ANO 2003/1

Oslo
February 6, 2003

Working Paper

Research Department

Age structure effects and consumption in Norway, 1968(3) – 1998(4)

by

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ISSN 0801-2504
ISBN 82-7553-208-6

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Solveig Erlandsen

Abstract

In this paper the effects of a changing age distribution on aggregate consumption are analysed. This is done by estimating a Norwegian consumption function which controls for age structure effects. The model is estimated on quarterly time series data from 1968(3) to 1998(4). The results show that changes in the age composition affect aggregate consumption significantly, giving support to the predictions of the Life Cycle Hypothesis that young adults and old persons have a higher average propensity to consume than the middle-aged. The consumption model encompasses a model which does not control for age composition effects.

Keywords: *Demography, consumption, time series models.*

JEL classification: *C22, E21, J1.*

*This paper is a revised version of my Master dissertation at the University of Oslo. Comments and suggestions from my supervisor, Ragnar Nymoen, are gratefully acknowledged. I would also like to thank Farooq Akram, Gunnar Bårdsen, Ida Wolden Bache, Øyvind Eitrheim, Michael Riis Jacobsen, Terje Skjerpen, Ingvild Svendsen and Fredrik Wulfsberg for valuable comments on econometric issues and computer software. Comments from seminar participants at two seminars in Norges Bank are also gratefully acknowledged. The work on this dissertation has been done during my student internship in Research Department, Norges Bank. In addition to financial support, Norges Bank has also provided excellent working conditions. The views expressed are those of the author and should not be interpreted as reflecting those of Norges Bank.

1 Introduction

Economic theory predicts that the age composition of the population affects macroeconomic variables. The Life Cycle Hypothesis (LCH),[1] for instance, suggests that an individual's consumption and saving decisions are dependent upon the individual's age. This follows from the consumption smoothing assumption of the theory, which implies that an individual borrows when young, saves as middle-aged, and dissaves when old. And, since aggregate consumption is the sum of all the individuals' consumption, the age composition of the population is thus expected to influence aggregate consumption.[2]

In this paper I investigate empirically whether changes in the age structure of the population affect Norwegian aggregate consumption. Like many other Western countries, Norway experienced low birth rates in the 1930s and a baby boom in the 25 years following World War II. As a result, the age composition of the Norwegian population have exhibited large variations over the last decades, making it possible to identify potential age structure effects.

The effects of a changing age distribution on consumption are investigated by introducing an age structure variable in a consumption function. The age structure variable is a modified version of the variable suggested by McMillan and Baesel (1990). It is constructed as the number of persons in age groups which are expected to have low propensity to consume to the number of persons in age groups which are expected to have high propensity to consume. Hence, the variable can be considered as a life cycle measure. To estimate the consumption model the Johansen method is applied to investigate whether a single-equation method can estimate the consumption model efficiently. Then, as it turns out that it can, the consumption function is modelled and estimated by a single-equation method. All the estimations are based on quarterly time series data from 1968(3) to 1998(4).

Despite the theoretical prediction that changes in the age composition of the population can affect consumption, demographic changes are not often taken into account in empirical consumption studies. On Norwegian data, Frøiland (1999) is one of few studies that includes a demographic variable in an empirical consumption function. By applying quarterly data for the period 1967(3)-1997(3), he finds significant short-run effects of changes in the age structure on aggregate non-housing consumption. Other studies have investigated the consumption behaviour of different socio-economic groups by using Norwegian time series data. For instance, Magnussen (1994) finds that there are considerably differences between the income elasticities of pensioners and workers, while Brubakk (1994) reports that the properties of an empirical consumption model for non-durables and services improve when the income growth of wage-earners and self-employed workers enter as regressors. Brubakk's (1994) study is not directly related to age composition effects. Its starting point is nevertheless similar to the one in this paper, namely that since consumers are heterogeneous, changes in the composition of the different groups of consumers may affect aggregate consumption.

The number of empirical studies which takes into account age structure effects on aggregate consumption is also relatively small on international data.[3] Among these is Berg (1996),

[1] Modigliani and Brumberg (1954, 1979) and Ando and Modigliani (1963).

[2] This argument must, however, not always hold, as changes in the age structure of the population also can effect other equilibrating mechanisms in the economy. As noted by Easterlin (1987), a large cohort size can, for instance, reduce the real wage for the members of the cohort, as increased competition for jobs generates a downward pressure on real wages.

[3] The impact of changes in the age composition of the population on other macroeconomic variables than consumption have been reported in several studies. McMillan and Baesel (1990) investigate for instance age composition effects on GDP, inflation, unemployment, and real interest rates on U.S. data, while Malmberg and Lindh (2000) examine age composition effects on the Swedish saving rate, investment rate, current account,

who investigates the relationship between the population age distribution and consumption on Swedish annual data from 1950 to 1995. He concludes that different age shares of the population have significant effects on the demand for 'pure consumption',[4] and reports that the estimated coefficients of the different age shares variables are consistent with the predictions of the LCH. Fair and Dominguez (1991) study the effects of a changing age composition on U.S. consumption data. Using quarterly data from 1954 to 1988 they find strong support for the hypothesis that the age structure of the population affects aggregate consumption. The pattern of the age coefficients Fair and Dominguez (op. cit.) report is in line with the predictions of the LCH.[5] Heien (1972), who estimates a multiperiod consumption function on annual U.S. data from 1948 to 1965, also reports a significant relationship between the age structure of the population and consumption of non-durables and services. However, his results contradicts those of Fair and Dominguez (1991).[6] Not all studies find significant age composition effects. Denton and Spencer (1976) is an example of this. By using both Canadian times series data and cross-section data for 21 OECD countries, Denton and Spencer (op. cit.) find that neither the average household size nor the age distribution of the population influence consumption significantly.[7]

The remainder of the paper is organized as follows. The theoretical background for introducing age structure effects in an aggregate consumption function is presented in Section 2. In Section 3 the empirical methodology is described, while data are presented in Section 4. A Norwegian consumption model which controls for age structure effects is then modelled and estimated in Section 5. Section 6 concludes.

2 Theoretical background

Several theories predict that demographic factors affect aggregate consumption. The Life Cycle Hypothesis (LCH), first developed by Modigliani and Brumberg (1954, 1979) and later extended by Ando and Modigliani (1963), is by far the most influential one of these, and the focus here will be on this theory. The LCH is presented below.

2.1 The Life Cycle Hypothesis

The LCH shares many common features with Friedman's (1957) Permanent Income Hypothesis (PIH). The key idea of both theories is that an individual uses saving and borrowing to smooth the path of consumption over the life cycle. There is, however, an important difference between the two theories, namely that the LCH by explicitly recognizing the finite lives of individuals can, as its name implies, deal with the changes in income and consumption "needs" that usually occur over an individual's life cycle. In general one can also say that the focus in the LCH and PIH differs; the LCH emphasises the role of age and asset accumulation as determinants of consumption, while the PIH is more concerned with the measurement links

GDP and inflation.

[4]See Berg (op. cit.) for a definition of the pure consumption concept.

[5]Their results are robust and unambigious for service consumption, nondurable consumption and housing investment, while the results for durable expenditures are mixed.

[6]More specifically, Heien (op. cit.) finds that consumption expenditures rise as the median age of the population above 24 years of age rises.

[7]The differences in the findings of these studies may be due to the way the age composition effects are modelled in the consumption functions. This issue is discussed in more detail in Section 3.2.

between current and permanent income.[8] The LCH as well as the PIH are based on utility maximizing consumers who face an intertemporal choice between consumption and saving. By assuming the existence of perfect capital markets the consumer choice theory provides a rationale for a decoupling of the time-pattern of earnings and assets from the desired pattern of consumption. This microeconomic basis of the theories is briefly presented below,[9] before the special characteristics of the LCH is outlined.

Consider a utility maximizing individual who lives for L periods, and who receives utility only from present and future consumption.[10] For simplicity the individual's subjective discount rate is set to zero. The individual's utility function is assumed to be separable, and hence it can be expressed as

$$U = \sum_{t=1}^{L} u(c_t), \quad u'(\cdot) > 0, \quad u''(\cdot) < 0, \tag{2.1}$$

where $u(\cdot)$ denotes the instantaneous utility function, i.e. the felicity function, and c_t is consumption in period t. Assume that the individual earns income, y, in the L periods of her life, and that a_0 denotes the individual's initial wealth. The individual takes both income and wealth as given. Capital markets are assumed to be perfect, and the interest rate is for simplicity set to zero. The individual's intertemporal budget constraint is thus

$$\sum_{t=1}^{L} c_t = a_0 + \sum_{t=1}^{L} y_t. \tag{2.2}$$

Given the utility function and the intertemporal budget constraint, the Lagrangian for the individual's maximization problem is

$$L = \sum_{t=1}^{L} u(c_t) + \lambda \left(a_0 + \sum_{t=1}^{L} y_t - \sum_{t=1}^{L} c_t \right), \tag{2.3}$$

and, hence, the first-order condition for c_t is

$$u'(c_t) = \lambda. \tag{2.4}$$

Two points are worth noting in equation (2.4). First, that the Lagrange-multiplier, λ, is constant over time, and second, that the marginal utility of consumption is a function only of current consumption. Thus, since the marginal utility of consumption is constant over time, this implies that also consumption must be constant, i.e. $c_1 = c_2 = ... = c_L$. Given this, equation (2.2) can be rewritten to

$$c_t = \frac{1}{L} \left(a_0 + \sum_{\tau=1}^{L} y_\tau \right) \quad \text{for all t}, \tag{2.5}$$

where the term in the parentheses is the individual's total lifetime resources. Equation (2.5) states thus that consumption in any period t is not dependent on the income earned in that

[8] The two theories can thus be seen as complements rather than substitutes to each other.
[9] This presentation is in large based on Romer (1996).
[10] The individual is assumed not to receive or leave any bequest.

period, but on total lifetime resources. Furthermore, it shows that the individual divide consumption equally between the periods.

Based on this microeconomic theory, the LCH emphasizes the role of age and wealth as determinants of consumption. The following example of the basic, or "stripped down" version of the LCH, given in Modigliani and Brumberg (1954), can illustrate this. Consider an individual who lives for 50 years, L = 50, of which she earns income in the first 40 years and is retired in the last 10 years. The income profile is flat over the earning span, and the income earned each year is denoted by y. The individual has no initial wealth, she leaves no bequest, and interest rates are set to zero. Under the assumption that consumption is constant over the life cycle, the individual will then consume $\frac{1}{L} = \frac{1}{50}$ of her total lifetime income each year. Consequently, the individual will accumulate wealth over the earning span. At the time of retirement wealth is at its peak, consisting of 20 per cent of total lifetime income. Thereafter, during the retirement years the wealth gradually decreases as the individual consumes out of it, reaching zero at the end of her life. Two important features of the LCH can be illustrated by this example. First, that the marginal propensity to consume (MPC) out of income depends on the individual's age. If an unexpected and temporary additional income unit, Δy, is earned in the first year the individual lives, consumption in this year (and in the following years) will increase by $\frac{1}{50}$ of Δy. If, on the other hand, the temporary income shock occurs when the individual is at age 35, the MPC will be $\frac{1}{16}$. Second, that wealth has an important role in determining consumption.

In this version of the LCH both the income stream and the consumption level are assumed to be constant, and known with certainty, over the earning and life spans, respectively. As demonstrated by Modigliani and Brumberg (1979) this assumption as well as other simplifying assumptions of the "stripped down" version can be replaced by more realistic ones. As pointed out by, among others, Modigliani (1986), labour income is far from being constant over the earning span in average. Rather it tends to increase with experience, reaching its peak either some time before or at the time of retirement. Thereafter it falls as a consequence of retirement. Also consumption varies usually with age. Different "needs" over the life cycle, for instance because of changes in the family size, is a major reason for this. The life cycle of the family size appears to have a hump-shaped profile, peaking somewhat earlier than income. Rødseth (1992) notes that the concept of consumption smoothing in the LCH hence could be interpreted as consumption relative to "needs" rather than to the level of consumption.

Allowing income to vary over the life cycle may imply that young workers save less than the middle-aged. This is due to that young workers have lower average income than the middle-aged, at the same time as their "needs" are larger because of "home building" and relatively large family sizes. For the retired persons, both versions of the model predict that they are to dissave.

So far the implications of the LCH for the consumption behaviour of an individual, or a household, have been described. Based on the derivation in Ando and Modigliani (1963), a way to aggregate the consumption function over the population is now presented. Given that the utility function of an individual is homogeneous with respect to consumption at different points in time, the consumption function for an individual at age T can be written as a proportional function of the individual's lifetime resources[11]

$$c_t^T = k_t^T v_t^T, \tag{2.6}$$

where c still denotes consumption, k is the proportionality factor, v is the present value of

[11] Given that capital markets still are assumed to be perfect.

the individual's total lifetime resources, subscript t denotes the time period, and superscript T denotes the age of the individual. Relaxing the previous assumption about the real interest rate, r, being zero, the proportionality factor k_t^T depends, in addition to the individual's age, on the utility function U and on r. The present value of total lifetime resources for an individual at age T in period t, v_t^T, can be expressed as

$$v_t^T = a_{t-1}^T + y_t^T + \sum_{\tau=T+1}^{N} \frac{y_t^{eT\tau}}{(1+r)^{\tau-T}}, \tag{2.7}$$

where a_{t-1}^T denotes the sum of net wealth carried over from the previous period, y_t^T denotes time t labour income, $y_t^{eT\tau}$ denotes the labour income the individual at age T expects at time t to earn at age τ,[12] and the period from T to N denotes the remaining years of the individual's earning span. The real interest rate r is assumed to remain constant over time.

The concept of 'average annual expected income', y_t^{eT}, is a useful one in this connection, and it can be defined in the following way

$$y_t^{eT} = \frac{1}{N-T} \sum_{\tau=T+1}^{N} \frac{y_t^{eT\tau}}{(1+r)^{\tau-T}}. \tag{2.8}$$

Given equations (2.7) and (2.8), equation (2.6) can then be rewritten as

$$c_t^T = k_t^T y_t^T + k_t^T (N - \mathrm{T}) y_t^{eT} + k_t^T a_{t-1}^T \tag{2.9}$$

If all the individuals in a given age group T have the same proportionality factor, k_t^T, aggregate consumption for age group T can be expressed as

$$C_t^T = k_t^T Y_t^T + k_t^T (N - \mathrm{T}) Y_t^{eT} + k_t^T A_{t-1}^T \tag{2.10}$$

where C_t^T, Y_t^T, Y_t^{eT} and A_{t-1}^T denote the aggregates for age group T of c_t^T, y_t^T, y_t^{eT}, and a_{t-1}^T, respectively. An aggregate consumption function over all the age groups can then be represented by

$$C_t = \alpha_1 Y_t + \alpha_2 Y_t^e + \alpha_3 A_{t-1}, \tag{2.11}$$

where C_t, Y_t, Y_t^e and A_{t-1} are aggregates of the corresponding variables in (2.10). The coefficients α_1, α_2 and α_3 can be regarded as weighted averages of the age specific coefficients. To ensure that these coefficients are stable over time Ando and Modigliani (1963) assume constancy over time in the parameters for every age group, in the age structure of the population and in the relative distribution of income, expected income and of net wealth over the age groups.

Expected income enters the aggregate consumption function in (2.11) as one of the explanatory variables. This variable is generally not observable, and hence it is not well-suited for estimation purposes. Ando and Modigliani (1963) suggest, however, that expected income can be expressed, among other candidates, as a function of current income

$$Y_t^e = \beta Y_t. \tag{2.12}$$

[12] Even though expected income enters the equation, the individual is assumed to know her future income with certainty.

Substituting this function into equation (2.11) gives the following expression for aggregate consumption

$$C_t = (\alpha_1 + \beta\alpha_2)Y_t + \alpha_3 A_{t-1} = aY_t + \alpha_3 A_{t-1} \tag{2.13}$$

where $a = \alpha_1 + \beta\alpha_2$. Equation (2.13) expresses aggregate consumption as a function of current income and wealth, with the parameters depending on age.

In the next section the empirical consumption function which forms the basis for the estimations is presented. Before this is presented, it is important to note that the aggregate consumption function given in equation (2.13) is not appropriate to use in its pure form in this paper. The reason for this is that, as mentioned above, this equation is based on the assumption of an unchanged population age structure over time. Since the purpose of this study is to investigate whether changes in the age structure of the population affect aggregate consumption, this assumption is thus expected to be violated.

3 Empirical methodology

In this section the empirical approach used in this paper is described. First, in Section 3.1 the empirical consumption function which forms the basis for the analysis is presented. Then, in Section 3.2, the way changes in the age structure of the population enters this empirical consumption function is shown. A brief overview of the literature on this subject is also presented in this section.

3.1 Empirical consumption function

Brodin and Nymoen (1992) find evidence of a cointegrating relationship between consumption, households' real disposable income and households' wealth (in real terms) on Norwegian data. Furthermore, they report that income and wealth are weakly exogenous in this relationship, and hence that the following long-run relationship can be interpreted as a consumption function

$$c_t = constant + 0.56y_t + 0.27w_t. \tag{3.1}$$

In the equation, c_t denotes log of total consumption expenditures, y_t log of households' real disposable income, w_t log of households' real wealth, while the coefficients 0.56 and 0.27 denotes the income and wealth elasticities with respect to consumption, respectively. As before, the subscript t denotes the time period. The findings of Brodin and Nymoen (1992) that changes in both income and wealth explain changes in consumption are in line with the predictions of the LCH.[13]

Equation (3.1) forms the starting point for the empirical analysis in this paper. More specifically, an age structure variable is introduced to this long-run relationship. Thereafter, an equilibrium correction model (EqCM), which includes both this long-run relationship and short-run dynamics, is formulated. The way changes in the age structure of the population is captured in the regression model is presented in the next sub-section, while Section 5 presents the modelling procedure and the estimation results.

[13] Cf. Section 2.

3.2 Modelling age composition effects

There are several ways to incorporate age composition effects in a regression model. One way could be to include all the shares of one-year age cohorts simultaneously in the regression model, which would yield almost a full representation of the population age composition. As the different age shares are highly multicollinear, this approach would have problems in identifying the individual age coefficients. In its pure form this approach is therefore seldom used in the literature.

Fair and Dominguez (1991) have, however, a similar starting point. They include 55 different shares of one-year age groups, the age groups from 16 to 70 years old, in an empirical consumption function on US data. Then, to bypass the multicollinearity problem, they impose two restrictions on the age group coefficients. First, that the age group coefficients sum to zero, and second, that the coefficients can be described by a second-degree polynomial. A weakness with this approach is, however, that the latter restriction may be too strict to be accepted by data. As pointed out by Malmberg and Lindh (2000), the fairly sudden change of behaviour that takes place when workers retire can be difficult to fit in with the polynomial restriction.

Another variation of this approach is to divide the population into aggregated age share groups, where the different groups reflect important phases of an individual's economic life cycle. Berg (1996) divides the population into the four age share groups: children and youngsters (0-19 years old), young adults (20-44 years old), middle-aged (45-64 years old) and old (above 64 years of age). Multicollinearity can also be a problem with this approach, although to a lesser degree than for the one-year age cohorts. To avoid multicollinearity Berg (op. cit.) includes the age share groups seperately in four different regression models. Malmberg and Lindh (2000), who also use this approach, include, on the contrary, all their six age share groups simultaneously in the regression model but leave the constant term out.[14]

A different approach for taking account of changes in the age structure in a regression model is to represent demographic changes by a single age measure. An example of such a measure is the median age of the adult population used by Heien (1972), while the average age of children used by Denton and Spencer (1976) is another example. This approach avoids the multicollinearity problem. A weakness with it is, however, that these measures only contain partial information of the age structure of the population.

A combination of the latter two approaches is another method which has been used extensively in the literature. This method uses a single measure, which is made up by combining different age share groups. An example of such a measure is the dependency rate,[15] where the dependency rate is defined as the share of the non-working population to the total population. Another example is the "life cycle" measure suggested by McMillan and Baesel (1990).[16] This measure, which is used in a modified version in this paper, is the ratio of middle-aged adults to the rest of the adult population. The motivation behind this measure is to separate the age groups which are expected, from the view of the LCH, to have a low average propensity to consume (APC) (numerator) from the age groups which are expected to have a relative high APC (denominator). Accordingly, consumption is expected to decrease when this measure increases.

The dependency rate and the "life-cycle" measure give a more complete representation of

[14] Another solution for avoiding the multicollinearity problem could be to include the constant term but leave one of the age share groups out.

[15] Leff (1969) is an early reference where this measure is used.

[16] Also Lenehan (1996) uses this measure.

the age structure of the population than for instance the median age measure, but still avoid the multicollinearity problem. The drawback of it is that the coefficients of the different age share groups are restricted relative to each other. The validity of the restriction is however testable.

As noted in Section 3.1, the age structure variable is introduced in a Brodin and Nymoen (1992) consumption function. The coefficient of the age variable will measure the impact of changes in the age structure of the population on the aggregate APC.

4 Data

The data used in the empirical analysis are presented in this section. All the time series are quarterly, none are seasonally adjusted, and they cover the period from 1967(2) to 1998(4). Because of the presence of lags in the empirical consumption function, the estimation period is from 1968(3) to 1998(4). The economic time series are from Norges Bank's database, RIMINI,[17] while the age composition variables are from Statistics Norway's KVARTS database. The sources of the original data, together with the variable definitions, are provided in Appendix A. In the remainder of the dissertation, lower case letters denote the logarithmic values of the corresponding capital letter variables.

In Section 4.1 the time series for the economic variables consumption, income and wealth are presented, while the time series for the variables used in constructing the age structure variable is described in Section 4.2.

4.1 Economic time series

Consumption, C, is defined as total private consumption expenditures and includes both durable and non-durable goods in addition to services. The variable is measured in million NOK in 1996 prices. Households' real disposable income, Y, consists of both labour income and other income, while households' real wealth, W, is the sum of households housing and financial capital. Both nominal income and nominal wealth are deflated by the implicit deflator of consumption ($1996 = 1$).

In Figure 1 the time series of the logarithmic values of consumption, income and wealth are plotted over the sample period, in addition to the saving rate (approximated by $y - c$). The three first panels in Figure 1 show that c, y and w are increasing over the sample period, indicating that they are generated from non-stationary processes. The augmented Dickey-Fuller (ADF) test provides a more formal test of the time series properties of the variables, and the results from this test are reported in Table 1. The ADF test statistic is denoted τ in the table. None of the test statistics reported are lower than the critical values, and hence the null hypothesis of unit roots in the series are accepted at a 1% significance level for all the three series. Presence of residual autocorrelation could not be rejected in the ADF regression for consumption. Hence, the test result for this variable should be interpreted with caution. It is also worth noting that the time series property of the income variable is consistent with the assumption made in Section 2 about expected future income being a function of current income. The I(1) property of the variable implies that a shock in current income propagates into future income, and hence this should be captured by the expectations.

The last panel in Figure 1 plots the saving rate. It shows that the saving rate have fluctuated over the last decades.

[17] The data is taken from the spring 2000 database.

Figure 1: Time series of consumption, income, wealth (in logs) and the saving rate

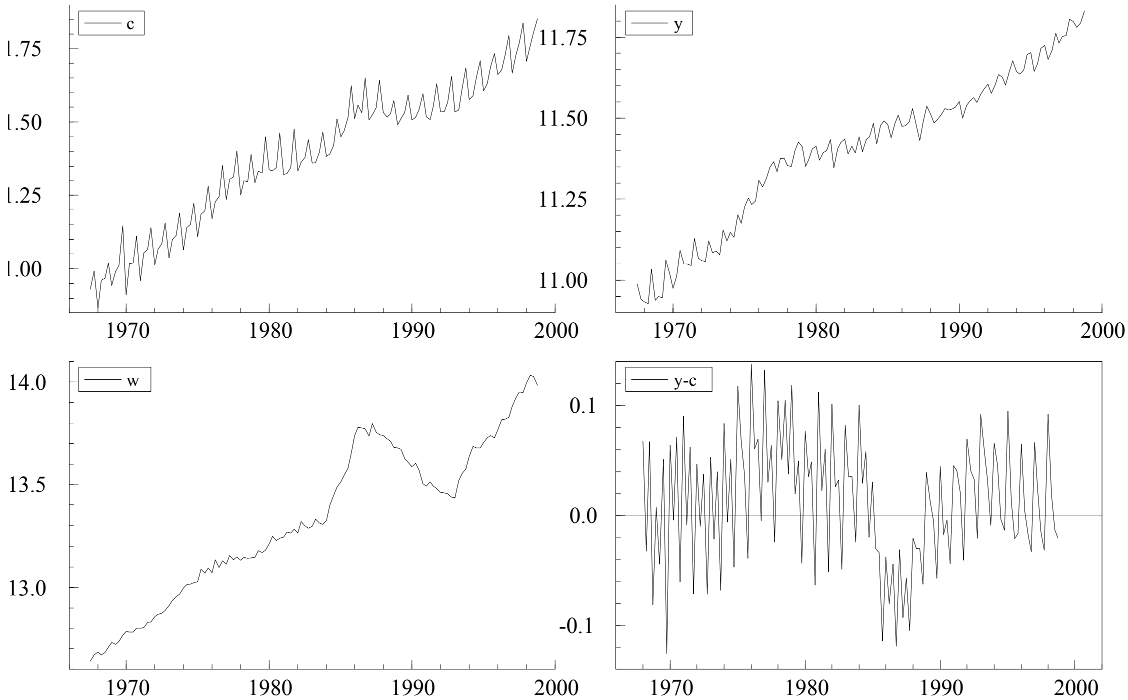


Table 1: ADF tests of consumption, income and wealth

Variable	Lags	τ
c	5	-2.42
y	4	-1.54
w	4	-3.43

A constant and a trend were included in the regressions. Critical values: –4.04 (1%) and –3.45 (5%) (taken from Hamilton (1994)).

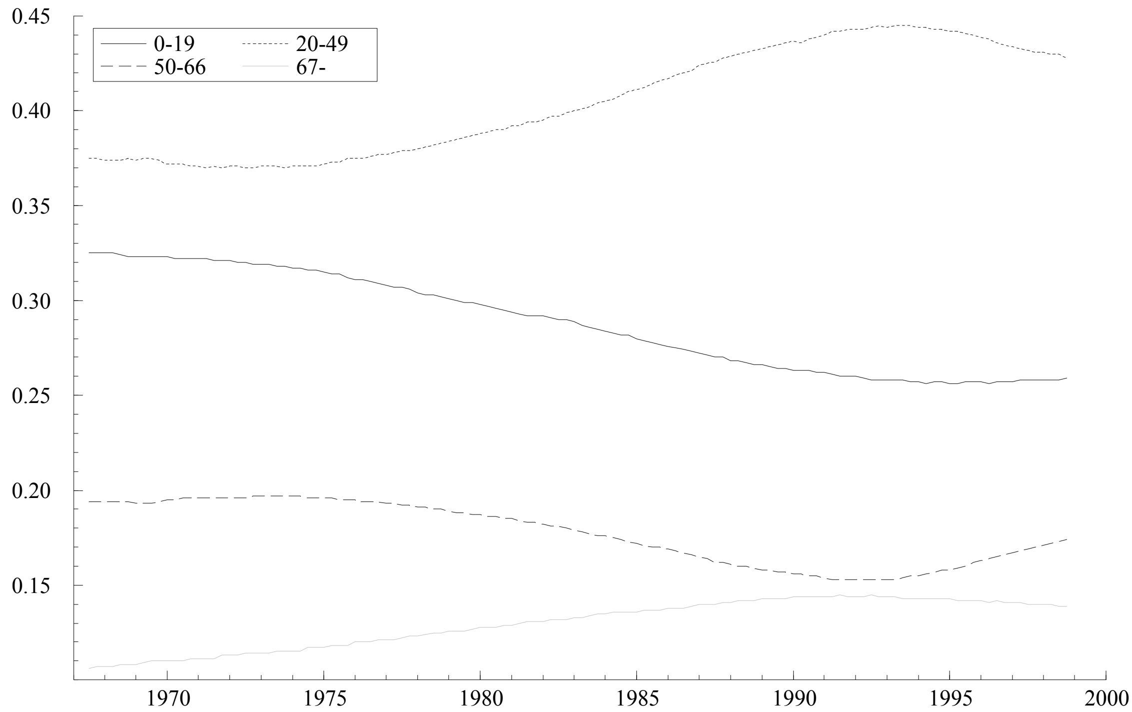
4.2 Demographic time series

Based on economic theory and preliminary estimations the population have been divided into four age groups: 0-19 years old, 20-49 years old, 50-66 years old and above 66 years old. The former group consists of children and youths, and the individuals in this group are expected to be economic dependent in average. The age group with the 20 to 49 years old is expected to earn less in average than those in the 50-66 years old group. At the same time the consumption "needs" are large for the 20-49 years old; new homes are being established and hence the purchases of durable goods are expected to be large, and the family size is usually large. Accordingly, a large part of the individuals in this group is expected to be net lenders. On the contrary, the average of the individuals in the age group from 50 to 66 years old is expected to be in a net wealth position. For this group income is relatively high, consumer durables have been acquired and the children are no longer economic dependent. At the same time, the individuals in the age group may save for retirement. The age group with individuals

Table 2: Correlation matrix for the age share groups, 1968(3)-1998(4).

	0-19	20-49	50-66	67-
0-19	1.000	-0.984	0.953	-0.979
20-49	-0.985	1.000	-0.984	0.953
50-66	0.953	-0.984	1.000	-0.947
67-	-0.979	0.954	-0.947	1.000

Figure 2: Shares of the population in different age groups



aged 67 and older consists mainly of retired persons.

Whether this aggregation of the age share groups is the most appropriate one can be discussed. In particular, whether the age group of individuals between 40 and 49 years old should be included in the "net lender" group or the "net wealth" group. McMillan and Baesel (1996) included for instance the individuals between 35 and 49 years in the latter group, whereas Berg (1996) included those from 40 to 44 in the "net lender" group, and the individuals between 45 and 49 in the "net wealth" group. Preliminary estimations on the Norwegian data suggest, however, that the average consumption behaviour for those aged between 40 and 49 is more similar to the "net lender" group than to the "net wealth" group.

The developments of the population shares of the four age groups over the sample period are depicted in Figure 2. A striking feature of the figure is the sharp increase in the share of the population between 20 and 49 years old from the mid-1970s to the beginning of the 1990s; from 37 percent of the population in 1975(1) to 45 percent in 1993(4). This increase is due to the "baby boom" in the period from 1946 to 1970. Accordingly, as the "baby boomers" now are turning middle-aged, the share of the 20-49 age group is declining at the same time as the share of the 50-66 years old individuals is increasing.

The age share groups are highly correlated with each other, cf. the correlation matrix for the groups in Table 2. The table shows that the age groups 0-19 and 50-66 are positively correlated with each other and negatively correlated with the age groups 20-49 and 67-.

5 Modelling consumption including an age structure variable

5.1 Long-run consumption functions including age share variables

As a starting point for the modelling procedure, it is first investigated whether the different age share groups presented in Section 4.2 have significant effects on consumption. The purpose of doing this is twofold. First, to get an early indication of the fruitfulness of modelling age structure effects in the consumption function. And, second, the age share coefficients can add information about how to compose the "best" age structure variable. This issue will be discussed in more detail in the next section.

In a similar manner to what Berg (1996) does, the (logs of) the four age share groups are included separately in four different static long-run consumption regressions. The reason for including the age share groups separately in the regressions is to avoid multicollinearity problems.[18] The consumption models are estimated by OLS, and the estimation period is from 1968(3) to 1998(4). The estimation results are presented in Table 3.[19,20]

The (logs of the) age share variables are denoted by *share* 0-19, *share* 20-49, *share* 50-66 and *share* 67-, and, as shown in the table, all the age share coefficients are significant on a 1% level. Furthermore, the signs of the coefficients of the latter three variables are in accordance with the predictions of the LCH. The positive coefficient signs of *share* 20-49 and *share* 67- and the negative coefficient sign of *share* 50-66 imply that the young workers and old persons have higher aggregate average propensity to consume (APC) than the middle-aged persons. The age share coefficient of children and youths is negative. Theory says little about the effect on consumption of changes in the share of children and youths in the population. However, as children and youths are financially dependent upon their parents in average, it can be argued that aggregate consumption is to decline when the share of these groups increase. The signs of the coefficients on all the age share groups are consistent with Berg's (1996) findings on Swedish data.

The income and wealth elasticities are not very sensitive to the choice of age share variables. As shown in the table, the estimated income elasticities vary between 0.53 and 0.58, while the wealth elasticity is estimated to be around 0.23 when the different age share variables are included in the regressions. Compared to the elasticities reported by Brodin and Nymoen (1992), cf. equation (3.1), the income and wealth elasticities are neither much affected by the introduction of the new variables in the long-run consumption functions.

The short-run dynamics are not modelled in the regressions reported in Table 3. The residuals of the model are therefore expected to be autocorrelated. The p-values of the fifth-order residual autocorrelation test statistics, denoted by AR1-5 in the table,[21] reveal that this is the case. As mentioned above, one of the purposes of this section is to investigate whether the age

[18] As reported in Table 2 the age share variables are highly collinear.

[19] The dummy variables are not reported in the table.

[20] EViews Version 4.0 is used to compute the coefficients and the standard errors, while PcGive Version 9.3 has computed the AR 1-5 and ADF test statistics.

[21] See Hendry and Doornik (1996) for details about the test.

Table 3: Long-run consumption functions; dependent variable: c

	(1)	(2)	(3)	(4)
Constant	1.99 (0.24)	2.22 (0.29)	1.34 (0.14)	2.50 (0.43)
y	0.53 (0.04)	0.57 (0.03)	0.58 (0.03)	0.55 (0.04)
w	0.22 (0.02)	0.23 (0.02)	0.24 (0.02)	0.23 (0.02)
share 0-19	−0.37 (0.08)			
share 20-49		0.31 (0.07)		
share 50-66			−0.17 (0.04)	
share 67-				0.23 (0.07)
AR 1-5	0.00**	0.00**	0.00**	0.00**
ADF	-4.92**	-4.92**	-4.86**	-4.57*

*Seasonal dummy variables (not reported) were also included in the regressions. Newey and West (1987)HAC standard errors in parenthesis. * and ** indicate 5% and 1% significance levels, respectively. AR (1-5) denotes residual autorcorrelation test and ADF denotes the augmented Dickey-Fuller test on residuals.*

structure of the population affects aggregate consumption rather than to develop a congruent consumption model. Thus, instead of removing the residual autocorrelation by modelling the short-run dynamics, Newey-West heteroscedasticity and autocorrelation consistent (HAC) standard errors[22] are applied to obtain reliable t-values. The standard errors are given in parentheses in Table 3.

ADF denotes the augmented Dickey-Fuller test statistics for unit roots on the residuals in Table 3. The null hypothesis of unit roots in the residuals is rejected on a 1% level for the three first regression models and on a 5% level for the last model.[23] According to the Engle and Granger (1987) test for cointegration, these results suggest that at least one cointegrating relationship is present in each of the models.

5.2 The age structure variable

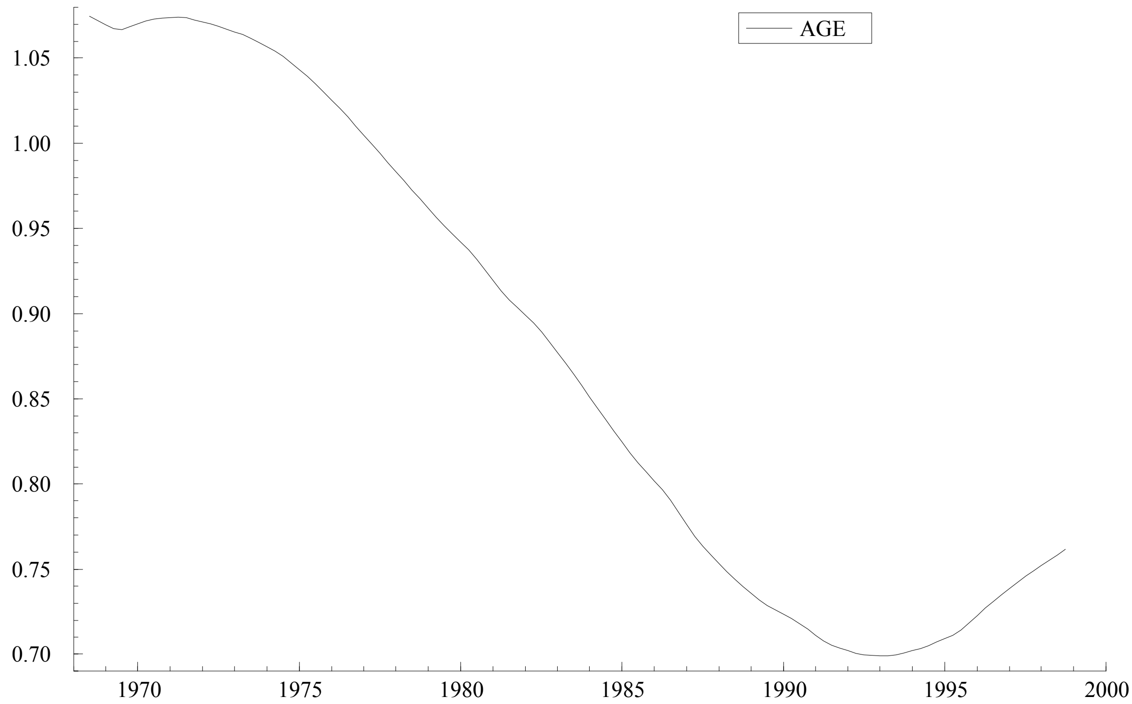
Based on the estimation results in the previous section, an age structure variable is to be included in a dynamic consumption model. By grouping the population in two groups, those with low APC and those with high APC, or, in other words, the age share groups with negative and positive coefficient signs, respectively, in Table 3, the following measure is obtained

$$age = \log\left[\frac{Population\ (0-19\ +\ 50-66)}{Population\ (20-49\ +\ 67-)}\right].$$

[22] Newey and West (1987).

[23] The critical values are –4.79 and –4.19 at 1% and 5% levels, respectively. These values are taken from MacKinnon (1991).

Figure 3: Age structure variable, *age*



When such a variable is constructed and used in regressions two points are worth noting. First, that the sum of the freely estimated partial effects of the different age groups not necessarily are the same as the effect of the composite age measure. Nevertheless, the measure is expected to have a negative effect on consumption since the age groups with low APC are in the numerator. Second, that the measure imposes restrictions on the coefficients of the different age groups relative to each other.[24]

Figure 3 plots the age structure variable over the period 1968(3)-1998(4). It shows that the number of childeren, youths and middle-aged persons relative to the rest of the population was decreasing until the beginning of the 1990s, and that it has been rising since then.

5.3 Multivariate cointegration analysis[25]

Efficient estimation of a dynamic consumption model in a single-equation approach relies on the model containing only one cointegration vector and that the right-hand side variables are weakly exogenous. In this section, it is investigated whether these criteria are satisfied for the consumption model by applying the Johansen multivariate system method.[26]

[24]By applying a χ^2-distributed likelihood ratio (LR) test in preliminary multivariate estimations it has been tested whether a symmetry restriction on the coefficients of the two age groups *share* (20-49 + 67-) and *share* (0-19 + 50-66) is valid. It turns out that it is. Although these two variables are not exactly the same as those in *age*, the test indicates that the symmetry restriction on the coefficients of the variables in the numerator and denumerator in *age* also is valid.

[25]The estimations in Section 5.3 are carried out in PcFiml Version 9.3.

[26]See Johansen (1988).

Table 4: System diagnostic tests for fifth-order VAR

Vector AR 1-5 F(45, 244)	1.185 [0.210]
Vector normality $\chi^2(6)$	7.788 [0.254]
Vector heteroscedasticity F(204, 357)	0.663 [0.999]

5.3.1 Formulating the VAR

The starting point for the Johansen approach is the formulation of the unrestricted VAR. The approach requires that the VAR is correctly specified, and accordingly, that the residuals of the model are white noise. The specification of the VAR and the results of the vector error mis-specification tests are shown below.

As is common when dealing with quarterly data, five lags on each of the potentially endogenous variables of the system, namely on c_t, y_t and w_t, are initially included. The demographic variable age_t is also expected to influence the long-run equilibrium of the model. It is, however, assumed to be weakly exogenous to the system,[27] and hence it enters the VAR as a non-modelled variable. To allow for linear trends in the levels of the data, a constant term is included unrestrictedly in the system. In addition to the constant term, three centered seasonal dummy variables and two other dummy variables, named VAT and $AUDI$, enter the VAR unrestrictedly. The reason for using centered seasonal dummies is that, since they sum to zero over time, they do not influence the asymptotic distributions of the reduced rank test statistics. VAT is a dummy for the introduction of the VAT in 1970, while the $AUDI$ variable consists of the two variables $\Delta STOP$, which is an income policy dummy for the wage and price freeze in 1978,[28] and the change in inflation, $\Delta\Delta_4 cpi$.[29] Since the VAR includes both dummies and a non-modelled stochastic variable (age), the available critical values of the trace-statistic are probably somewhat removed from the (unknown) true critical values. However, the inclusion of age which comes close to being I(1) over the sample, suggest that we follow the recommandations of Harbo et al. (1998) and include a linear trend component, restricted to lie in the cointegration space, in the VAR.

Table 4 reports the system mis-specification tests for the VAR over the sample period 1968(3)-1998(4). As the names of the tests imply, the tests checks for vector error autocorrelation, non-normality and heteroscedasticity.[30] None of the tests indicate vector error mis-specifications, and hence this fifth-order VAR is the basis for the cointegration analysis.

5.3.2 Testing for cointegration

Having specified the VAR, the next step is to determine the cointegration rank of the system. The results of the Johansen test is presented in Table 5. In the table, λ_{trace} denotes the observed trace statistic, while $\lambda_{trace,adj.}$ is its small sample adjusted counterpart.[31] Since the

[27] The assumption that the age structure of the population is weakly exogenous to the system does not necessarily hold, as economic factors, such as income, wealth and consumption, can influence the birth and death rates of the population. These effects are however expected to be small, and hence they are neglected here.

[28] See Appendix A for details on the dummy variables.

[29] More specifically, $AUDI = \Delta STOP - \Delta\Delta_4 cpi$. This symmetry restriction on the coefficients is imposed in Eitrheim et al. (2002), and to simplify the modelling procedure I do the same.

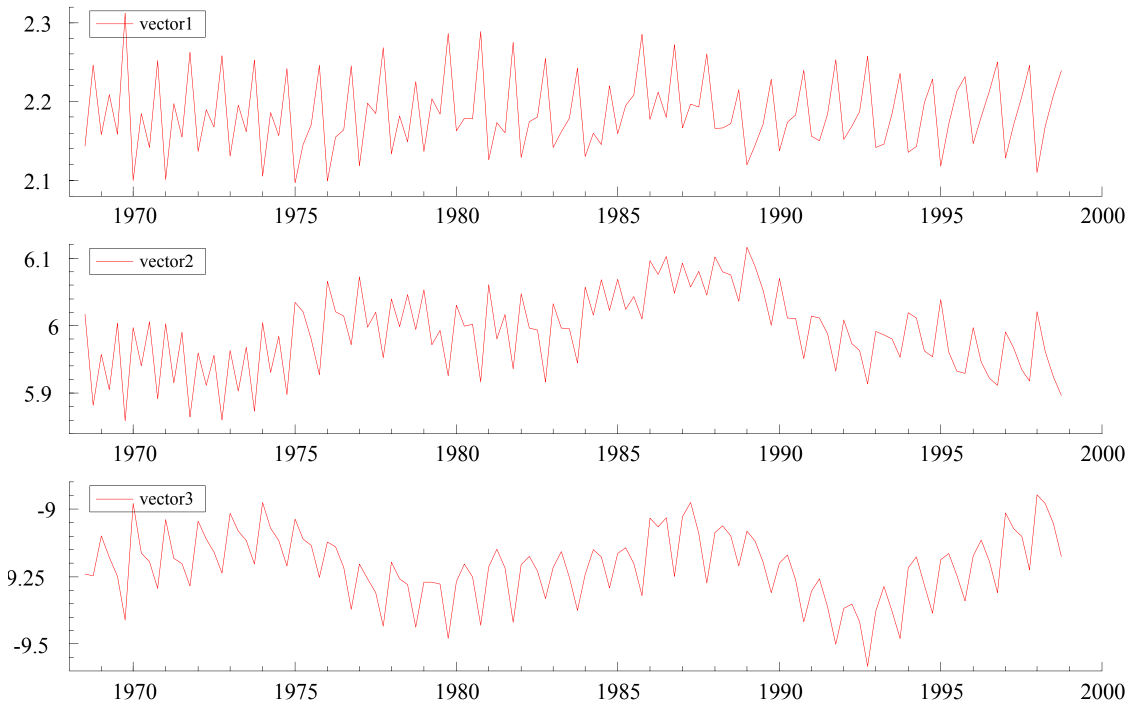
[30] See Doornik and Hendry (1997) for details of the tests.

[31] The adjusted test statistic is based on Reimers (1992).

Table 5: Johansen tests for cointegration

Eigenvalues	λ_{trace}				
λ_i	H_0	H_1	λ_{trace}	$\lambda_{trace,adj.}$	95%
0.1914	r = 0	r $\geq$ 1	46.33	40.64	49.6
0.1045	r $\leq$ 1	r $\geq$ 2	20.42	17.91	30.5
0.0553	r $\leq$ 2	r $\geq$ 3	6.95	6.10	15.2

Figure 4: Unrestricted cointegration vectors



model is conditioned upon the *age* variable, the asymptotic critical values at 5% significance level, denoted by 95% in the table, are taken from Harbo et al. (1998). These are, however, only indicative since dummy variables enter the system.

Strictly interpreted the results of the trace test indicate that there are no cointegrating vectors in the system. Being aware of, however, that the critical values only are indicative, it can be argued that there is a cointegrating vector in the system. Figure 4, which plots the unrestricted cointegrating vectors, supports this argument. The first vector seems clearly to be stationary, while it is more difficult to judge whether the last two vectors are stationary or not. As the argument of the existence of a cointegrating vector also is supported by economic theory, I proceed assuming that there is a cointegrating vector in the system. Brodin and Nymoen (1992) and Eitrheim et al. (2002), who estimate a Brodin and Nymoen (1992) type of consumption function on Norwegian data for the period 1968(3)-1998(4), also find little formal support for cointegration. Given the stability of their long run relationships over a decade, one may suspect that the formal test has little power.

The linear trend component was included in the VAR for inference purposes in the trace test. By imposing the restriction that there is a cointegrating vector, a χ^2-distributed LR test

Table 6: Normalized eigenvectors, β

c	y	w	age
1.000	-0.609	-0.190	0.150
-5.099	1.000	2.984	0.488
-8.208	7.012	1.000	-4.280

Table 7: Testing the significance of each of the variables in the cointegrating vector

	c	y	w	age
$\chi^2(1)$	16.078	16.945	10.877	11.205
p-value	0.000**	0.000**	0.001**	0.001**

can be used to test for the significance of the trend variable in the system. The p-value of the test statistic is 0.55, and hence the null hypothesis that the coefficient of the trend is equal to zero is accepted. The trend is therefore omitted from the I(0)-system in the following analysis.

In Table 6 the estimated eigenvectors $\boldsymbol{\beta}$', when the trend variable is dropped from the VAR, are presented. The $\boldsymbol{\beta}$-matrix is reported in normalized form, with one of the elements in each row of $\boldsymbol{\beta}$' set equal to 1. As the table reports, normalizing the estimated cointegrating vector on consumption gives the following long-run relationship

$$c_t = 0.609y_t + 0.190w_t - 0.150age_t. \tag{5.1}$$

The equation shows that the coefficient of the age structure variable has, as expected, a negative sign. Hence, when the number of children, youths and persons between 50 and 66 years of age increases with one percent relative to the rest of the population, consumption is expected to decrease by 0.15 percent in the long-run, given that y and w are constant. Comparing the estimated elasticities with those of Eitrheim et al. (2002), who report long-run income and wealth elasticities on Norwegian data to be 0.65 and 0.23, respectively, the introduction of the *age* variable seems to reduce the impact of both income and wealth on consumption. The LR tests for the significance of each of the variables in the cointegration vector show that all the variables are significant on a 1% level, cf. Table 7.

Table 8 reports the estimated adjustment, or loading, coefficients $\boldsymbol{\alpha}$. The estimated adjustment coefficient for the consumption equation is –0.655, showing that consumption adjusts relatively fast to changes in the underlying equilibrium relationship.

Table 8: Loading factors, α

c	-0.655	-0.002	-0.001
y	-0.108	-0.004	-0.003
w	-0.084	-0.026	0.000

A test for weak exogeneity of y_t and w_t corresponds to a test of the significance of their respective rows in Table 8. By transforming the system to an I(0) system, a LR test can be used to test for weak exogeneity. Table 9 reports the results of this test, and it shows that the joint test of y_t and w_t being weakly exogenous to the system is accepted, with a p-value at 0.82.

Table 9: Joint test for weak exogeneity

	(y, w)
$\chi^2(2)$	0.400
p-value	0.818

Having found a cointegrating vector and that y_t and w_t are weakly exogenous in the system, the consumption function can be estimated efficiently by a single-equation approach.

5.4 Single-equation approach

In this section, the consumption function is estimated as an equilibrium correction model (EqCM) with the long-run relationship found in the system analysis being imposed on it. A general-to-specific modelling strategy is used as a guideline for reducing the model from the general unrestricted model (GUM) to the final model.[32]

The GUM is formulated such that it is consistent with the VAR system outlined in Section 5.3, and hence the first-difference of each of the variables c_t, y_t and w_t enter the model with four lags. The long-run, or equilibrium correction, relationship in equation (5.1) is imposed on the GUM. To simplify the modelling procedure, the same lag lengths as in Eitrheim et al. (2002) is used in the EqCM term, and hence the term enters the GUM in the following way

$$EqCM_t = c_t - 0.609y_{t-4} - 0.190w_t + 0.150age_t. \tag{5.2}$$

The GUM is estimated by OLS, and the estimation period is from 1968(3) to 1998(4). The estimated coefficients of the GUM are reported in Table 10 with standard errors in parentheses. The table shows that the null hypothesis of all the diagnostic tests are accepted on a 5% significance level, indicating no residual mis-specification in the GUM. To investigate the parameter constancy of the model plots of the recursive residuals can provide valuable information. Plots of 1-step ahead residuals, which is obtained by a estimation of the GUM by recursive least squares, are shown in the first window of Figure 5. The bands in the figure depict the ±2 standard errors. The plot indicates an outlier in 1988, which can be due to the wage freeze of that year.[33] The plot shows also that some of the other observations in the 1980s are near the border of the band, leading to a slight increase in the ±2 standard error band in the 1980s. The band is, however, very stable in the 1990s, indicating a well-specified model for this period. The second plot of the figure, which shows the points of the 1-step Chow tests, confirms this picture. The break-point Chow test is depicted in the third plot.

[32] All the estimations in Section 5.4 is done in PcGive Version 9.3.

[33] Including a dummy variable that takes account of the wage freeze can remove the outlier. However, preliminary estimations show that the income coefficient is very sensitive to the inclusion of such a variable. Hence, since this can indicate that the period of the wage freeze contains valuable information about the consumption-income relationship, the dummy is left out.

Table 10: OLS estimates of general unrestricted model (GUM)

$$\begin{aligned}
\Delta c_t = \; & \underset{(0.241)}{1.159} - \underset{(0.114)}{0.091}\Delta c_{t-1} + \underset{(0.103)}{0.051}\Delta c_{t-2} + \underset{(0.097)}{0.048}\Delta c_{t-3} \\
& + \underset{(0.075)}{0.427}\Delta c_{t-4} + \underset{(0.062)}{0.324}\Delta y_t + \underset{(0.072)}{0.233}\Delta y_{t-1} + \underset{(0.076)}{0.248}\Delta y_{t-2} \\
& + \underset{(0.080)}{0.273}\Delta y_{t-3} + \underset{(0.086)}{0.190}\Delta y_{t-4} + \underset{(0.064)}{0.102}\Delta w_t + \underset{(0.065)}{0.062}\Delta w_{t-1} \\
& + \underset{(0.067)}{0.151}\Delta w_{t-2} + \underset{(0.063)}{0.012}\Delta w_{t-3} - \underset{(0.062)}{0.090}\Delta w_{t-4} - \underset{(0.127)}{0.612}EqCM_{t-1} \\
& - \underset{(0.011)}{0.057}CS1_t - \underset{(0.012)}{0.062}CS2_t - \underset{(0.011)}{0.039}CS3_t + \underset{(0.012)}{0.069}VAT_t \\
& + \underset{(0.066)}{0.185}(\Delta STOP_t - \Delta\Delta_4 cpi_t)
\end{aligned}$$

$R^2 = 0.973$ $\sigma = 1.41\%$ T = 122

Model diagnostics

Test	Test statistic	p-value
AR 1–5	$F(5, 96) = 1.436$	0.218
ARCH 4	$F(4, 93) = 0.735$	0.571
Normality	$\chi^2(2) = 1.732$	0.421
Heteroscedasticity	$F(37, 63) = 0.913$	0.612
RESET	$F(1, 100) = 0.128$	0.721

In this plot each of the points are the value of the Chow-test for that date against the final period. Accordingly, since the model is not well-specified for the 1980s but for the 1990s, the point values are not stable over the sample period, in particular for the values in the 1980s. Likewise for the forecasting Chow-test depicted in the fourth plot. This test increases the forecasting horizon from the initial sample in the recursive least squares estimation to the complete sample period, and hence the forecasting failures of the model in the 1980s affect all the following points. In all the Chow-tests the points are scaled by their 1% critical value in the figure. This recursive analysis of the residuals of the GUM indicates that there may be more to model in the 1980s. Since the model, however, seems well-specified for the 1990s the GUM is kept unchanged.

Several of the right-hand side variables in the GUM are insignificant on a 1% significance level. This suggests that the GUM can be simplified. By following the steps of the PcGets algorithm suggested by Hendry and Krolzig (1999) and Hendry (2000) it is investigated whether a reduced congruent version of the GUM can be obtained. By the use of "pre-search" reduction tests, multiple search paths and encompassing tests of the terminal models of the different search paths against their union, it turns out that a reduced version of the GUM is congruent. Accordingly, this model is chosen as the final model and is presented in Table 11.

The number of explanatory factors is reduced from 21 in the GUM to 14 in the final model, and all the variables of the final model are significant on a 1% level. The estimated equation standard error is 1.43%, slightly higher than the 1.41% of the GUM. It is, however, lower than the equation standard error of the consumption model in Eitrheim et al. (2002) at 1.53%. The coefficient of EqCM_{t-1} at –0.69 is somewhat higher in absolute value than

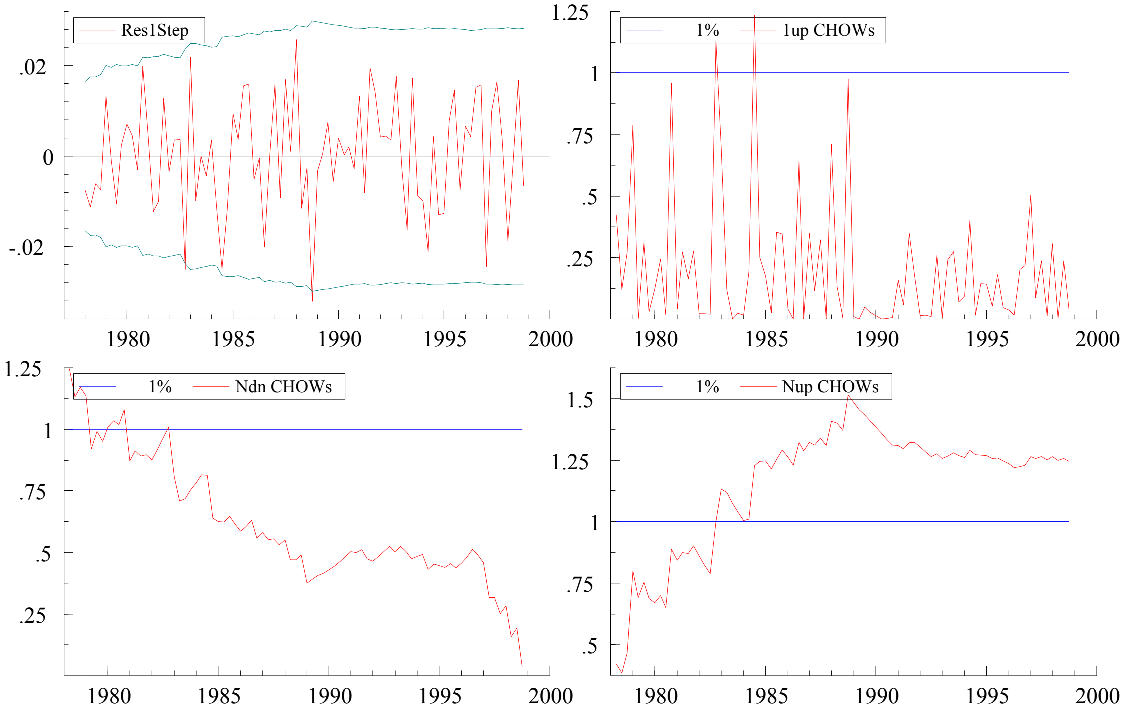
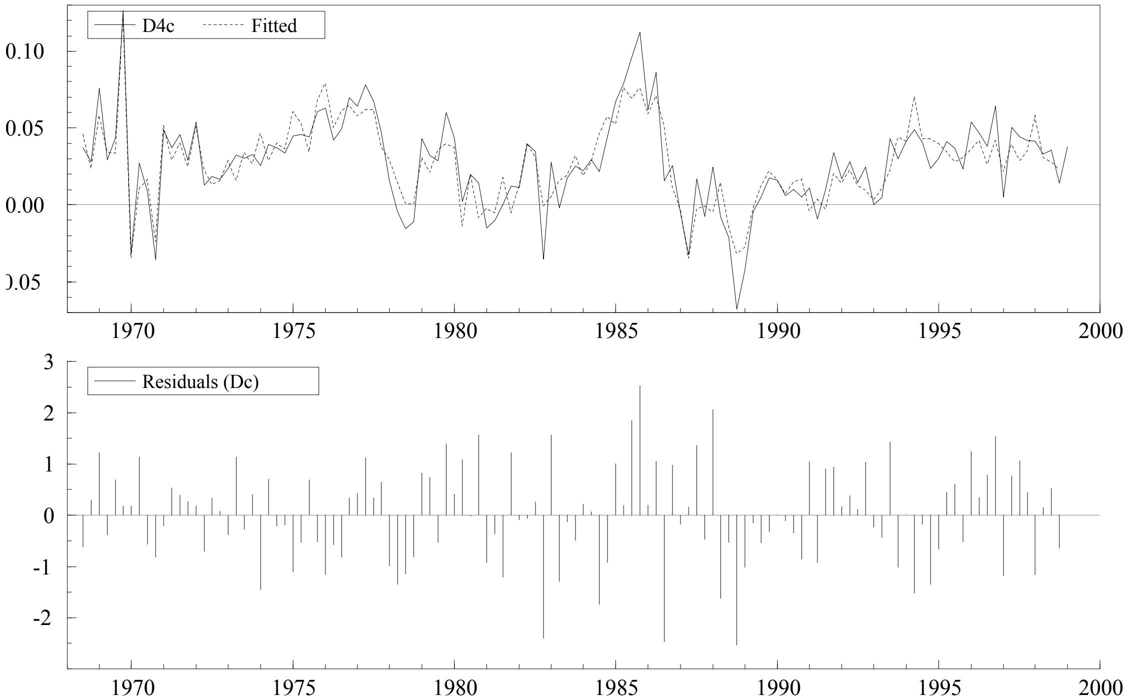


Figure 5: Recursive residuals of the GUM

the long-run adjustment coefficient in the GUM (–0.61), but only slightly higher than the one found in the system analysis (–0.66). It is thus still indicating a fast adjustment towards equilibrium. Figure 6 plots the actual and fitted values of the model (for readability these are reported for $\Delta_4 c_t$) and of the residuals. The plot of the residuals does not indicate any residual mis-specification. This is supported by the diagnostic tests, which shows that the null hypothesis of no mis-specification of all the tests are accepted on a 5% level. The test statistic for fifth-order autocorrelation has though become significant on a 10% level, partly due to the exclusion of several of the lagged first-differences of c_t. Recursive plots of the estimates with ± 2 standard errors for the variables of the model are given in Figure 6. The plots show that most of the parameters are constant over the sample period, in particular in the 1990s. The exceptions are the parameters for Δc_{t-4} and Δy_{t-3}, which seem to be trending slightly upwards. As distinct from the model of Eitrheim et al. (2002), the coefficient of the EqCM term in the final model is constant over the sample period. In the model of Eitrheim et al. (op. cit.) this parameter is declining in the 1980s before it stabilizes. With the exception of the age structure variable, the consumption model of Eitrheim et al. (2002) contains the same variables as the final model, and the two models are estimated on the same data set. The introduction of the age structure variable in the model is thus having a stabilizing effect on the long-run relationship.

Recursive residuals of the model together with residual Chow-tests are plotted in Figure 8. The figure shows that the outliers in the 1980s have become somewhat more significant than in the GUM.

Figure 6: Fitted values ($\Delta_4 c_t$) and residuals of the final model.



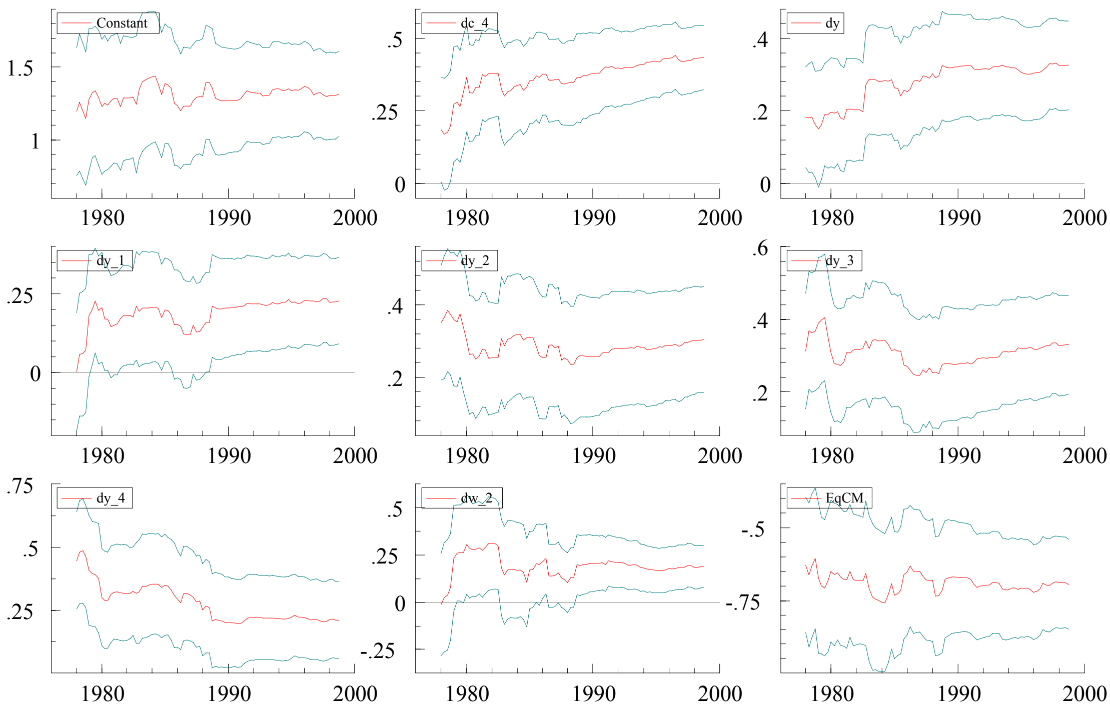


Figure 7: Recursive estimates of final model

Table 11: OLS estimates of final model including age

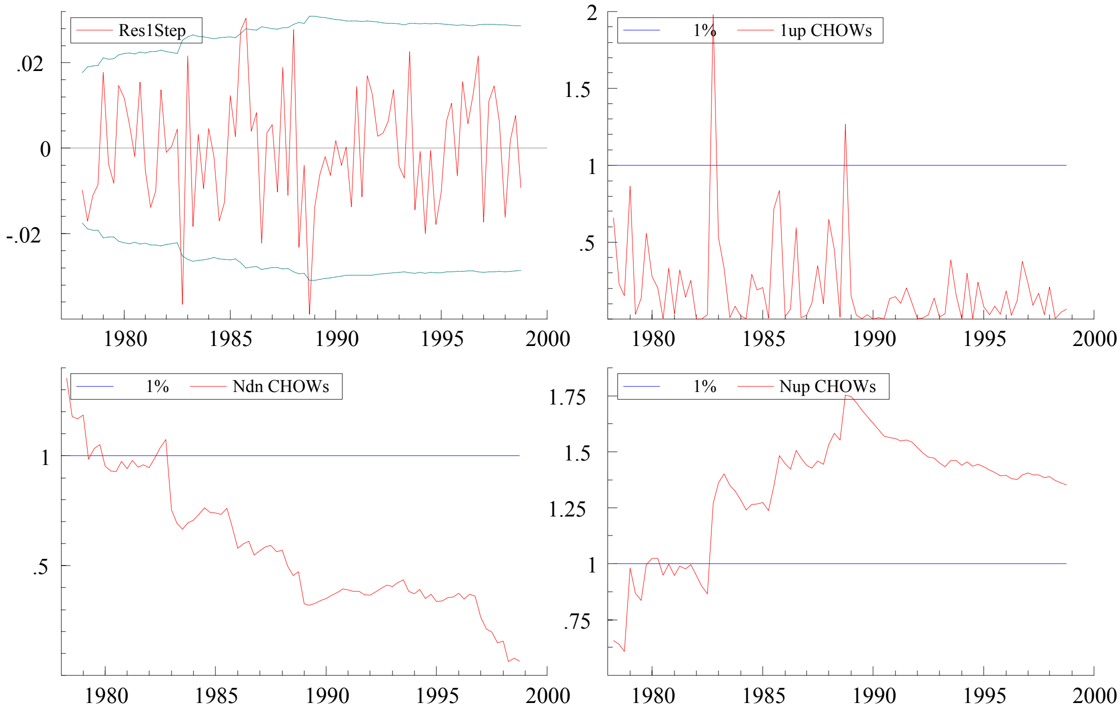
$$\begin{aligned}
\Delta c_t = \; & \underset{(0.147)}{1.315} + \underset{(0.056)}{0.433}\Delta c_{t-4} + \underset{(0.062)}{0.325}\Delta y_t + \underset{(0.069)}{0.228}\Delta y_{t-1} \\
& + \underset{(0.072)}{0.305}\Delta y_{t-2} + \underset{(0.068)}{0.330}\Delta y_{t-3} + \underset{(0.076)}{0.210}\Delta y_{t-4} + \underset{(0.056)}{0.190}\Delta w_{t-2} \\
& - \underset{(0.077)}{0.694}EqCM_{t-1} - \underset{(0.011)}{0.047}\Delta CS1_t - \underset{(0.006)}{0.044}\Delta CS2_t - \underset{(0.006)}{0.037}CS3_t \\
& + \underset{(0.012)}{0.074}VAT_t + \underset{(0.065)}{0.178}(\Delta STOP_t - \Delta\Delta_4 CPI_t)
\end{aligned}$$

$R^2 = 0.970$ $\quad \sigma = 1.43\%$ $\quad T = 122$

Model diagnostics

Test	Test statistic	p-value
AR 1–5	$F(5, 103) = 2.031$	0.080
ARCH 4	$F(4, 100) = 1.265$	0.289
Normality	$\chi^2(2) = 0.626$	0.7314
Heteroscedasticity	$F(23, 84) = 1.084$	0.380
RESET	$F(1, 107) = 0.004$	0.950

Figure 8: Recursive residuals of final model



6 Concluding remarks

The effects of a changing age distribution on Norwegian aggregate consumption are analysed in this paper. It has been shown that changes in the age structure of the population affect aggregate consumption significantly, and that the age structure impact is in line with economic theory. More specifically, the results support the predictions of the Life Cycle Hypothesis, which imply that young adults and old persons have a higher average propensity to consume than the middle-aged. Furthermore, the model is shown to encompass a consumption model which does not control for age composition effects. Compared to the consumption model of Eitrheim et al. (2002), who have estimated a similar Norwegian consumption model but witout the age structure variable, the model has both lower equation standard error and more stable parameters over the estimation period. The model is, however, not well-specified for the 1980s.

In contrast to economic variables, demographic variables are easy to forecast in the short and medium run. The age structure of the population is thus well-suited for forecasting purposes. An interesting project for future research programs can thus be to investigate the forecasting properties of the consumption model developed above. Since the share of middle-aged persons in the Norwegian population is to increase rapidly over the next ten years, the differences of the forecasts from this model and a model which does not control for age structure effects might be substantial in this period.

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Appendix A: Variable definitions and sources

Symbol	Definition and source
C	Total private consumption expenditure (including ideal organizations), fixed 1996 prices. Source: Statistics Norway.
CPI	Consumer price index (1996=1). Source: Statistics Norway.
PC	Price deflator for total private consumption expenditure. (1996=1). Source: Statistics Norway.
W	Real household wealth; nominal household wealth (including both financial and housing wealth) deflated by the price deflator for total private consumption expenditure (PC). (See Eitrheim et al. (2002) for more detailed description.) Source: NB and Statistics Norway.
Y	Households' real disposable income; households' nominal disposable income deflated by PC. Source: Statistics Norway.
SHARE 0-19, etc.	The share of the population in the age group from 0 to 19 years old. Source: Statistics Norway.
CD1, CD2, CD3	Centered seasonal dummies for the first, second and third quarter.
VAT	Dummy for the introduction of VAT in 1970(1). Takes the values 1 in 1969(4) and-1 in 1970(1).
STOP	Income policy dummy, constructed for catching up the inflationary pressures which were being built up during the wage- and price freeze in 1978. It takes non-zero values in the quarters from 1979(1) to 1980(1), and is zero elsewhere. See Brodin and Nymoen (1992) for details.

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