INFLATION EFFECTS IN THE CONSUMPTION FUNCTION

Carlo C.A. Winder

Research Memorandum 1987-42

November '87

VRIJE UNIVERSITEIT
FACULTEIT DER ECONOMISCHE WETENSCHAPPEN EN ECONOMETRIE
AMSTERDAM
INFLATION EFFECTS IN THE CONSUMPTION FUNCTION

Carlo C.A. Winder

November 1987

Comments welcome.

ABSTRACT

The purpose of the paper is to extend the consumption model with moving planning horizon investigated by Palm and Winder (1987) for inflation effects. The vehicle for incorporating inflation effects is the same as put forward by Deaton (1977). The chosen model leads to a consumption function which is similar to that of Davidson, Hendry, Srba and Yeo (1978). As in their specification we have to include inflation, the change in inflation and an error correction term as explanatory variables. In the empirical part we analyze the model using quarterly data for the Netherlands. The empirical results do not unequivocally confirm the theoretical model.

Helpful comments of Rob Alessie and stimulating discussions with Franz Palm are gratefully acknowledged.

*Department of Economics and Econometrics, Free University, P.O.Box 7161, 1007 MC, Amsterdam, Netherlands.
Section 1 Introduction.

Among the many articles that deal with extensions and refinements of Modigliani and Brumberg's (1955) life cycle consumption hypothesis, an important contribution is due to Hall (1978). He formulates the life cycle hypothesis as an intertemporal decision problem with a time additive utility function, and shows that the first order conditions for an intertemporal optimum imply a first order autoregressive process for the marginal utility of consumption. Consequently, the dynamics of consumption is basically determined by the structure of the preferences. When we relax the assumption of separability of the utility function a different stochastic process for consumption will arise. Winder (1987a,b) shows that for an exponential utility function, an appropriate choice of rational habit formation will lead to an arbitrary autoregressive integrated moving average (ARIMA) process for consumption. The role of income is very specific. Several authors (see e.g. Flavin (1981), Muellbauer (1983) and Wickens and Molana (1983)) have noticed that the consumption innovation is a transformation of the income innovation. The empirical analyses carried out in Palm and Winder (1987) and Winder (1987a) reveal that unanticipated structural changes in the income process will lead to one step change in the drift parameter of the consumption process and will in general affect persistently only the properties of the consumption innovation. Hence, structural changes in the ARIMA parameters of the consumption process can only be interpreted in this framework by the assumption of a change in the preference structure.

For some purposes however, it may be desirable to establish a more direct link between the consumption and income processes. Palm and Winder (1987) investigate a model of intertemporal utility maximization, in which the consumer uses a planning horizon which does not coincide with the expected life time. They argue that it is not unrealistic to imagine that the consumer will neglect periods far ahead in the future on which available information is scarce and unreliable, and will confine himself to more trustworthy information on the near future. When the time horizon differs from the life time, a mechanism that describes the adjustment of the planning horizon as time goes on has to be introduced in the model. Palm
and Winder (1987) adopt the simplest possible solution. They assume that the consumer uses a planning time span of constant length. They show that the drift parameter of the implied stochastic process of consumption is proportional to the one of the income process. Hence, an unanticipated change in the latter will have as a consequence that the former will alter. The model is capable to relate a change in the slope of the consumption line to a change in the slope of the income line. An attractive feature of the model is that it leads to a relationship between income and consumption which is highly similar to the mechanism underlying the consumption function of Davidson, Hendry, Srba and Yeo (1978). More specifically, as a result of adjusting the planning horizon, an error correction term has to be included in the consumption function. As no error is involved from the side of the consumer, Palm and Winder (1987) argue that it is more appropriate to speak about a correction term. After a careful empirical analysis Davidson et. al. (1978) choose an ultimate specification in which the basic mechanism between consumption and income is extended for the effects of inflation. Although the empirical analysis of Palm and Winder (1987) does not suggest the presence of any serious misspecification, the possible extension of the model to account for inflation effects is worth considering. The paper investigates this extension and provides empirical evidence for the Netherlands. The chosen framework for incorporating inflation effects is the same as put forward by Deaton (1977).

The paper is organized as follows. In section 2 we discuss the model. In line with Deaton (1977) we model the consumption decision as a two stage problem. In the first stage the consumer is assumed to solve an intertemporal optimization problem. The decision taken about real consumption determines together with the anticipated price level for the current period total anticipated expenditure. To describe the decision procedure in the first stage we adopt the model with moving planning horizon investigated by Palm and Winder (1987). Given total anticipated expenditure and anticipated prices of the individual goods, the consumer determines in the second stage the commodity demands. To model this decision we choose a linear expenditure system. When anticipated and actual prices differ, the actual and anticipated expenditure in the current period will not coincide. To determine actual expenditure on a certain commodity we assume in line with Deaton (1977), that the consumer remains
on the demand curve of that good, implied by the model for the second stage of his decision problem. This assumption enables us to find actual total expenditure in the current period. Together with the result obtained for the first stage of the consumption decision, we find the consumption function which depends among other things on future income expectations and anticipated prices.

We assume that the consumer has rational expectations about the future real income stream. Following Deaton (1977) it may be argued that the greater stability of real income changes compared with the nominal changes make them more easily predictable. The difficulties with predicting future real income seem to be most severe in times of high and changing inflation rates. Hence, we may expect problems when modeling the roaring 1970's. However, during that period the salaries in the Netherlands were automatically corrected for inflation effects. In the 1980's this system was no longer maintained, but the movements of the inflation rates during that period were much less turbulent. Therefore, it seems not unrealistic to assume that the consumers were able to assess future real income.

To complete the model we postulate some mechanisms concerning the anticipated prices. The framework does not preclude the incorporation of rational expectations with respect to anticipated prices. This will however complicate the estimation equation considerably. As we want to establish a link with the specification put forward by Davidson et. al. (1978), we choose therefore for a much simpler procedure for modeling the anticipated prices. More specifically, we assume that the anticipated price level for the current period equals the price level of the previous period. It will be argued that when the time span between two successive two stage decision problems is short enough, the mechanism may yield a satisfactory prediction. Notice that we preclude the possibility that real income expectations are formed indirectly from expectations on money income and prices. Because of the assumption concerning anticipated prices, we must doubt in that case whether the consumer is able to make rational predictions of future real income.

With these assumptions about future real income expectations and anticipated prices, we obtain a consumption function which is similar to the one of Davidson et. al. (1978). As in their specification we have to include inflation, the change in inflation and an error correction term as
explanatory variables.

Section 3 starts with an examination of the income series. The specified income process enables us to link the income expectations to past realizations of income. Moreover, the analysis of the income series may yield information on possible structural changes in the income process. In line with Lucas (1976) we pay attention to the effects of these structural changes. After the derivation of the estimation equation we give empirical evidence using quarterly data on total and on nondurable consumption for the Netherlands. The empirical results for total real consumption are not unsatisfactory. Information in the data, however, does not suggest that the inflation effects are present. These results contrast the ones for real nondurable consumption. With this consumption measure, we find a significant effect for inflation, but the empirical analysis suggests that the model is misspecified. For the planning time span we find estimates of 2.75 and 4.50 quarters for total and nondurable real consumption respectively. Based on empirical evidence, Friedman (1957) draws a dividing line at a horizon of about 3 years (see p.221), to classify the permanent and transitory components of income. Obviously, our empirical results suggest that the consumer is rather "shortsighted".

Finally, section 4 concludes the study.
Section 2 Theory.

In this section we describe the theoretical model. In line with Deaton (1977) we assume that at each period \( t \) the consumer makes his consumption decision in two parts. In the first stage he determines total expenditure in the current period by solving an intertemporal optimization problem and in the second stage the demands of the various commodities is determined. As we study a model with incomplete price information, it becomes necessary in the sequel to distinguish actual and anticipated variables. To describe the decision taken in the first stage, we choose the specification put forward by Palm and Winder (1987). More particularly, at each period \( t \) the consumer is assumed to solve

\[
\text{Max } \sum_{i=0}^{T} \beta^i U(c_{t+i}^*)
\]

subject to

\[
\sum_{i=0}^{T} (1+r)^{-i} c_{t+i}^* = (1+r)a_t + \sum_{i=0}^{T} (1+r)^{-i} E[y_{t+i} | I_t]
\]  

(2.1)

with

\[
U(c) = -\gamma^{-1} \exp(-\gamma c), \gamma > 0.
\]

Anticipated real consumption and real labor income are denoted by \( c_{t+i}^* \) and \( y_{t+i} \) respectively, \( a_{t-1} \) is real financial wealth, \( \beta \) is the time preference parameter (\( 0 < \beta < 1 \)), \( r \) is the real interest rate, which is assumed to be constant (\( 0 < r < 1 \)) and \( T \) denotes the length of the planning horizon, which is assumed to be independent of \( t \). Hence, the planning horizon is postulated to shift as time goes on. \( E \) denotes the expectations operator, conditional on \( I_t \), which is the set of information available at time \( t \). It is assumed that the consumer knows the value of \( y_t \) when taking a decision about \( c_t \). Hence, \( E[y_t | I_t] = y_t \). The first order conditions implied by (2.1) yield

\[
c_{t+i}^* = c_t^* + i\gamma^{-1} \ln[\beta(1+r)] \text{, } i=1,2,\ldots,T.
\]  

(2.2)

After substitution of (2.2) into the budget constraint of (2.1), we get for
\[ c_t^* = \gamma^{-1} \ln (\beta(1+r)) \tau_T - (1+r) a_{t-1} + \sum_{i=0}^{T} (1+r)^{-i} E(y_{t+i} | I_t), \quad (2.3) \]

where
\[ \eta_k = \sum_{i=0}^{k} (1+r)^{-i} \quad \text{and} \quad \tau_k = \sum_{i=1}^{k} i(1+r)^{-i}. \]

It can easily be shown that for \( \beta(1+r)=1 \), relationship (2.3) holds for any utility function \( U \) satisfying \( U'>0 \) and \( U''<0 \). Denoting the anticipated price level by \( p^*_c \), it follows from (2.3) that anticipated total expenditure is given by
\[ p^*_c c_t^* + \gamma^{-1} \ln (\beta(1+r)) \tau_T^p = (1+r) a_{t-1} p^*_c + \sum_{i=0}^{T} (1+r)^{-i} p^*_c E(y_{t+i} | I_t). \quad (2.4) \]

Given the total amount \( p^*_c \), the consumer determines in the second stage the purchases of individual goods. We assume that the preference ordering may be described by a Stone-Geary utility function, which will lead to a linear expenditure system. Formally, the consumer solves
\[
\max \prod_{k=1}^{n} (q_{kt}^* - \gamma_k)^{\beta_k} \\
\text{S.T.} \sum_{k=1}^{n} p_{kt} q_{kt} = c_t^* c_t^* \\
\text{with} \beta_i \in (0,1), i=1,\ldots,n, \sum_{i=1}^{n} \beta_i = 1 \text{ and } \gamma_i > 0, i=1,\ldots,n.
\]

Anticipated acquisitions and prices of good \( k \) are denoted by \( q^*_k \) and \( p^*_k \), respectively, the parameters \( \gamma_k \) may be interpreted as "necessary" quantities and \( n \) is the number of goods. We assume that the purchases take place sequentially and rank the goods in the order of purchase. The utility maximization problem (2.5) leads to the wellknown linear expenditure system.
and hence we have for the demand curves \( f_i(p^*_1, \ldots, p^*_n, c^*_p) \)

\[
 f_i(p^*_1, \ldots, p^*_n, c^*_p) = \gamma_i + \beta_i (c^*_p \cdot \sum_{k=1}^{n} p^*_k \gamma_k), \quad i=1, \ldots, n. \tag{2.7}
\]

At instant \( t \), assume the consumer is purchasing good \( i \). On the basis of the anticipated prices \( p^*_k \) and \( p^*_k \), \( k=1, \ldots, n \), he plans to buy the quantity \( q^*_i \). At the time of purchase, the actual price \( p_{it} \) is observed. The consumer has also knowledge of the actual prices \( p^*_j \), \( j=1, \ldots, i \). In contrast to Deaton (1977) we assume that he incorporates this knowledge in his decision about \( q^*_i \). When one of the actual values of \( p^*_j \), \( j=1, \ldots, i \) differs from the anticipated values \( p^*_j \), \( j=1, \ldots, i \), the consumer will buy a quantity of good \( i \) that deviates from the anticipated value. In line with Deaton (1977) we assume that the consumer remains on his demand curve and hence (2.7) determines the actual acquisition of good \( i \), say \( q_{it} \)

\[
 q_{it} = \gamma_i + \beta_i (c^*_p \cdot \sum_{k=1}^{n} p^*_k \gamma_k + \sum_{k=1}^{i} (p^*_k - p^*_k \gamma_k). \tag{2.8}
\]

Thus we have for the actual expenditure on good \( i \)

\[
 p^*_i q^*_i = p^*_i q_{it} + \gamma_i (1-\beta_i) (p_{it} - p^*_i) \tag{2.9}
\]

and

\[
 p^*_i q_{it} = p^*_i q_{it} + \gamma_i (1-\beta_i) (p_{it} - p^*_i) + \beta_i \sum_{k=1}^{i-1} (p^*_k - p^*_k), \quad i \geq 2.
\]

When we define actual total expenditure

\[
P_{ct} = \sum_{i=1}^{n} p^*_i q_{it},
\]

we have from (2.9)
It can easily be shown that (2.7) and (2.8) imply

$$\gamma_i(1-\beta_i) = q_{it}(1 + \frac{p_{it}}{q_{it}} \frac{\partial F_{it}}{\partial p_{it}})$$

(2.11)

where $\frac{\partial F_{it}}{\partial p_{it}}$ is evaluated in $(p_{it}, p_{it+1}, p_{it+2}, c_{it}, p_{it})$.

Substitution of (2.11) into (2.10) yields

$$p_{ct} = p_{ct}^{*} + \sum_{i=1}^{n} \gamma_i(1-\beta_i)(p_{it}^* - p_{it}) + \sum_{i=2}^{n} \gamma_i(1-\beta_i)(p_{kt}^* - p_{kt}) \gamma_k.$$  \hspace{0.5cm} (2.10)

This expression shows that we have a similar result as Deaton (eq.7). The difference concerns the last term of (2.12) which results from incorporating the information on the actual prices $p_{jt}$, $j=1,...,i-1$, in his decision about $q_{it}$. Instead of focussing on the saving ratio, we want to establish a link with the consumption function of Palm and Winder (1987). Therefore we substitute (2.10) into (2.4) and we get for total expenditure in period $t$

$$p_{t}^{*} - p_{t}^{*} c_{it}^{*} n_{t} + \sum_{i=1}^{n} q_{it}(1-\beta_i)(p_{it}^* - p_{it}) n_{it} - \sum_{i=2}^{n} \beta_i \sum_{k=1}^{i-1} (p_{kt}^* - p_{kt}) \gamma_k n_{kt} +$$

$$\gamma_{t}^{*} \ln[\beta(1+r)] n_{t} - (1+r) a_{t-1} - \sum_{i=0}^{T} (1+r)^{T-i} E(y_{t+i}|I_{t}).$$ \hspace{0.5cm} (2.13)

To investigate the dynamics in consumption, it is convenient to relate $c_{t}$ to $c_{t+1}$. Along the same lines as before, we find for total consumption expenditure in the next period

$$p_{t+1}^{*} p_{t+1} c_{t+1} n_{t+1} + p_{t+1}^{*} \sum_{i=1}^{n} q_{it}(1-\beta_i)(p_{it+1}^* - p_{it+1}) n_{it+1} + \gamma_{t+1}^{*} \ln[\beta(1+r)] n_{t+1} +$$

$$-p_{t+1}^{*} \sum_{i=2}^{n} \beta_i \sum_{k=1}^{i-1} (p_{kt+1}^* - p_{kt+1}) \gamma_k n_{kt+1}.$$
In line with the analysis of Deaton (1977), we assume that the difference between actual and anticipated expenditure will be (dis)saved. With the assumption of a constant real interest rate we have therefore
\[ a_t = (1+r)a_{t-1} + y_t - c_t. \]
Dividing (2.14) by 1+r, substituting \( a_t = (1+r)a_{t-1} + y_t - c_t \) and subtracting (2.13) leads to
\[
(1+r)^{-1}\eta_T = (1+r)^{-1}\ln(\beta(1+r))\eta_T (1+r)^{-1} -
\]
\[
- \sum_{i=1}^{T} (1+r)^{-i} (E(y_{t+i} | I_t) - E(y_{t+i} | I_t^-)) -
\]
\[
- \sum_{i=1}^{T} (1+r)^{-i} (E(y_{t+i} | I_t) - E(y_{t+i} | I_t^-)) -
\]
\[
+ \sum_{i=1}^{T} (1+r)^{-i} \gamma_i \beta_i (P_{it} - P_{it+1})
\]
\[
+ \sum_{i=1}^{T} (1+r)^{-i} \gamma_i \beta_i (P_{it} - P_{it+1})
\]
\[
+ (1+r)^{-(T+1)} E(y_{t_{T+1}} | I_t^-) - (1+r)^{-(T+1)} \ln(\beta(1+r))]. \quad (2.15)
\]
An advantage of this transformation is that financial wealth has been eliminated. Because of the scarcity of adequate data on this variable (see also Pesaran and Evans (1984)) concentrating on (2.15) will probably lead to more reliable conclusions. Notice that the mistake in the previous period will influence the consumption level in the current period. This can easily be seen, when we reformulate (2.15) in terms of anticipated consumption \( c_{t+1}^* \) and \( c_t^* \). Substituting (2.10) and the similar expression for \( c_{t+1}^* \) into (2.15) yields after some rearranging
\[
c_{t+1}^* - c_t^* = \gamma^{-1} \ln(\beta(1+r))(1-\eta_T (1+r)^{-T(T+1)})+
\]
The last term expresses the influence of the mistakes in period \( t \) induced by the wrong assessment of the price level, on the decision with respect to anticipated consumption in period \( t+1 \). Because of the assumption that the difference between anticipated and actual consumption expenditure will be (dis)saved, the error in period \( t \) will only affect the decision in the next period. Obviously, when anticipated and actual prices coincide, expression (2.16) passes into the consumption function put forward by Palm and Winder (1987).

In order to complete the model, we must specify mechanisms linking anticipated prices to actual values. The assumption of rational expectations about anticipated prices may be incorporated by substituting \( \pi_t - \pi_t = \gamma_t \) into (2.15). The resulting estimation equation will however be rather complicated and display an intricate form of heteroscedasticity. An alternative is to estimate the stochastic process for the prices, and next calculate the one step ahead prediction. This procedure will lead to a nonlinear (in the variables) specification and will make the comparison with the consumption function of Davidson et al. (1978) intransparent. Therefore, we look for a simple but not unrealistic alternative. As we want to concentrate on general inflation effects, it becomes necessary to make assumptions concerning the price changes of the individual goods. The most simple way is to postulate

ASSUMPTION 1: \( \pi_{i,t} = \pi_t^*, \pi_i^* = \pi_t^*, \, i=1,...,n \) for all \( t \) \hfill (2.17)

where \( \pi_{i,t} = (P_{i,t} / P_{i,t-1}) / P_{i,t-1} \) and \( \pi_t^* = (P_t / P_t-1) / P_t-1 \) denote the anticipated and actual relative price change of good \( i \) respectively and \( \pi_t^* \) and \( \pi_t \) are defined in a similar way. Following Deaton (1977), assumption 1 may be rationalized by the argument that the dominant effect of the (anticipated) relative price change is ascribed to general (anticipated) inflation. Finally, we must specify a model for anticipated inflation \( \pi_t^* \).
In contrast to Deaton (1977), who assumes that \( \pi_t^* \) is an arbitrary constant, we postulate

\[ \text{ASSUMPTION 2: } \pi_t^* = 0 \text{ for all } t. \]  

(2.18)

Clearly, (2.18) is the simplest possible assumption about \( \pi_t^* \). The reasonableness of assumption 2 depends crucially on the time span between two successive two stage decision problems. When it is short enough (e.g. a week), the resulting errors will be small. This argument becomes stronger when we notice that price changes of the individual goods take place discontinuously and usually unexpectedly. Of course over longer periods the cumulated errors may become large, but the natural way to remedy the wrong assessments is to extend the intertemporal decision problem for inflation effects. This route will not be followed here. A nice feature of assumption 2 is that it simplifies expression (2.15) considerably.

From (2.18) we have

\[ p_t^{*,-1} = (1+\pi_t^*) \text{ for all } t \]  

(2.19)

and it can be shown that (2.17) and (2.18) imply

\[ p_t^{*,-1} \sum_{i=1}^{n} \gamma_i (1-\beta_1)(p_{it}^* - p_{it}) = -\pi_t \sum_{i=1}^{n} \gamma_i (1-\beta_1)\xi_i \text{ for all } t \]  

(2.20)

and

\[ p_t^{*,-1} \sum_{i=2}^{n} \sum_{k=1}^{i-1} \beta_1 (p_{it} - p_{kt}) \gamma_k = -\pi_t \sum_{i=2}^{n} \sum_{k=1}^{i-1} \xi_k \gamma_k \text{ for all } t. \]  

(2.21)

where \( \xi_i = p_{it}/p_t \), which is time independent because of assumption 1.

Substituting (2.19), (2.20) and (2.21) into (2.15) leads after some rearranging to

\[ \Delta c_{t+1} = -\pi_t + \gamma_t \pi_t c_t + \gamma_t^{-1} \ln(\beta(1+r)) (1-\eta_T^{-1}(1+r)^{-T(T+1)}) \cdot \]

\[ -r \lambda \pi_t + (1+r) \lambda \pi_t c_t + \eta_T^{-1}(1+r)^{-T} (E(y_{t+T+1}|I_{t}, I_t) \cdot c_t) + \]
\[ + \eta_T^{-1} \sum_{i=0}^{T} (1+r)^{-i} (E(\gamma_{t+1+i}|I_{t+1}) - E(\gamma_{t+1+i}|I_t)). \] (2.22)

where

\[ \lambda - \sum_{i=1}^{n} \gamma_1 (1-\beta_1) \xi_i - \sum_{i=2}^{n} \beta_1 \sum_{k=1}^{i-1} \xi_k \gamma_k = \sum_{i=2}^{n} \gamma_1 \xi_i \sum_{k=1}^{i-1} \beta_k. \]

Expression (2.22) shows that we have a consumption function which is similar to the one put forward by Palm and Winder (1987). In particular, we have the error correction term \( E(\gamma_{t+1+i}|I_t) - c_t \). Its presence arises from the adjustment of the planning horizon as time goes on. A difference with their specification concerns the appearance of the inflation variables. They are included as a result of the wrong assessments of the anticipated prices. An important difference between our analysis and that of Deaton (1977) is that we make the assumption of rational expectations with respect to real income, whereas he postulates a deterministic adjustment mechanism which does not necessarily correspond to the one of a rational expectations formulation. This approach is very similar to the feedback control rules discussed by for instance Davidson and Hendry (1981). It is however interesting to investigate such a feedback rule. When we assume that the generating mechanism of the conditional expectations corresponds to the one when the change in income follows an autoregressive (AR) process of order 1, (2.22) implies a relationship between consumption, income and inflation which is similar to the consumption function put forward by Davidson et al. (1978). Let us assume

\[ \Delta y_t = \phi \Delta y_{t-1} + \nu_t. \] (2.23)

For the sake of simplicity we omit the constant term, which does not change the conclusions. It is straightforward to calculate from (2.23) the relevant conditional expectations of (2.22), which read like

\[ y_{t+1} - E(y_{t+1}|I_t) = \Delta y_{t+1} - \phi \Delta y_t \] (2.24)
Substituting (2.24), (2.25) and (2.26) into (2.22) gives after some rearranging

\[ \Delta c_{t+1} = \alpha_0 - \pi_{t+1} c_{t+1} + (1+r) \pi_t c_t + \alpha_1 \pi_{t+1} + \alpha_2 \Delta \pi_{t+1} + \alpha_3 \Delta y_{t+1} + \alpha_4 \Delta y_t + \alpha_5 (y_t \cdot c_t) \]  

(2.27)

with \[ \alpha_0 = \gamma^{-1} \ln[\beta(1+r)](1-\eta_T^{-1}(1+r)^{-T}(T+1)) \]

\[ \alpha_1 = -r \lambda \]

\[ \alpha_2 = (1+r) \lambda \]

\[ \alpha_3 = \eta_T^{-1} \sum_{i=0}^{T} (1+r)^{-i} \sum_{j=0}^{i} \varphi^j \]

\[ \alpha_4 = \eta_T^{-1} \sum_{i=0}^{T} (1+r)^{-i} \sum_{j=0}^{i} \varphi^{i+1} \]

and \[ \alpha_5 = \eta_T^{-1}(1+r)^{-T} \].

Expression (2.27) shows that apart from the term \(-\pi_{t+1} c_{t+1} + (1+r) \pi_t c_t\), we have a similar mechanism as found in Davidson et. al. (1978). In each period the consumer spends the same as he spent the previous period, modified by a proportion of inflation and the change in income, and by whether the change in those variables is itself increasing or decreasing, and by the error correction term. With our theoretical model we can determine the sign and the size of the coefficients. For \(\alpha_5\) we find that it...
should be positive and smaller than 1. For \( \alpha_1 \) and \( \alpha_2 \) we infer a negative and a positive sign respectively. The sign and the size of both \( \alpha_3 - \alpha_4 \) and \( \alpha_4 \) depend on the sign of \( \varphi \). It is easy to show that if \( 0 < \varphi < 1 \) we have \( 0 < \alpha_3 - \alpha_4 < 1 \) and \( \alpha_4 > 0 \), and when \( -1 < \varphi < 0 \) we have \( \alpha_3 - \alpha_4 > 1 \) and \( \alpha_4 < 0 \). In their empirical analysis, Davidson et. al. (1978) have found a coefficient for the change in income between 0 and 1, and negative coefficients for inflation, for the change in inflation and for the change in the change in income. Obviously, their empirical findings are at variance with the implications of our theoretical model.

As argued before, we prefer to make the assumption of rational expectations with respect to real income. Therefore, before we can estimate and test the consumption function (2.22), it becomes necessary to investigate first the income series. An empirical analysis of the model with moving planning horizon extended for inflation effects will be carried out in the next section.
Section 3 Empirical results.

In this section our concern will be to test the implications of the theoretical model described in the previous section using quarterly seasonally adjusted data for the Netherlands. Quarterly data on labour and transfer income, on total consumption and on the price index of total consumption for 1968(1)-1984(4) have been kindly provided by the Centraal Plan Bureau. The data are the same as those used in Palm and Winder (1987). The nominal income and consumption series have been deflated by the price index and they have been divided by the size of the population to obtain per capita real series. The base year is 1980. The data used are given in figures 1 to 3. As the appropriate concept in the theory is consumption rather than consumption expenditure, we have also estimated the model with data on nondurable consumption per capita only. This series has been constructed by multiplying total consumption by the nondurable consumption shares. A short description of the data is given in appendix A. Empirical results for real nondurable consumption per capita are given in appendix B.

As we work with the assumption of rational expectations with respect to real income, it is necessary in the first instance to analyze the income series. The specified income process will enable us to calculate the relevant conditional expectations of (2.22). Moreover, the analysis of the income series may yield information on possible structural changes in the income process. For rational expectations models, Lucas (1975) and Wallis (1980) have shown what the implications of a structural change in the process of the exogenous variables are for econometric modelling. In line with the analysis of Palm and Winder (1987), special attention will be paid to these implications. Notice that the postulate of incomplete price information does not preclude the possibility of rational expectations with respect to anticipated prices. We assume however that the model for the anticipated prices chosen in section 2 is valid during the whole sample period.

Inspection of figure 1 clearly shows that the change in income is not stationary. In Palm and Winder (1987) an extensive analysis of the series is carried out. For a detailed discussion we refer to that paper. Here we confine ourselves to reproducing the Maximum Likelihood (ML) estimates of
Fig. 1 Real labor and transfer income per capita in the Netherlands, 1968(1)-1984(4).

Fig. 2 Real nondurable consumption per capita in the Netherlands, 1968(1)-1984(4).
the income process:

$$\Delta y_t = 40.46d_{1t} + 25.19d_{2t} + 13.01d_{3t} + \nu_t - 0.428\nu_{t-1}$$  \hspace{1cm} (3.1)

$$\sigma^2 = 809.6$$

where $d_{1t} = 1$ for 1968(2)-1970(4)

$d_{2t} = 1$ for 1971(1)-1978(4)

$d_{3t} = 1$ for 1979(1)-1984(4)

and $t$-values are reported between parentheses. In Table 1 the values of a number of test statistics are given.

<table>
<thead>
<tr>
<th>(p)</th>
<th>BP</th>
<th>LB</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1.03</td>
<td>1.22</td>
</tr>
<tr>
<td>8</td>
<td>2.98</td>
<td>3.40</td>
</tr>
<tr>
<td>12</td>
<td>5.38</td>
<td>6.37</td>
</tr>
</tbody>
</table>
The Box-Pierce (BP) and the Ljung-Box (LB) test statistic based on residual autocorrelations has been computed for s=4,8,12 and 16. A Lagrange Multiplier (LM) test has been carried out for the null hypothesis that υ_t in (3.1) has a constant variance against the alternative hypothesis that the disturbance has an autoregressive conditional heteroscedastic (ARCH) (see Engle (1982) and Weiss (1984)) structure of order 1 and 4 respectively. The values are reported in table 1 as η(1) and η(4). Finally, the normality has been checked using the test statistics S_1 and S_2 put forward by Lomnicki (1961). All test statistics yield insignificant values and we conclude that specification (3.1) with the normality assumption of υ_t provides a fairly good description of the income process.

We proceed by deriving the estimation equation for the model discussed in the previous section. In the first instance we ignore the implications of the structural changes in the drift parameter of the income process. When the change in income is generated by a moving average (MA) process of order 1

\[ Δy_t = δ + υ_t - θυ_{t-1} \]

the relevant conditional expectations of (2.22) satisfy

\[ y_{t+1} - E(y_{t+1} | I_t) = υ_{t+1} \]  (3.2)

\[ E(y_{t+1} | I_{t+1}) - E(y_{t+1} | I_t) = (1-θ)υ_{t+1}, \quad i ≥ 2 \]  (3.3)

\[ E(y_{t+T+1} | I_t) = y_t + (T+1)δ - θυ_t \]  (3.4)

Substituting of (3.2), (3.3) and (3.4) into (2.22) yields
The last term of (3.5) can be expressed as

\[ \eta^{-1}_T[(1-\theta)\eta + \theta] \nu_{c+1} \]

and after substitution of (3.6) into (3.5) we get

\[ \Delta c_{t+1} + \pi_{t+1} c_{c+1} = (1+r)\pi_{t+1} c_{c+1} + \gamma^{-1} \ln(\beta(1+r))(1-\eta^{-1}_T(1+r)^{T(T+1)}) \cdot r\lambda \nu_{t+1} + \]

\[ (1+r)\lambda \Delta \pi_{t+1} + \eta^{-1}_T(1+r)^T \delta + \eta^{-1}_T(1+r)^T \Delta y_{c+1} + \]

\[ \eta^{-1}_T(1+r)^T (y_{c} - c_{c}) + \eta^{-1}_T \eta^{-1}_T(1-\theta(1+r)^{-1}) \nu_{t+1} \]

Under the assumption that the changes in the drift parameter of the income process were not anticipated, the model for consumption (3.7) needs revision. Let us assume that the constant term \( \delta \) moves to \( \delta' \). Using the closed form solutions for \( c_t \) and \( c_{t+1} \) derived in section 2, it can be shown that the structural change in the income process will give rise to a step change in the consumption model (3.7) equal to

\[ \delta' - \delta \eta^{-1}_T[(1+r)\pi_{t+1} - (1+r)^T] \].

Therefore, both in 1971(1) and 1979(1) we should expect a negative adjustment in the drift parameter of the consumption model (3.7). Moreover, because the constant term in (3.7) depends on \( \delta' \), we have also a persistent change of the constant term of the consumption function. This completes the derivation of the estimation.
equation. In conclusion, we have

$$\Delta c_t + \pi c_t = \sum_{i=1}^{5} \beta_i \Delta \pi_{t-i} + \alpha_1 \pi_{t-1} c_{t-1} + \alpha_2 \pi_t + \alpha_3 \pi_t + \alpha_4 \Delta y_{t-1} + \alpha_5 (y_{t-1} - c_{t-1}) + \epsilon_t$$  \hspace{1cm} (3.8)

with $d_{1t} = 1$ for 1968(2)-1971(1)
$d_{2t} = 1$ for 1971(1)
$d_{3t} = 1$ for 1971(2)-1979(1)
$d_{4t} = 1$ for 1979(1)
$d_{5t} = 1$ for 1979(2)-1984(4).

The coefficients $\alpha_i$ given in expression (3.7) and for the $\beta_i$'s we have

$$\beta_1 = \gamma^{-1} \ln[\beta(1+r)](1-\eta_T^{-1}(1+r)^{-T}(T+1)) + \eta_T^{-1}(1+r)^{-T}T\delta_1$$

$$\beta_2 = (\delta_2 - \delta_1)\gamma^{-1}[(1+r)T_{T+1} - (1+r)^{-T}]$$

$$\beta_3 = \gamma^{-1} \ln[\beta(1+r)](1-\eta_T^{-1}(1+r)^{-T}(T+1)) + \eta_T^{-1}(1+r)^{-T}T\delta_2$$

$$\beta_4 = (\delta_3 - \delta_2)\gamma^{-1}[(1+r)T_{T+1} - (1+r)^{-T}]$$

$$\beta_5 = \gamma^{-1} \ln[\beta(1+r)](1-\eta_T^{-1}(1+r)^{-T}(T+1)) + \eta_T^{-1}(1+r)^{-T}T\delta_3,$$

with $\delta_i$ being the coefficient of $d_{1t}$ in the model (3.1) for income. The resulting consumption function is similar to the specification put forward by Hendry (1983), except for $\Delta \pi_{t-1}$. As the explanatory variables are correlated with the disturbance term $\epsilon_t$, the model (3.8) has been estimated by instrumental variables (IV). We impose the restriction $\alpha_4 = \alpha_5$ and use the five dummy variables, $\pi_{t-1} c_{t-1}$, $\pi_{t-1}$, $\Delta \pi_{t-1}$, $\Delta y_{t-1}$ and $y_{t-1} - c_{t-1}$ as instruments. For total consumption, the following estimates have been obtained

$$\beta_1 = 93.87 \ (2.60)$$
$$\beta_2 = -31.50 \ (1.67)$$
$$\beta_3 = 87.18 \ (2.16)$$
$$\beta_4 = -33.26 \ (1.75)$$
\[ \beta_5 = 83.51 \pm 1.95 \]
\[ \alpha_1 = -0.68 \pm 0.49 \]
\[ \alpha_2 = 0.76 \pm 0.18 \]
\[ \alpha_3 = -3.45 \pm 0.71 \]
\[ \alpha_4 = 0.57 \pm 2.49 \]
\[ \sigma^2(\varepsilon_t) = 1348.3 \]  

with t-values given between parentheses. The test statistics for model (3.8) are given in Table 2.

<table>
<thead>
<tr>
<th>p</th>
<th>BP</th>
<th>LB</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.88</td>
<td>0.92</td>
</tr>
<tr>
<td>8</td>
<td>10.62</td>
<td>11.10</td>
</tr>
<tr>
<td>12</td>
<td>14.19</td>
<td>14.85</td>
</tr>
<tr>
<td>16</td>
<td>23.10</td>
<td>24.17</td>
</tr>
<tr>
<td>\eta(1)</td>
<td>1.16</td>
<td></td>
</tr>
<tr>
<td>\eta(4)</td>
<td>3.34</td>
<td></td>
</tr>
<tr>
<td>S_1</td>
<td>-0.48</td>
<td></td>
</tr>
<tr>
<td>S_2</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td>PFCF(8,49)</td>
<td>0.94</td>
<td></td>
</tr>
<tr>
<td>SCE(1)</td>
<td>0.26</td>
<td>SCE(4)</td>
</tr>
<tr>
<td>SCEF(1,50)</td>
<td>0.21</td>
<td>SCEF(4,47)</td>
</tr>
<tr>
<td>SCW(1)</td>
<td>0.12</td>
<td>SCW(4)</td>
</tr>
<tr>
<td>SCWF(1,50)</td>
<td>0.17</td>
<td>SCWF(4,47)</td>
</tr>
<tr>
<td>CRW(1)</td>
<td>2.95</td>
<td></td>
</tr>
<tr>
<td>CRWF(1,56)</td>
<td>2.50</td>
<td></td>
</tr>
<tr>
<td>CRLM(1)</td>
<td>3.22</td>
<td></td>
</tr>
<tr>
<td>CRLMF(1,56)</td>
<td>2.87</td>
<td></td>
</tr>
</tbody>
</table>

The residuals do not exhibit any significant correlation. The values of the
BP and LB test statistic based on the first 4,8,12 and 16 residual autocorrelations are insignificant. Above we found that normality and homoscedasticity for $\Delta y_t$ do not have to be rejected. Given that income is normally distributed and homoscedastic, the theory predicts that the disturbance term $\varepsilon_t$ should follow a normally distributed and homoscedastic process. In Table 2 we report the test statistics for the ARCH structure and normality of $\varepsilon_t$ respectively. Both tests are insignificant, so we conclude that in this respect the empirical results are in accordance with the theory.

We have also carried out several tests put forward by Kiviet (1985) in the context of instrumental variables estimation, and we adopt his notation. The statistic PFCF tests for postsample predictive failure. It is based on predictions for the period 1983(1)-1984(4). Under the null hypothesis, it has an F(8,49)-distribution. SCE(p) and SCW(p) are LM- and Wald-type statistics which test for an AR(p) process for the residuals. They are asymptotically $\chi^2(p)$ distributed under the null hypothesis that the disturbances are white noise. We also computed their F-type versions, denoted by SCEF and SCWF with the number of degrees of freedom reported between brackets. As instruments we used the five dummy variables, $\Delta y_{t-5}$, $\Delta y_{t-6}$, $\Delta y_{t-7}$, $\pi_{t-5}$, $\pi_{t-6}$, $\pi_{t-7}$, $\Delta c_{t-5}$ and $\Delta c_{t-6}$.

Finally, the model (3.8) has been estimated without the restriction $a_4=a_5$. The point estimates are $\hat{a}_4=-.11$ (.22) and $\hat{a}_5=.56$ (2.33). Several test statistics for the equality between the regression coefficients have been computed. CRW(1) and CRLM(1) refer to the Wald- and LM-type test statistics, which are asymptotically $\chi^2(1)$ distributed. In Table 2 we mention also their F-type versions. All statistics yield insignificant values for the one-sided tests and we conclude that the distributional and serial correlation properties of the IV residuals and the predictive performance of the model (3.8) are very satisfactory.

Next we consider the point estimates. From expression (3.7) we deduce for the disturbance term $\varepsilon_t$

$$\varepsilon_t = \eta^{-1}(1+r)^{-1} T^{-1} [1+\delta(1+r)^{-1}]^{-1} \nu_{t+1}.$$

As $\hat{\delta}=.428$, we have as an implication of the theoretical model that the variance of $\varepsilon_t$ is smaller than that of the income innovation. A comparison
of the values reported in (3.1) and (3.9) shows that the estimates do not confirm the theory on this point. Using the point estimates of the δ's in (3.1), it can be shown that the sign of β₁, β₃ and β₅ depends on that of γ⁻¹ln[β(1+r)](1+η⁻¹(1+r)⁻¹(T+1)). However, the following inequality has to hold: β₁<β₃<β₅. This restriction is indeed satisfied by the point estimates of (3.9). For the appraisal of the step changes we have to keep in mind that d₀ and d₅ absorb the joint effect of the adjustment in the consumption level and the transformed income innovation. From (3.1) we have an estimate of the income innovation and the MA parameter. With this knowledge we can show that the coefficient of d₀ should be negative. This requirement is satisfied. Because the expected step change in the constant term and the estimate of the income innovation in 1979(1) have opposite signs, we can not determine a priori the sign of β₄. From (3.7) we infer that α₁ should satisfy 1<α₁<2, a result that is not satisfied. The t-value for the hypothesis H₀:α₁=1 is 1.21, which is insignificant. The coefficients α₂ and α₃ ought to be negative and positive respectively. This criterion is violated by the point estimates in (3.9). Notice however that the estimates are highly insignificant. Finally, the criterion that the coefficient for the error correction term should be positive and smaller than 1 is met. From the estimate of α₄ we may infer an estimate of T. Noting that

\[ a₄ = \eta⁻¹(r(1+r)⁻¹(T+1)-1),\]

it can easily be shown that T=α₄⁻¹-1. Using (3.9) we find for T the estimate 1.75 (2.49). Hence, the consumer takes into account information on the next 2.75 quarters when taking a decision about anticipated consumption. Notice that the estimate is significantly different from zero, so that we have an empirical confirmation that the consumer displays forward looking behaviour.

From the empirical analysis we conclude that the model describes the data not unsatisfactorily. The values of the diagnostic test statistics do not suggest the presence of misspecification. Notice that we do not find a significant effect for inflation and the change in inflation. The wrong signs of the estimates of the coefficients of the inflation variables leads to the conclusion that the information in the data does not unequivocally
confirm the theoretical model.

From the empirical results for real nondurable consumption per capita reported in appendix B, we infer that the model is misspecified. The test for the equality of the coefficients of the change in income and the error correction term is (marginally) significant. More important however, is that the estimates of the coefficients of the inflation variables have the wrong sign and, in contrast to the results obtained for total consumption, are significant. As we used the data on the price index of total consumption, a possible explanation might be the inappropriateness of the inflation series.
Section 4 Concluding remarks.

In this paper we analyzed the consumption model with moving planning horizon put forward by Palm and Winder (1987) extended for the effects of inflation. In line with Deaton (1977) we modelled the consumption decision as a two stage decision problem. In the first stage the consumer is assumed to take a decision about total anticipated expenditure, and conditional on this he determines in the second stage commodity demands. As a result of the difference between actual and anticipated prices, inflation variables appear in the consumption function.

In an empirical examination we estimated and tested the model with data for the Netherlands. In line with Lucas (1976) we paid attention to the implications of structural changes in the income process. The empirical analysis carried out in section 3 illustrated that structural breaks in the income process will lead to structural changes in the consumption function and showed how we obviate Hendry's (1979) criticism of ad-hoc introducing parameter changes. The empirical results were not indisputable confirmative for the theoretical model. From the estimation results obtained for real total consumption per capita, we concluded that the wrong signs of the estimates of the coefficients of the inflation variables cast some doubt on the appropriateness of the model. The insignificance of the estimates prevent us from rejecting the model. The empirical analysis carried out with real nondurable consumption per capita leads to the conclusion that the information in the data is in disagreement with the theoretical model. An explanation may be the fact that we estimated the model with quarterly data. Possibly, the length of the time span between two successive two stage decision problems casts some doubt on the appropriateness of the assumption that the anticipated inflation equals zero. A solution might be the incorporation of time aggregation effects (see e.g. Muellbauer (1986)). We showed how the assumption of rational expectations with respect to anticipated prices may be incorporated in the model. For the functional forms of the preference structure chosen in this paper, this will lead to a rather complicated estimation equation. As we wanted to relate our specification to the consumption function put forward by Davidson et al. (1978), we refrained from this possibility. It seems however not superfluous to investigate more realistic mechanisms for the anticipated prices. The extension towards preference orderings exhibiting
rational habit formation could be established without too many problems along the lines of Winder (1987b). Other possible extensions deal with relaxing the assumption of a constant real interest rate (which is clearly not supported by the data during the sample period) and, possibly along the lines of Hendry and Von Ungern-Sternberg (1981) and Pesaran and Evans (1984), taking into account the effects of inflation induced capital losses.
References.


defects in small samples", Journal of Econometrics, 28, 327-362.


Appendix A Sources of the data.

The data on income, total consumption and inflation have kindly been provided by the Centraal Planbureau, 's-Gravenhage. The quarterly series on nondurable consumption per capita in prices of 1980 has been computed as the sum of consumption expenditures per capita on food and beverages and services and other nondurables. Monthly indices on these series and on total consumption expenditures are published in Centraal Bureau voor de Statistiek, Maandstatistiek Binnenlandse Handel en Dienstverlening, Staatsuitgevery, 's-Gravenhage. Annual figures on expenditures which are published in Centraal Bureau voor de Statistiek, Nationale rekeningen, Staatsuitgevery, 's-Gravenhage, have been used to transform the indices into monthly expenditures per capita expressed in prices of 1980. The monthly figures have been aggregated into quarterly data. To remove the seasonal pattern in the ratio of nondurable and total consumption, we have calculated the nondurable consumption shares as a moving average of the ratio's.
Appendix B Empirical results for real nondurable consumption.

In this appendix we present estimation results for real nondurable consumption. The numbers of the expressions and the table correspond to those used in the main text. A prime refers to nondurable consumption. With respect to the evaluation of the sign and size of the parameter estimates we refer to the discussion of section 3.

\[
\begin{align*}
\beta_1 &= -160.39 \ (3.55) \\
\beta_2 &= -51.09 \ (2.06) \\
\beta_3 &= -192.49 \ (3.86) \\
\beta_4 &= -13.98 \ (0.53) \\
\beta_5 &= -168.95 \ (4.12) \\
\alpha_1 &= -6.45 \ (3.29) \\
\alpha_2 &= 16.20 \ (3.88) \\
\alpha_3 &= -16.59 \ (3.32) \\
\alpha_4 &= 0.29 \ (4.13) \\
\sigma^2(e_t) &= 516.8
\end{align*}
\]

(3.9)'

Table 2' Test statistics of model (3.8)'.

<table>
<thead>
<tr>
<th>p</th>
<th>BF</th>
<th>LB</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>3.40</td>
<td>3.56</td>
</tr>
<tr>
<td>8</td>
<td>8.36</td>
<td>8.74</td>
</tr>
<tr>
<td>12</td>
<td>12.14</td>
<td>12.71</td>
</tr>
<tr>
<td>16</td>
<td>22.59</td>
<td>23.63</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$\eta(1)$</th>
<th>S1</th>
<th>S2</th>
<th>PFCF(8,49)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.72</td>
<td>.28</td>
<td>.21</td>
<td>.23</td>
</tr>
</tbody>
</table>
When the restriction $\sigma_4 = \sigma_5$ is not imposed, the IV estimates for $\sigma_4$ and $\sigma_5$ are $\hat{\sigma}_4 = -.21(.74)$ and $\hat{\sigma}_5 = .28(3.63)$. The test statistics for the hypothesis $H_0: \sigma_4 = \sigma_5$ are significant at a 5% level, but not at a significance level of .025.

The inequality between the variances in (3.9)' and (3.1), $\sigma^2_e < \sigma^2_u$, is satisfied. The restrictions $\beta_2 < 0$ and $0 < \alpha_4 < 1$ are again satisfied by the point estimates. From $\hat{\alpha}_4$ we infer an estimate of $T$: $3.48(4.13)$. The restrictions $\beta_3 < \beta_2 < \beta_1$, $1 < \alpha_1 < 2$, $\alpha_2 < 0$ and $0 < \alpha_3$ are violated. Because of the significance of the estimates the model has to be rejected.
1986-48 I. Evers, M. Fischer
P. Nijkamp
A cross-national comparative analysis of regional labour markets

1986-49 E.J. Develaar
P. Nijkamp
Spatial dispersion of technological innovation: the incubator hypothesis

1986-50 W. Barentsen
P. Nijkamp
Modelling non-linear processes in time and space

1986-51 P. Nijkamp
A. Reggiani
Analysis of dynamic spatial interaction models by means of optimal control

1986-52 J. de Groot
Landhervorming in de suikersector

1986-53 H. Clemens
Modernisering van de landbouw in socialistische perifere economieën

1986-54 A.J. Vermaat
Groepsvorming bij rationeel gedrag

1986-48 A. Steyn
A. F. de Vos

1987-4 E. Eeftink
D. Korf
Transforming the trade and industrialization regime in developing countries

1987-5 Pitou van Dijck
Transforming the trade and industrialization regime in developing countries

1987-6 Pitou van Dijck
The strong factor-intensity assumption reconsidered

1987-7 H. Visser
The gains from trade for developing countries reconsidered

1987-8 H. Visser
Macroeconomische aspecten van bedrijfs-economisch toezicht

1987-9 J. de Groot
H. Clemens
Stabiliseringen in de jaarrekening: verslag van een empirisch onderzoek

1987-10 J. de Groot
H. Clemens
Agrarian labour market and technology under different regimes: A comparison of cuba and the Dominican Republic

1987-11 J. Steyn
A. F. de Vos
Structural time series models for trends

1987-12 J.P. de Groot
Collective Rice-Farms in the Dominican Republic

1987-13 R.W. Veldhuizen
Valuta Management en Management Control

1987-14 J. Koelewijn
De achtergronden van het verdwijnen van de zelfstandige hypotheekbanken in de jaren tachtig

1987-15 H.C. Tijms
A quick and practical approximation to the waiting time distribution in the multi-server queue with priorities

1987-16 H.C. Tijms
Educatieve Operations Research Software: Wis en Waarschijnlijk

1987-17 P.C. Palm and C.C.A. Rinder
The life cycle consumption model under structural changes in income and moving planning horizons

1987-18 H.J. Bierens
Basic probability theory

1987-19 H.J. Bierens
Convergence

1987-20 H.J. Bierens
Introduction to conditioning

1987-21 H.J. Bierens
Nonlinear parametric regression analysis

1987-22 H.J. Bierens
Tests for model misspecification

1987-23 T. van der Meer
New perspective on price indices

1987-24 S. Flejteraki
Theoretische Aspecten van de Exportdiversificatie

1987-25 J. Rouwendal
A note on discrete choice under uncertainty

1987-26 P.H.M. Ruys and G. van der Laan
Computation of an industrial equilibrium

1987-27 H.G. Eijgenhuijsen
J. Koelewijn
H. Visser
Groeibeïnvloedende factoren en de rol van financiële instellingen bij de financiering van investeringen

1987-28 J.C.H. van Ommeren
Asymptotically exponential expansion for the waiting time probability in the single server queue with batch arrivals

1987-29 R.D. Nobel
Practical approximations for finite-buffer queuing models with batch-arrivals

1987-30 H. Linnemann
C. van Beers
Measures of export-import similarity, and the linder hypothesis once again

1987-31 W. van Lierop
H. de Neef
Dynamic Analyses with loglinear and disaggregate choice models