

## Tilburg University

### Interdependent preferences

Kapteyn, A.J.; van der Geer, S.; van de Stadt, H.; Wansbeek, T.J.

*Publication date:*  
1989

[Link to publication in Tilburg University Research Portal](#)

*Citation for published version (APA):*

Kapteyn, A. J., van der Geer, S., van de Stadt, H., & Wansbeek, T. J. (1989). *Interdependent preferences: An econometric analysis*. (CentER Discussion Paper; Vol. 1989-54). Unknown Publisher.

#### General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

#### Take down policy

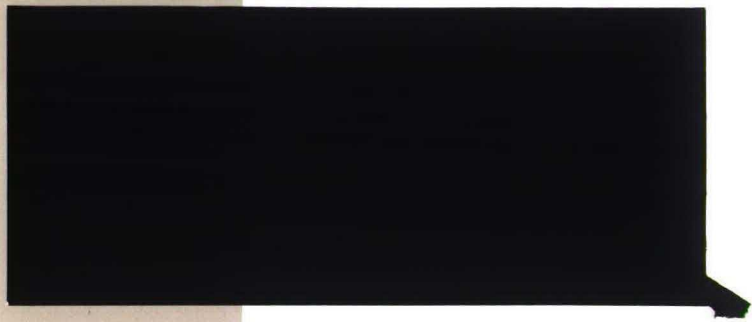
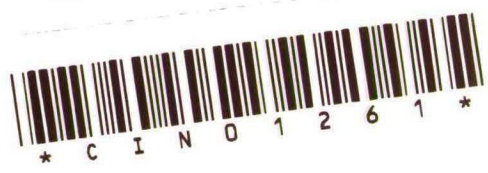
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

CBM  
CBM  
R  
for  
ic Research

8414  
1989

54

# Discussion paper





No. 8954

**INTERDEPENDENT PREFERENCES:  
AN ECONOMETRIC ANALYSIS**

by Arie Kapteyn, Sara van de Geer,  
Huib van de Stadt and Tom Wansbeek <sup>R43</sup>

330.115.12  
330.567

November, 1989

INTERDEPENDENT PREFERENCES:  
AN ECONOMETRIC ANALYSIS

Arie Kapteyn \*)  
Sara van de Geer \*\*)  
Huib van de Stadt \*\*\*)  
Tom Wansbeek \*\*\*\*)

- \*) Tilburg University and Center
- \*\*) Centre for Mathematics and Computer Science, Amsterdam
- \*\*\*) Netherlands Central Bureau of Statistics
- \*\*\*\*) Groningen University and Center Fellow

Financial support by the Netherlands Organization for Scientific research is gratefully acknowledged. We thank Ton Barten, Wouter Keller, Peter Kooreman and Rob Alessie for valuable comments and Erik van Elderen for research assistance.

## INTERDEPENDENT PREFERENCES: AN ECONOMETRIC ANALYSIS

### Abstract

The theoretical model of Gaertner (1974) and Pollak (1976) to analyze interdependence of preferences in the Linear Expenditure System is estimated for a cross-section of households. The interdependence of consumption of different households has implications for the stochastic structure of the model and for the identifiability of its parameters. Both aspects are dealt with.

The empirical results indicate a significant role played by the interdependence of preferences. One of its implications is that for a household, predictions of the effects of changes in exogenous variables differ according to whether the exogenous variable only changes for this household or for all households jointly.

## 1. Introduction

In his pioneering study, Duesenberry (1949) gave several kinds of evidence based on aggregate data to indicate the importance of preference interdependence for the explanation of consumer behavior. At about the same time Leibenstein (1950) extensively discussed various types of interdependencies in consumption behavior of individuals. Of course, these two authors were not the first ones to discuss preference interdependence. Leibenstein notes, for example, that the notion of 'conspicuous consumption' can be traced back as far as the works of Horace. Since the time the papers by Duesenberry and Leibenstein were published, some further work has been done on what has been called alternatively variable preferences, endogenous preferences, or interdependent preferences. In Kapteyn et al. (1980) we have given a brief review of most of this literature.

In the economics literature endogenous preferences are usually assumed to arise as a result of habit formation (e.g., Pollak and Wales, 1969, Houthakker and Taylor, 1970, Philips, 1972 and 1974, Manser, 1976, Spinnewijn, 1981, Philips and Spinnewijn, 1982, Muellbauer, 1988, Pashardes, 1986, Winder, 1988). Where in the older literature, habit formation was invariably myopic (or "naive"), in the more recent literature spawned by Spinnewijn (1981) habits are allowed to be rational, i.e. consumers may anticipate the effect of their current decisions on their future preferences. The empirical evidence on the extent to which habit formation is myopic or rational is mixed. Pashardes (1986) finds that entirely myopic habits are rejected by his data, but not fully rational habits, whereas Muellbauer (1988) finds habits to be predominantly myopic.

In the context of the Linear Expenditure System (LES), the two forms of habit formation are basically indistinguishable (Spinnewijn, 1981, Philips and Spinnewijn, 1982). As we will be concerned exclusively with the LES, we can therefore ignore the distinction.

In two rather closely related papers Gaertner (1974) and Pollak (1976) have studied some theoretical implications of the incorporation of preference interdependence in the LES. Darrough, Pollak and Wales (1983) estimate a Quadratic Expenditure System for three separate time series (one British and two Japanese) of grouped household budget data. They also consider specifications where some parameters depend on lagged consumption. Since the data are grouped according to income-demographic cells, one may interpret the dependence of

parameters on lagged consumption (i.e. the consumption of other people in the same cell, one period ago) as representing interdependent preferences. The authors find the specification with lagged consumption included to be empirically superior to static versions of their model.

Thus we have two theoretical papers within the systems approach that deal with preference interdependence and one empirical paper that can be interpreted as supporting the notion of interdependent preferences (but a habit formation interpretation is possible as well). In our paper we follow the lead of Gaertner and Pollak, but focus entirely on the econometric and empirical aspects of preference interdependence in the LES. The choice of the LES as our framework of analysis is mainly motivated by a desire for simplicity in this pioneering stage. Future work should extend to other systems.

The paper is organized as follows. Section 2 presents the LES with interdependence incorporated. Section 3 and appendix A concentrate on the stochastic assumptions required to render the model amenable to estimation on the basis of a cross-section. In section 4 we consider issues of identification. Section 5 contains the results of estimating the model for a household expenditure survey in The Netherlands. Section 6 concludes with some qualifications, and points at future research.

## 2. The deterministic part of the model

Our starting point is the Linear Expenditure System (LES):

$$x_{gn} = b_{gn} + \gamma_g \left[ y_n - \sum_{h=1}^G b_{hn} \right], \quad (2.1)$$

where the index  $n, n=1, \dots, N$ , indicates the  $N$  consumers (or households) in society;<sup>1)</sup> the index  $g, g=1, \dots, G$ , indicates goods;  $x_{gn}$  denotes the quantity of good  $g$  consumed by individual  $n$ ;  $y_n$  is total expenditures;  $\gamma_g$ , with  $\sum_g \gamma_g = 1$ , and  $b_{gn}$  are parameters. The system (2.1) arises from the maximization of the utility function

$$U_n(x_1, \dots, x_G) = \sum_{g=1}^G \gamma_g \log(x_g - b_{gn}) \quad (2.2)$$



subject to the budget constraint

$$\sum_{g=1}^G x_{gn} = y_n, \quad (2.3)$$

with  $y_n$  total expenditures of household  $n$ .<sup>2)</sup> Note that a maximization problem like this may arise in a rather general setting, like maximization of an intertemporally separable Stone-Geary utility function under a life time budget constraint. In such circumstances the maximization problem (2.2) - (2.3) arises in the second stage of a two-stage budgetting process. Introduction of certain forms of uncertainty or liquidity constraints does not affect the second stage. See, e.g., Blundell and Walker (1986) and Alessie and Kapteyn (1989).

We incorporate interdependence of preferences by expressing the parameters  $b_{gn}$  as a function of consumption by others:

$$b_{gn} = b_{g0} + \beta_g \sum_{k=1}^N w_{nk} x_{gk}, \quad w_{nn} = 0, \quad w_{nk} \geq 0, \quad \sum_k w_{nk} = 1, \quad 0 \leq \beta_g < 1, \quad (2.4)$$

with  $b_{g0}$  a good-specific intercept and  $\beta_g$  a good-specific coefficient, and the  $w_{nk}$  reference weights, representing the importance attached by consumer  $n$  to consumer  $k$ 's expenditures. Intuitively,  $\beta_g$  measures the conspicuousness of good  $g$ . The higher  $\beta_g$  is, the more one's consumption of good  $g$  is influenced by the consumption of others. The expression  $\sum_{k=1}^N w_{nk} x_{gk}$  represents mean expenditures on good  $g$  in the reference group of consumer  $n$ , where the reference group of individual  $n$  is defined as the set of individuals  $k$  for whom  $w_{nk} > 0$ .

To allow for differences in household composition, the model is extended slightly in the following simple way. Let  $f_n$  be the size of household  $n$ , however defined. It is assumed that the household's committed expenditures on good  $g$  increase with  $\mu_g f_n$ , where  $\mu_1, \dots, \mu_G$  are parameters. This corresponds to 'translating' as defined by Pollak and Wales (1981). Combining preference interdependence with translating leads to the following adaptation of the basic model. Let  $\tilde{x}_{gn}$  be defined as

$$\tilde{x}_{gn} = x_{gn} - \mu_g f_n, \quad (2.5)$$

then we replace (2.4) by

$$b_{gn} = b_{g0} + \mu_g f_n + \beta_g \sum_{k=1}^N w_{nk} \tilde{x}_{gk}. \quad (2.6)$$

Notice that (2.6) reduces to  $b_{gn} = b_{g0} + \mu_g f_n$  in either of two cases:  $\beta_g = 0$  or all  $\tilde{x}_{gk} = 0$ . We may call  $b_{g0} + \mu_g f_n$  the basic needs of household n, because it represents committed expenditures if the household does not refer to other households at all, or if all other households are just able to satisfy their own basic needs. It is only the excess of other households' expenditures on good g over their basic needs which raises committed expenditures.<sup>3)</sup>

### Discussion of the specification

The model is closely related to the ones analyzed by Gaertner (1974) and Pollak (1976), although these authors do not take into account demographic variables. Both authors mainly consider dynamic specifications in which the  $x_{gk}$  on the right hand side of (2.4) are lagged one period. Gaertner also specifies a relation for  $\gamma_g$ , where an individual's  $\gamma_g$  depends on relative changes in his permanent income. Furthermore, he considers various specifications in which the reference weights depend on consumption patterns of individuals. Both Gaertner and Pollak allow the reference weights to vary according to goods and also to be non-zero for  $k=n$ . Since for our empirical work we only have cross-section data available, a dynamic specification is ruled out. Assuming that the weight  $w_{nn}$  an individual gives to his own consumption is the same for everyone, it is impossible in a cross-section to distinguish empirically between  $w_{nn} = 0$  or  $w_{nn} \neq 0$ . So, taking  $w_{nn} = 0$  ('no habit formation') does not entail loss of generality (although the interpretation of parameter estimates depends on it). Alternatively, it may be argued that  $w_{nn} \neq 0$  does not make sense in a static framework.

Also, we do not follow Gaertner's lead to specify a model for  $\gamma_g$  and the  $w_{nk}$ , and in contrast to both Gaertner and Pollak the reference weights  $w_{nk}$  are assumed identical across commodities up to a constant of proportionality. These are major simplifications, inspired by our wish to have a model that can be estimated empirically.

It might be objected to the approach adopted by Gaertner, Pollak and by us that there is no clear theoretical reason why the notion of interdependence would be best captured by a linear weighting scheme like (2.4). One could argue that, for example, individuals will refer mainly to others with a

higher consumption level. Evidence from social psychology seems to be ambiguous in this respect. For instance, in studies that deal with feelings of equity about remuneration within organizations some find that individuals compare their income to others who are just above them and other studies report that individuals refer mainly to people who are just below them (cf. Von Grumbkov 1980, and references therein). Altogether, therefore, a linear weighting scheme does not seem inconsistent with the available evidence.

It is worth noticing that the  $b_{gn}$  are often interpreted as subsistence levels, so that (2.6) implies that subsistence levels are subject to social influences. In this connection it is of interest to mention some pieces of evidence collected by Smolensky (1965), Ornati (1966), and Mack (published in Miller, 1965, and quoted by Kilpatrick, 1973). In various budget studies, from 1903 till 1960, experts have estimated minimum subsistence levels for the U.S. It turns out that the regressions of the log of these subsistence levels on the log of real disposable income per capita in the same year yields elasticities between 0.57 and 0.84. This suggests strongly that, indeed, subsistence levels are subject to social influences. Similarly, responses to the survey question "What is the smallest amount of money a family of four needs each week to get along in this community?" have shown a trend over time, which is strongly correlated with per capita income (Kilpatrick, 1973, Sawhill, 1988).

### 3. Stochastic Specification

Combining (2.1), (2.5) and (2.6) and adding an i.i.d. disturbance term,  $\epsilon_{gn}$ , representing all effects on  $x_{gn}$  not captured by the systematic part of the model, yields

$$\begin{aligned}
 x_{gn} = & b_{g0} + \mu_g \left[ f_n - \beta_g \sum_{k=1}^N w_{nk} f_k \right] + \beta_g \sum_{k=1}^N w_{nk} x_{gk} + \\
 & + \gamma_g \left[ y_n - \sum_{h=1}^G \beta_h \sum_{k=1}^N w_{nk} x_{hk} \right] + \gamma_g \left[ \sum_{h=1}^G \beta_h \mu_h \sum_{k=1}^N w_{nk} f_k - \right. \\
 & \left. - \sum_{h=1}^G b_{h0} - \tilde{\mu} f_n \right] + \epsilon_{gn}, \quad (3.1)
 \end{aligned}$$

where  $\tilde{\mu} = \sum_{g=1}^G \mu_g$ . Thus, the model relates expenditures on different goods  $x_{gn}$  to total expenditures and family size ( $y_n$  and  $f_n$ ) and expenditures on different goods and family size of others ( $x_{gk}$  and  $f_k$ ) through a linear model with parameters  $b_{g0}$ ,  $\beta_g$ ,  $\gamma_g$ ,  $\mu_g$  and  $w_{nk}$ . The main problem in estimating the model is of course created by the large number of reference weights  $w_{nk}$ . A related problem is the simultaneity in the system caused by the presence of the  $x_{gk}$  on both the left and the right hand side.

In earlier work (Van de Stadt, Kapteyn, Van de Geer, 1985), in a different context, we have adopted the following approach to the estimation of the reference weights  $w_{nk}$ : It is intuitively plausible that consumers with a given set of personal characteristics (education, job, age, etc.) will on average attach a higher weight to expenditures of consumers sharing the same characteristics, than to those of consumers who have different characteristics.<sup>4)</sup> This notion can be used to parameterize the weights  $w_{nk}$  such that they become a function of the similarity in characteristics between consumers  $n$  and  $k$ . This function should of course contain a much lower number of parameters than  $N(N-1)$ , the number of linearly independent reference weights. Given such a parameterization, estimation of the newly introduced parameters along with the other ones becomes feasible, and does not only yield estimates of the demand system parameters but also of the reference pattern between groups in society.

Attempts to estimate such reference patterns directly were made by Kapteyn, (1977) and Kapteyn, Van Praag and Van Herwaarden (1978). It leads to very complicated models which are costly to estimate. The estimates of the parameters describing the pattern of reference weights tend to be unreliable. In this paper we opt for a different, simpler approach: the reference weights are considered to be drawings from a multivariate probability distribution. We do not specify this distribution completely, but make a few assumptions that partly characterize the distribution.

A central concept in our approach is the notion of a social group, i.e. a set of people who share certain characteristics like education, age, type of job, etc. The idea is to use the social group to which an individual belongs as a proxy for his reference group. To make clear under what circumstances such a procedure is justified and what errors of approximation may be involved, we make four explicit assumptions. These four assumptions are listed and discussed in appendix A. Here we only mention the main implication of the assumptions.

The parameters in (3.1) are estimated by first deriving the reduced form. It turns out that in this reduced form expressions like  $\sum_k w_{nk} \tilde{y}_k$ , where  $\tilde{y}_k = y_k - \tilde{\mu} f_k$ , appear as exogenous variables. The assumptions in appendix A allow us to approximate these variables as follows (cf. A.14):

$$\sum_k w_{nk} \tilde{y}_k = \kappa \tilde{\eta} + (1-\kappa) \tilde{y}_n + \hat{v}_n, \quad (3.2)$$

where  $\tilde{y}_n$  is the mean of  $\tilde{y}_k$  of all families in the social group of individual  $n$ ,  $\tilde{\eta}$  is the mean of all  $\tilde{y}_k$  in society,  $\hat{v}_n$  is an error term that up to terms of  $o_p(1)^5$  is uncorrelated with  $\tilde{y}_n$  and has mean zero. The interpretation of the parameter  $\kappa$  is that  $(1-\kappa)$  is an indicator of the share of the total reference weight that people assign, on average, to others within the same social group, whereas  $\kappa$  is the share given, on average, to all people in society, irrespective of whether they are within or outside an individual's social group. So, if  $\kappa=0$ , reference groups do not extend beyond one's own social group. If  $\kappa=1$ , the social group contains no information whatever on one's reference group. In other words, the smaller  $\kappa$  is, the better a proxy one's social group is for one's reference group. Of course, even if  $\kappa=0$  the social group is not a perfect proxy as long as the  $\hat{v}_n$  are not identically equal to zero.

Given the approximation (3.2) the reduced form of (3.1) takes a simple form, as will appear in the next section.

#### 4. The reduced form and identification

It is shown in appendix B that under the assumptions listed in appendix A, (3.1) implies the following reduced form

$$x_{gn} = d_g + \gamma_g y_n + \alpha_g f_n + r_g \bar{y}_n - r_g \tilde{\mu} \bar{f}_n + u_{gn}, \quad (4.1)$$

where  $\bar{y}_n$  is mean total consumption and  $\bar{f}_n$  is mean family size in the social group of individual  $n$ . The reduced-form parameters can be expressed in the structural parameters as follows:

$$r_g = (1-\kappa) \rho_g \quad (4.2)$$

$$\rho_g = \frac{\beta_g - p}{1-(1-\kappa)\beta_g} \gamma_g \quad (4.3)$$

$$p = \frac{\sum_{g=1}^G \frac{\beta_g \gamma_g}{1-(1-\kappa)\beta_g}}{\sum_{g=1}^G \frac{\gamma_g}{1-(1-\kappa)\beta_g}} \quad (4.4)$$

$$d_g = \frac{s_g - \varphi \gamma_g}{1 - \beta_g} \quad (4.5)$$

$$s_g = b_{g0} - \gamma_g \sum_{h=1}^G b_{h0} + \kappa \rho_g (\eta - \tilde{\mu}_g) \quad (4.6)$$

$$\varphi = \frac{\sum_{h=1}^G \frac{\beta_h s_h}{1-\beta_h}}{\sum_{h=1}^G \frac{\gamma_h}{1-\beta_h}} \quad (4.7)$$

$$\alpha_g = \mu_g - \tilde{\mu} \gamma_g. \quad (4.8)$$

It is easy to see that  $\alpha_g$ ,  $r_g$ ,  $\rho_g$  and  $d_g$  add up to zero, when summing over goods. The error term  $u_{gn}$  is well-behaved in the sense that up to terms of  $O(N^{-1})$  it has mean zero and is uncorrelated with the other variables on the right hand side of (4.1).

Under our assumptions, the reduced form parameters  $d_g$ ,  $\gamma_g$ ,  $\alpha_g$ ,  $r_g$  and  $\tilde{\mu}$  can be estimated consistently from cross-section data (some details follow in section 5). Knowing, or consistently estimating, the reduced form parameters does not suffice, however, to determine all structural parameters. This can be seen as follows. Use (4.3) to solve for  $\beta_g$ :

$$\beta_g = \frac{\rho_g + p \gamma_g}{\gamma_g + (1-\kappa)\rho_g}, \quad (4.9)$$

or, with (4.2),

$$1-(1-\kappa)\beta_g = \frac{\gamma_g(1-(1-\kappa)p)}{\gamma_g + r_g}. \quad (4.10)$$

It follows from the analysis in appendix B (last paragraph) that, even with  $\kappa$  known,  $p$  is unidentified. Since  $\kappa$  is unknown as well, we are lacking two pieces of information for the identification of the  $\beta_g$ . Assuming that  $0 \leq \kappa < 1$ , we are able, however, to infer a ranking of  $\beta_g$ 's from the reduced form estimates:

$$\beta_g < \beta_h \Leftrightarrow \frac{r_g}{\gamma_g + r_g} < \frac{r_h}{\gamma_h + r_h}. \quad (4.11)$$

The structural parameters  $\mu_g$  can be identified from the  $\alpha_g$  and  $\tilde{\mu}$ . Notice that without interdependence the  $\mu_g$  would not be identified, since the  $\alpha_g$  sum to zero. Consequently, we would have had only  $G-1$  independent pieces of information to identify the  $G$  parameters  $\mu_g$ . It is the presence of  $\tilde{f}_n$  which makes it possible to identify the sum of the  $\mu_g$ ,  $\tilde{\mu}$ , which provides the extra piece of information required.

The  $G$  parameters  $b_{g0}$  cannot be identified from (4.5), because the  $d_g$  sum to zero. Since the  $b_{g0}$  are of no particular interest we do not pay further attention to either the  $b_{g0}$  or the  $d_g$ .

## 5. Estimation results

Model (3.1) has been estimated using data on 2813 households from the Consumer Expenditure Survey 1981 conducted by the Netherlands Central Bureau of Statistics. As mentioned in section 2, households have been assigned to social groups with identical characteristics. The characteristics considered are the following ones:

- a) Educational attainment of head of household (3 categories distinguished);
- b) Age of head of household (5 categories);
- c) Type of job (5 categories).

This leads to a maximum of 75 distinct social groups, 56 of which appeared to be represented in the sample.

The variables  $\bar{y}_n$  and  $\bar{f}_n$  in (4.1) refer to population means in the social group to which individual  $n$  belongs. Obvious proxies for  $\bar{y}_n$  and  $\bar{f}_n$  are the corresponding sample means. Care has been taken, however, for each individual  $n$  to base the estimate of  $\bar{y}_n$  and  $\bar{f}_n$  only on the incomes and family sizes of all other sample households in the social group. Of course, replacement of  $\bar{y}_n$  and  $\bar{f}_n$  by sample means introduces measurement errors, but the variance-covariance matrix of measurement errors in  $\bar{y}_n$  and  $\bar{f}_n$  corresponding to group  $t$  can be estimated unbiasedly by  $1/(\tilde{N}_t-1)$  times the sample covariance matrix of  $y_n$  and  $f_n$  corresponding to social group  $t$ , where  $\tilde{N}_t$  is the number of consumers in the sample belonging to social group  $t$ .

The model has been estimated by means of the LISREL program (Jöreskog and Sörbom, 1981, Aigner, Hsiao, Kapteyn and Wansbeek, 1984, Bentler, 1983). Under the conditions given in lemma 4 in appendix B the LISREL output provides consistent estimates of the reduced form parameters, and the printed standard errors can serve as asymptotic approximations of the true standard errors of the estimates.

Two sets of estimates of model (3.1) will be presented, one ignoring the measurement error caused by the use of proxies for  $\bar{y}_n$  and  $\bar{f}_n$ , and one taking into account this measurement error. In the latter case the estimated variance-covariance matrices of measurement errors per group have been averaged over the groups. (Correlation of measurement error across individuals in the same group has been ignored.) This average error variance-covariance matrix indicates that measurement error accounts for 2.3% of the observed variance of  $\bar{y}_n$ , for 22.1% of that of  $\bar{f}_n$ , and for 1.3% of the covariance of  $\bar{y}_n$  and  $\bar{f}_n$ .

Seven expenditure categories are distinguished:

- (1) Food;
- (2) Housing;
- (3) Clothing;
- (4) Medical care;
- (5) Education, entertainment;
- (6) Transportation;
- (7) Other expenditures.

The correlation matrix of all variables involved plus their sample means and standard deviations, are given in an appendix available upon request.

Because of adding up restrictions the variance-covariance matrix of the  $u_{1n}, \dots, u_{Gn}$  is singular and the parameters satisfy restrictions across equations. As usual, these problems can be accounted for by dropping arbitrarily one of the seven equations (cf. Barten, 1969). We have chosen to drop the equation for other expenditures.

The survey records money outlays. In the case of durables these may have an investment character, so that recorded outlay is only a poor proxy of the true consumption of this durable. This is a case of measurement error in an endogenous variable, which worsens the fit of the model, but does not affect the consistency of the parameter estimates, assuming that the measurement error is distributed independently of the exogenous variables.

All money amounts are measured in thousands of guilders per annum. Family size  $f_n$  is simply defined as the number of members of household  $n$ . The variance-covariance matrix of the reduced form disturbances of the six maintained equations has been left unrestricted.



The results for different specifications of the model are given in table 1. The  $\chi^2$ -statistic is an indicator of the extent to which the model is compatible with the data.

Table 1. Estimation results

Parameter	Complete model	No measurement error	No interdependence
$\gamma_1$	0.131 (0.004)	0.131 (0.004)	0.126 (0.003)
$\gamma_2$	0.274 (0.006)	0.274 (0.006)	0.287 (0.006)
$\gamma_3$	0.081 (0.003)	0.081 (0.003)	0.080 (0.002)
$\gamma_4$	0.094 (0.003)	0.094 (0.003)	0.099 (0.002)
$\gamma_5$	0.172 (0.015)	0.172 (0.005)	0.171 (0.004)
$\gamma_6$	0.238 (0.006)	0.238 (0.006)	0.227 (0.005)
$r_1$	-0.021 (0.007)	-0.020 (0.007)	
$r_2$	0.052 (0.013)	0.052 (0.013)	
$r_3$	-0.003 (0.005)	-0.003 (0.005)	
$r_4$	0.018 (0.006)	0.018 (0.006)	
$r_5$	-0.004 (0.009)	-0.004 (0.009)	
$r_6$	-0.045 (0.012)	-0.045 (0.012)	
$\mu_1$	1.265 (0.154)	1.265 (0.154)	0.729 (0.032) <sup>b)</sup>
$\mu_2$	0.828 (0.360)	0.828 (0.361)	-0.317 (0.056)
$\mu_3$	0.492 (0.100)	0.491 (0.100)	0.157 (0.022)
$\mu_4$	0.543 (0.125)	0.543 (0.125)	0.148 (0.024)
$\mu_5$	0.517 (0.212)	0.517 (0.213)	-0.194 (0.041)
$\mu_6$	0.390 (0.276)	0.389 (0.277)	-0.583 (0.051)
$\tilde{\mu}$	4.131 (1.223)	4.129 (1.225)	
$R_1^2$ a)	0.594	0.594	0.593
$R_2^2$	0.535	0.535	0.532
$R_3^2$	0.443	0.443	0.443
$R_4^2$	0.483	0.483	0.481
$R_5^2$	0.426	0.426	0.426
$R_6^2$	0.430	0.430	0.427
$\chi^2$	15.34	15.34	57.76
df	5	5	12

a)  $R_g^2$  is defined as  $1 - \sigma_{ug}^2 / \text{var}(x_{gn})$

b) The estimates in this column refer to  $\alpha_1, \dots, \alpha_6$ .

Let us first consider the column 'complete model', which presents the results for the model which takes into account measurement errors in  $\bar{y}_n$  and  $\bar{f}_n$ . According to the  $\chi^2$ -statistic the model describes the data well. The estimates of all  $\gamma_g$  are positive and significantly different from zero. Out of the six estimated  $r_g$ , four are significantly different from zero.

The column headed 'no measurement error' presents the estimates of the model for the case that the proxies for  $\bar{y}_n$  and  $\bar{f}_n$  are assumed accurate. This neglect of measurement error does not affect the estimates of the  $\gamma_g$  or the values of the  $\chi^2$ -statistic up to two decimal places.

The column headed 'no interdependence' presents parameter estimates under the restriction  $r_1 = r_2 = \dots r_6 = 0$ . Although the fit of the equations, as gauged by the  $R^2$ 's, hardly changes and the  $\gamma_g$  and  $\alpha_g$  change only marginally, the  $\chi^2$ -statistic rejects the restrictions decisively. As a final comment on the statistical quality of the results, a  $\chi^2$ -test of the overidentifying restrictions on the coefficients of  $\bar{f}_n$  and  $\bar{f}_n$  does not lead to a rejection.

To start off a discussion of the economic significance of the results, we present information on the structural parameters in table 2. (The last column will be used later on).

Table 2. Values of structural parameters derived from the reduced form estimates for the complete model

expenditure category	$\frac{r_g}{\gamma_g + r_g}$	$\mu_g$	$\gamma_g$	$\gamma_g + r_g$
1. Food	-0.19	1.27	0.13	0.11
2. Housing	0.16	0.83	0.27	0.33
3. Clothing	-0.04	0.49	0.08	0.08
4. Medical care	0.16	0.54	0.09	0.11
5. Education	-0.02	0.52	0.17	0.17
6. Transportation	-0.23	0.39	0.24	0.19

Although the  $\beta_g$  are not identified, we can derive their relative ranking from table 2 in conjunction with relation (4.11), assuming that  $0 < \kappa < 1$  and all  $0 < \beta_g < 1$ . We find  $\beta_2 > \beta_4 > \beta_5 > \beta_3 > \beta_6 > \beta_1$ . Interpreting  $\beta_g$  as a measure of the conspicuousness of good  $g$ , we have that the order of conspicuousness is: housing, medical care, education/entertainment, clothing, transportation, food. Except, maybe, for the relative ranking of medical care and

transportation (cars), the ranking seems quite plausible. As to the position of medical care: this category comprises 'domestic services', a high ranking of which seems intuitively plausible. Moreover, there is an artefact at work here, as most households in the sample were compulsory insured via the sick fund, the contributions to which depend on income and hence, statistically, also on total expenditures in the reference group.

It is of interest to compare predictions of the model for aggregates of all consumers with predictions at the household level. Consider for instance an increase of total expenditures by one dollar. At the household level the effect on the expenditures  $x_{gn}$  is given by the marginal budget shares  $\gamma_g$ .

It follows from (4.1)-(4.8) that an increase of everyone's total expenditures with one dollar raises each  $x_{gn}$  with <sup>6,7)</sup>

$$\frac{\gamma_g}{1 - \beta_g} / \sum_h \frac{\gamma_h}{1 - \beta_h} \quad (5.1)$$

So the extent to which the aggregate consumption of a good responds to changes in total expenditures does not only depend on the good's marginal budget share, but also on its conspicuousness. One sees that the magnitude of the response for good  $g$  is positively related to both its marginal budget share and its conspicuousness.

If  $\kappa=0$  it is easy to show that (5.1) is equal to  $\gamma_g + r_g$ . Assuming for a moment that  $\kappa=0$ , the last two columns of table 2 can be used to compare the effect of an increase in total expenditures at the household level and in the aggregate. As one would expect, at the aggregate level effects are larger for conspicuous goods and lower for non-conspicuous goods. Differences can be fairly large. For food, for example, the aggregate effect is about 20% lower than at the household level whereas for housing the aggregate effect is about 20% larger.

In the (standard) model without interdependence individual and aggregate effects are of course identical. If one looks at the estimates of the marginal budget shares in the standard model, these appear to be somewhat in between  $\gamma_g$  and  $\gamma_g + r_g$  for the complete model. For certain goods the standard model would yield rather misleading predictions of aggregate effects. Taking the complete model as being correct, the standard model would overpredict aggregate effects for food by about 20%, whereas for housing the predictions would be about 10% too low.

Finally we pay attention to the  $\mu$ 's. An easy way to get a feeling for their interpretation is to look at an example. If a family's size increases

by one person, the utility function (2.2) implies that the extra expenditures required on each category to maintain the family's previous utility level are: food, Dfl. 1200 per annum; housing, Dfl. 500; clothing, Dfl. 400; medical care, Dfl. 400; education/entertainment, Dfl. 400; transportation, Dfl. 150. (A Dutch guilder is approximately U.S. \$ 0.50) These appear to be plausible numbers. Recall from section 4 incidentally that without interdependence the family size coefficients are not identified.

## 6. Concluding remarks

The main purpose of this paper has been to show that preference interdependence can be incorporated in a demand system and to investigate its empirical importance. The results confirm the suspicion that preference interdependence is an important determinant of consumer behavior; not so much for the extra variance in consumption which can be thus explained nor for the parameter estimates, most of which do not change very much, but certain conclusions from the model (e.g. what is the effect of an across-the-board change in total expenditures on the aggregate consumption of various goods?) do change rather substantially if preference interdependence is accounted for. So, to the extent that we want to use a model to predict aggregate responses to changes in exogenous variables, interdependence should not be neglected.

As noted in section 2, the allocation of total expenditures to a number of expenditure categories can be seen as the second stage in the typical two stage budgetting process that arises in life cycle models with intertemporally separable preferences. Here we have restricted ourselves to the second stage, but generally one would surmise that also in the first stage (the determination of the level of total expenditures in any one period) preference interdependence may play a role. Modelling this would probably bring us close to an integration of Duesenberry's relative income hypothesis and Friedman's permanent income hypothesis.

Although spelling out the stochastic assumptions that are required to arrive at a well-behaved reduced form asks for a fair amount of space (appendix A), and although the derivation of this reduced form is rather tedious (appendix B), the result is quite simple. Estimation of the model by means of the widely available LISREL computer program is, moreover, straightforward. This suggests that there is really no practical reason to ignore preference interdependence in demand analysis or in other empirical applications of micro-economic theory. Obvious extensions of the analysis in this paper include

preference interdependence in labor-supply models and oligopolistic models of firm behavior. Lemma 1 of appendix B provides a rather general framework for the study of interdependencies in linear models of interdependent behavior. Of course, most of the simplicity is due to the linearity of the specification. Future work should be directed towards an extension of the analysis to more flexible specifications.

A second extension is to supplement preference interdependence with habit formation. Not only will that probably increase the explanatory power of the model, it will also aid in identifying the structural parameters. This extension requires the availability of panel data.

A third extension has to be in the modelling of reference groups. In this paper we have basically described the distribution of reference weights by means of one parameter  $\kappa$ . It should be possible to refine this specification. Ideally, of course, one would like to have a formal theory of how reference groups are formed. To our knowledge no such theory exists at this moment.

Appendix A. Stochastic assumptions

Here we introduce and discuss four assumptions that justify the approximation (3.2) and the reduced form given in section 3.

If individual  $n$  is a member of social group  $t$ ,  $t=1, \dots, T$ , we denote this as  $n \in G_t$ , and we denote the size of social group  $t$  (i.e. the number of individuals in it) as  $N_t$ . As in section 3 we define  $\tilde{y}_k = y_k - \tilde{\mu}f_k$ , which is in effect translated total expenditures of household  $k$ .

Assumption 1. Within each social group the  $\tilde{y}_n$  are random drawings from a bivariate distribution with mean  $\tilde{y}_n$ , i.e.

$$\tilde{y}_n = \tilde{y}_n + \xi_n, \quad (\text{A.1})$$

where  $E\xi_n = 0$ ;  $\xi_n$  is distributed independently from  $\tilde{y}_n$  and  $w_{nk}$  for any  $n$  and  $k$ .

As a matter of notation, notice that  $\tilde{y}_n$  is constant within a social group. Sometimes we shall write  $\tilde{y}_t$  for the value of  $\tilde{y}_n$  with  $n \in G_t$ .

Let  $\tilde{\eta}$ ,  $\tilde{y}_n^*$  and  $p_{ns}$  and  $p_n$  be defined as

$$\tilde{\eta} = \frac{1}{N} \sum_t N_t \tilde{y}_t \quad (\text{A.2})$$

$$\tilde{y}_n^* = \frac{1}{N-N_t} \sum_{s \neq t} N_s \tilde{y}_s, \quad n \in G_t \quad (\text{A.3})$$

$$p_{ns} = \sum_{k \in G_s} w_{nk} \quad n \in G_t, s \neq t \quad (\text{A.4})$$

$$p_n = \sum_{k \in G_t} w_{nk}. \quad n \in G_t \quad (\text{A.5})$$

We will refer to  $\tilde{\eta}$  as mean translated consumption (mean total expenditures) in society, and to  $\tilde{y}_n^*$  as mean translated consumption outside individual  $n$ 's social group. Obviously,  $p_{ns}$  is the total reference weight assigned by individual  $n$  to all individuals in social group  $s$ , whereas  $p_n$  is the total reference weight assigned by this individual to all individuals in his own social group.

Assumption 2

$$\sum_{s \neq t} p_{ns} \left[ \tilde{y}_s - \tilde{y}_n^* \right] = \alpha_n \left[ \tilde{y}_t - \tilde{\eta} \right] + o_p(1), \quad n \in G_t \quad (\text{A.6})$$

where  $\alpha_n$  is expected to be positive

(The symbol  $o_p(1)$  has been defined in footnote 5).

The left hand side of (A.6) can be interpreted roughly as a covariance between the mean consumption level of a social group and the total reference weight assigned to it. Equation (A.6) says that this covariance tends to be positive if individual  $n$  belongs to a social group with an above average level of consumption and that it will be negative if individual  $n$  belongs to a social group with a below average consumption level. The motivation for the assumption is that generally, one would expect that people will more often tend to assign reference weights to others who are similar (see footnote 4) than to others who are dissimilar. Thus, generally if someone has a high consumption level he will assign on average more weight to others who also have a high consumption level. This induces a correlation between reference weights and consumption levels which is positive. On the other hand, someone with a low consumption level will primarily give weights to others with a low consumption level. This induces a negative correlation between reference weights and consumption. Assumption 2 is a simple way to capture these effects.

As mentioned in section 3, in the reduced form of the system (3.1) a variable like  $\sum_k w_{nk} \tilde{y}_k$  appears. The two assumptions made so far allow us to circumvent the problem of having to specify the reference weights  $w_{nk}$ . To see this, first notice that (A.2) and (A.3) imply

$$\tilde{\eta} = N_t \tilde{y}_n + (N - N_t) y_n^*, \quad n \in G_t \quad (\text{A.7})$$

so that



$$\tilde{y}_n^* = \frac{N}{N - N_t} \tilde{\eta} - \frac{N_t}{N - N_t} \tilde{y}_n, \quad n \in G_t. \quad (\text{A.8})$$

Secondly, define

$$v_n = \sum_k w_{nk} \tilde{y}_k; \quad (\text{A.9})$$

$v_n$  is a random variable with zero mean and independent of  $\tilde{y}_n$ ,  $\tilde{y}_n^*$ . We have

$$\begin{aligned} \sum_k w_{nk} \tilde{y}_k &= \sum_k w_{nk} \tilde{y}_k + v_n = p_n \tilde{y}_n + \sum_{s \neq t} p_{ns} \tilde{y}_s + v_n \\ &= p_n \tilde{y}_n + \left[ \sum_{s \neq t} p_{ns} \right] \tilde{y}_n^* + \sum_{s \neq t} p_{ns} \left[ \tilde{y}_s - \tilde{y}_n^* \right] + v_n \\ &= p_n \tilde{y}_n + (1 - p_n) \tilde{y}_n^* + \alpha_n \left[ \tilde{y}_n - \tilde{\eta} \right] + o_p(1) + v_n \end{aligned} \quad (\text{A.10})$$

Using (A.8) this carries over into

$$\sum_k w_{nk} \tilde{y}_k = (1 - \kappa_n) \tilde{y}_n + \kappa_n \tilde{\eta} + v_n + o_p(1) \quad n \in G_t \quad (\text{A.11})$$

where

$$\kappa_n = \frac{(1 - p_n)N}{N - N_t} - \alpha_n \quad (\text{A.12})$$

To gain some intuition for the meaning of  $\kappa_n$ , let us consider some extreme cases. First, suppose  $p_n = 1$ , i.e. individual  $n$  only assigns weights to others within the same social group. From (A.6) it is clear that then, generally,  $\alpha_n = 0$ . Thus  $\kappa_n = 0$  and (A.11) reduces to

$$\sum_k w_{nk} \tilde{y}_k = \tilde{y}_n + v_n + o_p(1).$$

Since individual  $n$ 's reference group is confined within his social group, the social group mean  $\tilde{y}_n$  is a "perfect" indicator of the mean consumption in his reference group.

Next, suppose  $\kappa_n = 1$ . Then (A.11) reduces to

$$\sum_k w_{nk} \tilde{y}_k = \tilde{\eta} + v_n + o_p(1).$$

Obviously, the social group mean now does not convey any information about the mean consumption in the reference group of individual  $n$ .

Basically, (A.11) reduces the number of unknown parameters from about  $N(N-1)$  to about  $N$ . A further reduction of the number of unknown parameters is obtained by assumption 3.

### Assumption 3

$$\kappa_n = \kappa + \delta_n, \quad (\text{A.13})$$

where  $\delta_n$  is a random variable with mean zero;  $\delta_n$  and  $\delta_k$  are independently distributed for  $n \neq k$ ,  $\delta_n$  is independent of  $w_{k\ell}$  for  $k \neq n$ ,  $\ell=1, \dots, N$ .

This assumption mainly serves to further reduce the number of unknown parameters. In particular, it implies a further simplification of (A.11)

$$\sum_k w_{nk} \tilde{y}_k = (1-\kappa) \tilde{y}_n + \kappa \tilde{\eta} + v_n - \delta_n \left[ \tilde{y}_n - \tilde{\eta} \right] + o_p(1) \quad (\text{A.14})$$

Under the above assumptions,  $v_n - \delta_n \left[ \tilde{y}_n - \tilde{\eta} \right]$  is independent of  $\tilde{y}_n$ . So, rather than having  $N(N-1)$  reference weights to deal with we are left with one unknown parameter  $\kappa$ .

To arrive at a reduced form with a well-behaved error term we need one more assumption. Define  $w_{nm}^{(2)} = \sum_k w_{nk} w_{km}$  and  $w_{nm}^{(\ell)} = \sum_k w_{nk} w_{km}^{(\ell-1)}$  for  $\ell > 2$ .

Assumption 4  $E w_{nm}^{(\ell)} = O(N^{-1})$ , for  $\ell \geq 2$ .

Notice that  $w_{nm}^{(2)}$  is the weight assigned by  $n$  to  $m$  'via all others'. Assumption 4 therefore states that on average the indirect influence of any individual on any other individual will tend to zero if the number of individuals in society tends to infinity.

For the derivation of the reduced form we shall employ the following implication of the assumptions:

$$\sum_k w_{nk}^{(\ell)} \left[ \tilde{y}_k - \tilde{\eta} \right] \delta_k = o_p(1), \quad \text{for } \ell \geq 2. \quad (\text{A.15})$$

The proof of (A.15) is an application of Chebychev's Lemma.

Appendix B. Derivation of the reduced form

This appendix presents the derivation of the reduced form (4.1) under the assumption given in appendix A. We first derive a version of (4.1) in terms of translated variables, and then adapt the results by including family size.

Let

$$\tilde{x} = (\tilde{x}_{11}, \dots, \tilde{x}_{1N}, \dots, \tilde{x}_{G1}, \dots, \tilde{x}_{GN})', \quad GN \times 1 \quad (B.1)$$

$$b = (b_{11}, \dots, b_{1N}, \dots, b_{G1}, \dots, b_{GN})', \quad GN \times 1 \quad (B.2)$$

$$b_0 = (b_{10}, \dots, b_{G0})', \quad G \times 1 \quad (B.3)$$

$$\gamma = (\gamma_1, \dots, \gamma_G)', \quad G \times 1 \quad (B.4)$$

$$\tilde{y} = (\tilde{y}_1, \dots, \tilde{y}_N)', \quad N \times 1 \quad (B.5)$$

$$B = \begin{bmatrix} \beta_1 & & & & \\ & \cdot & & & \\ & & \cdot & & \\ & & & \cdot & \\ & & & & \beta_G \end{bmatrix}, \quad G \times G \quad (B.6)$$

$$\epsilon = (\epsilon_{11}, \dots, \epsilon_{1N}, \dots, \epsilon_{G1}, \dots, \epsilon_{GN})', \quad GN \times 1 \quad (B.7)$$

$$u = (u_{11}, \dots, u_{1N}, \dots, u_{G1}, \dots, u_{GN})', \quad GN \times 1 \quad (B.8)$$

$$W = \begin{bmatrix} w_{11} & \dots & w_{1N} \\ \vdots & & \vdots \\ \vdots & & \vdots \\ w_{N1} & & w_{NN} \end{bmatrix}, \quad N \times N \quad (B.9)$$

$$\tilde{\tilde{y}} = (\tilde{\tilde{y}}_1, \dots, \tilde{\tilde{y}}_N)', \quad N \times 1 \quad (B.10)$$

$$\rho = (\rho_1, \dots, \rho_G)', \quad G \times 1 \quad (B.11)$$

$$\beta = (\beta_1, \dots, \beta_G)', \quad G \times 1 \quad (B.12)$$

Let  $\iota$  denote a vector of ones, with a subscript that indicates its length. (So, e.g.  $B \iota_G = \beta$ .) Equation (3.1), can now be written as

$$\begin{aligned}\tilde{x} &= b_0 \theta \iota_N + (B\theta W)\tilde{x} + \gamma \theta \{\tilde{y} - (\iota_G' \theta \iota_N)(b_0 \theta \iota_N + (B\theta W)\tilde{x})\} + \epsilon = \\ &= c \theta \iota_N + \{(B - \gamma \beta') \theta W\} \tilde{x} + \gamma \theta \tilde{y} + \epsilon,\end{aligned}\quad (B.13)$$

where  $c$  is defined as

$$c = b_0 - \iota_G' b_0 \gamma. \quad (B.14)$$

Obviously,  $\iota_G' c = 0$ .

To state our first lemma we need a number of definitions:

$$A = B - \gamma \beta' \quad (B.15)$$

$$\rho = [I_G - (1-\kappa)A]^{-1} A \gamma \quad (B.16)$$

$$\nu = (I_G - A)^{-1} (c + \kappa \tilde{\eta} A \rho) \quad (B.17)$$

$$z = (1-\kappa) \tilde{y} + \kappa \tilde{\eta} \iota_N. \quad (B.18)$$

Furthermore, let  $\delta = (\delta_1, \dots, \delta_N)'$ ,  $\tilde{Y} = \text{diag}[\tilde{y}_1, \dots, \tilde{y}_N]$ ,  $v = (v_1, \dots, v_N)'$ .

Lemma 1. Under assumptions 1, 2 and 3, (B.13) implies

$$\tilde{x} = \nu \theta \iota_N + \gamma \theta \tilde{y} + \rho \theta z + u, \quad (B.19)$$

where  $u$  satisfies:

$$(I_{GN} - A\theta W)u = \epsilon - \rho \theta \left[ \tilde{Y} - \tilde{\eta} I_N \right] \delta + A \gamma \theta v + o_p(1). \quad (B.20)$$

Proof We show that substitution of (B.19) in (B.13) leads to an identity with  $u$  satisfying (B.20). Equations (B.19) and (B.13) imply

$$\nu \theta \iota_N + \gamma \theta \tilde{y} + \rho \theta z + u = c \theta \iota_N + (A\theta W) \{\nu \theta \iota_N + \gamma \theta \tilde{y} + \rho \theta z + u\} + \gamma \theta \tilde{y} + \epsilon, \quad (B.21)$$

or, using  $Wt_N = t_N$ ,

$$\psi\theta t_N - c\theta t_N - A\psi\theta t_N + \rho\theta z - A\gamma\theta\tilde{W}\tilde{y} - A\rho\theta Wz + (I_{GN} - A\theta W)u = \epsilon. \quad (B.22)$$

Since, according to (B.17),  $\psi - A\psi = c + \kappa\tilde{\eta}A\rho$ , the first three terms of the left-hand side of (B.22) are equal to  $\kappa\tilde{\eta}A\rho\theta t_N$ . So we have

$$(I_{GN} - A\theta W)u = \epsilon + A\gamma\theta\tilde{W}\tilde{y} + A\rho\theta Wz - \rho\theta z - \kappa\tilde{\eta}A\rho\theta t_N. \quad (B.23)$$

From (A.14) and using (B.18) we have

$$\begin{aligned} \tilde{W}\tilde{y} &= (1-\kappa)\tilde{\bar{Y}} + \kappa\tilde{\eta}t_N + v - \left[ \tilde{\bar{Y}} - \tilde{\eta}I_N \right] \delta + o_p(1) = \\ &= z + v - \left[ \tilde{\bar{Y}} - \tilde{\eta}I_N \right] \delta + o_p(1). \end{aligned} \quad (B.24)$$

Since from (A.1) and (A.9)  $\tilde{\bar{W}}\tilde{y} = \tilde{W}\tilde{y} - v$ , we have for  $Wz$  (using again B.18):

$$Wz = (1-\kappa)\tilde{\bar{W}}\tilde{y} + \kappa\tilde{\eta}t_N = (1-\kappa)\left\{ z - \left[ \tilde{\bar{Y}} - \tilde{\eta}I_N \right] \delta + o_p(1) \right\} + \kappa\tilde{\eta}t_N. \quad (B.25)$$

Collecting terms, we find for (B.23):

$$\begin{aligned} (I_{GN} - A\theta W)u &= A\gamma\theta z + (1-\kappa)A\rho\theta z - \rho\theta z + \epsilon + A\gamma\theta v - \\ &- [A\gamma + (1-\kappa)A\rho]\theta \left[ \tilde{\bar{Y}} - \tilde{\eta}I_N \right] \delta + o_p(1). \end{aligned} \quad (B.26)$$

It follows immediately from (B.16) that  $A\gamma + (1-\kappa)A\rho = \rho$ . Hence (B.26) simplifies to (B.20).  $\square$

### Lemma 2

$$[I_{GN} - A\theta W]^{-1} = I_{GN} + A\theta W + A^2\theta W^2 + A^3\theta W^3 + \dots \quad (B.27)$$

Proof For any integer  $\ell > 1$ :

$$\begin{aligned} & \left[ I_{GN} + A\theta W + A^2\theta W^2 + \dots + A^{(\ell-1)}\theta W^{(\ell-1)} \right] [I_{GN} - A\theta W] = \\ & = I_{GN} - A^\ell \theta W^\ell. \end{aligned} \quad (B.28)$$

So to prove (B.27) it is sufficient to prove that  $A^\ell \theta W^\ell$  converges to zero if  $\ell$  tends to infinity. Since  $W$  is a Markov matrix,  $W^\ell$  is a Markov matrix as well. Hence the elements of  $W^\ell$  are bounded (they have values between zero and one). It is therefore sufficient to prove that  $A^\ell \rightarrow 0$  for  $\ell$  to infinity. We show this by proving that the eigenvalues of  $A$  are all within the unit circle (Oidenburger, 1940).

First assume that all  $\beta_g$  are different and strictly positive. Then the eigenvalues of  $A$  follow from the determinantal equation

$$|A - \lambda I_G| = |B - \lambda I_G - \gamma \beta'| = |\beta - \lambda I_G| \{1 - \beta' (B - \lambda I_G)^{-1} \gamma\} = 0. \quad (B.29)$$

The expression between braces equals

$${}'_G(B - \lambda I_G)(B - \lambda I_G)^{-1} \gamma - \beta' (B - \lambda I_G)^{-1} \gamma = -\lambda {}'_G(B - \lambda I_G)^{-1} \gamma, \quad (B.30)$$

so  $\lambda = 0$  or  ${}'_G(B - \lambda I_G)^{-1} \gamma = 0$ . In scalar notation, the latter expression reads

$$\sum_{g=1}^G \frac{\gamma_g}{\beta_g - \lambda} = 0. \quad (B.31)$$

Each of the terms under the summation sign is an orthogonal hyperbola in  $\lambda$  with  $\lambda = \beta_g$  as its vertical asymptote. So (B.31) has a solution between each two successive  $\beta_g$ , giving the remaining  $G-1$  roots of (B.29). So all roots are non-negative and smaller than the largest  $\beta_g$ , which by assumption is less than 1.

This still holds when not all  $\beta_g$  are different or strictly positive. This follows directly from the continuity of eigenvalues of a matrix as a function of its elements.  $\square$

Lemma 3 Under assumptions 1, 2, 3 and 4 and ignoring terms of order  $o_p(1)$ , the vector  $u$  satisfying (B.22) has mean zero and

$$Eu\tilde{y}' = A\gamma\theta EW + o(N^{-1}). \quad (\text{B.32})$$

Proof Use lemma 2 to rewrite (B.20) as

$$\begin{aligned} u &= (I_{GN} - A\theta W)^{-1}\{\epsilon + A\gamma\theta v\} - (I_G + A)\rho\theta W\left[\tilde{Y} - \tilde{\eta}I_N\right]\delta - \\ &\quad - \sum_{j=2}^{\infty} A^j \rho\theta W^j \left[\tilde{Y} - \tilde{\eta}I_N\right]\delta + o_p(1). \end{aligned} \quad (\text{B.33})$$

(A.15) implies

$$\sum_{j=2}^{\infty} A^j \rho\theta W^j \left[\tilde{Y} - \tilde{\eta}I_N\right]\delta = \sum_{j=2}^{\infty} A^j \rho\theta o_p(1) = A^2(I_G - A)^{-1}\rho\theta o_p(1) = o_p(1). \quad (\text{B.34})$$

So we have for  $u$ ,

$$u = (I_{GN} - A\theta W)^{-1}\{\epsilon + A\gamma\theta v\} - (I_G + A)\rho\theta W\left[\tilde{Y} - \tilde{\eta}I_N\right]\delta + o_p(1). \quad (\text{B.35})$$

The first term on the right hand side involves  $\epsilon$  and  $v = W\zeta$  where  $\zeta = (\zeta_1, \dots, \zeta_N)'$ . Since both  $\epsilon$  and  $\zeta$  are independent of  $W$ , and have expectation equal to zero, this first term has expectation zero as well. In the second term the random variables are  $W$  and  $\delta$ . A typical element of  $W\left[\tilde{Y} - \tilde{\eta}I_N\right]\delta$  is  $\sum_{k \neq n} \left[\tilde{y}_k - \tilde{\eta}\right] w_{nk} \delta_k$ . Since  $\delta_k$  has mean zero and is independent of  $w_{nk}$  for  $k \neq n$ , this element has mean zero. Consequently the second term has mean zero. Neglecting the  $o_p(1)$  term, we conclude that  $u$  has mean zero.

To prove the second part of the lemma, we first observe that  $\delta$  and  $\epsilon$  are independent of  $y$ . So we only have to consider

$$\begin{aligned} E(I_{GN} - A\theta W)^{-1}(A\gamma\theta v)\tilde{y}' &= E(I_{GN} - A\theta W)^{-1}(A\gamma\theta W\tilde{y}\tilde{y}') = \\ &= E(I_{GN} - A\theta W)^{-1}(A\gamma\theta WE(\tilde{y}\tilde{y}')) = \sigma_y^2 E(I_{GN} - A\theta W)^{-1}(A\gamma\theta W), \end{aligned} \quad (\text{B.36})$$



where the second equality sign is based on the independence of  $W$  and  $\zeta$ . Next we write

$$\begin{aligned}
 E(I_{GN} - A\theta W)^{-1}(A\gamma\theta W) &= E\{A\gamma\theta W + A^2\gamma\theta W^2 + A^3\gamma\theta W^3 + \dots\} = \\
 &= A\gamma\theta EW + A^2\gamma\theta EW^2 + A^3\gamma\theta EW^3 + \dots = \\
 &= A\gamma\theta EW + A^2\gamma\theta O(N^{-1}) + A^3\gamma\theta O(N^{-1}) + \dots = \\
 &= A\gamma\theta EW + A^2(I-A)^{-1}\gamma\theta O(N^{-1}) = A\gamma\theta EW + O(N^{-1}),
 \end{aligned}$$

B.37)

where the third equality follows from assumption 4. □

Note that the diagonal elements of  $W$  are identically equal to zero. As a result, an element of  $u$  corresponding to a certain observation is uncorrelated with the element of  $\tilde{y}$  corresponding to that same observation. Of course, any element of  $u$  does correlate with elements of  $\tilde{y}$  corresponding to different observations, but that does not affect the asymptotic distribution of the ML-estimator. This statement is made somewhat more precise in lemma 4.

Let us define the 'conventional' ML-estimator of the reduced form parameters  $\psi$ ,  $\gamma$ , and  $\rho$  in (B.19) as the estimator that maximizes the likelihood of the observations under the assumption that  $u$  follows a normal distribution (with mean zero) with a variance-covariance matrix of the form  $\Gamma\theta I_N$ , where  $\Gamma$  is unrestricted. This estimator provides us with consistent estimates of  $\psi$ ,  $\gamma$ , and  $\rho$  under assumptions 1-4, but in order to use the corresponding conventional standard errors an extra assumption is needed. This is summarized, somewhat informally, in lemma 4.

Lemma 4 Under assumptions 1, 2, 3, and 4, the conventional ML-estimator of the reduced form parameters is consistent. If we strengthen assumption 4 to

$$E w_{nm} = O(N^{-1}),$$

then the conventional standard errors are consistent estimates of the true standard errors.

Proof To prove the first part, ignore for a moment the overidentifying restriction implicit in the definitions of  $\tilde{x}$  and  $\tilde{y}$  (both depend on the  $\mu$ -s). Then (B.19) is simply a system of seemingly unrelated regressions where the same explanatory variables appear in each equation. Consequently, the conventional ML-estimator is identical to the OLS-estimator applied equation by equation. Since the diagonal elements of  $W$  are identically equal to zero, it follows from lemma 3 that the elements of  $u$  are uncorrelated with the explanatory variables corresponding to the same observation. It follows immediately that the OLS-estimator is consistent. Now, taking into account the overidentifying restrictions does not impair consistency.

Concerning the second part of the lemma, we observe that the strengthened version of assumption 4 in conjunction with lemma 3 implies that we can neglect the correlation between  $u$  and  $\tilde{y}$ . Furthermore, considering (B.33) it is clear that the only source of correlation of elements of  $u$  across observations arises from terms involving  $W$ . By assumption these terms can be neglected. As a result  $u$  has the variance covariance matrix assumed by the conventional ML-estimator and its standard errors are consistent estimates of the true standard errors of the parameter estimates. □

To conclude the derivation of the reduced form, we rewrite (B.19) in terms of non-translated variables. Define:

$$d = \psi + \tilde{\eta}\kappa\rho \tag{B.38}$$

$$\alpha = \mu - \tilde{\mu}\gamma \tag{B.39}$$

$$r = (1-\kappa)\rho. \tag{B.40}$$

Now we have

Lemma 5 Under assumptions 1-4, (B.19) implies

$$x = d\theta^t_N + \alpha\theta^t_f + \gamma\theta^t_y + r\theta^t_{\tilde{y}} - r\tilde{\mu}\theta^t_{\tilde{f}} + u. \tag{B.41}$$

Up to terms of  $O(N^{-1})$  the error term  $u$  has mean zero and  $u_{gn}$  is uncorrelated with  $y_n$  and  $f_n$ . Lemma 4 applies.

The error term  $u$  satisfies an expression similar to (B.22) and the properties of  $u$  follow from arguments similar to lemma 3. It is also a matter of analogy to prove that lemma 4 applies, except for one slight complication. In (B.41) there are overidentifying restrictions on the reduced form parameters so that ML is no longer identical to OLS equation by equation. Since imposition of correct restrictions does not impair consistency, the consistency of the ML-estimator still follows from the consistency of the OLS-estimator.

Finally we substantiate the remark following (4.10) in section 4, by using (B.16) to express  $\beta$  as a function of  $\gamma$ ,  $\rho$  and  $\kappa$ . First rewrite (B.,16) as

$$A\gamma + (1-\kappa)A\rho = \rho \quad (\text{B.42})$$

or

$$(I_G - \gamma\gamma'_G)B(\gamma + (1-\kappa)\rho) = \rho. \quad (\text{B.43})$$

Let  $\Delta$  be the diagonal matrix with typical diagonal element  $\gamma_g + (1-\kappa)\rho_g$ . Then (B.43) is equivalent to

$$(I_G - \gamma\gamma'_G)\Delta\beta = \rho. \quad (\text{B.44})$$

As  $I_G - \gamma\gamma'_G$  has rank  $G-1$ ,  $\Delta\beta$  can not uniquely be inferred from (B.44). Using the algebra of singular linear systems (e.g. Searle, 1971), the general solution of (B.44) is, for arbitrary  $p$ ,

$$\Delta\beta = (I_G - \gamma\gamma'_G)\rho + p\gamma = \rho + p\gamma \quad (\text{B.45})$$

or

$$\beta = \Delta^{-1}(\rho + p\gamma). \quad (\text{B.46})$$

This is equivalent to (4.9).

Notes

- 1) For the purpose of this paper we use the terms 'household', 'family', 'individual', 'consumer' as synonyms.
- 2) Notice that in (2.3) the prices of all goods are equal to one. Since we will be dealing with a cross-section where all consumers face the same prices, this does not involve any loss of generality. As a result we will use 'consumption' and 'expenditures' as synonyms.
- 3) It would be tempting to call  $\tilde{x}_{gn}$  'discretionary spending' on good  $g$ , but we prefer to adhere to the more common definition of discretionary spending as  $x_{gn} - b_{gn}$ .
- 4) It follows from Festinger's theory of social comparison processes (Festinger, 1954) that people will compare primarily to others who are similar, and a large amount of empirical evidence supports this contention to varying degrees. Borrowing from attribution theory, Goethals and Darley (1977) are able to be more specific about how "similar others" have to be defined. If an individual wants to evaluate a particular ability, for example, he will seek comparison with others who are comparable with respect to attributes related to that ability. Major and Forcey (1985), find that in evaluations of the level of pay received for a job, individuals compare to others who have the same job and sex.
- 5) The symbol  $o_p(1)$  is defined as follows: the random variable  $x_m$  is  $o_p(1)$  if for any  $\epsilon > 0$ ,

$$\lim_{m \rightarrow \infty} \Pr(|x_m| > \epsilon) = 0.$$

In the present context  $m$  refers to the number of individuals in a social group or in society. We shall use the symbol  $o_p(1)$  for both scalars, vectors and matrices.

- 6) Here and in what follows we ignore the supply side of the market for consumption goods, i.e. we assume that changing demands can be met without affecting prices. This allows us to equate demand with consumption.

7) It is somewhat tedious to show this; (5.1) can be derived more directly by using (B.16), (B.17) and (B.19).

## References

- Aigner, D.J., C. Hsiao, A. Kapteyn and T.J. Wansbeek, 1984, Latent variable models in econometrics in: Griliches, Z. and M.D. Intriligator (eds.), Handbook of econometrics (North-Holland, Amsterdam), vol. 2, pp. 1331-1393.
- Alessie, R.J.M. and A. Kapteyn, 1989, Consumption, savings and demography. In A. Wenig and K.F. Zimmerman (eds.), Demographic Change and Economic Development (Springer-Verlag Berlin Heidelberg), pp. 272-305.
- Barten, A.P., 1969, Maximum likelihood estimation of a complete system of demand equations. *European Economic Review* 1, pp. 7-73.
- Bentler, P.M., 1983, Simultaneous equation-systems as moment structure models; with an introduction to latent variable models. *Journal of Econometrics* 22, pp. 13-42.
- Blanciforti, L. and R. Green, 1983, An almost ideal demand system incorporating habits: An analysis of expenditures on food and aggregate commodity groups. *The Review of Economics and Statistics* 65, pp. 511-515.
- Blundell, R. and I. Walker, 1986, A life cycle consistent empirical model of family labour supply using cross section data. *Review of Economic Studies* 53, pp. 539-558.
- Darrough, M., R.A. Pollak and T.J. Wales, 1983, Dynamic and stochastic structure: An analysis of three time series of household budget studies. *The Review of Economics and Statistics* 65, pp. 274-281.
- Duesenberry, J.S., 1949, *Income, saving and the theory of consumer behavior* (Harvard University Press, Cambridge).
- Festinger, L., 1954, A theory of social comparison processes. *Human Relations* 7, pp. 117-140.

- Gaertner, W., 1974, A dynamic model of interdependent consumer behavior. *Zeitschrift für Nationalökonomie* 34, pp. 327-344.
- Goethals, G.R. and J.M. Darley, 1977, Social comparison theory. An attributional approach. In J.M. Suls and R.L. Miller (eds.), *Social Comparison Processes* (Hemisphere Publishing Corporation, New York).
- Houthakker, H.S. and L.D. Taylor, 1970, *Consumer demand in the United States 1929-1970*, H.S. and L.D. Taylor, 1970, *Consumer demand in the United States 1929-1970, analysis and projections* (Harvard University Press, Cambridge).
- Jöreskog, K.G. and D. Sörbom, 1984, LISREL VI - Analysis of linear structural relationships by maximum likelihood, instrumental variables and least squares methods (Department of Statistics, University of Uppsala).
- Kapteyn A., A theory of preference formation. Unpublished Ph.D. Thesis (Leyden University).
- Kapteyn, A., B.M.S. van Praag and F.G. van Herwaarden, 1978, Individual welfare functions and social reference spaces. *Economics Letters* 1, pp. 173-178.
- Kapteyn, A., T.J. Wansbeek and J. Buyze, 1980, The dynamics of preference formation. *Journal of Economic Behavior and Organization* 1, pp. 123-157.
- Kilpatrick, R.W., 1973, The income elasticity of the poverty line. *The Review of Economics and Statistics* 55, p. 327-332.
- Leibenstein, H., 1950, Bandwagon, snob, and Veblen effects in the theory of consumer's demand. *Quarterly Journal of Economics* 64, pp. 183-207.
- Major, B. and B. Forcey, 1985, Social comparisons and pay evaluations: preferences for same-sex and same-job wage comparisons. *Journal of Experimental Social Psychology* 21, 393-405.

- Manser, M.E., 1976, Elasticities of demand for food: An analysis using non-additive utility functions allowing for habit formation. *Southern Economic Journal* 43, pp. 879-891.
- Miller, H.P., 1965, Changes in the number and composition of the poor. In: M.S. Gordon, ed., *Poverty in America* (Chandler, San Francisco), pp. 81-101.
- Muellbauer, J., 1988, Habits, Rationality, and myopia in the life-cycle consumption function, *Annales d'Economie et de Statistique*, vol. 9, pp. 47-70.
- Oldenburger, R., 1940, Infinite powers of matrices and characteristic roots. *Duke Mathematical Journal* 6, pp. 357-361.
- Ornati, O., 1966, *Poverty amid affluence* (Twentieth Century Fund, New York).
- Pashardes, P., 1986, Myopic and forward looking behaviour in a dynamic demand system. *International Economic Review* 27, pp. 387-397.
- Phlips, L., 1972, A dynamic version of the linear expenditure model. *The Review of Economics and Statistics* 54, pp. 450-458.
- Phlips, L., 1974, *Applied consumption analysis* (North-Holland, Amsterdam).
- Phlips, L. and F. Spinnewijn, 1982, Rationality versus myopia in dynamic demand systems. *Advances in Econometrics*, vol. 1, pp. 3-33.
- Pollak, R.A., 1976, Interdependent preferences. *American Economic Review* 66, pp. 309-320.
- Pollak, R.A., and T.J. Wales, 1969, Estimation of the linear expenditure system. *Econometrica* 37, pp. 611-628.
- Pollak, R.A., and T.J. Wales, 1981, Demographic variables in demand analysis. *Econometrica* 49, pp. 1533-1552.



- Sawhill, I.V., 1988, Poverty in the U.S.: Why is it so persistent? *Journal of Economic Literature* 26, pp. 1073-1119.
- Searle, S.R., 1971, *Linear models* (Wiley, New York).
- Smolensky, E., 1965, The past and present poor. In: *The concept of poverty* (U.S. Chamber of Commerce, New York), pp. 35-67.
- Spinnewijn, F., 1981, Rational habit formation, *European Economic Review* 15, pp. 91-109.
- Stadt, H. van de, A. Kapteyn and S van de Geer, 1985, The relativity of utility: evidence from panel data. *The Review of Economics and Statistics* 67, pp. 179-187.
- Von Grumbkov, J., 1980, *Sociale vergelijking van salarissen*, Ph. D.-thesis, University of Groningen.
- Winder, C.C.A., 1988, *Modelling intertemporal consumer behaviour*, (Free University Press, Amsterdam).

Discussion Paper Series, CentER, Tilburg University, The Netherlands:

No.	Author(s)	Title
8801	Th. van de Klundert and F. van der Ploeg	Fiscal Policy and Finite Lives in Interdependent Economies with Real and Nominal Wage Rigidity
8802	J.R. Magnus and B. Pesaran	The Bias of Forecasts from a First-order Autoregression
8803	A.A. Weber	The Credibility of Monetary Policies, Policy-makers' Reputation and the EMS-Hypothesis: Empirical Evidence from 13 Countries
8804	F. van der Ploeg and A.J. de Zeeuw	Perfect Equilibrium in a Model of Competitive Arms Accumulation
8805	M.F.J. Steel	Seemingly Unrelated Regression Equation Systems under Diffuse Stochastic Prior Information: A Recursive Analytical Approach
8806	Th. Ten Raa and E.N. Wolff	Secondary Products and the Measurement of Productivity Growth
8807	F. van der Ploeg	Monetary and Fiscal Policy in Interdependent Economies with Capital Accumulation, Death and Population Growth
8901	Th. Ten Raa and P. Kop Jansen	The Choice of Model in the Construction of Input-Output Coefficients Matrices
8902	Th. Nijman and F. Palm	Generalized Least Squares Estimation of Linear Models Containing Rational Future Expectations
8903	A. van Soest, I. Woittiez, A. Kapteyn	Labour Supply, Income Taxes and Hours Restrictions in The Netherlands
8904	F. van der Ploeg	Capital Accumulation, Inflation and Long-Run Conflict in International Objectives
8905	Th. van de Klundert and A. van Schaik	Unemployment Persistence and Loss of Productive Capacity: A Keynesian Approach
8906	A.J. Markink and F. van der Ploeg	Dynamic Policy Simulation of Linear Models with Rational Expectations of Future Events: A Computer Package
8907	J. Osiewalski	Posterior Densities for Nonlinear Regression with Equicorrelated Errors
8908	M.F.J. Steel	A Bayesian Analysis of Simultaneous Equation Models by Combining Recursive Analytical and Numerical Approaches

No.	Author(s)	Title
8909	F. van der Ploeg	Two Essays on Political Economy (i) The Political Economy of Overvaluation (ii) Election Outcomes and the Stockmarket
8910	R. Gradus and A. de Zeeuw	Corporate Tax Rate Policy and Public and Private Employment
8911	A.P. Barten	Allais Characterisation of Preference Structures and the Structure of Demand
8912	K. Kamiya and A.J.J. Talman	Simplicial Algorithm to Find Zero Points of a Function with Special Structure on a Simplotope
8913	G. van der Laan and A.J.J. Talman	Price Rigidities and Rationing
8914	J. Osiewalski and M.F.J. Steel	A Bayesian Analysis of Exogeneity in Models Pooling Time-Series and Cross-Section Data
8915	R.P. Gilles, P.H. Ruys and J. Shou	On the Existence of Networks in Relational Models
8916	A. Kapteyn, P. Kooreman and A. van Soest	Quantity Rationing and Concavity in a Flexible Household Labor Supply Model
8917	F. Canova	Seasonalities in Foreign Exchange Markets
8918	F. van der Ploeg	Monetary Disinflation, Fiscal Expansion and the Current Account in an Interdependent World
8919	W. Bossert and F. Stehling	On the Uniqueness of Cardinaly Interpreted Utility Functions
8920	F. van der Ploeg	Monetary Interdependence under Alternative Exchange-Rate Regimes
8921	D. Canning	Bottlenecks and Persistent Unemployment: Why Do Booms End?
8922	C. Fershtman and A. Fishman	Price Cycles and Booms: Dynamic Search Equilibrium
8923	M.B. Canzoneri and C.A. Rogers	Is the European Community an Optimal Currency Area? Optimal Tax Smoothing versus the Cost of Multiple Currencies
8924	F. Groot, C. Withagen and A. de Zeeuw	Theory of Natural Exhaustible Resources: The Cartel-Versus-Fringe Model Reconsidered

No.	Author(s)	Title
8925	O.P. Attanasio and G. Weber	Consumption, Productivity Growth and the Interest Rate
8926	N. Rankin	Monetary and Fiscal Policy in a 'Hartian' Model of Imperfect Competition
8927	Th. van de Klundert	Reducing External Debt in a World with Imperfect Asset and Imperfect Commodity Substitution
8928	C. Dang	The $D_1$ -Triangulation of $R^n$ for Simplicial Algorithms for Computing Solutions of Nonlinear Equations
8929	M.F.J. Steel and J.F. Richard	Bayesian Multivariate Exogeneity Analysis: An Application to a UK Money Demand Equation
8930	F. van der Ploeg	Fiscal Aspects of Monetary Integration in Europe
8931	H.A. Keuzenkamp	The Prehistory of Rational Expectations
8932	E. van Damme, R. Selten and E. Winter	Alternating Bid Bargaining with a Smallest Money Unit
8933	H. Carlsson and E. van Damme	Global Payoff Uncertainty and Risk Dominance
8934	H. Huizinga	National Tax Policies towards Product-Innovating Multinational Enterprises
8935	C. Dang and D. Talman	A New Triangulation of the Unit Simplex for Computing Economic Equilibria
8936	Th. Nijman and M. Verbeek	The Nonresponse Bias in the Analysis of the Determinants of Total Annual Expenditures of Households Based on Panel Data
8937	A.P. Barten	The Estimation of Mixed Demand Systems
8938	G. Marini	Monetary Shocks and the Nominal Interest Rate
8939	W. Güth and E. van Damme	Equilibrium Selection in the Spence Signaling Game
8940	G. Marini and P. Scaramozzino	Monopolistic Competition, Expected Inflation and Contract Length
8941	J.K. Dagsvik	The Generalized Extreme Value Random Utility Model for Continuous Choice

No.	Author(s)	Title
8942	M.F.J. Steel	Weak Exogeneity in Misspecified Sequential Models
8943	A. Roell	Dual Capacity Trading and the Quality of the Market
8944	C. Hsiao	Identification and Estimation of Dichotomous Latent Variables Models Using Panel Data
8945	R.P. Gilles	Equilibrium in a Pure Exchange Economy with an Arbitrary Communication Structure
8946	W.B. MacLeod and J.M. Malcomson	Efficient Specific Investments, Incomplete Contracts, and the Role of Market Alternatives
8947	A. van Soest and A. Kapteyn	The Impact of Minimum Wage Regulations on Employment and the Wage Rate Distribution
8948	P. Kooreman and B. Melenberg	Maximum Score Estimation in the Ordered Response Model
8949	C. Dang	The $D_3$ -Triangulation for Simplicial Deformation Algorithms for Computing Solutions of Nonlinear Equations
8950	M. Cripps	Dealer Behaviour and Price Volatility in Asset Markets
8951	T. Wansbeek and A. Kapteyn	Simple Estimators for Dynamic Panel Data Models with Errors in Variables
8952	Y. Dai, G. van der Laan, D. Talman and Y. Yamamoto	A Simplicial Algorithm for the Nonlinear Stationary Point Problem on an Unbounded Polyhedron
8953	F. van der Ploeg	Risk Aversion, Intertemporal Substitution and Consumption: The CARA-LQ Problem
8954	A. Kapteyn, S. van de Geer, H. van de Stadt and T. Wansbeek	Interdependent Preferences: An Econometric Analysis

P.O. BOX 90153 5000 LE TILBURG THE NETHERLANDS

**Bibliotheek K. U. Brabant**



17 000 01113850 1