sum_{n}(\sigma_{n}-\bar{\sigma})^{2}\right\}$$

$$=m_{\sigma\sigma}E\{(\alpha_{*}-\alpha)^{2}(\alpha-\mu_{\alpha})\}$$

$$=-2m_{\sigma\sigma}(\alpha_{*}-\mu_{\alpha})\sigma_{\alpha}^{2}. \tag{C.12}$$

If, as with (C.10), we replace both α_{*} and μ_{α} by m_{α} we find a zero covariance. So α and $\hat{\sigma}_{\zeta}^{2}$ are drawn independently in the simulation.

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