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Housing equity, saving and debt dynamics over the Great Recession

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Housing equity, saving and debt dynamics over the Great Recession*

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Abstract

This paper uses the large and heterogeneous house price shocks in Denmark from 2006-2009 to provide new evidence on the contested determinants of the correlation between house prices and saving. Crucially, to compare the savings behaviour of home-owners who experienced different house price shocks but similar shocks to income expectations, we exploit the structure of the wage setting process in the Danish public sector. We find strong evidence of a causal link between changes in house prices and saving for young and old home-owners, both through a direct wealth effect and through housing equity serving as collateral or precautionary wealth.

JEL Codes: D14, D91, E21, R20. *Keywords*: Housing, Saving, Wealth effect, Collateral, Debt dynamics.

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1 Introduction

The dramatic simultaneous drops in house prices and consumption experienced in many developed countries in the wake of the Great Recession have sparked a renewed interest in the links between the housing market and the consumption and saving decisions of households. In the literature, the co-movement of house prices and consumption is well documented (see e.g. Case et al. (2005)). There is, however, disagreement over the causes of the link.

Four main explanations of the link between house prices and consumption have been emphasised by the previous literature. *The housing wealth effect* (Muellbauer and Murphy (1990)): increases in house prices raise housing wealth, which causes households to increase consumption.[1] *Housing equity serving as collateral* (Aoki et al. (2004)) *and precautionary wealth* (Carroll (1997)): increases in house prices increase housing equity. This raises consumption by removing current credit constraints and by lowering the probability that households will be credit constrained in the future. *The common factor of income expectations* (King (1990) and Pagano (1990)): an increase in expected income raises both present consumption and the demand for housing, which in turn increases house prices. *The common factor of overall credit conditions and financial liberalisation* (Attanasio and Weber (1994)): when credit conditions loosen it increases both consumption and house prices.

This paper uses a new empirical design and rich administrative individual-level panel data to disentangle the different proposed drivers of the correlation and test whether house price changes *cause* households to change their consumption and saving decisions. We show that there is indeed a housing wealth effect and that the collateral or precautionary wealth channel is important for the consumption and saving decisions of some households.

The life-cycle model serves as the theoretical framework for understanding how households choose consumption today, while weighing the benefit of saving for future consumption. Households plan their consumption path based on the information available in the current period. Non-credit constrained households should therefore only deviate from their planned consumption paths if house price changes are unexpected or if income expectations are altered. A central challenge in the literature is therefore to separate the expected and unexpected house price changes and to control for the effect of shocks to income expectations. The research design developed in this paper differs in two key aspects from previous approaches.

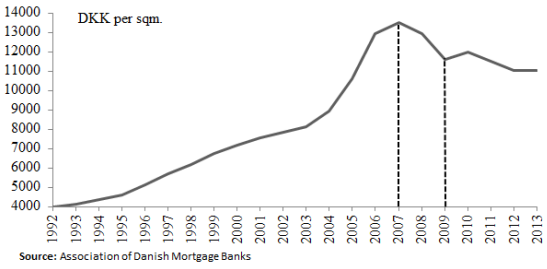
First, we use a quasi natural experiment provided by the large and geographically heterogeneous house price variation experienced in Denmark. We argue that the (timing of the) 18 percent real house price drop between 2007 and 2009 (see Figure 1a), following 15 years of increasing house prices, was unexpected.[2] Additionally, we use that some municipalities experienced house price falls in excess of 20 percent, while some experienced virtually unchanged house prices over the Great Recession (see Figure 1b). This provides the necessary variation enabling us to estimate the effect of shocks to house prices on saving.

[1] However, as Sinai and Souleles (2005) point out, even though financial wealth increase when house prices increase it does not necessarily imply an increase in households real wealth as higher house prices leads to higher (implicit) rental costs. Thus, for households with long expected tenures, an increase in house prices reflects a compensation for the higher associated renting costs making home-owners perfectly hedged against fluctuations in rents.

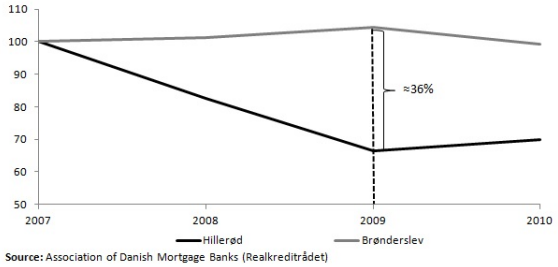
[2] Allowing for different types of individual heterogeneous house price expectations does not affect the findings of the paper, see Section 6.

Figure 1: House price development in Denmark

(a) Historic turnaround in national house prices



(b) Heterogeneous municipality-level house price changes



Second, we use a novel approach to control for the important role of shocks to income expectations. We exploit an institutional feature of Danish public sector wage setting. In Denmark, nearly all public sector employees have their wage set by collective bargaining, and the majority of public sector wages are determined centrally, typically resulting in similar percentage-wise salary increases for all employees, regardless of differences in productivity and demand (see Produktivitetskommissionen (2013)).[3] We therefore consider couples where both individuals were public sector employees throughout the sample period. These households received very similar shocks to income expectations, but were exposed to heterogeneous house price changes depending on where they lived.

In addition to this, we exploit the detailed data available to identify households that are likely to be affected by credit constraints and individuals who had low levels of precautionary wealth, as Aoki et al. (2004) and Carroll (1997) point out that these household are expected to react more strongly than non-credit constrained households.

This paper exploits rich panel-data available from Danish administrative registers with information on individual house prices (estimated by the Danish tax authority for taxation purposes), housing ownership, income, wealth and individual characteristics for the full Danish population of 5.5 million. Using this data and the novel research design described above we can separate the four proposed drivers of the empirical observed correlation and isolate the causal effect of shocks to house prices on saving.

We show that both young and old home-owners increase annual saving by around 2.2 DKK for every 100 DKK of housing wealth loss. When including renters in the analysis, we find that renters do not save more when house prices decline. Furthermore, we find evidence of a sharp adjustment in saving following a house price decline for couples that are likely to be affected by credit constraints. This suggests that the role of housing equity serving as collateral (or the precautionary saving motive) is important for the consumption and saving decisions of some households. In addition, we show that couples who were likely to be affected by credit constraints used the additional housing equity obtained from house price increases to increase cheap housing debt to pay off more expensive bank debt and to finance a higher level of consumption.

Our results are robust across three alternative specifications exploring the validity of the two

[3]See the research design section for a more thorough discussion and some data evidence that supports this identifying assumption.

identifying assumptions (similar shocks to income expectations and unexpected house price shocks): excluding highly educated couples employed in the central government (as you might think that these individuals were differently affected by shocks to their outside option); allowing for heterogeneous house price expectations as current house price expectations may depend on previously realised house price changes; and excluding couples living in Copenhagen (where house prices had begun to decline already in 2007). Furthermore, we find that our results do not appear to be driven by capital gains/passive saving.

There is a large literature that investigates the links between the housing market and the consumption and saving decisions of households. However, these papers reach different conclusions as to what is the main driver of the relationship. Even papers that use the same data but different research designs arrive at contradicting conclusions.

Campbell and Cocco (2007) estimate an equation for consumption growth and find evidence that older households respond more to house price shocks relative to younger renters and they therefore conclude that the housing wealth effect is the main driver of the link between house prices and consumption. Disney et al. (2010) find no evidence of differences in the responses of old and young home-owners. Similar to this paper, they find that renters and home-owners respond differently to house price shocks. Attanasio et al. (2009) use the exact same data as Campbell and Cocco (2007) but reach different conclusions using a different model specification, where they model a consumption function (an equation for the level of consumption).[4] Attanasio et al. (2009) find that the co-movements of house prices and consumption are driven by common factors and not a causal housing wealth effect, as they find that the correlation between changes in house prices and consumption is stronger for young households. Similarly, the paper by Browning et al. (2013) finds no evidence of a housing wealth effect.[5]

Our paper adds to this literature of conflicting conclusions by using a new research design that mitigates some of the shortcomings of the approaches used in the earlier literature. One particular issue in this literature has been to isolate and credibly control for the important role of income expectations. By using the structure of the Danish public sector wage setting process to control for the role of shocks to income expectations and the rich individual-level panel data to separate out the responses of households likely to be affected by credit constraints we can isolate the housing wealth channel.

It is important to note that there might not be one "true" size of the housing wealth effect as different historical episodes might be driven by different channels. Nonetheless the major turnaround in the housing market studied in this paper is particularly important to analyse as it is crucial to understand how such significant changes in the housing market impact the wider economy. Furthermore, studying a large change ensures that adjustment costs do not dominate any optimal responses. Overall, we therefore consider this a particularly attractive period to analyse the consumption and saving consequences of shocks to house prices.

Our results also relate to an emerging literature that focuses on the effects of high levels of

[4]See Christini and Sevilla-Sanz (2014) for a detailed comparison of the two empirical studies.

[5]There are a number of other prominent empirical papers not covered by this brief discussion that uses microeconomic data to investigate the relationship between house prices and consumption/saving. See e.g Carroll et al. (2011), Cooper and Dynan (2013), Christelis et al. (2015), and Berger et al. (2015).

household debt on the adjustment in consumption in times of crises. Dynan (2012) investigates the consumption responses of highly leveraged households following the Great Recession. Identifying and labelling highly leveraged households in a way that to a large extent corresponds to how we label households as likely to be affected by credit constraints, she finds that households that were highly leveraged in 2007 experienced greater declines in spending between 2007 and 2009 - even after controlling for housing wealth effects. Similarly, Mian et al. (2013) find that retail sales declined far more in U.S. counties where households were more leveraged (though not controlling for possible housing wealth effects). Thus, Mian et al. (2013) and Dynan (2012) both find evidence supporting that the "debt overhang" (the high debt relative to assets) depressed consumer spending following the Great Recession. Our findings echo these results and we use the detailed individual level data to expand their analysis by decomposing the responses in saving in order to show through which channels the adjustment took place.

The results presented in this paper highlight that it is not only the size of the house price shock and the resulting loss in wealth that matter: the *distribution* of the wealth losses are important for determining the following consumption responses. Highly leveraged households may contribute to prolonged crises following house price shocks as high leverage creates a need for deleveraging that could suppress consumption and economic recovery. Our results therefore indicate that allowing households to accumulate large amounts of debt during economic upturns could result in higher overall macroeconomic volatility. Despite the large benefits of having a flexible mortgage system that allows households to borrow against their housing equity (enabling them to smooth consumption) this highlights a potential cost of such a system.

The remainder of this paper is organised as follows: Section 2 briefly introduces the Danish institutional context. Section 3 goes through our research design in more detail and reviews and contrast it to the approaches used in earlier studies. Section 4 describes the data, while section 5 presents the results. Section 6 investigates the robustness of our findings to different specifications and assumptions. Finally, section 7 concludes.

2 The Danish mortgage credit market

In this section we briefly introduce key elements of the Danish mortgage credit market as it is important for understanding how people in Denmark save. In Denmark real property is primarily financed through mortgage banks, where households can borrow up to 80 percent of the property value with the real property serving as collateral for the loan. Because of this rule, the last 20 percent will have to be financed through a combination of savings and loans in commercial banks, which are generally more expensive relative to the loans in the mortgage banks due to the lower seniority of the loans. Furthermore, since a reform in 1992 Danish households have been able to use housing equity as collateral for mortgage loans (up to 80 percent of the house value) to finance non-housing expenditure. This implies that in times of rising house prices (as was the case in Denmark in the years leading up to the great recession) households can finance non-housing consumption by borrowing against their increased housing collateral.

Given that we look at a period where many households experience a house price drop, it is important to stress that the 80 percent borrowing limit only binds in the period where the loan is

set up. As a result households are not forced to repay loans in the event of a house price drop. But it may affect a household's ability to obtain an additional cheap mortgage bank loan for consumption, if the house price drop increases the loan-to-value to around or above 80 percent.

3 Research design

Our research design is set up to isolate the housing wealth channel, controlling for the important role of shocks to income expectations. Additionally, we wish to analyse the heterogeneity in the responses of households that are likely to be credit constrained, relative to those who are not.

In a standard life-cycle model, households with rational expectations will attempt to smooth consumption such that discounted expected marginal utility is constant, given the present information. This implies that households should only change their saving behaviour in response to house price changes that are unexpected (abstracting from credit constraints). A central challenge when identifying the housing wealth effect is therefore to separate the expected and unexpected house price changes.

This paper uses the historical turnaround in Danish house price that occurred from 2007-2009, see Figure 1a above. We argue that the timing of the national real house price decline of more than 18 percent from 2007 to 2009 in Denmark was unexpected.[6] The house price fall followed 15 years of increasing house prices, and although concerns of imbalances in the housing market were raised by some housing market experts, no one was forecasting the timing (and extent) of the house price fall. For example the Danish Ministry of Finance wrote in their Economic Survey in February 2008:

> *It is expected that house prices will be virtually unchanged at a national level in 2008 and 2009*
>
> Ministry of Finance (2008, February)

In other words, in the spring of 2008, where house prices had already begun to decline, the Ministry of Finance were still forecasting flat house prices for 2008 and 2009. Furthermore, the Danish Economic Council in November 2007 forecasted that nominal house prices would increase with 1.4 and 1.9 percent in 2008 and 2009 (see DORS (2007)).[7]

In periods where house price shocks are small, optimisation frictions and lack of salience can impede households from responding. This could explain why some earlier papers do not find evidence of a housing wealth effect. The large house price shock studied in this paper (coupled with the fact that the average Danish family held more than 60 percent of their total gross wealth as housing wealth when house prices peaked, see RKR (2014)), implies that some Danish households experienced significant decreases in household wealth. This makes the period considered in this paper an

[6] A potential concern is that we consider only a negative house price shock. However, both Disney et al. (2010)(for households with positive equity) and Browning et al. (2013) find no evidence of asymmetric responses to house price shocks suggesting that only analysing a house price decline does not limit the external validity of this study.

[7] Although the leading forecasters in Denmark expected house prices to be "virtually unchanged" we cannot be sure that this was in line with the house price expectations of Danish households. In the robustness section we therefore test the sensitivity of our results to heterogeneous house price expectations across households (where the individual house price expectations depend on the house price increase experienced in the previous period). Allowing for these heterogeneous house price expectations does not change our conclusions.

attractive period to analyse the effects of house price shocks on household saving behaviour.

The approach used in this paper differs from the approach used previously in the literature. Campbell and Cocco (2007), Disney et al. (2010), Attanasio et al. (2009) and Browning et al. (2013) all follow a similar identification strategy for separating the expected and unexpected house price changes: they estimate a house price process for all agents in their sample. They then divide the development of house prices into an expected part described by the predictions of the process, and an unexpected part described by the innovations.[8]

An unexpected change in national house prices is not sufficient to isolate the causal effect on saving from shocks to house prices. In any econometric estimation the ideal scenario would be to observe the saving behaviour of a given household that did not experience a house price shock, while at the same time observing the saving behaviour of the same household in a situation where they did experience a house price shock. To mimic this counter-factual scenario we exploit the quasi natural experiment provided by the large and heterogeneous variation in house prices across the different municipalities of Denmark, see Figure 1b above. Figure 1b shows that house prices in Hillerød (a suburban municipality in Region Zealand) fell 20 percent from 2007 to 2009, whereas house prices in Brønderslev (a rural municipality in the North Denmark Region) were more or less unchanged.

A challenge when using the unexpected house price changes from 2007 to 2009 is that they occurred at the same time as the Great Recession was unfolding. The Great Recession influenced not only house prices, but also expectations about future incomes and job market situations (which in turn influenced saving behaviour) and we therefore need to control for the role of shocks to income expectations.

The existing literature described above handles this in different ways. Disney et al. (2010) include a crude measure of self-reported changes in financial expectations to control for expected changes in income. Browning et al. (2013) follow a similar method to that used to identify shocks to house prices: they estimate an income process and use the innovations to this process as the shocks to income. In a related and highly influential paper Mian and Sufi (2011) use housing supply elasticity as an instrument for a city's exposure to the housing boom–bust cycle to identify the causal effect of house price changes on housing debt accumulation.[9] Campbell and Cocco (2007) include the regional unemployment count to proxy for regional business conditions. They do not, however, find a significant effect of this proxy for regional business cycles, and since their estimates only change slightly when including it they conclude that "house prices have an independent effect on consumption and are not merely proxying for the regional business cycle." As mentioned above, these papers arrive at contradicting conclusions highlighting the importance of credibly controlling

[8] A potential weakness of the approaches used by Disney et al. (2010), Campbell and Cocco (2007) and Browning et al. (2013) is that they use data for the full period to estimate the house price process and use the innovations to the process in each year as the unexpected house price changes. In this way, agents base their house price expectations on information that is not in their information set at the time of the shock. This method is therefore likely to underestimate the innovations because agents become too good at predicting future house prices, when their expectations are formed using knowledge of future house prices. If one wishes to use an AR process to model house price expectations, another approach would have been to model the house price process in a given year t using house price information until t-1, and then form expectations using an out of sample prediction to obtain the residual that describes the unexpected house price change in year t. In this way, agents would only use historical data to form expectations.

[9] However, a recent paper by Davidoff (2013) criticises the first stage relevance of the instrument used by Mian and Sufi (2011).

for the important role of shocks to income expectations.

We use a fundamentally different approach that utilises Danish administrative registers that contain data for the full Danish population of 5.4 million individuals. In order to separate the shocks to house prices from shocks to income expectations we restrict and cut our sample such that we are left with a sample of households that were similarly affected by shocks to income expectations following the Great Recession. When we restrict the sample there is a trade-off. On the one hand, we want to select as specific a group as we can, because we in this way will be sure that our sample were subject to more or less identical shocks to income expectations (i.e. we can obtain internally valid results - something which has been a challenge within the literature). On the other hand, we want to have a sufficient number of households in our sample such that we have sufficient power in our statistical tests and such that we limit sample selection issues and get as externally valid conclusions as possible. We propose comparing couples of public employees where both individuals are employed in the public sector, as the labour market faced by public employees is relatively homogeneous across the country.[10] The institutional set up in Denmark is such that the wages of almost all public employees are set by collective bargaining (see The Danish Productivity Commission (2013)), thereby minimising regional differences in the wage setting process. The Danish Productivity Commission writes:

> *The majority of public wages are determined centrally - typically resulting in the same percentage-wise salary increases for all employees - despite the fact that there may exist differences in productivity and demand*
>
> The Danish Productivity Commission (2013)

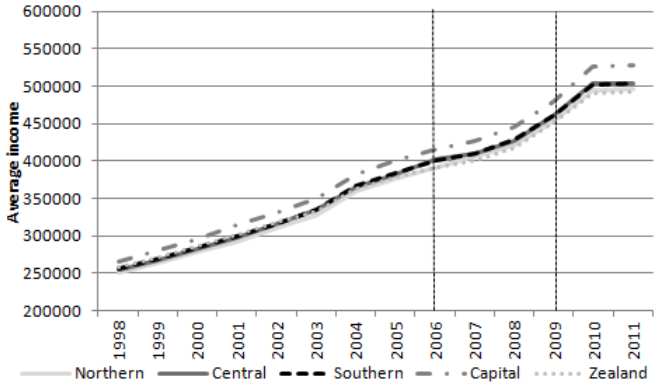
To augment the arguments provided by the institutional set up Figure 2 shows the average disposable income over time across different regions for the couples who were public employees between 2006 to 2009. Note that we have only restricted the couples used in the figure to be employed in the public sector within our sample period. Thus, before 2006, and after 2009, we do not restrict couples to be employed in the public sector. Any (differential) changes in income for our sample before or after our sample period could therefore represent (differential) changes in regional public sector wages, the composition of public/private sector employment, or both.

The figure shows that both the level and the changes in income are remarkably similar throughout the period.[11] Although the changes in income over time does not necessarily reflect the income

[10] In this paper we focus on saving responses of couples, as saving is a household decision, and the saving decisions of a couple differs from those made by singles. One reason is that there are economies of scale in a household. Another reason is that couples cohabiting can insure each other against adverse labour market and health shocks (see e.g. Gruber and Cullen (1996)).

[11] We see that there is a slightly higher level of income in the capital region (though, importantly, the changes are similar to the other regions). This is explained by the fact that there is a greater share of individuals working in the central government (where wages are generally slightly higher compared to other public employees) and the fact that some occupations may get an additional compensation for working in the Capital Region.

Figure 2: Disposable income between 1998 and 2011 for our main sample (by Region), DKK year 2000 prices



Note: Throughout the sample period (shown by the area between the dotted lines) all individuals in our sample are restricted to be employed in the public sector. Outside our sample period individuals are not restricted to be employed in the public sector.

expectations of individuals, the data presented in Figure 2 verifies that actual incomes were affected similarly in the period that we consider. We take this as evidence in favour of similar income shocks across regions as the great recession unfolded for the group of public employees.

A potential critique of our research design is that - even though couples of public employees experienced similar income changes - there might be differences across regions in the outside options available to public employees. So despite the similar changes in actual income, they could potentially have experienced different shocks to income expectations. For example, it could be that couples living in the Capital Region, where a higher share work in central government, to a greater extent consider the private labour market as an outside option. However, there are three reasons that suggests that differences across regions in the outside option available is not important for the group analysed in this paper.

First, Figure 2 shows a strikingly similar pattern in the realised incomes across regions both before and after our sample period (where we do not restrict individuals to be employed in the public sector). This suggests that any potential heterogeneous propensity to switch between the public and private sector across regions did not lead to a differential change in average income outside our sample period. Even in periods with non-normal changes outside our sample period such as 2004 and 2011, the development in average wages is close to being identical across regions.[12] Second, certain sectors in Denmark such as education and health care are predominantly dominated by the public sector. Thus, for a significant part of our sample the private sector outside option available will be limited. Third, public sector employment for the group analysed in this paper is highly persistent with more than 92% still employed in the public sector in 2001, five years before the beginning of our sample (see Figure 8 in the appendix). In other words, public/private sector mobility for the group analysed in this paper in fairly low (and relatively similar across regions).

[12]The greater increase in disposable income in 2004 is due to a tax reform that lowered taxes on labour income, while the flat growth in 2011 can be explained by public wages being kept at their 2010 level because the growth of public wages had outperformed the growth of private wages in the years following the Great Recession.

Overall, we take these three arguments as evidence that differences in the outside option available across regions is not important in driving the results we find.[13]

All in all we therefore believe that the structure of the Danish labour market for public employees and the data presented above supports our identifying assumption that couples of public employees received similar shocks to income expectations as the Great Recession unfolded.

During the Great Recession credit tightening affected households' consumption decisions (see e.g Rangvid (2013)). When house prices decline the response of credit constrained couples will both be influenced by the housing wealth effect and the effect from credit constraints that become binding. Thus, to isolate the housing wealth channel, we therefore allow for a different saving response to changes in house prices for couples likely to be affected by credit constraints, and separately examine the responses of credit constrained couples.

So far we have described the research design that allows us to isolate the housing wealth channel by controlling for the role of income expectations and allowing for a separate response for credit constrained households. Some of the previous literature has taken a different approach to separate the four proposed explanations. It has relied on the intuition of the simple life-cycle model which suggests that if the wealth effect is the dominant driver of the correlation then old home-owners will increase saving more (relative to the young) following a negative house price shock as they have fewer years ahead to smooth the wealth loss across.[14] However, simple extensions of the life-cycle model (e.g. the presence of a stronger bequest motive among older household) could explain why we would not necessarily find such differences between the responses of old and young home-owners despite the fact that responses are driven by housing wealth effects.

As a consequence, we find it instructive to analyse the responses of a group of renters that is similar to our group of home-owners despite the fact that home-ownership might not be an exogenous decision. If we find that renters exhibit the same behaviour as home-owners when house prices change it could suggest that the identified responses are not driven by the change in housing equity. Instead it could indicate that the responses are driven by an omitted variable that correlates with changes in house prices (across municipalities) and saving (e.g. changes in income expectations).

4 Data

We uses data from multiple Danish administrative registers, which include annual observations for the entire Danish population of 5.4 million individuals. We can follow individuals over time using unique personal identifiers and observe individual house prices, housing ownership, income, wealth, family composition and background variables.

Our main dependent variable is the change in annual saving. Saving is not directly observed in

[13] Furthermore, as a robustness check, we run a regression where we exclude highly educated individuals employed in the central government as they might be thought of as particularly likely to view the private labour market as an outside option to public sector employment. This does not change our conclusions.

[14] Additionally, younger households are likely to benefit more from the lower price of future housing needs and the lower price of upsizing in the housing market, see Sinai and Souleles (2005).

the data and we therefore construct it. We use detailed individual information on the stock of assets (cash in the bank and the market value of stocks and bonds - but not pension assets), the stock of liabilities (bank debt and the market value of mortgage debt and mortgage deed liabilities), as well as the flow of pension contributions to construct our measure of saving:

$$\begin{aligned} Saving_t &= \Delta\text{stocks}_t + \Delta\text{bond assets}_t + \Delta\text{bank assets}_t + \alpha\,[\text{pension contributions}] \\ &\quad - [\Delta\text{bond debt}_t + \Delta\text{bank debt}_t + \Delta\text{mortgage deed liabilities}_t] \end{aligned} \tag{1}$$

, where $\alpha = 0.6$ as we adjust pension contributions to account for future tax liabilities (see Jørgensen (2007)). This constructed saving measure consists of both active and passive saving. Active saving, the variable of interest, is defined as the amount of income not spent on consumption. Passive saving is defined as the changes in wealth due to non-behavioural changes such as capital gains (See e.g. Skinner (1996) and Engelhardt (1996) for a discussion of active and passive saving). Stock prices were very volatile in the years considered in this paper, with an average loss of 47% in 2008 and average gains in excess of 35% in 2009 and 2010. To correct for this systematic passive saving in stocks, we assume that the individuals owning stock had a return similar to the average yearly return of the top-tier stock index at the Copenhagen Stock Exchange, the OMXC20. Hence, we net out the average return to the stock portfolio when defining the individual saving in stocks: $\Delta stocks_{i,t} = stock\ value_{i,t} - (1 + \%\ change\ in\ OMXC20_{t-1,t}) stock\ value_{i,t-1}$. Although this does not capture the large variance in returns between different portfolios, it mitigates any systematic differences in saving between stock owners and non-stock owners. Importantly, we undertake a robustness check where we exclude all couples that own any stocks or bonds (see Section 6) to ensure that the results found are not driven by passive saving. This analysis suggest that our results are not driven by this measurement error.

Having constructed saving in each year we construct the change in saving over two years (following Disney et al. (2010)):

$$\Delta Saving_i = Saving_{i,2009} + Saving_{i,2008} - (Saving_{i,2007} + Saving_{i,2006}) \tag{2}$$

This is done to limit the noise in our saving variable originating from the fact that the stock of assets and liabilities are only observed at the last day of the year. Further, by considering a two year period, we allow households more time to adjust their saving following the house price shock. Finally, by considering saving in 2008 and 2009 we include the entire period where house prices declined. This is desirable because a larger shock, and more time to react, increases the chance that households adjust their saving in the presence of adjustment costs.

In a life-cycle model, individuals change their planned consumption path when they receive a shock to their expected permanent income. We therefore follow Leth-Petersen (2010) and Sheiner (1995) and normalise all monetary variables by a proxy for permanent income in order to obtain a relative measure. We use the fact that we have a very long panel containing income information to construct a proxy for permanent income given by 10 years of disposable income (prior to the house price fall) from 1998 to 2007. We use disposable income rather than gross income to take the progressive tax system into account. We then define the change in normalised saving as:

$$\Delta Saving_i^n = \frac{\Delta Saving_i}{Permanent\,income_i} \tag{3}$$

By normalising the nominal variables by a measure of permanent income we avoid that the estimates being dominated by very large absolute saving responses of the very wealthy.

Because we observe each of the sub-components of saving we are able to expand on the main analysis and analyse the channels through which couples change their saving behaviour following a house price shock. For example, to consider the contribution to the change in saving from the change in bank asset accumulation we use the following definition:[15]

$$\Delta(Bank\,assets\,accumulation)_i^n = \frac{\Delta Bank\,assets_{i,09} + \Delta Bank\,assets_{i,08} \text{ -}\Delta Bank\,assets_{i,07} + \Delta Bank\,assets_{i,06}}{Permanent\,income_i}$$

Having defined our left hand side variables we turn to the key explanatory variable: $\Delta House\ price$, the change in house prices between the end of 2007 and the end of 2009. In the administrative registers we have access to public appraisals of each property in our sample (calculated by the Danish tax authorities for taxation purposes). This gives us an individual house price *level* for each property in 2009. We then use municipality specific house price indices from the Association of Danish Mortgage Banks (RKR) based on actual traded houses within each year in each municipality to track the *changes* of the individual house prices over time (see Realkreditrådet (2010) for further details). Thus, we multiply the individual level of house prices by the change in the municipality-specific house price index. We use the house price indices to track changes as they are better (relative to using the change in public valuations) at capturing house price changes over time.[16] Thus, we exploit variation both within and between municipalities (however, the majority of the variation in house prices is driven by the heterogeneous shocks to house prices across municipalities, see Figure 1b). Finally, we also normalise $\Delta House\ price$ by permanent income:

$$\Delta House\ price_i^n = \frac{House\,Price_{i,2009} - House\,Price_{i,2007}}{Permanent\,income_i} \tag{4}$$

We identify and label households as likely to be affected by credit constraints if they both have a low level of liquid assets and a high loan to value ratio in 2007, the year before the large house price decline. We label individuals as having low levels of liquid assets if their total value of stocks, bonds and bank assets is less than 1.5 months of their disposable income. Furthermore, we label individuals as having a high loan to value ratio if the sum of bond- and mortgage deed liabilities exceeds 60 percent of their housing value in 2007 (as described in Section 2, households can borrow up to 80 percent of their housing equity in mortgage banks).[17]

Our analysis focuses on households in which the oldest spouse is between 22 and 59 years (following Browning et al. (2013)). We exclude households where the oldest spouse is older than 59 years to avoid interference with the retirement decision. To test whether old couples increase saving

[15] In order to get a better understanding of how a change in asset (and liability) accumulation affect the changes in saving consider the following example: suppose a household increase their bank assets by 100,000 DKK in 2006 and 2007 and "only" increase their bank assets by 70,000 DKK in 2008 and 2009. This will constitute a *fall* in saving *relative to the period before* as the households have lowered their bank asset accumulation by 30,000 DKK.

[16] This is similar to Andersen et al. (2014) that also adjust their house price measure to adjust for average differences between the public appraisals and actual selling prices.

[17] Column (3) of Table 5 in Section 6 presents an alternative specification where we define couples as likely to be affected by credit constraints if they have less than one month of disposable income in liquid assets and a LTV>0.7. Our results are robust to this alternative specification.

more relative to young couples, we define households as young if the oldest member is less than 50 years of age in 2007. By this definition slightly over half the households are young in our sample.[18]

We follow (among others) Engelhardt (1996) and Leth-Petersen (2010) and exclude households that bought or sold any part of a property within the period of interest. This is because households that plan to move in the near future are likely to change their saving behaviour as moving is associated with moving costs, which we observe as dis-saving thereby leading to a different saving pattern for this selected group of households. Furthermore, we deflate all nominal variables with the CPI index such that all nominal variables are measured in year 2000-prices. Finally, we trim 0.5 % in each end of the distributions of our measure of permanent income and the normalised house price shocks, while we trim 2.5% in each end of the distribution of the normalised saving (as there is more measurement noise in this variable). The final distribution of permanent incomes, normalised changes in saving and normalised house price shocks can be found in Figure 5, 6, and 7 in the appendix.

This leaves us with a data set containing 13,260 couples of public employees. Table 1 presents some descriptive statistics of $\Delta Saving$ (net of housing), $\Delta House\,price$, permanent income and $\Delta Income$. The table presents the descriptives separately by the 5 regions of Denmark to illustrate how different the house prices shocks were across the different regions and municipalities. The table shows that the largest house price drop occurred in the Capital Region where house prices on average fell by 2.6 times permanent income, whereas house prices only declined by 0.2 times permanent income in the North Denmark Region between 2007 and 2009. At the same time, we observe that the Capital Region experienced the largest average increase in saving, while the North Region had a substantially smaller increase in saving. Thus, a pattern emerges: regions that experienced the largest house price drops between 2007 and 2009 also saw the largest increases in saving from 2006/07 to 2008/09. Another important finding of Table 1 is that while $\Delta saving$ and $\Delta House\ price$ varies a lot between regions, $\Delta Income$ looks very similar across regions.

Table 2 presents the sample means for each of the subgroups we use in the analysis below. The table shows that even though young and old couples had relatively similar changes in house prices, the old group increased saving considerably more than the young group (both in DKK and relative to permanent income). However, below we find that the correlation between house prices and saving is not different between old and young. Thus, though the raw correlations suggest one thing, our analysis finds no evidence of the proposed age heterogeneity between young and old households in the response to shocks to house prices.

It is also interesting to consider the group of credit constrained households who experienced a much smaller house price drop, both in DKK and relative to permanent income. In spite of this, the increase in saving was much greater both in DKK and relative to permanent income. Additionally, the average net financial position in 2007 for non-credit constrained households was 1,604,699 DKK while credit-constrained households had a strikingly low net financial net position of 5,372 DKK.

[18] As the definition of young/old households is inherently somewhat arbitrary we test the sensitivity of our conclusions to this definition. Column (2) of Table 5 in Section 6 present the estimation results in a specification where we have defined households as being young if the oldest individual in the household is below 45 years of age in 2007 (following Disney et al. (2010)). Further, Table 6 in the appendix presents estimation results for a specification where we include three age groups in our regression: young (oldest individual in household less than 40 years in 2007), middle-aged (40-50 year old) and old (50+). None of the other splits change the conclusions of this paper.

Table 1: Key descriptives across regions

	Mean	Median	N
Capital Region			
ΔSaving	37,914	34,763	3,491
ΔHouse price	-1,026,674	-990,396	3,491
ΔSaving/10y inc. avg.	0.10	0.08	3,491
ΔHouse price/10y inc. avg.	-2.58	-2.53	3,491
10y inc. avg.	396,663	384,782	3,491
ΔIncome	36,267	34,503	3,491
Central Denmark			
ΔSaving	8,051	16,648	2,965
ΔHouse price	-234,163	-194,212	2,965
ΔSaving/10y inc. avg.	0.02	0.05	2,965
ΔHouse price/10y inc. avg.	-0.63	-0.56	2,965
10y inc. avg.	362,969	353,305	2,965
ΔIncome	36,567	34,691	2,965
Northern Denmark			
ΔSaving	8,840	14,767	1,620
ΔHouse price	-79,953	-74,690	1,620
ΔSaving/10y inc. avg.	0.03	0.04	1,620
ΔHouse price/10y inc. avg.	-0.22	-0.22	1,620
10y inc. avg.	351,996	341,584	1,620
ΔIncome	40,081	37,474	1,620
Southern Denmark			
ΔSaving	12,088	17,435	2,667
ΔHouse price	-136,209	-110,389	2,667
ΔSaving/10y inc. avg.	0.04	0.05	2,667
ΔHouseused price/10y inc. avg.	-0.37	-0.31	2,667
10y inc. avg.	359,131	347,492	2,667
ΔIncome	35,985	36,881	2,667
Zealand			
ΔSaving	30,955	29,414	2,517
ΔHouse price	-610,963	-501,339	2,517
ΔSaving/10y inc. avg.	0.09	0.08	2,517
ΔHouse price/10y inc. avg.	-1.65	-1.41	2,517
10y inc. avg.	363,286	356,915	2,517
ΔIncome	32,323	33,582	2,517
Denmark			
ΔSaving	21,169	23,913	13,260
ΔHouse price	-475,792	-296,124	13,260
ΔSaving/10y inc. avg.	0.06	0.07	13,260
ΔHouse price/10y inc. avg.	-1.23	-0.84	13,260
10y inc. avg.	369,788	358,764	13,260
ΔIncome	35,995	35,334	13,260

Table 2: Sample means for subgroups of the population

	Total sample	Young	Old	CC	Non-CC
ΔSaving	21,169	14,909	29,741	71,786	14,357
ΔHouse price	-475,792	-452,708	-507,398	-158,243	-518,532
ΔSaving/10y inc. avg.	0.06	0.04	0.08	0.21	0.04
ΔHouse price/10y inc. avg.	-1.23	-1.21	-1.26	-0.47	-1.34
10y inc. avg.	369,788	357,596	386,479	333,544	374,666
Avg. net financial pos.	1,414,975	1,196,249	1,714,439	5,372	1,604,699
N	13,260	7,663	5,597	1,573	11,687

Finally, as discussed in the research design section, we wish to compare to the sample of home-owners with a comparable group of renters. We therefore construct a comparable group of stable renters who rented the same property in all years, and who are a stable couple where both are employed in the public sector in all years. For the group of renters we attribute the average house price change between 2007 and 2009 within the municipality that they live as their house price shock.

5 Results

In this section we present the reduced form regression equation that operationalises the research design set out above and the results of estimating this equation. Furthermore, we present the results showing through which of the sub-components of saving households adjusted following the house price shock.

5.1 Main specification

The main specification estimated in this paper is given by equation 5 below:

$$\begin{aligned} \Delta Saving_i^n &= \beta_0 + \beta_1 \Delta House\,price_i^n + \beta_2 Young_i \cdot \Delta House\,price_i^n \\ &\quad + \beta_3 Young_i + \beta_4 CC_i + \beta_5 Young_i \cdot CC_i \\ &\quad + \beta_6 CC_i \cdot \Delta House\,price_i^n + \beta_7 Young_i \cdot CC_i \cdot \Delta House\,price_i^n \\ &\quad + \gamma X_i + u_i \end{aligned} \tag{5}$$

where $\Delta Saving_i^n$ is the normalised difference in saving for household i between 2006/07 and 2008/09; $\Delta House\,price_i^n$ is defined as $House\,price_{i,2009}^n - House\,price_{i,2007}^n$; CC_i is the indicator variable that is equal to one if the couple is likely to be credit constrained in 2007; $Young_i$ is an indicator variable that is equal to one if the age of the oldest spouse is less than 50 in 2007; the vector of controls, X_i, contains the level of education for the spouse with the highest education and an indicator variable for whether the couple has any children living at home. The results are presented in column (1) in Table 3.

Wealth effect

The significant and negative estimate of the coefficient on $\Delta House\,price^n$ of -0.0215 is interpreted as follows: a house price decrease from 2007 to 2009 equal to 1 year of permanent income lead to an

Table 3: Regression output

$\Delta Saving_i^n$	(1) Main reg	(2) Renters
$\Delta House\,price_i^n$	-0.0215***	-0.0211***
	(0.00718)	(0.00722)
$Young_i \cdot \Delta House\,price_i^n$	-0.0108	-0.0108
	(0.0101)	(0.0101)
$Renter_i \cdot \Delta House\,price_i^n$		0.0505*
		(0.0287)
$Renter_i \cdot Young_i \cdot \Delta House\,price_i^n$		-0.0296
		(0.0362)
$CC_i \cdot \Delta House\,price_i^n$	-0.324***	-0.324***
	(0.0515)	(0.0515)
$CC_i \cdot Young_i \cdot \Delta House\,price_i^n$	0.0873	0.0874
	(0.0584)	(0.0584)
$Renter_i \cdot CC_i \cdot \Delta House\,price_i^n$		0.311***
		(0.0649)
$Renter_i \cdot CC_i \cdot Young_i \cdot \Delta House\,price_i^n$		-0.0494
		(0.0752)
$Constant$	0.0666	0.0624*
	(0.0473)	(0.0354)
Observations	13260	14955
Adjusted R^2	0.018	0.021

Standard errors clustered at the municipality level are reported in parentheses. Besides the estimates presented we also control for $Young$, CC, $CC \cdot Young$, the level of education, if the couple have children. In column (2) we additionally control for $Renter_i$, $Renter_i \cdot Young_i$, $Renter_i \cdot CC_i \cdot Young_i$, and $Renter_i \cdot CC_i$.
* $p < 0.1$, **$p < 0.05$, ***$p < 0.01$

increase in saving in 2008 and 2009 relative to 2006 and 2007 of 2.2 percent of permanent income. Since we have divided both our dependent variable and our explanatory variable ($\Delta House\,price$) by the same individual specific permanent income, our regression coefficients can be interpreted as a marginal propensity to save out of a shock to housing wealth. This implies that households who experience a house price fall of 100 DKK increase annual saving by 2.2 DKK. For our sample this estimate translates into an average increase in saving of 10,800 DKK (year 2000 prices) for non-credit constrained households following the decline in house price changes.[19]

As discussed above some of the previous literature has relied on the predictions of the simple life-cycle model to identify housing wealth effects. According to the simple model, older house-

[19] With an estimated coefficient of -0.0215, an average change in house prices relative to permanent income of -1.34 (see Table 1), and an average yearly permanent income of $374,666$ DKK, the house price fall from experienced from 2007 to 2009 is, on average, associated with an increase in saving of $[(-1.34) \cdot (-0.0215) \cdot 374,666 \approx]$ 10,800 DKK.

holds will increase saving relatively more following an unexpected house price decline (i.e. $Young \cdot \Delta House\ price > 0$). From the results in Table 3 we see that this is not what we find. The coefficient on $Young \cdot \Delta House\ price$ is insignificant and, if anything, negative. We therefore find no evidence in favour of the proposed age heterogeneity in the saving responses of old and young households.

Despite the potential sample selection issues with using renters as a control group it is interesting to analyse the regression results where we include renters. From (2) in Table 3 we see that we find a significant and positive estimate of 0.051 on the coefficient $Renter \cdot \Delta House\,price$. In other words, renters do not change their saving when there is a shock to house prices in their municipality. Though we place less emphasis on the specification that compares renters and home-owners, the fact that renters do not react to house price shocks seems at odds with shocks to income expectations driving our results. If anything the point estimates suggest that renters decrease saving when house prices decrease (as $-0.0215 + 0.051 > 0$). This reaction is expected as purchasing a house is now cheaper (for the renters planning to do so) and/or future housing costs for renters are now lower (insofar as rental costs follow house prices).

In sum, we find that households who experienced a negative house price shock responded by increasing saving. Since we control for the role of shocks to income expectations and separate out the credit/precautionary saving channel, and as that we find no response for the group of renters, we interpret this as evidence of a causal housing wealth effect.

In many ways this finding is similar to the findings in Disney et al. (2010) who also find a non age-heterogeneous wealth effect. One explanation for why we find evidence of a housing wealth effect, but no evidence in favour of the proposed age heterogeneity could be the presence of a bequest motive that is stronger among older couples (e.g. because higher house prices makes their children relatively poorer or because of mental accounting (see Thaler (1985))). This is just one possible explanation that is consistent with our empirical findings, and it will be important in future work to quantify its relevance, and investigate other possible mechanisms that explains these results.

Credit constraints through housing equity as collateral

We now analyse the results for the group of couples likely to be affected by credit constraints. From column (1) in Table 3 we see that (both young and old) credit constrained couples increase saving significantly more than unconstrained couples in response to a house price decline. The statistically significant and negative coefficient of $-0.0215 - 0.324 = -0.3455$ shows that the 1,573 credit constrained couples on average increased their annual saving sharply when they experienced a negative house price shock. For credit constrained couples the estimates translates into an average increase in saving associated with the house price decline of around $[(-0.47) \cdot (-0.3455) \cdot 333,544 \approx]$ 54,200 DKK. That is, couples that were likely to be affected by credit constraints increased their saving, on average, 5 times more than non-credit constrained households.

The sharp increase in saving following a house price fall for credit constrained couples is in accordance with two different explanations. First, the life-cycle model predicts that credit constrained couples will increase their saving following a house price decline both because they experience a loss in wealth (the housing wealth effect) *and* because the decline in housing equity limits their

capacity to use housing equity as collateral to smooth consumption. Second, the strong reaction of the couples we label as likely to be affected by credit constraints is also in accordance with the precautionary saving framework. A decline in house prices will cause a substantial drop in their already small or negative precautionary wealth. This will cause them to increase saving in order to rebuild their precautionary wealth, and because their buffer of precautionary wealth is small to begin with, the theory suggests that the response will be non-linearly larger (see Carroll (1997)). We are unable to determine which of these two theories drives the results found - distinguishing these two mechanisms remains an avenue for future research.

When we analyse the results that include the population of renters in column (2) in Table 3 we see that there is a significant and positive estimate on $Renter \cdot CC \cdot \Delta House\,price$ and that this estimate almost precisely cancels out the estimate of $CC \cdot \Delta House\,price$. Thus, we find no credit (or precautionary wealth) effect through changes in house prices for the group of renters. This suggests that the estimated effect for the group of credit constrained home-owners is in fact caused by the house price change, and not a spurious correlation.

5.2 Decomposition of saving responses

This subsection utilises the detailed information available in the Danish registers to decompose the saving responses into the different asset and liability types to explore through which channels the saving responses found above take place.

Table 4 presents the results of the main specification and 6 new regressions that together explain the responses observed in the main regression. Overall, couples can save in two different ways; they can increase their assets or lower their liabilities. The estimates in the main regression can therefore be found as the sum of the coefficients to changes in asset accumulation (i.e column (4)-(7)) minus the sum of the changes in liability accumulation (i.e column (2) and (3)). We therefore analyse Table 4 horizontally to uncover which adjustments in assets and liabilities that drives the observed responses in saving.

Credit constrained couples increased housing debt prior to the crisis to pay off bank debt: the debt portfolio effect

We start by analysing the row of $CC \cdot \Delta House\,price$ in Table 4 to get a better understanding of what drives the large responses of credit constrained couples in the main regression. From column (2) we see that it is largely driven by a lower housing debt accumulation (i.e. the estimate to $CC \cdot \Delta House\,price$ is 0.571).[20] Furthermore, we see from the estimate in column (3) (-0.290) that some of this sharp reaction in the housing debt accumulation is mitigated by the change in bank debt accumulation. However, we cannot determine from these estimates alone to what extent the estimate to e.g. housing debt is driven by a large decrease in housing debt during the Great Recession, or a large increase in housing debt prior to the the Great Recession, or both. To separate these possible explanations and to show how the changes in debt for credit constrained couples correlate with the changes in house prices, we show the median changes in housing debt and bank

[20] We interpret the parameter $CC \cdot \Delta House\,price$ as follows: when house prices decline with permanent income, households decrease the rate of housing debt accumulation by 0.571 of permanent income.

Table 4: Decomposition of saving responses

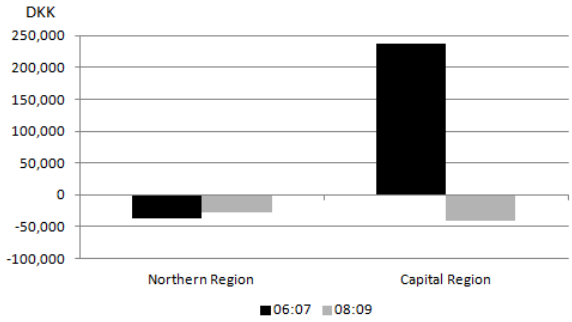
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$\Delta Saving =$	-$\Delta Liability\,accumulation$			$+\Delta Asset\,accumulation$		
Dependent variable	Saving	Housing Debt	Bank Debt	Bank assets	Stocks	Bonds	Pensions
$\Delta House\,price_i^n$	-0.0215***	0.0243**	0.0155*	0.0204**	-0.00104	-0.00415	0.00303*
	(0.00718)	(0.0118)	(0.00903)	(0.00919)	(0.00303)	(0.00294)	(0.00156)
$Young_i \cdot \Delta House\,price_i^n$	-0.0108	0.0111	-0.0309**	-0.0331***	-0.000839	0.00563	-0.00223
	(0.0101)	(0.0132)	(0.0118)	(0.0107)	(0.00296)	(0.00352)	(0.00190)
$Young_i$	-0.0653***	-0.0165	0.0199	-0.0816***	0.00944	0.00722	0.00305
	(0.0162)	(0.0210)	(0.0188)	(0.0173)	(0.00571)	(0.00790)	(0.00267)
CC_i	0.0447	0.0926**	0.0121	0.112***	0.0187***	0.0233***	-0.00495
	(0.0422)	(0.0461)	(0.0436)	(0.0252)	(0.00624)	(0.00656)	(0.00553)
$CC_i \cdot Young_i$	0.0534	-0.0575	0.0567	0.0675**	-0.0118*	-0.00567	0.00258
	(0.0492)	(0.0523)	(0.0479)	(0.0268)	(0.00633)	(0.00744)	(0.00604)
$CC_i \cdot \Delta House\,price_i^n$	-0.324***	0.571***	-0.290***	-0.0346	0.000692	0.00445	-0.0127*
	(0.0515)	(0.0640)	(0.0669)	(0.0257)	(0.00320)	(0.00299)	(0.00691)
$CC_i \cdot Young_i \cdot \Delta House\,price_i^n$	0.0873	-0.0625	0.0135	0.0348	0.000903	-0.00521	0.00781
	(0.0584)	(0.0853)	(0.0896)	(0.0287)	(0.00317)	(0.00354)	(0.00800)
Constant	0.0666	0.125**	-0.0934*	0.0847	-0.0220	0.00245	0.0327***
	(0.0473)	(0.0605)	(0.0477)	(0.0558)	(0.0175)	(0.00843)	(0.00475)
Observations	13260	13260	13260	13260	13260	13260	13260
Adjusted R^2	0.018	0.021	0.016	0.007	0.001	0.000	0.008

Standard errors clustered at the municipality level are reported in parentheses. The dependent variable for each regression (i.e. for each column) is shown in the row above the parameter estimates. Besides the estimates presented we also control for the level of education and if the couple have children. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

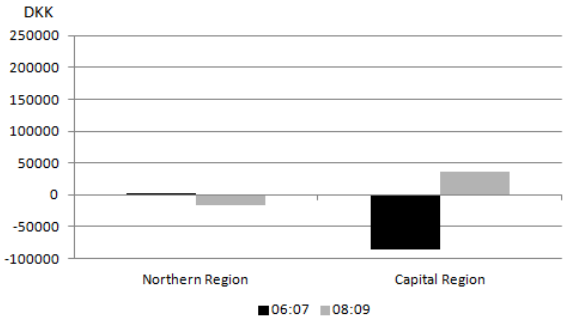
debt of credit constrained couples in two different regions. The Northern Region, where house prices were roughly unchanged across our period of interest and the Capital Region where house prices increased substantially in the years up to 2008 and declined sharply in 2008 and 2009.

Figure 3: Median changes in debt (not normalised by permanent income)

(a) ΔHousing debt for credit constrained



(b) ΔBank debt for credit constrained



Note: Credit constrained in this figure refers to couples likely to be affected by credit constraints as defined in the data section.

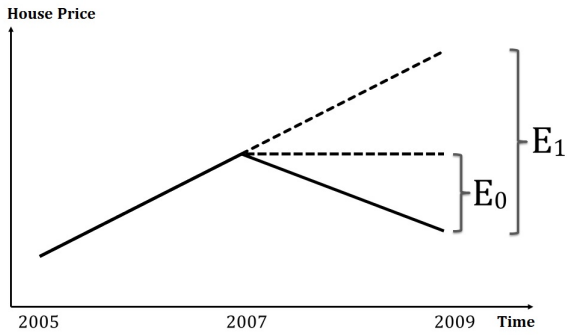
Figure 3a shows that credit constrained couples in the Capital Region increased their housing debt substantially in 2006 and 2007 only to lower it in 2008 and 2009. This is in stark contrast to credit constrained couples living in the Northern Region of Denmark who lowered their housing debt both before and after the Great Recession. When looking at the changes in bank debt presented in Figure 3b we see that prior to the Great Recession credit constrained couples living in the Capital Region used some of their increased housing debt to pay off a substantial part of their more expensive bank debt. This is in contrast to those living in the Northern Region who only changed their bank debt slightly in both periods. In sum, Figure 3a-3b and Table 4 shows that some credit constrained couples used increases in house prices to gain access to credit through housing equity as collateral to re-optimise their debt portfolio in 2006 and 2007 and substitute away from expensive bank debt to cheaper housing debt. We label this as the *debt portfolio effect*.

Furthermore, we find that the couples likely to be affected by credit constraints only used around half the raised housing debt to pay off bank debt. That is, they also used the increased housing debt to finance a higher level of consumption. We cannot, however, determine whether they slowed down their consumption as the Great Recession unfolded due to stricter access to credit (both because of a general credit tightening and because of the lower level of housing equity that could be used as collateral) or whether it was driven by a desire to increase their level of precautionary wealth.

6 Robustness

This section tests how our main conclusions fare across various robustness checks. We start by introducing the motivation for each of the robustness checks we have carried out before summing up the results of our robustness checks.

Figure 4: Heterogeneous house price expectations



When we regress the change in saving on the house price change from 2007 to 2009 we are effectively assuming that all couples throughout the country had "flat" house price expectations, as we are using the actual fall as if it was completely unexpected (depicted by E_0 in Figure 4). We used the historic turnaround and the forecasts of the leading forecasters to argue why we think that this is a reasonable assumption. Nevertheless, we want to investigate how sensitive our main conclusions are to this identifying assumption. Specifically, we allow couples to have expectations based on the house price increases experienced between 2005 and 2007 where house prices developed differently across municipalities and regions. For example, the house price increase in Region Zealand from 2005 to 2007 was 1.3 times the permanent income, while the house price increase in the North Denmark Region was 0.7. It could be that these heterogeneous house price increases led to heterogeneous house price expectations for 2008 and 2009.

We explore this hypothesis, by investigating two different scenarios where we introduce heterogeneity in the house price expectations over the different municipalities (and households). Column (4) shows the results from estimating a specification where we assume that couples expected the house price change between 2007 and 2009 to be equivalent to the house price increase that they experienced from the end of 2005 until 2007. We have illustrated this by the unexpected house price drop marked by E_1 in Figure 4. In this case the unexpected change in house prices is given by the house price drop between 2007 and 2009, minus the house price increase between 2005 and 2007. Since the municipalities that experienced the largest declines in house prices in DKK relative to permanent income between 2007 and 2009 also saw the largest increases between 2005 and 2007 this specification will tend to, on average, increase the size of the unexpected house price drops. Additionally, column (5) presents the results of a specification where we assume that households expected the house price increase to be half of the house price increase they experienced between 2005 and 2007. The idea is that some households may have suspected that the house price increases from 2005-2007 were not sustainable and they therefore did not expect the full increase to be replicated between 2007 and 2009.

In our main specification we regress on the house price change between the end of 2007 and the end of 2009. However, the house price decline in Copenhagen actually began earlier in 2007. It could therefore be that couples living in Copenhagen had different expectations regarding house

prices compared to the rest of the country at the end of 2007. Column (7) therefore presents the results of a regression where we have excluded households living in Copenhagen.[21]

An identifying assumption of our research design is that we have cut our sample, such that we obtain a homogeneous sample that was affected similarly by shocks to income expectations following the Great Recession. There is obviously a trade-off between on the one hand restricting the group to make it credible that this identifying assumptions hold, and on the other hand obtaining a large enough sample in order to obtain precise estimates. However, one concern with our design is that there could be differences between the different types of public employees. It could be that highly educated individuals in central government to a higher extent consider the private sector as an alternative to public employment. If this is true, then this group may have experienced a larger negative shock to future expected earnings following the Great Recession. Thus, it could be that highly educated couples employed in central government, who are more likely to live in the Capital Region where house prices fell more on average, experienced a larger shock to income. If such a correlation exists, then the results from our main specification will be biased. To test for this, and to test whether our results are robust to restricting our sample even further in order to achieve an even more homogeneous group that experienced similar shocks to income expectations, column (6) presents results from a regression where we exclude any highly educated couples where any of the two individuals where employed in the central government at any time throughout the period.

Finally, we test the sensitivity of our results to an alternative specification that seeks to mitigate potential measurement errors in our dependent variable. This paper seeks to identify the *behavioural* saving response to falling house prices and a key issue is therefore to separate active saving from passive saving. Even though we have corrected our saving measures for average stock returns (described above in Section 4), this correction will not eliminate capital gains from our saving variable, as we do not know the composition of individual stock portfolios. As a result we therefore risk classifying these financial windfalls as changes in saving behaviour. This passive saving could potentially bias our results with respect to a housing wealth effect if this "omitted variable" (for example the returns to stocks) is correlated with $\Delta House\ price$. To eliminate issues associated with passive saving we therefore estimate a version where we exclude couples that own any stocks or bonds.[22] This regression is presented in column (8).

Table 5 presents the results for each of the robustness checks discussed above. These regressions suggest that our main findings are robust across a wide array of specifications. In all regressions,

[21] One can effectively think of these different heterogeneous house price expectations as mimicking the AR(1) process used by the previous literature to model the expectations of households.

[22] Although we exclude couples owning stocks or bonds, passive saving though housing debt could still potentially be a cause for concern. In the Danish mortgage market home-owners face a choice between fixed rate mortgages (where the interest rate is typically fixed for 30 years) and adjustable rate mortgages (where the interest rate is typically fixed between 1 to 5 years). This is important because housing debt used in this analysis is measured at its market value. If the interest rate drops, the market value of the underlying bond of a fixed rate mortgage increases relatively more than the market value of an adjustable rate mortgage. Systematic differences between portfolio choices of fixed rate and adjustable rate mortgages across the municipalities of Denmark could therefore lead to systematic measurement error in our dependent variable. Unfortunately, we cannot observe the individual household's type of mortgage. However, we do have access to data that contains the portfolio choices of mortgage loans across the regions of Denmark at an individual level in 2013 (4 years after our sample period ends). This data shows that the share of fixed rate mortgages were relatively similar across regions. This suggests that passive saving through housing debt is not a problem for this analysis.

we find that both old and young households significantly increase saving when their house prices decline. Furthermore, we find a large increase in saving following a house price decline for couples likely to be affected by credit constraints in all specifications. Finally, we find that the debt-portfolio effect is robust to a different specification of how we label couples as likely to be affected by credit constraints (see Table 7 in the appendix).

7 Conclusion

This paper investigates the impact of shocks to house prices on households' saving behaviour, disentangling each of the four proposed drivers of the empirically observed correlation. Understanding the mechanisms that drive this correlation is important as it, for example, facilitates sensible regulation of the housing market, a market that constitutes the majority of many households wealth.[23] The previous empirical literature investigating this has reached diverging conclusions depending on the choice of research design, country and period. Even when the exact same data is used, studies have reached different conclusions due to differences in research designs. This paper uses a new research design that overcomes some of the weaknesses of previous work.

We find three main conclusions. First, we find that both young and old home-owners significantly increase annual saving by 2.2 DKK for every 100 DKK of house price loss. Furthermore, we find that renters do not increase their saving following shocks to house prices. If anything, renters decrease saving following a negative house price shock, which is what we would expect as purchasing a house is now cheaper and/or future housing cost for renters are now lower. As our research design isolates a group that were similarly affected by shocks to income expectations and as we have separated out the responses of households affected by credit constraints, we take the response among home-owners as evidence that there is a significant and causal housing wealth effect. Second, we find households who are likely to be affected by credit constraints respond strongly to changes in house prices suggesting that housing equity serving as collateral (or precautionary wealth) is important for the consumption and saving decisions of some households. Third, we find that couples likely to be affected by credit constraints re-optimised their debt portfolio and used the increase in housing equity prior to the Great Recession to increase housing debt in order to pay off more expensive bank debt (the debt portfolio effect). In addition to this, they used some of the increased housing debt to finance a higher level of consumption.

In the light of the diverging conclusions of previous papers we see the research design used in this paper as a significant strength, as it allows us to obtain internally valid results. Albeit the choices made does not come without a cost, and it will be important for future work to investigate the importance of the housing wealth effect in other countries and in other periods as there might not be one "true" size of the housing wealth effect. Nonetheless the major turnaround in the housing market studied in this paper is important to analyse as it is crucial to understand how such significant changes in the housing market impact the wider economy.

Overall the research presented in this paper highlights that it is not only the size of the house price

[23] In Denmark home equity accounts for around 60 percent of household financial wealth, see RKR (2014).

Table 5: Robustness analysis

	(1) Main reg	(2) Young	(3) CC-strict	(4) HPexpFull	(5) HPexpHalf	(6) W/O Copenh	(7) W/O cntrl gov	(8) No Stock/Bonds
$\Delta House\,price_i^n$	-0.0215***	-0.0218***	-0.0204***	-0.0115**	-0.0154**	-0.0226***	-0.0217**	-0.0294**
	(0.00718)	(0.00583)	(0.00686)	(0.00529)	(0.00613)	(0.00759)	(0.00872)	(0.0114)
$Young_i \cdot \Delta House\,price_i^n$	-0.0108	-0.0181	-0.0102	-0.00828	-0.00951	-0.0139	-0.0200*	-0.00564
	(0.0101)	(0.0112)	(0.00968)	(0.00730)	(0.00853)	(0.0104)	(0.0120)	(0.0148)
$CC_i \cdot \Delta House\,price_i^n$	-0.324***	-0.272***	-0.478***	-0.185***	-0.241***	-0.322***	-0.350***	-0.338***
	(0.0515)	(0.0370)	(0.0992)	(0.0348)	(0.0414)	(0.0516)	(0.0572)	(0.0518)
$CC_i \cdot Young_i \cdot \Delta House\,price_i^n$	0.0873	0.0289	0.0750	0.0278	0.0486	0.0808	0.108	0.108*
	(0.0584)	(0.0574)	(0.127)	(0.0380)	(0.0462)	(0.0594)	(0.0648)	(0.0581)
$Constant$	0.0666	0.0568	0.0706	0.0664	0.0658	0.0718	0.0657	0.0255
	(0.0473)	(0.0476)	(0.0476)	(0.0482)	(0.0477)	(0.0492)	(0.0485)	(0.0551)
Observations	13.260	13.260	13.260	13.260	13.260	12765	10896	7.783
Adjusted R^2	0.024	0.024	0.011	0.024	0.024	0.019	0.021	0.027

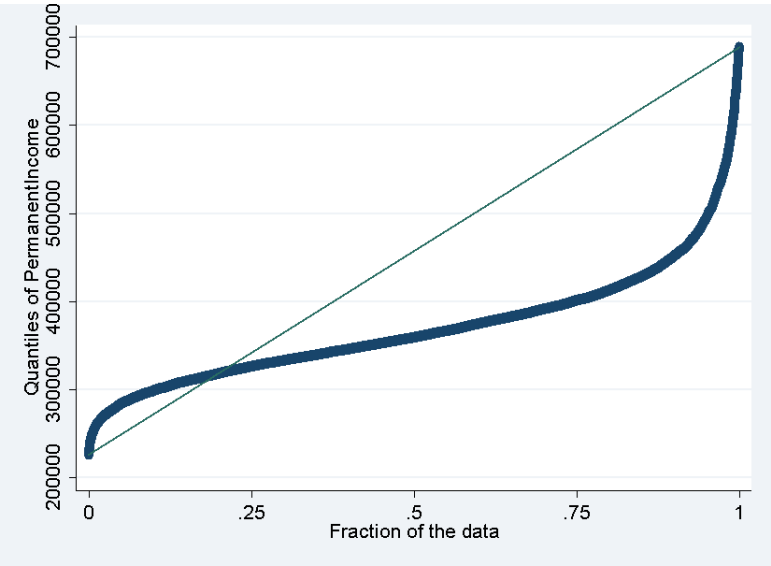
Note: Standard errors clustered at the municipality level are reported in parentheses. Besides the estimates presented we also control for $Young$, CC, $CC \cdot Young$, the level of education and if the couple have children. (2) young is defined as the oldest household member being younger than 45; (3) Couples are defined as likely to be affected by credit constraints if they have less than 1 months of disposable income in liquid assets and if their LTV0>.7; (4) and (5) House price shocks are corrected to account for heterogeneous house price expectations; (6) excludes any couples living in Copenhagen; (7) excludes couples that contain highly educated individuals employed in the central government; (8) excludes couples that own any stocks or bonds. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

shock and the resulting loss in wealth that matter: the distribution of the wealth losses are important for determining the following consumption responses. Furthermore, this research highlights how high leverage in households may contribute to prolonged crises following shocks to household wealth as high leverage creates a need for deleveraging that may suppress consumption and economic recovery.

Our results therefore indicate that allowing households to accumulate large amounts of debt during economic upturns could result in higher overall macroeconomic volatility. Despite the large benefits of having a flexible mortgage system that allows households to borrow against their housing equity (enabling them to smooth consumption) this highlights a potential cost of such a system.

8 Appendix

Figure 5: Distribution of permanent incomes



Note: The figure shows the distribution of the trimmed yearly average net income of stable couples of public employees from 1998-2007.

Figure 6: Distribution of trimmed changes in saving, normalised with permanent income

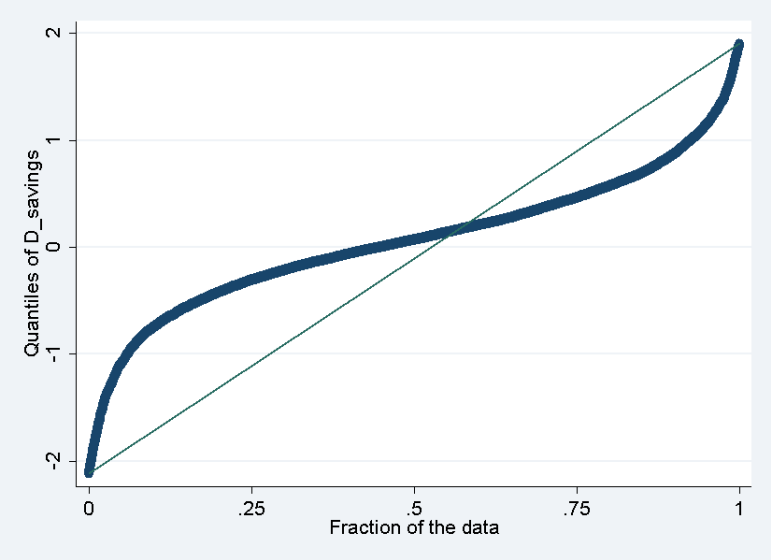


Figure 7: Distribution of trimmed changes in house prices from 2007 to 2009, normalised with permanent income

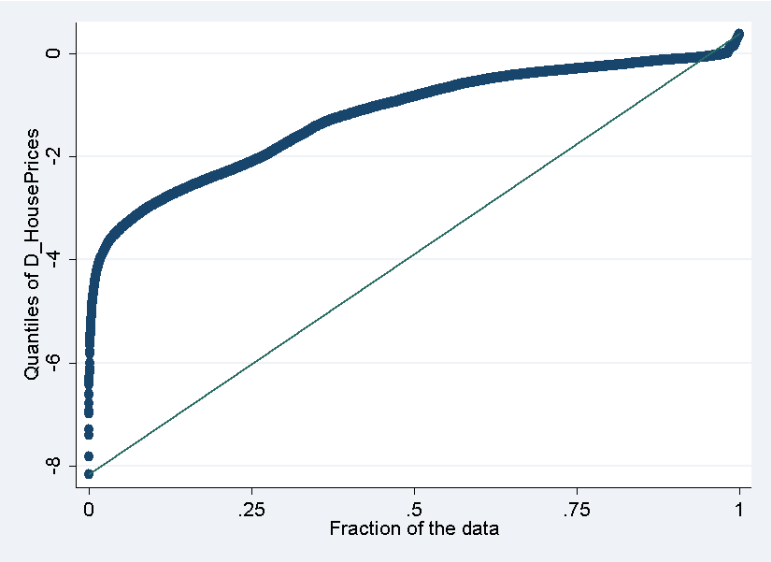


Figure 8: Share in public sector

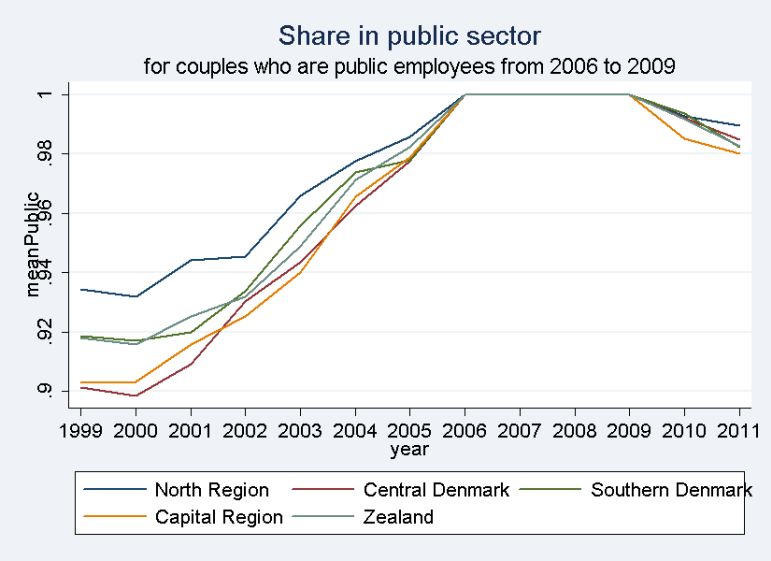


Table 6: Estimation results with three age groups

$\Delta Saving$	(1) Main specification
$\Delta House\,price_{50+}$	-0.0220***
	(0.00765)
$Middle_{40-50} \cdot \Delta House\,price$	-0.0108
	(0.0101)
$Young_{<40} \cdot \Delta House\,price$	-0.00218
	(0.0176)
$Young_{<40}$	-0.0684**
	(0.0289)
$Middle_{40-50}$	-0.0616***
	(0.0151)
CC	0.0542
	(0.0413)
$Middle_{40-50} \cdot CC$	0.0384
	(0.0496)
$Young_{<40} \cdot CC$	0.0355
	(0.0574)
$CC \cdot \Delta House\,price$	-0.316***
	(0.0601)
$CC \cdot Middle_{40-50} \cdot \Delta House\,price$	0.0409
	(0.0713)
$CC \cdot Young_{<40} \cdot \Delta House\,price$	0.143*
	(0.0773)
$Constant$	0.0703
	(0.0475)
Observations	13260
Adjusted R^2	0.019

Cluster-robust standard errors are in parentheses. Besides the estimates presented we also control for the level of education and if the couple have children. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Decomposition of saving responses using strict definition of CC

	(1) Saving	(3) Housing debt	(4) Bank Debt	(6) Bank assets	(7) Stocks	(8) Bonds	(9) Pensions
$\Delta House\,price$	-0.0204***	0.0272**	0.0156*	0.0231**	-0.000543	-0.00350	0.00324**
	(0.00686)	(0.0118)	(0.00888)	(0.00890)	(0.00290)	(0.00286)	(0.00151)
$Young \cdot \Delta House\,price$	-0.0102	0.0132	-0.0281**	-0.0273***	-0.000994	0.00580*	-0.00247
	(0.00968)	(0.0131)	(0.0118)	(0.0103)	(0.00282)	(0.00333)	(0.00184)
$Young$	-0.0532***	-0.0304	0.0401**	-0.0629***	0.00894*	0.00801	0.00248
	(0.0156)	(0.0210)	(0.0178)	(0.0163)	(0.00524)	(0.00727)	(0.00245)
CC	0.0518	0.0372	0.0337	0.107***	0.0170***	0.0185***	-0.0199**
	(0.0569)	(0.0707)	(0.0762)	(0.0348)	(0.00586)	(0.00607)	(0.00778)
$CC \cdot Young$	0.0278	0.0506	-0.0406	0.0381	-0.0114*	-0.00431	0.0154*
	(0.0654)	(0.0803)	(0.0822)	(0.0346)	(0.00581)	(0.00656)	(0.00877)
$CC \cdot \Delta House\,price$	-0.478***	0.748***	-0.374**	-0.0953	-0.0000429	0.000669	-0.00953
	(0.0992)	(0.154)	(0.146)	(0.0953)	(0.00341)	(0.00309)	(0.0122)
$CC \cdot Young \cdot \Delta House\,price$	0.0750	0.0851	-0.0700	0.0861	0.00213	-0.00422	0.00606
	(0.127)	(0.179)	(0.204)	(0.0962)	(0.00331)	(0.00406)	(0.0129)
$Constant$	0.0706	0.129**	-0.0922*	0.0900	-0.0205	0.00398	0.0336***
	(0.0476)	(0.0603)	(0.0478)	(0.0556)	(0.0174)	(0.00824)	(0.00477)
Observations	13260	13260	13260	13260	13260	13260	13260
Adjusted R^2	0.011	0.011	0.008	0.003	0.001	0.000	0.009

Cluster-robust standard errors are in parentheses. Couples are defined as likely to be affected by credit constraints if they have less than 1 months of disposable income in liquid assets and if their LTV¿0.7. Besides the estimates presented we also control for the level of education and if the couple have children. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

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