Modelling private consumption in ADAM

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Abstract

In this paper we present and compare several different models for private consumption in Denmark. Based on some straightforward theoretical assumptions we formulate three basic functional forms. The first is a log-log model inspired by the celebrated DHSY consumption function, which is the formulation presently used in the macro econometric model ADAM. The second is a linear model based on the pure life cycle and permanent income models. Finally, the third formulation is a mixed log-linear model inspired by Muellbauer and Lattimore (1996).

We estimate and compare different versions of the three models and show that it is very difficult to select a single model, if the choice is to be made on statistical properties, including model diagnostics and predictive power.

In order to highlight the effect of the different specifications we pick out four rival models and include each of these in ADAM. We subsequently present the predicted impact on consumption and GDP from two standard policy experiments. The result of this exercise is that the different models lead to very similar conclusions regarding the effect of policy changes.

Overall, we find that an extended version of the DHSY consumption function, a linear function, and the mixed log-linear model of Muellbauer and Lattimore are all good candidates for a future consumption function in ADAM.

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1. Introduction

Since the early 1970s Statistics Denmark has maintained and developed the macro econometric model ADAM (Annual Danish Aggregate Model), originally created by Professor Ellen Andersen (Andersen, 1975). As in most Keynesian inspired large scale econometric models, private consumption expenditure is a key element in short term forecasts and in model based policy experiments. Also in line with macro econometric models throughout Europe and the US, the consumption function in ADAM, meaning the equation relating total private consumption expenditure to a measure of disposable income, has undergone only a few but important changes in the twenty-five years following Andersen (1975). Eskil Heinesen (1988) summarizes the development up to 1987, and there has only been minor changes, i.e., slight changes in data definitions, from 1987 to the most recent version of the model, ADAM, April 2000.

In the year 2000 the econometric analysis of the consumption function was intensified. The prime cause was a renewed interest in exploring whether different wealth components (money, bonds, houses, shares, etc.) have varying impacts on private consumption expenditure. This interest called for a new study of the formulation of the consumption function for the first time in more than ten years. This paper presents some results of this analysis.

From 1982 and onwards the consumption function in ADAM has been inspired by the Davidson, Hendry, Srba, and Yo (DHSY, 1978) study which explicitly introduced error-correction in the consumption function. This implies a relatively weak theoretical foundation. Instead, the interest has centered around the long run properties of the consumption function, in complete accord with the recommendations of the LSE-school. In the early years (1982-1986) the basic hypothesis was an assumption of a constant steady state consumption ratio, $c/y = k^*$. This was embedded in a standard log-linear error-correction model where c_t is total private consumption, y_t is disposable income, and Δ is the difference operator.

$$\Delta \log c_t = \beta_0 + \beta_1 \Delta \log y_t - \alpha \log(c_{t-1}/y_{t-1}) + \varepsilon_t,$$

This model did not do well in terms of predictive power, which is why the definition of disposable income was changed several times in the period 1982-1986.

In 1987 wealth (A_t) was introduced. There are several ways to include wealth in the consumption function. In ADAM the preferred formulation was based on the idea that in the long run consumption and wealth are related by the ratios

$$c/y = k^*(A/y)^\gamma.$$

This relationship can be based on the life-cycle model in Franco Modigliani and Richard Brumberg (1979), as they show that both the consumption ratio and the wealth to income ratio will be constant in a steady state given certain assumptions about technology and population growth. In a time series terminology, the ratios are stationary and may be used as error-correction mechanisms in the consumption function.[1] Hence, the error-correction model, which has been used since May 1987, has the form

$$\Delta \log c_t = \beta_0 + \beta_1 \Delta \log y_t + \beta_2 \Delta \log A_t \\ - \alpha(\log(c_{t-1}/y_{t-1}) - \gamma \log(A_{t-1}/y_{t-1})) + \varepsilon_t. \quad (1)$$

The main purpose of this paper is to compare this consumption function with two alternative formulations; one linear and one mixed log- and linear in which wealth is easy to decompose. A second objective is to relate the traditional consumption function used in large scale models to the Euler equation approach, which has been the corner stone in most of the micro-econometric work on private consumption.

The paper is organized as follows. In section 2 the two alternative consumption functions are derived from simple versions of the permanent income and life cycle models of consumption. Subsequently, extensions of the stylyzed model, such as decomposition of wealth and inclusion of unemployment in the consumption function are briefly discussed. The theoretical section ends with a specific statement of the three rival formulations of the consumption function. The empirical results are gathered in section 3. The section which begins with a short description of the data, followed by a presentation of the estimation results. Moreover, the rival models are compared statistically using model diagnostics and encompassing tests. The main result is that it is not possible to make a decisive choice solely on statistical grounds. In section 4 we evaluate the impact on policy conclusions of the different formulations by comparing the resulting multipliers from a couple of the standard policy experiments in ADAM. The result of the multiplier experiments is that the specific choice of consumption function makes little difference for policy simulations with ADAM. Finally, section 5 offers brief concluding comments.

2. Theoretical considerations

Our basic working hypothesis is the simple idea that consumers seek to smooth consumption over the life time. This desire for consumption smoothing can be formulated in a simple way as

$$\mathrm{E}_t(c_{t+i}) = g_c i + c_t \qquad i = 1, 2, \ldots . \quad (2)$$

[1] Although it is not evidently clear that the ratios will Granger cause consumption.

Here, $\mathrm{E}_t(c_{t+i})$ is planned consumption in period $t+i$ conditional on information up to and including period t.

Robert Hall (1978) showed that equation (2) is the necessary condition for an optimal consumption path for a consumer endowed with an intertemporally separable utility function with quadratic felicity functions and a constant discount rate which is equal to the market rate of interest. Under these assumptions $g_c = 0$, and consumption is a martingale process. However, as our objective is not to test Hall's result we simply perceive equation (2) as a starting point for the analysis.

The deterministic drift term in the consumption process may arise through several channels. Ricardo Caballero (1990) showed that infinitely-lived consumers with a constant absolute risk aversion will have a drift component in the consumption process. The drift will be constant if labor income follows an ARIMA-process with *iid* innovations.[2] Moreover, if equation (2) is thought of as representing per capita consumption in an OLG-economy with productivity growth, then the drift term will be a function of the growth in income, because young consumers entering the economy have a relatively higher expected life time income compared to the old consumers who are leaving the economy.[3]

We wish to find a consumption function, i.e., a relation between consumption, income, and wealth. This can be accomplished by combining equation (2) with the life time budget constraint

$$\sum_{i=0}^{\infty}(1+r)^{-i}c_{t+i} \leq A_t + \sum_{i=0}^{\infty}(1+r)^{-i}y_{t+i},$$

where A_t is initial wealth and y_{t+i} is labor income in period $t+i$. Throughout, labor income is assumed to be exogenous.

As future income is unknown at time t, we consider instead the consumption plan

$$\sum_{i=0}^{\infty}(1+r)^{-i}\,\mathrm{E}_t(c_{t+i}) = A_t + \sum_{i=0}^{\infty}(1+r)^{-i}\,\mathrm{E}_t(y_{t+i}). \tag{3}$$

Inserting (2) into (3) yields an explicit solution for current consumption as a function of initial wealth and expected labor income (human capital)

$$c_t = \tfrac{r}{1+r}[A_t + \textstyle\sum_{i=0}^{\infty}(1+r)^{-i}\,\mathrm{E}_t(y_{t+i})] - \tfrac{1}{r}g_c. \tag{4}$$

This equation is closely related to a 'modern' version of Friedman's permanent income model. (See Flavin, 1981; Campbell, 1987; or Deaton, 1992). As seen, consumption

[2] If the innovations are Gaussian the drift will be proportional to the variance of the innovations.

[3] See Clarida (1991) for an exposition of the implications of aggregating over consumers with finite lives.

is the annuity value of total wealth, being the sum of discounted future income and current asset holdings. A constant is subtracted either because of precautionary saving or aggregation over consumers as explained above.

It is well known that a purely deterministic version of the model can be deduced from the life-cycle model of Modigliani and Brumberg (1954, 1979) and the model can be specified explicitly with finite lives as in Oliver Blanchard (1985). This will change the annuity factor, but not the main idea. Overall we consider equations (2) and (4) to be a good starting point in the formulation of a consumption function for ADAM.

2.1. A linear consumption function

The changes in consumption expenditure are related to innovations in labor income. Specifically, by inserting the law of motion for wealth in the consumption plan (4) and differencing we obtain a stochastic difference equation for consumption

$$\Delta c_t = g_c + \psi \varepsilon_t, \tag{5}$$

where the random error, ε_t, is the innovation in labor income, and the factor of proportionality, ψ, (the marginal propensity to consume out of 'news') is a function of the parameters of the income process and the interest rate. (See Campbell and Deaton, 1989 or Deaton, 1992, *inter alia*). The explicit relation between the innovations and the income process is

$$\psi \varepsilon_t = r \sum_{i=0}^{\infty} (1+r)^{-i} (\mathrm{E}_t(y_{t+i}) - \mathrm{E}_{t-1}(y_{t+i})). \tag{6}$$

This relation also hold in the case of a consumer with a constant absolute risk aversion, and Richard Clarida (1991) shows that it is a good approximation for per capita consumption in an OLG-model in which consumers (with quadratic preferences) have finite lives. In the latter case the marginal propensity to consume out of news should be redefined to be the average MPC for the consumers in the economy. In the present context, the important result is that we can still relate changes in consumption to innovations in labor income in a simple way.

Equation (5) can be rewritten to an error-correction model for consumption. The important difference compared to the consumption plan (4) is that we insert a model for the news in the income process, ε_t, instead of a model for the discounted sum of future incomes. In the present version of ADAM information about current income is already used in the prediction of current consumption. Hence, setting up a model for the news is just another way of interpreting the consumption equation; the important point being that it is the news model that induces error-correction in consumption.

When saving, and thus non-labor income, is included in the model, the error-correction form becomes a natural choice regardless of the underlying theory, as they all predict that savings is a stationary process. Here, we follow John Campbell (1987) and define saving as total disposable income minus consumption[4]

$$s_t \equiv \tfrac{r}{1+r} A_t + y_t - c_t .$$

Inserting this definition in (4) and solving for s_t we find a negative association between current saving and expected future income changes

$$s_t = \tfrac{1}{r}(g_c - g_y) - \sum_{i=1}^{\infty}(1+r)^{-i}\, \mathrm{E}_t(\Delta y_{t+i} - g_y), \tag{7}$$

where g_y is the mean of the changes in income i.e., the deterministic drift in the income process.

As noted by Campbell (1987) equation (7) shows that, theoretically, a reduced form forecasting model for income should include lagged savings. A simple example of a reduced form model for income which still generates an ARIMA-process, is

$$\Delta y_t - g_y = -\gamma_s(\tfrac{r}{1+r} A_{t-1} + y_{t-1} - c_{t-1}) + \varepsilon_t . \tag{8}$$

This prediction model can be solved for the innovations and subsequently inserted into (5), resulting in a linear error-correction type consumption function:

$$\Delta c_t = (g_c - \psi g_y) + \psi \Delta y_t + \psi \gamma_s(\tfrac{r}{1+r} A_{t-1} + y_{t-1} - c_{t-1}). \tag{9}$$

This formulation is our point of departure for the linear consumption function. The function is directly comparable to the dynamic life cycle model proposed in Albert Ando and Franco Modigliani (1963, footnote 22).

The simplest way to introduce random fluctuations into this model is to assume that individual consumers have private information not known to the econometrician. In this case there will be an expectation error in the macro-prediction model for income (8) which will carry over to an error in the consumption function (9) along with "macro-parameters" that are slightly biased compared to the individual consumer's "micro-parameters". However, this macro bias seems unavoidable.

2.2. A mixed log-linear consumption function

John Muellbauer and Ralph Lattimore (1996) argue strongly against the Euler equation approach. Instead they start directly from the consumption plan (4), which they denote

[4]This defines saving as the discounted change in wealth $s_t = (1+r)^{-1}(A_{t+1} - A_t)$.

the solved out consumption function. This function can be reformulated as

$$c_t = y_t + \tfrac{r}{1+r} A_t - \tfrac{1}{r}(g_c - g_y) + \sum_{i=1}^{\infty} (1+r)^{-i} \, \mathrm{E}_t(\Delta y_{t+i} - g_y), \tag{10}$$

in accordance with Campbell's savings result in (7).

Muellbauer and Lattimore point out that it seems reasonable to expect the variance in random consumption fluctuations to be proportional to the consumption level.[5] This leads them to use a mixed log-linear approximation of the consumption plan. The specific transformation used by Muellbauer and Lattimore is interesting in that it allows for disaggregation of wealth into several components.

The transformation of the consumption plan into a quantifiable consumption function is done in four steps. First, the consumption plan is scaled by current labor income

$$c_t = y_t \left[1 + \tfrac{r}{1+r} \tfrac{A_t}{y_t} - \tfrac{1}{r} \tfrac{g_c - g_y}{y_t} + \sum_{i=1}^{\infty} (1+r)^{-i} \, \mathrm{E}_t \left(\tfrac{\Delta y_{t+i} - g_y}{y_t} \right) \right].$$

Second, three approximations are introduced: (i) The sum in brackets on the right hand side is expected to be close to one, hence the approximation $\log(1+x) \simeq x$ is used. (ii) $\sum \mathrm{E}_t((\Delta y_{t+i} - g_y)/y_t) \simeq \sum \mathrm{E}_t(\Delta \log y_{t+i} - g_y)$, and (iii) $(g_c - g_y)/y_t$ is zero, i.e., the drift in consumption is solely caused by productivity growth, or constant, in which case it is an assumption of a constant average relative risk aversion. The approximations leads to a mixed log-linear consumption plan

$$\log c_t = \gamma_g + \log y_t + \tfrac{r}{1+r} A_t / y_t + \sum_{i=1}^{\infty} (1+r)^{-i} \, \mathrm{E}_t(\Delta \log y_{t+i} - g_y). \tag{11}$$

In the third step a dynamic formulation is given. Here Muellbauer and Lattimore refer, somewhat loosely, to habit formation, durable goods, and adjustment costs, which can all be modeled by partial adjustment. The partial adjustment model can be given in the error-correction form

$$\begin{aligned} \Delta \log c_t = {} & \gamma_c \gamma_0 + \gamma_c \Delta \log y_t - \gamma_c \log(c_{t-1}/y_{t-1}) \\ & + \gamma_c \tfrac{r}{1+r} A_t / y_t + \gamma_c \sum_{i=1}^{\infty} (1+r)^{-i} \, \mathrm{E}_t(\Delta \log y_{t+i} - g_y). \end{aligned} \tag{12}$$

Finally, a prediction model for future relative income changes is introduced. Muellbauer and Lattimore consider a moving average of future growth rates in income. We find it

[5] This assumption is akin to Campbell and Deaton's (1989) approximation of the PIH when log income is assumed to be a random walk.

more appropriate to use a prediction model as in the linear model. Hence, we consider a reduced form for the growth rate in income, say,

$$\Delta \log(y_{t+1} - g_y) = \alpha_y(\Delta \log y_t - g_y) - \gamma(\alpha_a A_t/y_t - \alpha_c \log(c_t/y_t)) + \nu_t.$$

When this reduced form for future income is inserted into (12) we obtain an estimable model for consumption.

Note that the linear and the mixed log-linear consumption functions are both based on a common theoretical basis. The differences are entirely due to different approximations of the stochastic part of consumption and income. Therefore, any choice between the two model must be an empirical matter.

2.3. Extensions of the basic models

Although many macro consumption functions are estimated using (1) or (9) it is well recognized that these simple consumption functions are inadequate as they miss important aspects of consumption. Some of the problems are habit formation, durable goods, and credit constrains, which are all known to lead to violation of Hall's random walk result. However, these complications can be formulated such that they only affect the size of the parameters while leaving the functional form of the solved out consumption functions unchanged. As the objective of the present paper is to formulate and estimate different versions of the solved out function, we do not discuss these complications. However, some extensions of the simple model are of interest in macro econometric models: varying liquidity of different assets and the impact of unemployment and inflation. These extensions will be briefly commented on below.

2.3.1. Wealth

The empirical measure of wealth, given as the sum of different wealth components, need not be directly comparable to the theoretical wealth variable A_t. In the theoretical model wealth is highly liquid, as it must be possible to spend the total initial wealth within a single period. In an economy with complete (frictionless) capital and insurance markets this is an innocent assumption. However, if insurance markets are incomplete and assets differ in the degree of liquidity, then the different wealth components may well have varying spendability weights. Often it is argued that less liquid assets have low spendability weights. If so, the composition of wealth, i.e, portfolio decisions, will have effects on consumption.

In ADAM it is of interest to consider the returns from four assets; (broad) money, bonds, houses, and real assets. Hence, we let the return to total wealth be given by

$$\frac{r}{1+r}A_t = \rho_m M_t + \rho_b B_t + \rho_h H_t + \rho_k K_t. \tag{13}$$

The parameters ρ_j, $(j = m, b, h, k)$ are composite parameters, which are best interpreted directly as spendability weights in the consumption function.

2.3.2. The impact of unemployment

The total impact of unemployment on consumption is difficult to predict *a priori* as there are several partial effects. From neo-classical theory we know that there is a substitution effect if consumers enjoy leisure. The substitution effect gives rise to a negative association between consumption and unemployment. An income effect may appear if unemployment is a good predictor for future income changes. In this case unemployment may have a partial, positive impact on consumption, conditional on current income changes. Another impact may be via the variance in the income innovations. In this case unemployment may impact on precautionary saving. Finally, there may be an interaction between unemployment and credit rationing, say, if certain groups of consumers that have high unemployment risk are also often rationed on the credit markets.

Overall, the effect of unemployment is indeterminate and, moreover, it is important to be aware of the potential simultaneity bias when relating total private consumption expenditure and the average unemployment rate. However, we do not think that the simultaneity problem between unemployment and consumption expenditure is more severe than the one between consumption and disposable income. Therefore, we include the unemployment rate in both the linear and the mixed log-linear consumption functions.

2.3.3. The impact of inflation

As for unemployment, inflation and consumption are related though several channels. But in contrast to unemployment we know from the outset that the total impact of inflation is in all likelihood negative. However, the main effects should be from unanticipated inflation as the consumption plan is in terms of real consumption expenditure based on expected price movements. A positive shock to inflation implies that the purchasing power of the stock of real assets is lower than expected. This induces a decrease in consumption as long as the expected future real labor income is unaltered. Furthermore, inflation may lead to a signal extraction problem giving rise to a negative impact on total consumption because of the confusion between relative price movements and inflation; see Angus Deaton and John Muellbauer (1980, section 12.3).

There are also possible effects through income. First, because inflation may be used as a predictor for future real income changes alongside unemployment and, second, there may be a relation between the level of inflation and the variability in income innovations leading to changes in precautionay saving.

2.4. The specific formulation of the three consumption functions

Drawing together the theoretical considerations above we can formulate three rival consumption functions. The equations we wish to estimate are given below.

$$\Delta \log c_t = \alpha_0 + \alpha_1 \Delta \log y_t + \alpha_2 \log(c_{t-1}/y_{t-1}) + \alpha_3 M_t/y_t + \alpha_4 B_t/y_t + \alpha_5 H_t/y_t + \alpha_6 K_t/y_t + \alpha_7 \Delta u_t + \alpha_8 u_t + \alpha_9 \pi_t + \alpha_{10} t + \varepsilon_t^1. \quad (14)$$

$$\Delta c_t = \beta_0 + \beta_1 \Delta y_t + \beta_2 (c_{t-1} - y_{t-1}) + \beta_3 M_t + \beta_4 B_t + \beta_5 H_t + \beta_6 K_t + \beta_7 \Delta u_t + \beta_8 u_t + \beta_9 \pi_t + \beta_{10} t + \varepsilon_t^2. \quad (15)$$

$$\Delta \log c_t = \delta_0 + \delta_1 \Delta \log y_t + \delta_2 \log(c_{t-1}/y_{t-1}) + \delta_3 \log(A_{t-1}/y_{t-1}) + \delta_4 \log(H_{t-1}/A_{t-1}) + \delta_5 \Delta \log A_t + \delta_6 t + \varepsilon_t^3. \quad (16)$$

Equation (14) is the mixed log-linear formulation by Muellbauer and Lattimore while equation (15) is the linear relation derived directly from the Euler approach. In both equations wealth is replaced by the private sectors net stock of the four assets. In addition, unemployment is included both as changes and the level of unemployment. This is done in order to take account of possible dynamic effects.[6]

Turning to equation (16) this is a slight generalization of the consumption function in the present version of ADAM. The change in the formulation is made in order to enable a test of the hypothesis that the spendability weight of the value of houses is different from the rest of the assets. Specifically, if $\delta_4 \neq 0$, housing and non-housing wealth have different spendability weights.

3. Empirical results

3.1. The data

The data used in the estimations are annual observations for the period 1955-1999. The data for the last three years are still preliminary, and therefore these observations are

[6] Recall that the dynamic structure $\tau_1 x_t + \tau_2 x_{t-1}$ can be formulated as $(\tau_1 + \tau_2)x_t - \tau_2 \Delta x_t$.

Figure 1: Per capita consumption and income (Changes)

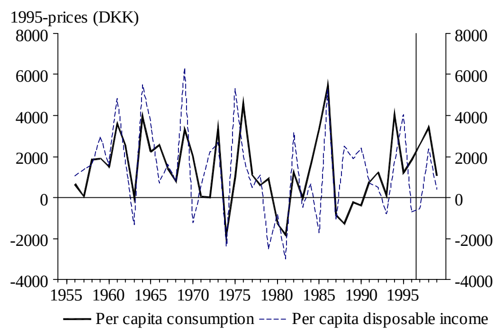


Figure 2: Per capita consumption and income (Levels)

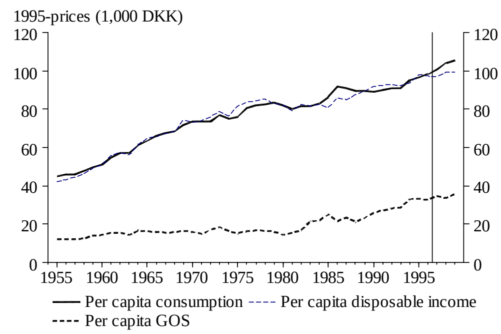


Figure 3: Money, Bonds, and Housing stock (Bonds are liabilities)

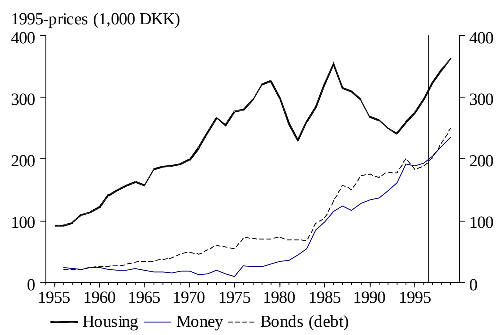
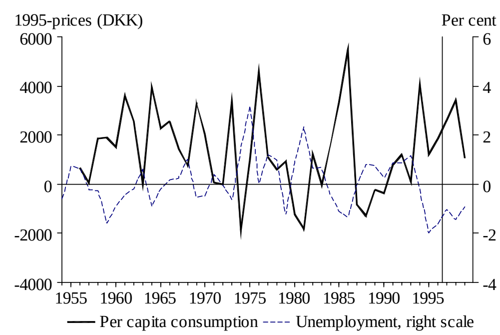


Figure 4: Per cap. consumption and unemployment (Changes)



excluded from the estimation sample. Instead the observations are used for post sample prediction tests. Due to differencing and lags the effective estimation sample is 1956-1996 for equations (14) and (15) and 1957-1996 for equation (16).

The series for consumption corresponds to total private consumption in the national account although housing expenditure and consumption of vehicles is replaced by flow of service measures. The income variable is disposable income in the private sector, including imputed income for self-employed. Wealth consist of four assets. Money in the private non-banking sector and the net stock of bonds are considered the most liquid assets.[7] The value of houses is given as the physical housing stock times the average price on owner occupied single-family houses. Finally, due to lack of data for the market value of real capital, we use two approximate measures; (i) the income flow generated by real

[7]The net stock of bonds is measured as liabilities because the private non-banking sector is a net debtor of bonds.

assets measured by the after tax value of the gross operating surplus and mixed income from the national account (GOS), and (ii) the replacement value of real capital. All variables are deflated by the price on total private consumption in the current year. The price index on total private consumption is also used to construct the inflation variable.

Figures 1-4 are time series plots of the most important variables. Figure 1, giving the changes in per capita consumption and income, shows a strong correlation in the first part of the sample from the mid 1950's to around 1980. In the later period (1980-99) the correlation is much weaker. This may partly explain why the consumption functions in the early 1980's had such difficulties in predicting future consumption. Figure 2 shows that it is not only the changes in the two series that are closely related; the levels are also surprisingly close, and both series have a significant positive drift over the sample period, 1956-1996. The average annual increase in per capita consumption is DKK 1.297 in 1995-prices while it is DKK 1.346 for per capita income. As seen from Figure 2 this small difference in the average drifts is completely random. The significant drift in both series have resulted in a doubling of per capita income and consumption over the sample period, from around DKK 45.000 in 1956 to roughly DKK 100.000 in 1996. This corresponds to an average annual growth rate of 2 percent.

The third series in Figure 3 is the per capita disposable gross operating surplus and mixed income (GOS). This series is fairly constant over the period 1956-1980 after which there seems to be a small positive drift. The ratio of GOS to disposable income varies quite a lot over the sample period from around 1/4 in the 50's and 60's down to 1/5 in the 70's and subsequently rising to around 1/3 in the late 90's.

Turning to the development in wealth, Figure 3 makes clear that the value of the housing stock constitute by far the largest share of total wealth when the value of real assets is not included. The rather large movements in the value of the housing stock in the early 1980's and the early 1990's were caused by large changes in the house price. The stock of houses as such has shown a smooth, slightly growing trend over the last 40 years. Regarding the most liquid assets, money and bonds, it is seen that the private non-banking sector has been a net debtor in these assets. The money stock has been smaller than bond liabilities in most of the period. Notice that the two series are tracking each other quite close, and that the difference between the two series may be related to the changes in the value of the housing stock.

In terms of an asset to income ratio, combining Figures 2 and 3 reveals that the overall ratio (the sum of the three assets relative to disposable income) has risen from about 2.5 in the 1950's to around 3.5 in 1996. Hence, the constancy of this ratio, as predicted by the life cycle model of Modigliani and Brumberg (1979), does not seem to hold for this data set. Furthermore, the changes in house prices has resulted in rather large movements in the asset-income ratio in the last 20 years.

Finally, looking at the correlation between consumption and unemployment we find, from Figure 4, that changes in per capita consumption are negatively related to changes in the unemployment rate throughout the period. The close correlation may not carry over to the partial correlation conditional on income and wealth. However, the immediate impression is that the dominating relation between consumption and unemployment is likely to be a precautionary savings motive or possibly credit rationing.

3.2. Regression results

Tables 1, 2 and 4 report regression results for the three different model specifications. Results for the mixed log-linear model are gathered in Table 1 while a smaller subset of results for the linear model are given in Table 2. Table 4 shows the results of augmenting the present ADAM specification.

Regression (1) in Table 1 is a rather over-parameterized general model which serves as the point of departure. The most interesting result in regression (1) is that the point estimate of the impact of gross operating surplus is negative. This result is also found for the linear model in regression (6) in Table 2. However, in both regressions the joint impact of the change in and the lagged level of GOS is highly insignificant. Consequently we exclude GOS from the two models.[8] In moving from regression (1) to (2) in Table 1 and from (6) to (7) in Table 2 we also impose the restriction that money and bonds have equal spendability weights. This restriction is also accepted at conventional levels of significance. The *p*-values of Wald tests of the joint hypotheses leading to the reductions of the two models are reported in the bottom row in the tables.

It should be clear from regression (2) in Table 1 that the model is still over-parameterized. But the significance of the individual parameters now depends on the reduction sequence. This is shown in regressions (3)-(5) in which we present three non-nested sub-models of (2). In the three regressions all parameters have *t*-values (well) above 2 and, as seen from the bottom part of the table, the models all pass the standard battery of diagnostic tests.[9] The Wald tests of the reductions from regression (2) to the sub-models also have what is often called strong empirical support, as the *p*-values are quite high.

In regressions (3) and (4) we find the spendability weight on housing to be about one third of the weight on financial wealth (money and bonds). The partial effect of wealth is seemingly a little higher in regression (4) compared to (3), but taking account of the dif-

[8] Inclusion of the replacement value of the stock of real capital likewise resulted in highly insignificant parameter estimates.

[9] (i) First order serial correlation in the residuals tested by the Breuch-Godfrey test. (ii) Residual heteroskedasticity as a function of the level variables in the regressions tested by the Breuch-Pagan test. (iii) Residual normality tested by the Jarque-Bera test.

Table 1: Regression results for the mixed log-linear model

Dependent variable	Change in log consumption				
Regression no.	(1)	(2)	(3)	(4)	(5)
Change in log income	0.467	0.458	0.491	0.473	0.519
	(0.087)	(0.091)	(0.073)	(0.074)	(0.077)
Log consumption ratio (lagged)	−0.589	−0.448	−0.396	−0.448	−0.558
	(0.139)	(0.113)	(0.075)	(0.074)	(0.088)
Money-income ratio	0.152	0.043	0.048	0.066	0.047
	(0.062)	(0.021)	(0.017)	(0.016)	(0.010)
Bond-income ratio	−0.084	−0.043	−0.048	−0.066	−0.047
	(0.041)	(0.021)	(0.017)	(0.016)	(0.010)
Housing-income ratio	0.027	0.021	0.015	0.024	0.047
	(0.022)	(0.020)	(0.006)	(0.006)	(0.010)
Change in GOS over income	−0.151				
	(0.176)				
GOS income ratio (lagged)	−0.512				
	(0.305)				
Change in unemployment	−0.376	−0.416	−0.660		
	(0.281)	(0.339)	(0.249)		
Unemployment	−0.326	−0.055		−0.255	−0.344
	(0.368)	(0.266)		(0.063)	(0.066)
Inflation	−0.153	−0.216		−0.225	−0.326
	(0.168)	(0.118)		(0.102)	(0.084)
Log House price	0.005	0.002			−0.072
	(0.071)	(0.067)			(0.025)
Trend × 100	−0.211	−0.068	−0.058		
	(0.125)	(0.079)	(0.020)		
$\bar{R}^2$	0.780	0.758	0.756	0.759	0.760
Standard error × 100	1.191	1.247	1.255	1.246	1.242
Autocorrelation[a]	0.802	0.777	0.878	0.660	0.802
Heteroskedasticity[b]	0.628	0.563	0.119	0.370	0.750
Normality[c]	0.590	0.691	0.109	0.803	0.583
Test of reduction[d]		0.111	0.331	0.404	0.437

Note: The sample is 1956-1996. Standard errors in parentheses. [a]The p-value of a Breuch-Godfrey test for first order autocorrelation. [b]The p-value of a Breuch-Pagan for heteroskedasticity using the level variables as regressors. [c] The p-value of a Jarque-Bera normality test. [d]The p-value of a Wald test of the reduction in the preceding nesting model.

Table 2: Regression results for the linear model

Dependent variable	Change in per capita consumption (1000-DKK. 1995-prices)			
Regression no.	(6)	(7)	(8)	(9)
Change in per capita income	0.458	0.445	0.443	0.462
	(0.112)	(0.092)	(0.092)	(0.108)
Per capita (consumption−income)	−0.515	−0.352	−0.350	−0.342
(lagged)	(0.180)	(0.092)	(0.089)	(0.113)
Per capita money stock	0.108	0.045	0.046	0.073
	(0.068)	(0.023)	(0.021)	(0.024)
Per capita bonds (debt)	−0.072	−0.045	−0.046	−0.073
	(0.042)	(0.023)	(0.021)	(0.024)
Per capita housing stock	0.029	0.016	0.016	0.015
	(0.013)	(0.008)	(0.008)	(0.007)
Change in per capita GOS	−0.023			
	(0.269)			
Per capita GOS (lagged)	−0.335			
	(0.370)			
Change in unemployment	−0.114	−0.533	−0.509	
	(0.373)	(0.209)	(0.193)	
Unemployment	−0.224	0.022		−0.166
	(0.254)	(0.089)		(0.061)
Inflation (percent)	−0.079			
	(0.145)			
Trend	−0.078	−0.072	−0.065	
	(0.139)	(0.050)	(0.035)	
$\bar{R}^2$	0.641	0.629	0.639	0.576
Standard error	1.038	1.056	1.041	1.129
Autocorrelation	0.765	0.939	0.938	0.854
Heteroskedasticity	0.109	0.025	0.015	0.012
Normality	0.852	0.862	0.819	0.837
Test of reduction		0.581	0.801	0.017

Note: The sample is 1956-1996. Heteroskedasticity robust standard errors in parentheses using White and McKinnon's HC2. See Table 1 for explanations of the test statistics.

ference in the estimated effect of lagged consumption we find only minor differences in the dynamic wealth effects. Thus, the specification of the impact of unemployment, inflation, and the time trend is the only real difference between (3) and (4). Unfortunately, economic theory has little to say about the specification of these variables.

Regression (5) shows that we can restrict the spendability weights to be equal if the house price (i.e., the log of the relative price on houses, $\log(p_t^h/p_t^c)$) is included. The resulting regression has a negative partial impact of the house price. This is to compensate for the relatively high impact of the value of the housing stock. An interesting result in this regression is that the spendability weight on net financial assets is somewhat smaller compared to regressions (3) and (4). At the same time the contemporaneous impact of unemployment and inflation is a bit larger in (5) compared to (4).

Moving on to the linear specification we, once more, start out with a fairly general and over parameterized model in Table 2. As mentioned we test the significance of disposable operating surplus and cannot reject the hypothesis of no impact. The reduced model, in which we also restrict the spendability weights on money and bonds and exclude inflation, is regression (7) in Table 2.[10]

The linear models do not pass the diagnostic tests as well as did the mixed models. Specifically, the null hypothesis of homoskedasticity can only be marginally accepted at a 1 percent level of significance. This result is not surprising in light of other empirical studies. Assuming the growth rate rather than just the growth in income is constant, Campbell and Deaton (1989) suggest to use a model in which the innovation variance in the income process is proportional to the lagged level of income. Weighting the regression as suggested results in only minor changes in the parameter estimates, as expected. We have, therefore, decided to rely on OLS estimates and a heteroskedasticity consistent variance estimator.

The level of unemployment is highly insignificant in regression (7) and the only reduction from (7) to (8) is that we have excluded this variable. The alternative model where the changes in unemployment and the time trend are excluded simultaneously is shown as regression (9). This alternative reduction of model (7) is rejected at a 5 percent level according to the Wald test in the bottom row in Table 2. Hence, regression (8) is the only relevant linear model.

The spendability weights on assets are comparable across the two models and in Table 3 we present the estimated spendability weights for the four interesting specifications. The outlier is regression (5) which has a significantly smaller weight on financial assets compared to the other three specifications. An interesting result is that the estimated

[10] We do not report results for the linear model where the house price is included as a regressor. The reason is that the variable is insignificant throughout.

Table 3: Estimated spendability weights on finacial assets and housing

Asset	Regression			
	(3)	(4)	(5)	(8)
Financial assets	0.122	0.147	0.084	0.132
	(0.037)	(0.037)	(0.014)	(0.067)
Housing	0.039	0.053		0.045
	(0.015)	(0.013)		(0.028)

Note: The estimated weights are obtained by dividing the coefficient on the assets by the coefficient on lagged consumption. The standard errors in parentheses are calculated using the delta method.

weights on financial assets correspond closely to the calculated "expected" parameter values in Ando and Modigliani (1963, Table 1). Hence, the results in Tables 1 and 2 could certainly be taken as empirical support for that version of the life cycle hypothesis.

Turning, finally, to the results of the third specification we find that the different impact of housing compared to financial wealth found in Tables 1 and 2 does not carry over to the specification in Table 4. This is shown in the reduction from regresson (10) to (11). But this is not the only difference. In accordance with the consumption function in the present version of ADAM we use another measure of income compared to Tables 1 and 2. The income entering as the lagged level in Table 4 is the sum of disposable household income and disposable gross operating surplus net of consumption of total capital. In order to test if the marginal propensity to consume (MPC) out of contemporaneous household income is different from the MPC on GOS, a special weighted income measure is used instead of the change in log income (see Table 4). Moreover, the wealth measure includes the replacement value of real capital. All of these differences in data makes direct comparisons of (functions of) parameter values across the tables rather difficult. Nevertheless, it is of interest to compare the statistical properties of the models, as the dependent variable is the same in Tables 1 and 4.

Regression (11) in Table 4 is a standard extension of the DHSY model of consumption where the consumption-income ratio is assumed to be related to the wealth-income ratio. As seen we do not attempt to augment the model with unemployment, inflation, or the house price. It is possible to get a significant effect of inflation and the house price when these variables enter jointly and the change in log wealth is excluded. This results in a negative effect of inflation and a positive effect of the house price. However, we have chosen to restrict the attention to just one specification in Table 4.

The reduction from regression (11) to (12) is just exclusion of the time trend. This restriction is firmly rejected and the reason why we report this regression is because the

Table 4: Regression results for the present ADAM model

Dependent variable	Change in log consumption		
Regression no.	(10)	(11)	(12)
Change in weighted income[a]	0.496	0.494	0.587
	(0.079)	(0.077)	(0.091)
Change in weighted GOS[b]	0.341	0.337	0.223
	(0.124)	(0.119)	(0.144)
Change in log wealth	0.171	0.169	0.181
	(0.055)	(0.053)	(0.066)
Log consumption-income ratio (lagged)	−0.623	−0.620	−0.288
	(0.111)	(0.108)	(0.096)
Log wealth-income ratio (lagged)	0.186	0.186	0.025
	(0.053)	(0.052)	(0.046)
Log housing-wealth ratio (lagged)	0.003		
	(0.021)		
Trend × 100	−0.122	−0.120	
	(0.030)	(0.027)	
$\bar{R}^2$	0.779	0.786	0.669
Standard error × 100	1.207	1.189	1.478
Autocorrelation	0.771	0.754	0.778
Heteroskedasticity	0.350	0.258	0.058
Normality	0.323	0.313	0.916
Test of reduction		0.879	0.000

Note: The sample is 1957-1996. Standard errors in parentheses. See Table 1 for explanations of the test statistics. [a] $\Delta y_t/(y_{t-1}+ \text{GOS}_{t-1})$. [b] $\Delta\text{GOS}_t/(y_{t-1}+ \text{GOS}_{tz1})$.

Table 5: Encompassing tests of the rival models

Model	I	II	III	V
I		0.19	0.35	0.05
II	0.24		0.26	0.19
III	0.45	0.29		0.17
V	0.17	0.19	0.33	

Note: The entries in the table are p-values from F-tests of the hypothesis that the artificial nesting model (row+column models) can be reduced to the row model.

formulation in (12) is the one currently used in ADAM. Notice the sharp drop in the coefficient upon the lagged consumption ratio. This is accompanied by an even more dramatic drop in the coefficient upon the wealth ratio whereby the spendability elasticity of total wealth drops from 0.3 in (11) to an insignificant estimate of 0.09 in (12).

In the next sections we will compare regressions (3), (4), (5), (8), and (11). These regressions will henceforth be denoted model I to model V.

3.3. Comparisons of the rival models

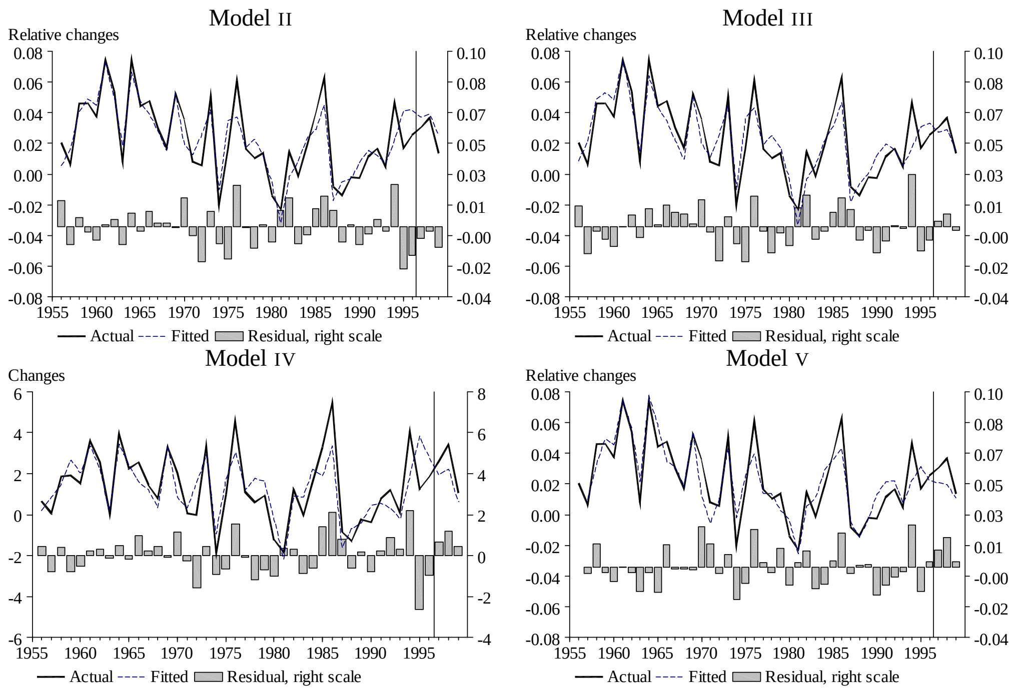
The models I-III and V are non-nested linear regression models. This means that we can compare the models using simple encompassing tests.[11] We have chosen to use the Atkinson procedure which imply that we formulate an artificial nesting model. Within this auxiliary model we simply use an F-test of the restrictions leading to each of the two rival models.

The p-values of the F-tests are given in Table 5. An encompassing test of two rival models, say, I versus II is performed in two steps. First we test if the artificial model can be reduced to model I. This test is reported in row 1 column 2. Second, we test if the artificial model can be reduced to model II. This test is reported in row 2 column 1. As seen both reductions are supported by the data. The conclusion is therefore that neither of the two models have information not included in the rival model.

The interesting encompassing tests in Table 5 are the comparisons between the mixed log-linear models I, II, and III and model V. The p-values of the F-test statistics for these comparisons are reported in row 4 and column 4 of Table 5. It is evident that it is difficult to discriminate between the specifications based on the encompassing tests. However, if anything there is weak evidence against choosing model I.

[11] See Gourieroux and Monfont (1994) for a good presentation of testing non-nested hypotheses.

Figure 5: Actual and fitted values for the four rival models



In addition to the encompassing tests we can also compare the fit of the rival models. As we have already established that all models pass the diagnostic tests, the interesting comparison is how the models predict the (relative) change in consumption in certain critical years. Figure 5 plots the changes in (log) consumption alongside the fitted values and residuals for four of the competing models. The plots lends support to the encompassing tests in that it is very difficult to find major differences between the fits. The four models seem to do equally well or equally bad in some of the more volatile periods such as 1962-64, 1974-76, and 1986-87.

As a second comparison of the rival models we test parameter constancy and post sample predictive power. These tests are reported in Table 6.

Parameter constancy is tested using three different statistics. First we look at the instability test proposed by Jukka Nyblom (1989) and Bruce Hansen (1992). This test in which the null-hypothesis of constant parameters is tested agaist an alternative of random walk parameters does not have a standard limiting distribution, but critical values are given in Hansen (1992). The 20 percent critical value in a model with 8 parameters (7 mean parameters and the variance) is 1.66. As seen from table 6, parameter constancy cannot be rejected in any of the models using this test.

Table 6: Parameter stability and forecast performance

Model		I	II	III	IV[a]	V
Nyblom instability test		1.16	0.96	1.02	1.39	0.76
Break point Chow test	(1980)	0.12	0.12	0.13	0.24	0.34
Prediction Chow test	1997-99	0.76	0.84	0.94	0.75	0.56
One-step forecast errors $(100 * (\Delta \log(c_t) - \Delta \widehat{\log(c_t)}))$						
Year	1997	0.82	-0.68	0.29	0.92	0.98
		(0.59)	(0.50)	(0.22)		(0.77)
	1998	1.26	-0.24	0.74	0.61	1.67
		(0.91)	(0.18)	(0.53)		(1.29)
	1999	0.80	-1.16	-0.21	0.04	0.29
		(0.58)	(0.83)	(0.14)		(0.23)

Note: t-values in parentheses. The 20 percent critical value for the Nyblom test is 1.66 (8 parameters), see Hansen (1992). [a]For the linear model we report the prediction error of the growth rate $100 * (\Delta \log(c_t) - \Delta \log(\hat{c}_t))$).

The second test is a standard break point Chow test with pre and post 1980 as the two samples. The year 1980 is not chosen at random as it markes a change in the housing market towards less restrictive regulations on the financing of houses.[12] Table 6 shows that all models pass the break point Chow test at conventional levels though the mixed log-linear models seems to be more sensitive to spliting the sample compared to the two rival formulations.

The final test is a prediction Chow test in which we make use of the preliminary data for the years 1997-1999. The test reveals that all specifications do surprisingly well in forecasting the growth rate in consumption. This can also be seen from the one-step forecast errors reported in Table 6. Most of the forecast errors are less than one percent of the target, and non of the errors are significantly different from zero.

Overall, there are no signs of parameter instability or ‘structural breaks’ in the models. Hence, based on the statistical information in the 40 years of data we cannot make a decisive choice of model for private consumption. Nevertheless, we have chosen to exclude model I in the next section.

[12]The financial regulations of the housing market were also changed in 1970 and several minor changes happened throughout the 1970’s. However, 1980 (or the early 1980’s) is often regarded as the year (period) in which the housing marked was “liberalized”.

4. Policy experiments

In this section we turn to a somewhat different analysis of the rival models, as we look at the properties of the macroeconometric model ADAM when this model is endowed with each of the four consumption functions.[13]

In working with ADAM it is a standard procedure to look at 'multiplier experiments' for different specifications before deciding on a single formulation. In the present paper we present results of two standard experiments: (i) a permanent increase in public spending on goods of one billion 1995-DKK (roughly equivalent to 0.1 percent of GDP in 1999), and (ii) a permanent one percentage point decrease in the foreign interest rates. In the experiments shown below we use a version of ADAM in which the (nominal) domestic interest rate is pegged to the foreign rates. Hence, the nominal interest rate is constant in the first experiment and decreases by one percentage point in the second.[14]

In Figures 6 and 7 we show the impact on total private consumption and gross domestic product at market prices. Eventhough ADAM was originally intented as a short run model with emphasis on the business cycle frequencies it is nowadays common practice to record the predicted changes over 30 to 60 years. Here, we present the effects over a 60 year period.

We will not comment much on the actual impact of the policy experiments, but concentrate on the differences induced by the choice of consumption function. However, the rather long business cycle fluctuations in ADAM, which are seen not to depend on the formulation of the consumption function, are caused by fluctuations in the house price, which is highly dependent on changes in production and income.[15]

Figure 6 plot the percentage change in private consumption and GDP following the increase in public spending. The main difference between the effects is a small variation in the phase with models IV and V having the longest cycles. For model V the result is a consequence of the choice of dynamic specification as the latter model includes savings and initial wealth lagged one year while the three contesting models include only initial wealth.

It is interesting to note that the log-log formulation in model V is closer to the linear model IV than the two mixed models. The two mixed models II and III have almost equal responses. Model III, however, has sligthly larger amplitude. This is probably a consequence of a larger responsiveness to variations in the house price.

[13] ADAM is documented on line on the economic modelling homepage at Statistics Denmark.

[14] As allways, the relevance of experiments of this kind can be questioned on many accounts. However, evaluation of responses to these policy experiments is an integral part of model evaluation in ADAM.

[15] For an elaborate discussion of the policy experiments, see Poul Uffe Dam (1996).

Figure 6: The impact of a permanent increase in public spending of one billion 1995-DKK

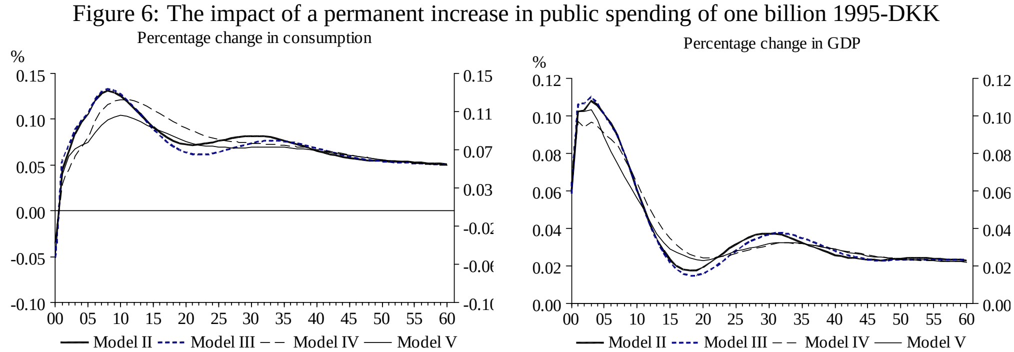
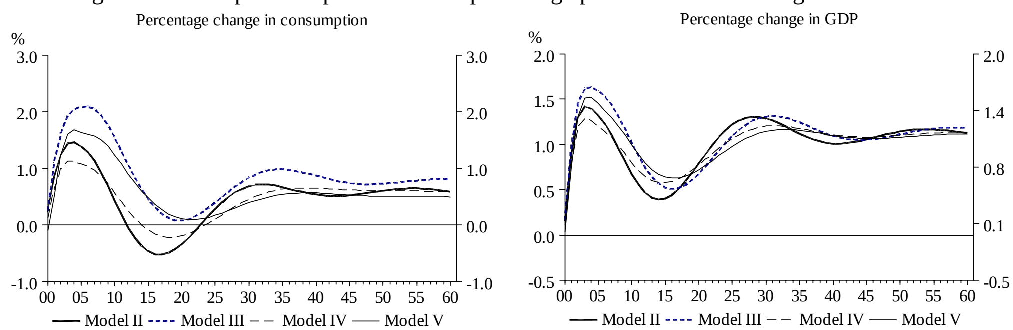


Figure 7: The impact of a permanent one percentage point decrease in foreign interest rates



Overall the differences in the responses to the change in public spending are small, making a choice bewteen the models very difficult.

Moving to the effect of a permanent decrease in the interest rates in Figure 7 we note that the relative differences between the responses are somewhat larger in this experiment. A likely explanation is that the decrease in the domestic interest rate has an relatively larger impact on wealth compared to the increse in public expenditure in the first experiment. This means that the varying spendability weights shown in Table 3 come into play in this experiment; however, not in a simple way.

The largest short run response is recorded for the model III, both in terms of the change in consumption and the change in GDP, while the smallest response is recorded for model IV. The long run effects (50-60 years) are all within a narrow margin just below a one perventage change in consumption and just abowe a one percentage change in GDP.

Considering the duration of the cycles in the responese it appears that mode II has the shortest cycle, while models III and V have the longest cycles. However, for the changes in GDP the changes are again minor.

5. Conclusion

In this paper we have compared three different formulations of a macro consumption function using annual Danish data for the period 1956-96. The main reason for introducing alternative specifications of the consumption function was to analyze if different assets (money, bonds, houses, shares) have varying impacts on consumption expenditure according to the liquidity of the assets. The answer to this question turns out to be both yes and no depending on the choice of specification. If we specify either a linear consumption function, closely related to the original Ando and Modigliani (1963) specification, or a mixed log-linear function inspired by Muellbauer and Lattimore (1996), we find that the marginal propensity to consume out of disposable gross operating surplus is very close to zero, in fact we must restrict the MPC to zero to avoid a perverse result. The MPC out of housing wealth is about one third of the MPC out of money and bonds. This supports a hypothesis of a relation between liquidity and spendability weights. However, using a logarithmic consumption function inspired by Davidson, Hendry, Srba, and Yoo (1978), we reject the hypothesis of different spendability weights on assets.

A quite detailed statistical comparison, i.e., residual diagnostics, parameter constancy, ex post forecasting ability, and encompassing of rival models, revealed that all specifications perform well. Thus, based on data congruency it is not possible to select a single formulation.

As the consumption function is to be used in the macroeconometric model ADAM it is natural to give much attention to the properties of the model when it is endowed with each of the three specifications. Therefore we made a selection of four rival formulations, which were each included in ADAM. Subsequently, we looked at differences in responses to two standard policy experiments. Again, the results are very close, showing that the choice of functional form makes very little difference. Yet, there are small variations in the length of the resulting business cycle so if this is used as a decisive indicator, a mixed log-linear model with different spendability weights on shares, housing, and money should be preferred.

The latter choice could also be based on medium-term forecasting properties, as the mixed log-linear model with varying spendability weights is the only specification for which we are able to exclude a time trend. However, we think of this as a rather weak basis for decision.

Finally, the linear and the mixed log-linear formulations are both easier to relate to economic theory compared to the logaritmic specification. Since the models have equally good statistical properties, this certainly gives weight for a choice of either the linear or the mixed model. However, we must bare in mind that the theory is better suited for micro economic analysis than macro consumption functions.

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A. Data definitions

Series name in tables and figures	*Series name in* ADAM
Consumption	Cp4/pcp4v
Income	Ydphk/pcp4v
GOS	Ydpsk/pcp4v
Money	$(\text{Wpqkpc}_{-1}+\text{Wzbkr}_{-1})/\text{pcp4v}$
Bonds (debt)	$\text{Wzbkr}_{-1}/\text{pcp4v}$
Housing	$\text{phk}_{-1}\text{fKnbh}_{-1}/\text{pcp4v}$
Unemployment	bul
Inflation	Δ log(pcp4v)
House price	phk/pcp4v

Per capita series are calculated by dividing with the total population. In ADAM this series is denoted U.

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