House Prices and Consumption: A Micro Study

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Abstract

Empirical evidence shows that house prices and consumption are closely synchronized. However, previous contributions disagree over the causes of this link. According to the life cycle model, households plan lifetime consumption based on their expectations about the development in their total wealth, including housing wealth, and households should only react to innovations in house prices. However, the previous literature has promoted three alternative explanations. One explanation is that the observed correlation may be due to "common causality" since rising house prices may be correlated with expectations on general productivity increases in society. Other contribution focus on the fact that housing serves as collateral, implying that credit constrained households may show excess sensitivity to house price changes. Finally, extensive financial liberalizations in many countries may have stimulated both house prices and consumption in general. This paper investigates whether the wealth effect can explain the development in consumption and house prices in Denmark in 1987-1996. The paper explores a rich panel data set with information on individual house ownership, income and wealth for 10 percent of the Danish population. We construct a panel of imputed consumption based on the imputation method developed by Browning and Leth-Petersen (2003). In order to investigate the life cycle model and in particular the wealth explanation, it is essential to distinguish between expected and unexpected changes in housing capital and income. We model households' expectations on the development in house prices and income in order to differentiate between innovations to housing wealth and human capital at the individual level. Having access to such a rich panel data set is unique by international standards. One of the main advantages is that we can differentiate between the reactions of younger and elderly households, between long-term renters and house owners, and between credit-constrained and unconstrained households. In 1993, a financial liberalization reform as well as a tax reform took place. We therefore divide the analysis into two periods: Before 1993 and after 1993. We find no significant response to changing house prices before 1993. After 1993, we find a positive effect of both anticipated house price changes and house price shocks. The effect is more pronounced for younger than for older households. This result, which is evidence against the wealth explanation, is in line with the findings of Attanasio et al. (2005) and Attanasio and Weber (1994). The positive effects of house prices on consumption is most pronounced for liquidity-constrained households, which suggests that housing is an important collateral for households who are borrowing-constrained.

1. Introduction

It is a widespread empirical finding that house prices and consumption are closely synchronized. Several studies establish a correlation between changes in annual real house prices and consumption growth, but the previous contributions disagree over the causes of this link.

Changes in house prices affect *household wealth*. According to the life-cycle hypothesis, households adjust their lifetime plan regarding consumption, labour supply etc. when they receive new information on their lifetime wealth. Thus, unexpected changes in assets through e.g. house price changes may affect household consumption through a wealth effect.

The previous literature has proposed a number of alternative hypotheses for the co-movement of consumption and house prices. One alternative explanation focuses on houses' role as a *collateral* available to homeowners and may therefore improve households' options for borrowing based on the house as security. Another hypothesis is that house prices and consumption are influenced by common factors. Expectations on *productivity* growth affects wages and expected income over the life cycle. This may affect both house prices and consumption in the same direction. Thus, the correlation between house prices and consumption does not necessarily reflect a causal relationship between house prices and consumption, but rather mirrors that there are common factors which simultaneously affect house prices and consumption. Moreover, the period analyzed was characterized by extensive *financial liberalizations* which may *both* have driven up house prices and at the same time stimulated consumption by relaxing borrowing constraints. Consequently, the correlation between house prices and consumption does not reflect a causal relationship between house prices and consumption, but rather the effect of financial liberalizations on both house prices and consumption.

Thus, apart from the wealth channel, a number of other factors may contribute to the positive correlation between house prices and consumption. Whether the wealth effect dominates in explaining the positive relationship between house prices and consumption is mainly an empirical question. This paper examines the empirical relationship between total expenditure and house prices in Danish households. The paper exploits a rich panel data set with information on housing ownership, income, wealth, and background factors for 10 percent of the Danish population in the period 1988-1996. Having access to such a rich panel data set is unique by international standards. One of the main advantages is that it allows us to investigate the link between house prices and consumption for subgroups of the population.

Increasing house prices generate increasing wealth for homeowners, but also increase the price of future housing needs. Thus, younger households who expect to trade up in the housing market may be less inclined to convert capital gains on housing into higher consumption. On the other hand, elderly households may be willing to trade down in housing and thus realize some of the capital tied in their house. Therefore, we may observe that elderly house owners capitalize the capital gains on their house into higher consumption to a larger extent than younger house owners. An empirical observation of this sort would work in favour of the wealth explanation.

On the other hand, changes in productivity affect households differently depending on their age and situation in the labour market. Younger households may be more sensitive to productivity increases than elderly households since younger households expect to stay in the labour market for a longer period than elderly households. Thus, a stronger correlation between house price changes and consumption among younger households would suggest that the observed reaction is more likely to be due to productivity changes.

Another important distinction is between renters and owners. If the wealth explanation is important, renters who hope to enter the housing market should increase savings (and decrease consumption) when house prices rise unexpectedly. However, young renters would share the reactions of young house owners and increase consumption when house prices increase if the productivity explanation is dominating.

These ex-ante predictions motivate that we investigate our research question by comparing the reactions to changing house prices of different household types. More specifically, we compare the reactions across younger versus older households, owners versus renters, and credit constrained versus unconstrained households.

An important advantage of having access to real panel data is that it allows us to ignore possible influence from unobserved household-specific parameters governing time preferences, attitudes to risk and self-selection in the owner market. Furthermore, our rich data set enables us to disregard cohort effects and to more fully distinguish between long-term owners and long-term renters. As opposed to this, analyses based on synthetic panel data suffer from the disadvantage that the group composition changes endogeneously. Thus, synthetic panel data analyses do not take proper account of unobserved heterogeneity. If moving (from renter to owner and vice versa) is correlated with income and house prices, the results may be biased.

In theory, the close link between house price changes and consumption cannot necessarily be reconciled within the context of the life-cycle model. According to the general interpretation of the life cycle hypothesis, households will seek to smooth consumption over their lifetime. In an economy with perfect credit markets and forward-looking households, households can borrow in order to smooth consumption if they expect an increase in wealth (housing wealth, human capital etc.). Thus, ideally, a change in house prices or income will only affect consumption if it is unanticipated. In order to assess this problem, we distinguish between predictable and unpredictable changes in house prices and consumption by setting up a model for the house price and the income processes, respectively. The aim of this exercise is to distinguish “true” wealth effects from other effects such as collateral effects, precautionary savings, or myopic behaviour. If we observe that consumption changes with changes in wealth that have been anticipated, this suggests that consumers are myopic or that credit markets are imperfect. We examine this by comparing the reactions of households with low liquidity with households with high liquidity.

2. Previous literature

The previous literature on the correlation between house prices and expenditure point at different causes of the empirical relationship.

A number of papers conclude that the wealth explanation is the most reasonable explanation for the observed co-movement of house prices and consumption. Contributions that support the wealth hypothesis are Muellbauer and Murphy (1990), Campbell and Cocco (2007), Case, Quigley and Schiller (2005). Muellbauer and Murphy (1990) investigate the relationship using aggregate UK data. Other important findings in Muellbauer and Murphy (1990, 1997) and Aron, Muellbauer and Murphy (2006) are that credit constrained households are more sensitive to house price changes, and they point at the financial liberalizations that took place in the UK in the 1980'es and 1990'es as important drivers of the development in private consumption.

Campbell and Cocco (2005) use the UK Family Expenditure Survey (FES), which is a pseudo-panel, in their empirical analysis. They estimate the largest effect of house prices on the consumption of older homeowners, and consequently attribute their finding to the wealth channel explanation.

Skinner (1994) examines the relationship on US data and finds that house price changes have a significant impact upon consumption at the household level through life-cycle wealth effects.

Other contributions to the literature point at the common causality or productivity explanation as the main driver of the co-movement of house prices and consumption. A number of papers by Attanasio and co-authors, see Attanasio and Weber (1994) and Attanasio et al. (2005), analyse growth in consumer spending in Britain over a period from 1978-2001/02. As Campbell and Cocco (2005), data from the Family Expenditure Survey (FES) is used. However, Attanasio and co-authors find that young homeowners respond more strongly to house price changes than older houseowners. Thus, these results contradict the wealth explanation and rather suggest that common causality is the most important factor behind the link between house prices and consumption. Moreover, they find that renters show much the same consumption change as homeowners which also contradicts the wealth channel and points towards increasing productivity in society as the main driver of both house prices and consumption, i.e. common causality.

Results in King (1990) and Pagano (1990) are in line with Attanasio and Weber (1994) and Attanasio et al. (2005).

A number of papers find that credit-constrained households react more strongly to house price changes, even if these are anticipated, see Muellbauer and Murphy (1990), Aron and Muellbauer (2006), Campbell and Cocco (2007), Leth-Petersen (2006), Aoki et al. (2004), Iacoviello (2004). *More…* Thus, the presence of credit constraints may explain why some studies find excess sensitivity to house prices, meaning that households react not only to surprises, but also to expected changes in house prices.

Disney, Gathergood and Henley (2007) examine the relationship between changing housing wealth and "active saving". "Passive saving", i.e. appreciations or depreciations of assets are imputed. They find no evidence that increasing house prices lead households in the UK to reduce financial assets. They find that house price changes have a particularly strong effect on consumption of liquidity-constrained households. However, since the proportion of UK households who are liquidity constrained is low, their impact on the aggregate effect is small. Disney, Gathergood and Henley differentiate between expected house price changes and innovations to house prices, but they only examine the effect of innovations on consumption. Thus, the possible effect of expected house price changes which reflects excess sensitivity to increases in wealth is not explicitly examined.

Most of the recent literature has studied the empirical relationship in a period where extensive financial liberalizations which promoted consumers access to credit took place, see Muellbauer and Murphy (1990, 1997), Attanasio and Weber (1994), Aron and Muellbauer (2006), Campbell and Cocco (2007).

The housing market during the 1980'es and 1990'es went through both booms and busts in many countries, including UK, US and Denmark. A couple of papers find an asymmetry in households' reactions to gains and falls in house prices. Both Engelhardt (1996) and Skinner (1994, 1996) find asymmetric responses to house prices in the US. Thus, they find that falling house prices lead to a stronger response on consumption than increasing house prices. Disney (2007) finds no general asymmetric behaviour between house price rises and falls. However, Disney finds a strong asymmetry for households in negative equity.

Intergenerational altruism and bequest motives among older households should be considered when comparing the responses to houseprices across younger and older generations, see Venti and Wise (1990), Disney, Henley and Stears (2002).

3. Institutional background and the housing market in Denmark

The housing market has undergone some quite dramatic changes during the period observed. House prices peaked in 1986 after a period of rather constant price increases. During the years 1987-1993, real house prices went down by some 30 percent on average. The fall in house prices in this period followed a fiscal tightening in the second half of 1986 and a tax reform in 1987 which implied a considerable cut in the tax value of tax deductions on interest payments on (mortgage) loans. The tax reform had important implications for many Danish house owners who had taken up fixed interest rate loans in a period where there interest rate was close to 20 percent and the inflation rate was high. The simultaneous effect of lower inflation rates, a lower value of tax deductions on interest payments and fixed-rate high interest loans with no possibility of re-mortgage meant that many households experienced liquidity problems, and consequently, many houses were the subject of a compulsory sale.

In 1992, the Danish parliament passed a change of the law on mortgage credit which opened up for the possibility of re-mortgage of existing loans in houses. In 1993, another tax reform was passed. The new tax system further reduced the possibilities for tax-deductions of interest rate payments. From 1993-2001, real house prices have more than doubled in certain parts of the country.

For the period analysed, we therefore observe a period with falling real house prices (1989-92) and a period with increasing house prices (1993-1996). Moreover, some important institutional changes took place around 1993 which affected credit opportunities and liquidity for house owners. In our analyses, we therefore distinguish between the two sub-periods before and after 1993, respectively. This approach is consistent with the notion that the reactions to house price shocks are asymmetric, which has been suggested and examined by Disney et al. (2007) on UK data, and by Engelhardt (1996) and Skinner (1994, 1996) on US data. Thus, a possible shift in the response to house price changes around 1993 can be attributed to a combination of the tax reform, the credit reform and an asymmetry in responses to positive and negative house price changes. We will try to disentangle the effect of these three simultaneous, but independent, shifts by identifying different groups that we believe to be extra sensitive to tax reform or credit reform after 1993. Table 1 below summarizes the institutional setup before and after 1993.

Table 1. Institutional setup before and after 1993

	1987-1992	1993-1996
Mortgage market	20 year repayment period Fixed interest rate No remortgage No use of equity as collateral	30 year repayment period Fixed or variable interest rate (flex) Allow remortgage Equity can be used as collateral
Tax system	Tax deduction of interest 52% Marginal tax rate 64%	Tax deduction of interest 46% Marginal tax rate 64% ➔ 58%

4. Data

The data used in this paper is based on Danish public administrative registers for a random sample of 10% of the Danish population aged 16+ who are followed in the period 1987-1996. Due to the collection of a wealth tax in this period, the administrative registers contain rather detailed information on wealth along with income and a number of personal and household characteristics.[1] For this paper, we focus on a sub-sample of households who are married or cohabiting, who remained a stable couple, and who were either home owners or renters throughout the period of interest.

Expenditure imputation

One of the advantages of having access to longitudinal information on wealth in combination with income is the possibility of deriving an imputed expenditure measure at the household level over time. Browning and Leth-Petersen (2003) develop and test a number of different imputation methods for total expenditure. Their preferred – and also simplest - approach to derive an expression for total household expenditure is based on an accounting identity where total expenditure in a period is calculated as total income in the period minus the change in total wealth from the previous period to the present period:

$$c_{it} = y_{it} - \Delta W_{it} \qquad (1)$$

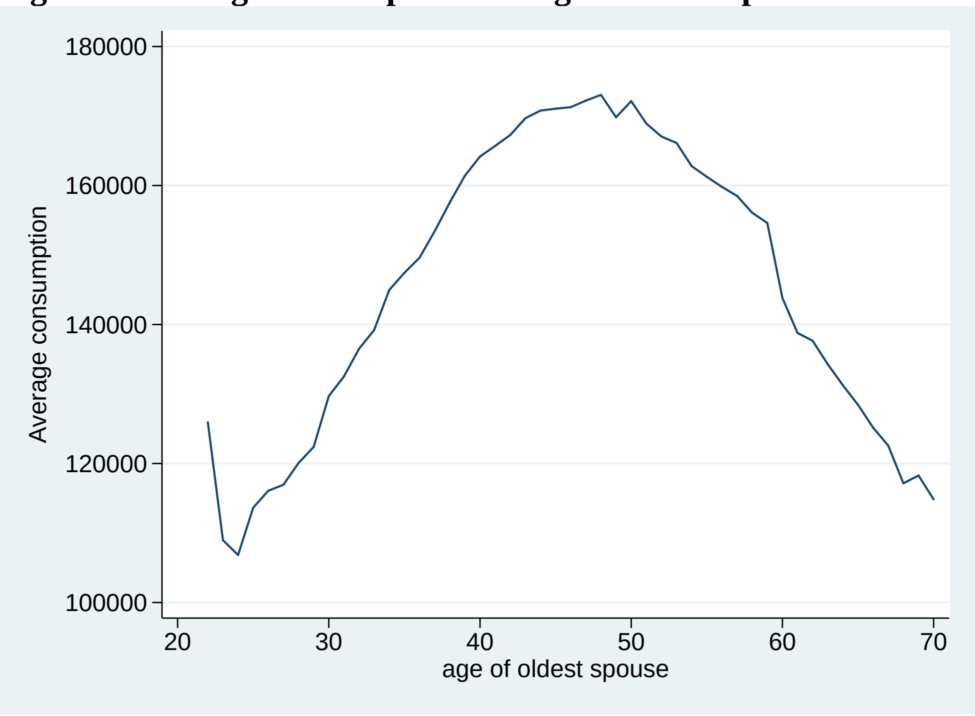
where c_{it} is total expenditure of household i in period t, y_{it} is disposable income of household i in period t, and ΔW_{it} is the change in household i's total net financial wealth (savings) from period t-1 to period t. Disposable income consists of labour

[1] The wealth tax was abandoned in 1997. Therefore, register information on wealth is insufficient to impute expenditure after 1997.

income, transfer income and capital income net personal taxes. Wealth consists of all financial assets, i.e. stocks, bonds, bank deposits etc. minus debt, i.e. mortgage debt, bank debt etc. All figures have been deflated with relevant price indices to reflect real terms (1990 price levels). We apply the same definition of imputed consumption as in Browning and Leth-Petersen (2003). Total expenditure is imputed at the household level based on disposable after-tax income minus the change in net wealth. Household disposable income is defined as the sum of gross income including interest income, housing transfers and dividends from share capital; from this sum we deduct taxes on income, taxes on shares, surplus on owner-occupied housing and tax-exempted interest rate expenses. Household net wealth is defined as assets minus liabilities. Assets include the market value of share capital, bank deposits, the market value of bonds and securities. Browning and Leth-Petersen (2003) verify that imputed consumption fits rather well with data on household expenditure from the Danish Expenditure Survey.

Housing consumption cannot be treated as a one-time consumption durable purchase. The desired flow of housing services changes with family formation and again when adult children leave their parents' home. We expect that younger households will react differently to house price changes than elderly households. Moreover, total expenditure varies across age groups. Figure 1 shows average consumption over age of the oldest spouse (for single households, age of the individual). It appears that household consumption increases from the beginning of the 20'es until around the age of 40, from 40 to 55, consumption is rather flat, and after 55 household consumption decreases monotonically. Due to this age pattern, the sample has been subdivided into two age groups; the younger group consists of households where the oldest spouse was 20-40 years old in 1987 and the older group where the oldest spouse was 41-55 years in 1987.

Figure 1. Average consumption and age of oldest spouse



House prices

We use data on average sales prices for traded single-family houses at the municipality level for the period 1985-2001. Data has been collected by the Danish tax authorities. In this period, there were 275 municipalities in Denmark. House prices vary between different regions in the country. We subdivide the sample according to level of house prices in 1985.[2] Figure 2a below shows real house prices for six different municipalities which are, respectively, at the 10^{th}, the 25^{th}, the median, the 75^{th}, the 90^{th} and the 95^{th} position in the percentile distribution. Figure 2b shows the yearly changes in log real house prices at the same points in the house price distribution. From the graphical presentation, it appears that municipalities in different parts of the country seem to follow similar house price processes.

[2] The municipalities with the top 5 percent house prices are situated in the Northern suburbs of Copenhagen, the 90^{th} to the 95^{th} percentile consists of houses found around Copenhagen and Aarhus mainly, the 75^{th} to 90^{th} percentiles are Copenhagen municipality and other larger cities including Odense and Aalborg, the 50^{th} to 75^{th} percentile consists of medium-sized cities, the 25-50 percentile consists of houses situated in smaller towns and rural areas. The lowest quartile (percentile 10-25 and percentile 0-10) consists of municipalities in rural areas including the most "remote" areas of Denmark.

Figure 2a. Regional trends in house prices at different percentiles in distribution

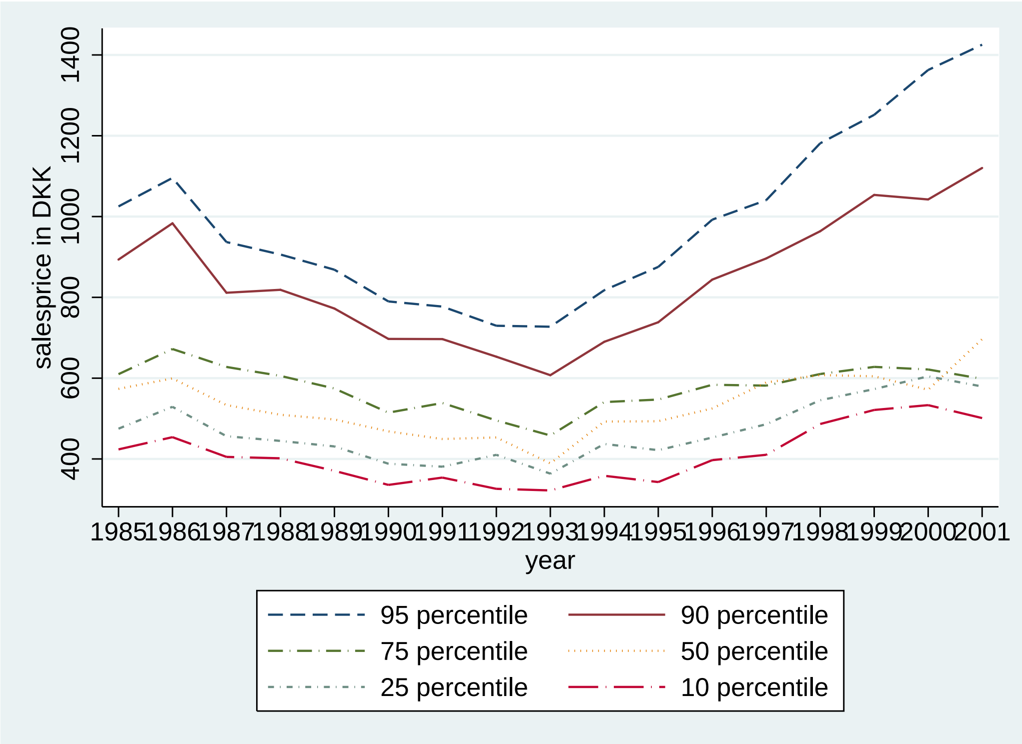
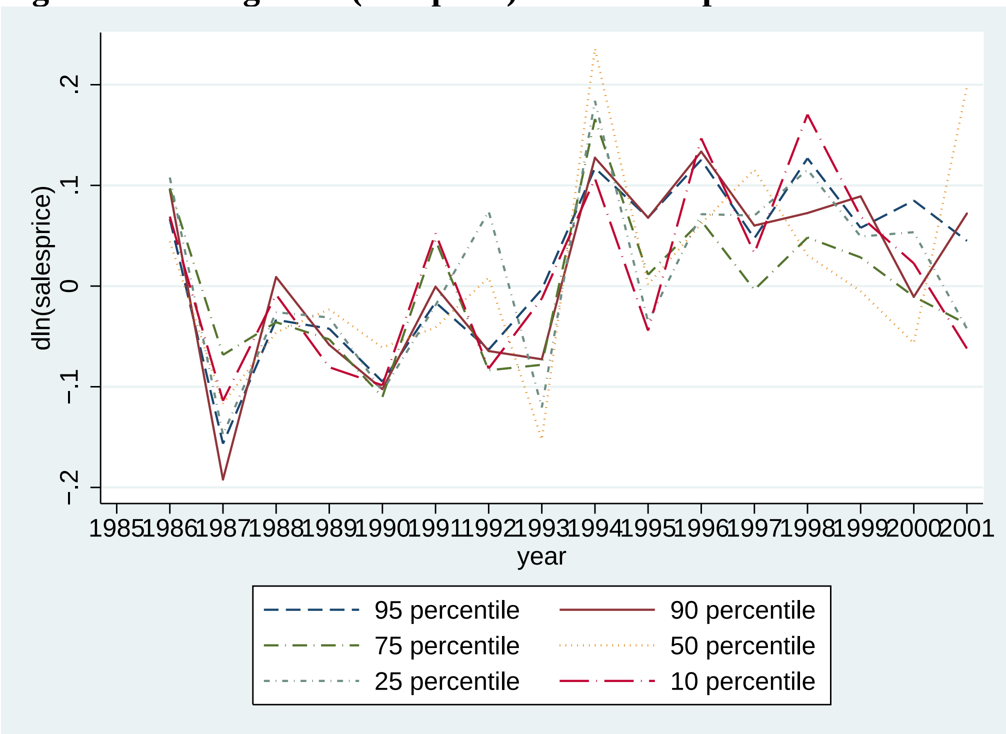


Figure 2b. Change in ln(salesprice) at different percentiles in distribution



Source: Sales prices based on traded houses by municipality. Statistics Denmark and publications from Danish tax authorities (Skat).

5. An empirical model of consumption and house prices

The life cycle model asserts that individuals/households choose a path of consumption to secure constant marginal utility of consumption over time. A common interpretation of the life cycle model suggests that individuals smooth consumption over their life, given their information about household assets at the beginning of the planning horizon and their expectations of the development of wealth over the planning horizon. Wealth includes financial assets (net), human capital, housing capital etc. The model in its general form assumes that households are forward looking and credit markets are perfect. Deviations from the individual consumption plan are due to the arrival of new information or *unexpected* changes in wealth.

Innovations to human capital through unexpected individual productivity changes may lead to an adjustment of the permanent income and consumption level. Moreover, changes in housing wealth through unexpected price changes may affect total expenditure. In principle, price changes that were already expected at the beginning of the planning period do not affect consumption, provided capital markets are perfect and there are no credit market constraints. Given perfect capital markets, a household that expects wealth (e.g. housing or human capital) to change tomorrow can borrow or save today to smooth its consumption path. If we observe that consumption reacts to *expected* house price changes, this may indicate e.g. that the household is myopic or that the household is credit constrained due to credit market imperfections.

We therefore propose and investigate an empirical model where changes in consumption are regressed on expected and unexpected changes in house prices, unexpected changes in disposable income and the real after-tax interest rate. We control for demographic characteristics.

$$\Delta c_{it} = \pi_0 + \pi_1 r_t + \pi_2 E\left(\Delta y_{it}\right) + \pi_3 \hat{\theta}_{it}^{y} + \pi_4 E\left(\Delta p_{mt}\right) + \pi_5 \hat{\theta}_{it}^{p} + \pi_6 Z_{it} + \lambda_t + u_{it} \tag{2}$$

where c_{it} indicates log total household consumption (except housing consumption) for household *i* at time *t*. r_{it} is the after-tax interest rate. $E\left[\Delta y_{it}\right]$ symbolises the household's expected change in disposable income between *t-1* and *t*, and $\hat{\theta}_{it}^{y} = \Delta y_{it} - E\left[\Delta y_{it}\right]$ is the surprise or innovation to income changes in period t, i.e. the difference between expectations formed at t-1 about the income change in period t and the realized income change in period t. $\hat{\theta}_{it}^{p}$ signifies the surprise or the innovation to house prices. $E\left[\Delta p_{it}\right]$symbolises household expectations of the development in house prices between *t-1* and *t*, and $\hat{\theta}_{it}^{p} = \Delta p_{it} - E\left[\Delta p_{it}\right]$ is the difference between expectations formed at t-1 of the house price change in t and the realized house price change in period t. λ_t is a common national shock, and v_{it} is an independent error term. By estimating the model in first-differences, unobserved heterogeneity in household characteristics due to e.g. differences in preferences, attitudes to risk, individual discounting rates etc. are eliminated from the model.

Expected house price changes are estimated by a model of the house price process. A model of individual income processes is estimated accordingly.

The house price process

In order to distinguish between expected and unexpected house price changes, we investigate the time series characteristics of house prices. Households form their expectations on house prices in period t based on their observation on house prices in the past in their local area (municipality or region), *k*. Initially, we assume that house prices follow a first-order autoregressive (AR1) model with unobserved individual-specific effects and serially uncorrelated disturbances:

$$p_{kt} = \alpha p_{kt-1} + \left(1-\alpha\right)\eta_k + \beta x_{kt} + \delta_t + v_{kt}, \quad \text{k} = 1,...,K, \ \ t = 2,...,T \tag{3}$$

In the empirical application of the house price model, we experiment with specifications of the AR model with more than one lag. p_{kt} is the natural log of the house price in municipality *k*, η_k captures unobserved heterogeneity in house prices, x_{kt} symbolises observed characteristics of houses in municipality *k* (i.e. the average size of houses in the municipality measured by the number of square meters and number of rooms of an average house) and δ_t captures common shocks at time t. Household expectations on the development in local house prices are formed by $E\left[\Delta p_{kt}\right] = E\left[p_{kt}\right] - p_{k,t-1}$. The innovation (surprise) in average municipality level house prices experienced in period *t* is then $\hat{\theta}_{kt}^{p} = p_{kt} - E\left[p_{kt}\right]$. Under the assumption that households understand the house price generating process in model (3), household expectations on the average municipality house price are found by $E\left[p_{kt}\right] = \hat{p}_{kt}$. Furthermore, to establish the mapping to household level house prices, we need to assume that households base their expectations on the price development of their own house on the expected price development in their municipality. Thus, estimation of the municipality house price process is crucial to distinguish between unexpected and expected changes in house prices. More details on the model for the house price process can be found in Appendix 1.

The income process

Estimation of the model of consumption changes over time in (2) requires that we distinguish between expected and unexpected changes (innovations) to disposable income. Thus, we need to specify a model for household formation of expectations on their disposable income. The literature on earnings processes of individuals and households has proposed various dynamic models, see Browning, Ejrnæs and Alvarez (2002) and Browning and Lusardi (1996). In this paper, the main focus is on the consumption equation, and we adopt a somewhat simpler formulation of the income process. More specifically, we assume an AR(1) income process where individual income in period t is based on lagged income from period t-1 (and possibly more lags). We control for household characteristics as the presence of children, age of oldest spouse in the household (captured by *z*), and time dummies (captured by δ_t):

$$y_{it} = \alpha y_{it-1} + (1-\alpha)\eta_i + \beta z_{it} + \delta_t + u_{it}\ , \ i = 1,...,N, \ t = 2,...,T, \qquad E\left[u_{it}\right] = 0 \tag{4}$$

At time *t*, $E(y_{it-1}) = y_{it-1}$. This implies that the difference between realised income changes and expected price changes - the predicted surprise term, $\hat{\theta}_{it}^{y}$ - can be calculated by $\hat{\theta}_{it}^{y} = y_{it} - E\left[y_{it}\right]$. More details on the income process can be found in Appendix 2.

6. Results

The empirical model consists of three parts. First, we estimate house price and income processes. Secondly, based on the estimation results from the house price and income processes, we derive predictions of expected and unexpected house price and income changes. These predictions are used in the consumption equation.

Estimation of the house price process

Data consists of yearly observations on average sales prices of single-family houses in 275 Danish municipalities during the period 1985-2001. The key issue when choosing a suitable estimator for (3) is to establish whether the model is stationary $(\alpha < 1)$, or whether the process has a unit root $(\alpha \equiv 1)$. In the unit root case, any shock to the price process is permanent and accordingly should impact consumption, and OLS provides consistent and efficient estimates. However, when the process is stationary, OLS estimates are upwards biased. In case of a stationary process, the system GMM (GMM-SYS) estimator proposed by Arellano-Bover (1995), Ahn-Schmidt (1995) and Blundell-Bond (1998) is unbiased and efficient. See Appendix 1 for tests for unit root versus stationarity and a more elaborated discussion of the choice of estimator.

The test results summarized in Appendix 1 all point in the direction of a stationary house price process. Estimations of the house price process using the GMM-SYS estimator suggests that the AR process should include two lags of house prices. The parameter estimate for the first lag is around 0.706, and the parameter for the second lag is 0.290. Thus, a 5 percent increase in house prices will be halved after 4 years, and will eventually die out after 10 years. Subsequently, we calculate predictions for anticipated house price increases and house price innovations $\hat{\theta}_{kt}^{p}$.

One may speculate whether households can indeed predict aggregate movements in the price process, i.e. the part of the house price process which is partialled out by time dummies. Like most other authors in this literature, we assume that common shocks to the house price process are part of the anticipated changes in house prices. We assume that individual households base their expectations on the price development of their own house on the average price change in the municipality. This may be a crude approximation. Over time, it may be that certain neighbourhoods in a municipality go through a different development than households in other neighbourshoods. These differences may be due to e.g. investments in infrastructure, quality improvements in certain schools, the establishment of new local firms, shopping opportunities etc. We do not have information on local house prices in smaller districts than the municipality. Moreover, we do not catch improvements in individuals houses due to e.g. renovation, reconstruction, modernization etc. These neighbourhood and individual house characteristics are captured in the error term and may therefore reduce the quality of our house price predictions.

Estimation of the income process

The income process is estimated for three education groups separately, the group of households where none of the partners have an education beyond primary school, households where the maximum educational level among the partners is a shorter education (vocational or other) and the group of households where at least one of the partners has a medium-long or longer education. Log disposable income is the dependent variable, and explanatory variables include two lags of disposable income, log age (of the oldest spouse), log age squared, and number of children. Furthermore, we control for time-specific common shocks. Since households belonging to different cohorts are assumed to react differently to common national shocks, we also include an interaction variable of the time dummies and log age. The test of a unit root in the income process is strongly rejected for all education groups, see details in Appendix 2. Consequently, the income process is estimated by GMM-SYS as in the case of the house price process. We find that the formation of household disposable income can be described by an AR(2) process. The estimation results for the GMM-SYS estimation of (4) extended with an extra lag in *y* as explanatory variable are shown in table 2 below. More detailed results are found in Appendix 2. Test results confirm that for the AR(2) process, we can accept the hypothesis of no 2nd order autocorrelation in the error term for households belonging to either one of the three education groups. The Sargan test of overidentifying restrictions rejects the null that the overidentifying restrictions are valid for households with short education, but accepts for households with no education or medium/long education.

Overall, we find the autoregressive parameter estimate to be around 0.60-0.62 for the first lag, and around 0.06-0.09 for the second lag.

Table 2. The income process, disposable household income

	No education	Short education	Medium/long education
Lag1(ln disposable income)	0.620 **	0.607 **	0.603 **
Lag2(ln disposable income)	0.077 **	0.098 **	0.042 **

A number of other studies of income processes focus on (net) earned income for male workers, see e.g. Browning, Ejrnæs and Alvarez (2006). By contrast, our study focuses on net disposable income, i.e. after-tax income from both labour income and social transfers, and we work with two-person households where one or two of the partners may be unemployed or out of the labour force…. *More….*

The consumption regression

In the following, we investigate model (2) empirically. Our primary interest lies in examining changes in household consumption behaviour due to changes in disposable income and house prices. Moreover, we aim at establishing whether and to what extent households react to anticipated and/or unexpected changes.

Our sample consists of married and cohabiting couples where the oldest spouse is younger than 55, who stayed together in the same house of apartment in the period analyzed. We focus on households who were either renters or homeowners throughout the period. Thus, we drop renters who become homeowners, and we drop homeowners who become renters. The change in log consumption is the dependent variable in the model, and the explanatory variables included are the real after-tax interest rate, variables capturing expected as well as unexpected changes in disposable income and house prices, respectively. We control for household characteristics including age of oldest spouse, the presence of children, educational level of the person in the household with the maximum level of education, and time dummies.

First, we examine the "raw" correlations in the data. Overall, we find a positive and significant relationship between consumption and the aggregate change in house prices over the whole period 1988-96, i.e.:

$$\Delta c_{it} = 0.053^{**} + 0.059^{**}\,\Delta p_{it}$$

Furthermore, we find a positive and significant relationship between expected changes in house prices and expected changes in disposable income. However, we do not find a significant relationship between innovations in disposable income and innovations in house prices:

$$\Delta \hat{p}_{it} = -0.001^{***} + 0.080^{***}\,\Delta \hat{y}_{it}$$

$$\hat{\theta}_{it}^{p} = 0.002^{***} - 0.0003\hat{\theta}_{it}^{y}$$

In the following, we analyze the results for owners and renters separately, and we subdivide the period into two subperiods: 1988-1992 and 1993-1996.

Before 1993

We first focus on the period pre-1993. Before 1993, house owners did not have the option to remortgage or take up additional loans in their equity. The reforms on the financial markets which opened up for re-mortgaging of existing loans and extra loans based on equity took place around 1992. Therefore, in principle there are only two possible explanations for a correlation between household production and consumption before 1993: The wealth explanation and the common causality (productivity) explanation.

Table 3 shows the estimation results for homeowners and renters before 1993. We differentiate between reactions to house price changes that were anticipated and innovations to house prices. Furthermore, we interact all explanatory variables, including house price changes with age group. Baseline reaction is the response to house prices for younger households (beyond 41 years). “Old” households are households aged 41-55 in this sample. Neither homeowners nor renters show a significant response to house prices.

Table 3. Expenditure reaction to house price changes, 1988-92

	Owners			Renters		
	Coef.		Std.	Coef.		Std.
dyhat	0.410	**	0.033	0.733	*	0.046
dyhat_old	0.039		0.043	-0.202	*	0.079
th_y	0.530	**	0.022	0.700	**	0.028
th_y_old	-0.030		0.028	-0.106	*	0.053
dphat	0.262		0.368	-0.179		0.402
dphat_old	-0.271		0.494	0.234		0.623
th_p	-0.029		0.041	0.029		0.069
th_p_old	0.098	(*)	0.057	0.039		0.111
lagth_p	0.071		0.140	-0.135		0.183
lagth_p_old	-0.033		0.188	0.260		0.283
old	0.195		0.132	0.059		0.201
realrbond	0.029		0.019	0.003		0.027
dchild	0.000		0.008	-0.013	(*)	0.008
educ1	0.001		0.007	0.000		0.006
educ2	0.001		0.008	-0.006		0.011
educ3	-0.014		0.012	-0.010		0.016
realrbondold	-0.017		0.027	-0.012		0.042
dchildold	-0.006		0.009	0.013		0.010
educ1old	0.004		0.009	0.015		0.010
educ2old	-0.003		0.011	0.020		0.018
educ3old	-0.003		0.016	0.037		0.028
d1990	0.417	**	0.013	0.046	**	0.014
d1991	0.452	**	0.019	0.051	*	0.022
d1992	0.276	**	0.011	-0.003		0.015
d1990old	-0.156	**	0.017	-0.009		0.022
d1991old	-0.176	**	0.026	-0.054		0.033
d1992old	-0.074	**	0.015	0.026		0.023
constant	-0.423	**	0.095	-0.016		0.130
N	138,468			31,329		

We investigated the reactions to changing house prices for subgroups of homeowners who were credit constrained (i.e. who had few liquid assets relative to their income), but found no significant response for households under credit constraints, either.

Post-1993

Several institutional changes took place around 1993. As mentioned above, the credit reform in mid-1992 enabled homeowners to re-mortgage existing loans and to take up additional loans on equity. This enabled homeowners to obtain loans on more favourable conditions and thereby to reduce their monthly mortgage payments. Moreover, the opportunity to take up additional loans on equity induced many households to increase their mortgage debt in order to borrow for improvements in the house, investment in cars, durables etc. or – possibly – to enhance consumption. Furthermore, the political regime shift in 1993 from a conservative-liberal government

(1982-1993) to a socialdemocratic-center government (1993-2001) was followed by a number of social and labour market reforms, and an upward international economic trend started in this period. From 1994 and onwards, house price increased and unemployment fell.

The credit reform of 1993 meant that house owners who had previously been credit constrained (e.g. based on evaluations of their income situation) suddenly obtained the opportunity to raise a mortgage loan based on the collateral available in their house. We therefore investigate whether house owners who were credit constrained exhibit excess sensitivity to house price changes compared to house owners who were not credit constrained. Leth-Petersen (2007) used the same data to show that low liquidity households used the collateral reform to take out collateral. We therefore pay special attention to liquidity constrained households, who are identified based on their amount of liquid funds. Thus, households with liquid funds (cash and bonds) amounting to less than 1½ months of disposable income are considered liquidity constrained. On the other hand, households with liquid funds amounting to more than half a year's disposable income are considered high-liquidity households.

The results for the population as a whole (not shown) show that households respond positively and significantly to both anticipated and unanticipated house price changes. Furthermore, we find that it is mostly younger households who respond in a positive direction. A positive and significant response to anticipated house price changes is a sign of excess sensitivity. When focusing on low- and high-liquidity households, we find that only households with low liquidity are sensitive to changes in anticipated changes, whereas we find no sign of excess sensitivity among households with high liquidity, cf. table 4. Moreover, we find a strong positive and significant response to house price shocks for low-liquidity households, especially for younger households. This finding suggests that there is no wealth effect. Instead, one or more of the three alternative hypotheses: the common causality (productivity) explanation, the collateral explanation or the financial liberalizations are more suitable in explaining the correlation between house prices and expenditure. For example, the positive reaction to changing house prices for younger homeowners may reflect that increasing productivity in the economy as a whole leads *both* to increasing house prices *and* to increasing private consumption. This explanation is in accordance with the common causality hypothesis. Also, the strong positive reaction for especially credit-constrained households agrees with the collateral explanation.

Table 4. Expenditure reaction to house price changes 1993-96

	High-liquidity hh			Low-liquidity hh			Renters		
	Coef.		Std.	Coef.		Std.	Coef.		Std.
dyhat	0.199	**	0.062	0.912	**	0.046	0.781	**	0.029
dyhat_old	-0.013		0.081	0.214	**	0.069	-0.023		0.063
th_y	0.335	**	0.039	0.513	**	0.028	0.755	**	0.021
th_y_old	0.002		0.052	0.000		0.043	0.007		0.044
dphat	0.312		0.563	1.229	**	0.381	0.217		0.191
dphat_old	-0.192		0.750	-0.068		0.626	0.076		0.362
th_p	-0.023		0.103	0.230	**	0.066	0.007		0.062
th_p_old	-0.050		0.138	-0.219	*	0.108	0.107		0.115
lagth_p	0.159		0.190	0.527	**	0.127	0.102		0.085
lagth_p_old	-0.126		0.255	-0.113		0.209	0.003		0.158
old	-0.331	*	0.156	-0.292	*	0.140	-0.042		0.091
realrbond	-0.053	(*)	0.030	-0.004		0.021	-0.008		0.012
dchild	-0.006		0.013	0.005		0.011	0.002		0.005
educ1	-0.016		0.016	0.015		0.009	-0.003		0.005
educ2	0.006		0.019	0.004		0.012	-0.004		0.006
educ3	0.001		0.025	0.039	*	0.020	-0.017	*	0.008
realrbondold	0.047		0.039	0.045		0.035	0.006		0.023
dchildold	0.009		0.016	-0.016		0.014	0.014	(*)	0.008
educ1old	0.014		0.020	-0.001		0.015	-0.006		0.009
educ2old	0.002		0.024	-0.025		0.018	0.001		0.015
educ3old	-0.022		0.031	-0.038		0.028	0.004		0.020
d1994	-0.321	**	0.058	-0.734	**	0.039	0.006		0.020
d1995	0.023		0.030	-0.011		0.021	0.007		0.010
d1996	-0.203	**	0.064	-0.559	**	0.043	-0.001		0.022
d1994old	0.227	**	0.077	0.210	**	0.064	0.005		0.038
d1995old	0.023		0.040	0.035		0.034	0.017		0.020
d1996old	0.173	*	0.085	0.183	*	0.071	-0.008		0.040
constant	0.444	**	0.118	0.362	**	0.084	0.031		0.049
	32,550			58,310			35,875		

The 1993 tax reform lead to a reduction in the tax value of interest rate deductions in taxable income. The reform was especially burdensome for households who experienced a high burden from repaying their mortgage. This was investigated by identifying in the sample households who are sensitive to changes in the burden of interests on mortgage loans, i.e. by interacting price reactions with a measure of relative mortgage debt to gross income. Thus, we identified households who are sensitive to changes in real after-tax mortgage payments by calculating for each household (mortgage debt)/(house value). Based on this measure, around one-fifth of Danish households in the sample are highly sensitive to mortgage debt. Dummies for high sensitivity to mortgage debt were interacted with price change. The estimation results (not shown) from this specification showed that households who are relatively burdened by mortgaged debt dominate among households that show excess sensitivity to anticipated prices.

6. Summary and conclusion

This paper investigates the empirical relationship between house prices and consumption. We apply a unique Danish dataset with information on house prices and wealth at the household level. These data are used to impute a panel of total consumption at the household level. Furthermore, we model the processes of house prices and disposable income and derive expressions for innovations to house prices and income. Overall, we find no support for the wealth explanation. Before 1993, we find no significant relationship between house prices and consumption. After 1993, we find a positive and significant relationship between both anticipated house prices and house price shocks. Moreover, we find that the reactions for younger households are larger than the reactions for older households. Thus, we do not find evidence of the wealth explanation. Instead, several alternatives to the wealth explanation seem to agree with the data. Our results do not allow us to determine whether the common causality (productivity) explanation, the collateral explanation or the credit market liberalizations dominate in explaining the correlation between house prices and expenditure. However, it seems reasonable to suppose that the trends we observe are a combination of several alternative explanations to the wealth hypothesis.

References

Arellano, M. (2003): *Panel Data Econometrics*. Oxford University Press.

Arellano, M., L.P. Hansen and Sentana (1999): Underidentification? Unpublished paper.

Attanasio, O; Weber, G. (1994): The UK Consumption Boom of the Late 1980s: Aggregate Implications of Microeconomic Evidence; *Economic Journal.* November 1994; 104(427): 1269-1302.

Attanasio, O; Blow, L.; Hamilton; Leicester (2005): *Booms and Busts: Consumption, House Prices and Expectations*; IFS Working Paper, WP05/24

Banks, J.; Blundell, R.; Oldfield Z.; Smith, J; (2004): *House Price Volatility and Housing Ownership over the Life-cycle;* University College of London, Discussion Paper 04-09.

Bond, S., C. Nauges and F. Windmeijer (2005): Unit Roots: Identification and Testing in Micro Panels. *Cemmap working paper* CWP07/05. The Institute for Fiscal Studies. Department of Economics, UCL.

Bound, J., and A. Krueger (1991): *Journal of Labor Economics,*

Browning, M., M. Ejrnæs and J. Alvarez (2002): Modelling income processes with lots of heterogeneity. *CAM Working Paper*, No. 2002-1.

Browning, M.; Leth-Petersen, S. (2003): Imputing Consumption from Income and Wealth Information; *Economic Journal.* June 2003; 113(488): F282-301.

Browning, M., A. Lusardi (1996): Household Saving: Micro Theories and Micro Facts. *Journal of Economic Literature*, Vol. 34, No. 4. (Dec., 1996), pp. 1797-1855.

Cambell, J.; Cocco (2004): How Do House Prices Affect Consumption? Evidence from Micro Data; *Harvard Institute of Economic Research Discussion Paper No. 2045. (appeared in Journal of Monetary Ecoonomics in 2005/6)*

Case, B.; Quigley, J. M. (1991): The Dynamics of Real Estate Prices; *Review of Economics and Statistics.* February 1991; 73(1): 50-58

Case, K. E.; Schiller, R. J. (1989): The Efficiency of the Market for Single-Family Homes; *American Economic Review.* March 1989; 79(1): 125-37

Disney, R., J. Gathergood and A. Henley (2007): House Price Shocks, Negative Equity and Household Consumption in the United Kingdom. May 1, 2007.

Dynan and Maki (2001): Does Stock Market Wealth Matter for Consumption?; Board of Governors of the Federal Reserve System, FEDS Working Paper No. 2001-21.

Engelhardt, G.V. (1996): House prices and home owner saving behavior. *Regional Science and Urban Economics*, 26, pp. 313–336.

Engelhardt, G.V., (1994): House Prices and the Decision to Save for Down Payments; *Journal of Urban Economics.* September 1994; 36(2): 209-37.

Guiso, L.; Paiella, M. and Visco I. (2005): Do Capital Gains Affect Consumption? Estimates of wealth effects from Italian Housholds' Behaviour; Temi di discussione del Servizio Studi; Banca D'Italia, No. 555, June 2005

Hurst, E.; Stafford, F. (2004): Home Is Where the Equity Is: Mortgage Refinancing and Household Consumption; *Journal of Money, Credit, and Banking.* December 2004; 36(6): 985-1014.

Iacoviello, M. (2004): Consumption, house prices and collateral constraints: a structural econometric analysis. *Journal of Housing Economics*, 13, 304-320.

Leth-Petersen, S. (2004): *Intertemporal Consumption and Credit Constraints: Does Total Expenditure Respond to an Exogenous Shock to Credit?*; AKF Working Paper, October 2004.

Poterba, James (2000): Stock Market Wealth and Consumption; The Journal of Economics Perspectives, vol 14, no. 2, pp. 99-118

Sheiner, L. (1995): Housing Prices and the Savings of Renters; *Journal of Urban Economics.* July 1995; 38(1): 94-125.

Sinai, T.; Souleles, N. (2005): Owner Occupied Housing as a Hedge Against Rent Risk; *Quarterly Journal of Economics*, vol. 120, number 2 (May 2005), pp. 763-789.

Skinner, J. (1996): Is Housing wealth a side show?; In Advances in the Economics of Aging, D. Wise, ed. Chicago; University of Chigaco Press; pp. 241-268

Appendix 1. The house price process

The house price process

In order to distinguish between expected and unexpected house price changes, we investigate the time series characteristics of house prices. Households form their expectations on house prices in period *t* based on their observation on house prices in the past in their local area (municipality or region). We assume that house prices follow a first-order autoregressive (AR1) model with unobserved individual-specific effects and serially uncorrelated disturbances:

$$p_{kt} = \alpha p_{kt-1} + (1-\alpha)\eta_k + \beta x_{kt} + \delta_t + v_{kt}, \quad k = 1,...,K, \; t = 2,...,T \qquad \text{(A2.1)}$$

p_{kt} is the natural log of the house price in municipality *k*, η_k captures unobserved heterogeneity in house prices, x_{kt} symbolises observed characteristics of houses in municipality i (i.e. the average size of houses in the municipality measured by the number of square meters and number of rooms of an average house) and δ_t captures common shocks at time t. The observations are independent across individuals and the error term satisfies:

$$E(\eta_k) = 0, \; E(v_{kt}) = 0 \; for \; k = 1,...,K \; and \; t = 2,...,T$$

There are two sources of persistency in the model. One source of persistency stems from the autoregressive mechanism described by the AR parameter, α, which is constant across individuals. Another source of persistency comes from the unobserved individual parameter, η_k. A higher AR parameter generally means that more persistency is ascribed to the common autoregressive mechanism and less to unobserved individual-specific effects. In the extreme case of an AR parameter of unity, all persistency in the time series stems from the autoregressive mechanism.

Household expectations on the development in local house prices are formed by $E[\Delta p_{kt}] = E[p_{kt}] - p_{k,t-1}$. The innovation (surprise) in house prices experiences in period t is then:

$$\begin{aligned} \hat{\theta}^p_{kt} &= \Delta p_{kt} - E[\Delta p_{kt}] \\ &= p_{kt} - p_{k,t-1} - (E[p_{kt}] - p_{k,t-1}) \\ &= p_{kt} - E[p_{kt}] \end{aligned}$$

Under the assumption that households understand the house price generating process in model (A2.1), expectations on the house price are found by $E[p_{kt}] = \hat{p}_{kt}$. Thus, estimation of the price process is crucial when distinguishing between unexpected and expected changes in house prices.

Data

Data consists of yearly observations on average sales prices of single-family houses in 275 Danish municipalities during the period 1985-2001 (i.e. 275 municipalities * 17 years = 4675 observations). Data has been collected by the Danish tax authorities and Statistics Denmark. Municipality level prices for owner-occupied apartments have only been recorded for the period after 1992. Thus, we focus on the development in single-family houses, which is by far the most widespread type of owner-occupied housing.

Summary statistics are shown in table A1.1 below.

Table A1.1. Summary statistics, house price data

	N	Mean	Std.	Minimum	Maximum
Avg. house price, 1000 Dkr	4675	579.1	248.4	186.1	2587.6
Avg. square meters	4675	139.7	8.2	104.8	165.9
Avg. # of rooms	4675	4.7	0.2	3.9	5.7

Choice of estimator under different assumptions about the house price process

Our choice of estimator for (A2.1) depends on the size of α. The model reduces to a random walk when $\alpha = 1$. In the unit root case $(\alpha \equiv 1)$, any shock to the price process is permanent and should impact consumption. In this case, OLS on (A2.1) provides consistent and efficient estimates.

Two alternative estimators are also consistent when $\alpha = 1$, see Bond, Nauges and Windmeijer (2005), but the variance of these estimators is higher in the unit root case. The two possible alternatives are a modified OLS estimator proposed by Breitung and Meyer (BM) and the system GMM (GMM-SYS) estimator proposed by Arellano-Bover (1995), Ahn-Schmidt (1995) and Blundell-Bond (1998). This estimator builds on the Arellano-Bond (1991) first-differenced GMM estimator which uses multiple lagged levels of the endogeneous variable to instrument the endogeneous variables in the first-differenced AR1 model. The GMM-SYS estimator extends the moment conditions of the first-differenced GMM estimator with T-2 extra linear moment conditions where multiple lags of the first-differenced endogeneous variable serve as instruments in the AR1 model in levels.

When the process is stationary, $(\alpha < 1)$, OLS and BM are likely to produce upwards biased estimates of α, see Bond, Nauges and Windmeijer (2005). In the case of mean (and covariance) stationarity, GMM-SYS is recommended as an unbiased and efficient estimator.[3]

Test of unit root versus stationarity

The discussion above highlights the need for establishing whether the AR1 process can be characterized by a unit root or whether the house price process is stationary. Thus, we want to test the null hypothesis that $\alpha = 1$ against the alternative that $\alpha < 1$. Bond, Nauges and Windmeijer (2005) suggest combining the insights we get from performing t-tests of the null based on estimation results from three estimators:

1. OLS
2. BM: A modified OLS-estimator developed by Breitung and Meyer
3. The Arellano-Bond GMM estimator

According to Bond, Nauges and Windmeijer (2005), the simple test based on OLS in the levels equation is sensitive to the relationship between the variance of the

[3] On the other hand, the "traditional" first-differenced GMM estimator developed by Arellano and Bond (1991) may produce results with a strong downwards bias.

unobserved heterogeneity and the variance of v_{kt}, i.e. σ_η^2/σ_v^2. To take this problem into account, Breitung and Meyer proposed to use OLS estimates on a transformation of model (A2.1), i.e.:

$$p_{kt} - p_{k1} = \alpha(p_{k,t-1} - p_{k1}) + ... + \varepsilon_{kt}, \quad t = 3,...,T$$
$$\text{where } \varepsilon_{kt} = v_{kt} - (1-\alpha)(p_{k1} - \eta_k) \qquad \text{(A2.2)}$$

As OLS, this estimator is upwards biased when $\alpha < 1$, but the power of a test of $\alpha = 1$ is not affected by σ_η^2/σ_v^2.

Bond, Nauges and Windmeijer (2005) also suggest testing for a unit root by applying a test for the validity of the moment conditions proposed by Arellano, Hansen and Sentana (AHS, 1999) (a test for "underidentification"). The point made in Bond, Nauges and Windmeijer is that when $\alpha = 1$, the rank condition is not satisfied as the instruments are uncorrelated with the endogenous variable, and therefore α is not identified. Thus, the Sargan test statistic for overidentifying restrictions has an asymptotic χ^2 distribution with T(T-1)/2 degrees of freedom when the model is underidentified. When the Sargan test rejects, the model is not underidentified. For the simple AR(1) model, a test for identification is equivalent to a unit root test.

The results from the estimation of (A2.1) by OLS and the Breitung-Meyer (BM) estimator are shown in the table below. According to the OLS estimates and the t-test on α, the null hypothesis of $\alpha = 1$ is rejected (although marginally) with a p-value of 0.077. The Breitung-Meyer estimation finds a somewhat smaller estimate of α of 0.94, and the t-test on this estimate strongly rejects a unit root. The GMM DIF, which is generally downwards biased, produces a much smaller estimate of the AR(1) parameter. According to the χ^2 test, a unit root can be strongly rejected based on this test.

The combination of the results from these three tests lead us to reject a unit root. For values of $\alpha < 1$ and under mean stationary initial conditions, OLS and BM produce upwards biased results, whereas the GMM-SYS estimator produces consistent and efficient estimates under both a unit root and stationarity, cf. Bond, Nauges and Windmeijer (2005).

Table A1.2. Estimation results for carrying through unit root tests

	OLS		Breitung-Meyer		GMM-DIF (AHS-test)	
	Coef.	Std.	Coef.	Std.	Coef.	Std.
laglnhprice	1.0042**	0.0030	0.9403**	0.0075	0.767**	0.015
lnavgsq.meter	-0.0115	0.0307	-0.0042	0.0301	-0.649**	0.098
lnavg#rooms	-0.0277	0.0342	-0.0323	0.0339	0.249**	0.086
const	0.1586	0.1171	0.1568	0.1086	4.373**	0.426
N	4400		4400		4125	
test H0: $\alpha = 1^*$						
p-value	0.077		0.000		0.000	

*) One-sided alternative, $\alpha < 1$.
Note: Time dummies were applied in regressions.

Estimation of the house price process

The tests above all point in the direction of a stationary house price process. Therefore, we carry through the consumption regression by assuming a stationary price process (where GMM-SYS is consistent and efficient), cf. table A1.3 below. Our results suggest than an AR(2) process agrees best with the data since allowing for two lags in the house price process allows us to accept the hypothesis of no 2nd order correlation in the error terms which is a necessary assumption when using the GMM estimator in a dynamic panel context.

Table A1.3. GMM-SYS estimation results

	Coef.		Std.
lag(lnrealhp)	0.706	**	0.025
lag2(lnrealhp)	0.290	**	0.026
lnavg_m2	-0.267		0.181
lnavg_nr	0.152		0.185
d1987	-0.139	**	0.007
d1988	-0.099	**	0.009
d1989	-0.099	**	0.008
d1990	-0.137	**	0.009
d1991	-0.066	**	0.009
d1992	-0.099	**	0.013
d1993	-0.069	**	0.011
d1994	0.041	**	0.010
d1995	0.018	*	0.009
d1996	0.068	**	0.009
d1997	0.033	**	0.007
d1998	0.066	**	0.007
d1999	0.034	**	0.007
d2000	0.013	(*)	0.007
constant	1.145		0.709
N	4125		

Based on the estimation results for GMM SYS, we calculate a set of predictions for house price innovations $\hat{\theta}_{kt}^{p}$ and predicted house price changes $\hat{p}_{kt}$.

We analyse the household consumption response to anticipated and unanticipated house price changes using predictions from the stationary house price process.

$$E(\Delta p_{kt}) = \hat{p}_{kt} - p_{kt-1}$$

$$\hat{\theta}_{kt}^{p} = p_{kt} - E(p_{kt}) = p_{kt} - \hat{p}_{kt}$$

The stationary case is estimated by GMM-SYS which is consistent and efficient under mean (and covariance) stationarity.

Appendix 2. The income process

Households' individual expectations on future income are assumed to be based on their information on household income in the past. More specifically, we assume an income process where individual income in period t is based on lagged income from period t-1 (and possibly more lags). We control for household characteristics as the presence of children, age of oldest spouse in the household (captured by *z*), and time dummies (captured by δ_t):

$$y_{it} = \alpha y_{it-1} + (1-\alpha)\eta_i + \beta z_{it} + \delta_t + u_{it} \qquad E[u_{it}] = 0 \qquad \text{(A3.3)}$$

At time t, $E(y_{it-1}) = y_{it-1}$. This implies that the difference between realised income changes and expected price changes - the predicted surprise term, $\hat{\theta}_{it}^{y}$ - can be calculated by:

$$\begin{aligned} \hat{\theta}_{it}^{y} &= \Delta y_{it} - E[\Delta y_{it}] \\ &= y_{it} - y_{i,t-1} - (E[y_{it}] - y_{it-1}) \\ &= y_{it} - E[y_{it}] \end{aligned} \qquad \text{(A3.4)}$$

Thus, we assume that households form their expectations on income in period t based on predicted income for period t, i.e. $E(y_{it}) = \hat{y}_{it}$.

Estimation of the income process

The income process is estimated for three education groups separately, the group of households where none of the partners have an education beyond primary school, households where the maximum educational level among the partners is a shorter education (vocational or other) and the group of households where at least one of the partners has a medium-long or longer education. Households are classified according to maximum educational level in the period. Thus, households who shift from being without education to having a short or medium/high education within the period studied, are classified according to the educational level that they attain during the period. Due to computational considerations, we work with a random sample of the population.

The natural log disposable income is the dependent variable. Explanatory variables are two lags of disposable income, ln age (of the oldest spouse) and ln age squared number of children. Furthermore, we control for time-specific common shocks. Since households belonging to different cohorts are assumed to react differently to common national shocks, we also include an interaction variable of the time dummies and ln age. Summary statistics are shown in table A2.1 below. As expected, average disposable household income is increasing with educational level, whereas families with no education tend to be older and (partly as a consequence) have fewer children living at home.

Table A2.1. Summary statistics for data used for the income process

		N	Mean	Std.	Minimum	Maximum
No education	dispinc	41978	158250	50440	70079	597908
	child	41978	0.6	1.0	0.0	9.0
	ageold	41978	53	13	21	70
Short education	dispinc	76251	176339	51585	70117	599906
	child	76251	0.9	1.0	0.0	8.0
	ageold	76251	46	12	21	70
Medium/long education	dispinc	51501	207535	70577	70027	599968
	child	51501	1.0	1.0	0.0	7.0
	ageold	51501	45	11	21	70

The income process in levels is estimated by OLS and GMM-SYS as in the case of the house price process. The OLS estimates of α in the AR(1) process in (A3.1) are around 0.82 for all three education groups. Based on the simple t-test mentioned in Appendix 1 on OLS estimates of the AR(1) version of (A3.1), we can strongly reject a unit root in the income process. In this case, OLS is biased. Assuming mean stationarity and no higher (2^{nd}) order autocorrelation in the error term, the GMM-SYS is consistent and efficient, see the discussion about the house price process.

Our investigations on the appropriate number of lags in the income equation lead us to conclude that household disposable income can be described by an AR(2) process. The results for the GMM-SYS estimation of (A3.1) extended with an extra lag in y as explanatory variable are shown in the table below. We test for autocorrelation in the error term by employing the Arellano-Bond test. With this specification, we can accept the hypothesis of no 2^{nd} order autocorrelation in the error term for households belonging to either of the three educational groups. The estimation results are used to calculate innovations to disposable income based on formula (2).

The Sargan test of overidentifying restrictions rejects the null that the overidentifying restrictions are valid for households with short education, but accepts for households with no education or medium/long education.

Overall, we find the autoregressive parameter estimate to be around 0.60-0.62 for the first lag, and around 0.06-0.09 for the second lag.

Table A2.2. The income process, disposable household income

	No education			Short education			Medium/long education		
	Coef.		Std.	Coef.		Std.	Coef.		Std.
Lag1(ln disposable income)	0.620	**	0.016	0.607	**	0.011	0.603	**	0.014
Lag2(ln disposable income)	0.077	**	0.011	0.098	**	0.009	0.042	**	0.011
Number of children	0.007		0.005	-0.003		0.003	-0.003		0.004
Ln age of oldest spouse	-0.058		0.980	0.150		0.844	0.440		1.165
Square ln of oldest spouse	-0.011		0.131	-0.013		0.117	-0.044		0.163
Dummy 1985	3.960	*	1.820	3.168	*	1.539	3.250		2.069
Dummy 1986	4.082	*	1.839	3.288	*	1.554	3.403	(*)	2.087
Dummy 1987	4.098	*	1.858	3.183	*	1.572	3.124		2.112
Dummy 1988	4.265	*	1.879	3.318	*	1.589	3.449	(*)	2.127
Dummy 1989	4.145	*	1.892	3.279	*	1.602	3.433	(*)	2.142
Dummy 1990	4.342	*	1.912	3.472	*	1.618	3.482	(*)	2.163
Dummy 1991	4.380	*	1.931	3.567	*	1.636	3.644	(*)	2.184
Dummy 1992	4.543	*	1.953	3.692	*	1.656	3.667	(*)	2.210
Dummy 1993	4.464	*	1.976	3.661	*	1.677	3.689	(*)	2.232
Dummy 1994	4.818	*	1.999	4.007	*	1.696	3.970	(*)	2.261
Dummy 1995	4.891	*	2.024	3.969	*	1.717	3.954	(*)	2.285
Dummy 1996	4.932	*	2.048	4.079	*	1.740	4.084	(*)	2.315
Dummy 1997	5.019	*	2.079	4.119	*	1.761	4.142	(*)	2.341
Dummy 1998	5.132	*	2.110	4.255	*	1.787	4.261	(*)	2.371
Dummy 1999	5.376	*	2.118	4.528	*	1.797	4.334	(*)	2.379
Dummy 2000	5.366	*	2.156	4.411	*	1.818	4.287	(*)	2.405
Dummy 2001	5.293	*	2.181	4.368	*	1.838	4.099	(*)	2.431
Ln age of oldest spouse * 1986	-0.032		0.018	-0.030	*	0.015	-0.040	(*)	0.024
Ln age of oldest spouse * 1987	-0.030		0.021	0.001		0.019	0.046		0.029
Ln age of oldest spouse * 1988	-0.073	**	0.025	-0.033		0.021	-0.039		0.030
Ln age of oldest spouse * 1989	-0.042		0.027	-0.026		0.024	-0.038		0.032
Ln age of oldest spouse * 1990	-0.091	**	0.031	-0.075	**	0.027	-0.050		0.037
Ln age of oldest spouse * 1991	-0.098	**	0.036	-0.096	**	0.031	-0.086	*	0.041
Ln age of oldest spouse * 1992	-0.139	**	0.041	-0.130	**	0.036	-0.094	*	0.047
Ln age of oldest spouse * 1993	-0.117	**	0.046	-0.122	**	0.041	-0.096	(*)	0.053
Ln age of oldest spouse * 1994	-0.196	**	0.052	-0.198	**	0.046	-0.158	**	0.060
Ln age of oldest spouse * 1995	-0.219	**	0.058	-0.193	**	0.051	-0.159	**	0.066
Ln age of oldest spouse * 1996	-0.230	**	0.064	-0.223	**	0.056	-0.190	**	0.073
Ln age of oldest spouse * 1997	-0.249	**	0.071	-0.231	**	0.062	-0.205	**	0.080
Ln age of oldest spouse * 1998	-0.273	**	0.079	-0.263	**	0.068	-0.229	**	0.087
Ln age of oldest spouse * 1999	-0.335	**	0.086	-0.332	**	0.073	-0.252	**	0.094
Ln age of oldest spouse * 2000	-0.333	**	0.096	-0.303	**	0.079	-0.239	**	0.101
Ln age of oldest spouse * 2001	-0.311	**	0.101	-0.291	**	0.084	-0.191		0.108
Sargan test of overidentifying restrictions									
	chi2		p-value	chi2		p-value	chi2		p-value
	180.335		0.211	271.172		0.000	171.734		0.364
Arellano-Bond test of autocorrelation in errors									
	Z		p-value	z		p-value	z		p-value
1st order	-20.401		0.000	-31.320		0.000	-24.826		0.000
2nd order	0.572		0.568	-0.894		0.371	0.087		0.931
3rd order	-0.049		0.961	1.735		0.083	0.359		0.720
4th order	0.297		0.766	0.770		0.441	1.584		0.113
N	31408			58802			38629		