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HOMEOWNERS' FINANCIAL VULNERABILITY OVER THE HOUSE PRICE CYCLE

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ABSTRACT

This paper investigates the dynamics of financial vulnerability of indebted homeowners over the housing cycle with an agent-based housing market model. The model is calibrated using UK micro data. I find that financial vulnerability is driven by previous period house purchases and by dissaving due to a wealth effect on consumption. While the first channel is more important in the upswing, the dissaving channel is more important at high price levels. A second finding is that current vulnerability is path-dependent on past purchases at high prices, as due to the wealth effect, these past purchases lead to temporary high consumption.

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Abstract

This paper investigates the dynamics of financial vulnerability of indebted homeowners over the housing cycle with an agent-based housing market model. The model is calibrated using UK micro data. I find that financial vulnerability is driven by previous period house purchases and by dissaving due to a wealth effect on consumption. While the first channel is more important in the upswing, the dissaving channel is more important at high price levels. A second finding is that current vulnerability is path-dependent on past purchases at high prices, as due to the wealth effect, these past purchases lead to temporary high consumption.

JEL Classification: G51, C63, R31

1 Introduction

The Great Financial Crisis of 2007/08 exemplified the dangers that households' balance sheets can pose to the stability of the macroeconomy. The rapid build-up of mortgage debt prior to the crisis increased households' vulnerability to economic shocks. When the crisis hit and households were faced with falling house prices and rising unemployment, many of them cut back on their consumption or even defaulted on their mortgage loan payments, slowing the economic recovery and destabilising lenders' balance sheets. In order to prevent these negative consequences, policymakers need to understand the causes of financial vulnerability. This paper tries to further this understanding using a housing market model that allows to investigate housing market and mortgage dynamics and their effects on the individual households' balance sheets. This focus on the housing market is motivated by the fact that mortgages form the largest part of households' debt.

Two channels affecting financial vulnerability are of interest here. Portfolio reshuffling towards and away from housing impact households' liquidity and their ability of paying the monthly debt service, consumption decisions also impact households' liquidity. Portfolio reshuffling can make households vulnerable even though they hold considerable housing wealth but lack a liquid financial buffer. These households are sometimes called wealthy hand-to-mouth households (Kaplan, Violante, and Weidner 2014).

The other channel affecting financial vulnerability is consumption induced by housing wealth effects. A wealth effect can lead to homeowners becoming financially vulnerable in a house price upswing if they consume too much of their financial buffers. Typically, the effect of housing wealth on consumption is viewed through the lens of its impact on aggregate demand and not on creating financial vulnerability itself. In the literature concerned with aggregate demand the housing wealth effect accelerates the empirically observed fact that house price collapses preceded by sharp increases (IMF 2012; Jordá, Schularick, and Taylor 2016; Bezemer and Zhang 2019) and/or high levels of mortgage debt are usually followed by longer and more severe recessions (Bunn and Rostom 2015; Baker 2018). Highly indebted homeowners, in particular with low income—who are usually financially vulnerable—are more likely to cut back on consumption in the face of falling house prices (Mian, Rao, and Sufi 2013).

To analyse the effects of the housing market and consumption decisions on homeowners' financial vulnerability, an agent-based model is employed in the paper at hand. The model reflects a high degree of household heterogeneity and simulates individual market transactions. These include interactions between households buying and selling property and between households and a commercial bank. The bank applies loan-to-value (LTV) limits to mortgage loan applications. The high degree of heterogeneity allows to replicate the unequal distribution of financial assets, housing wealth, mortgage debt and income observed in UK household microdata. This matching is crucial for the calibration of the wealth effect to get the right picture about financial vulnerability, as both depend on the balance sheet and the income of the respective household. In addition, the distribution of financial wealth and income influences portfolio decisions towards real estate assets. In the model, market interactions give rise to a house price cycle in which turnover fluctuates significantly, which leads to a fluctuating share of financially vulnerable households.

By taking out too much mortgage loans before, some of the lower-income households become vulnerable to shocks to their income, due to a negative financial margin[1] and the depletion of their liquid assets. This explains a substantial part of financial vulnerability dynamics over the house price cycle. Interestingly, also the consumption decisions of homeowners are very important. Specifically, in the model, consumption induced by housing wealth leads to steadily increasing (decreasing) financial vulnerability during phases of high (low) house prices. This dynamic is in line with the findings of Bartscher et al. (2020) for long-term US household data. In the model, the share of financially vulnerable households will only be half as large as in the case without this type of consumption channel.

Another finding is that previous house price booms influence the financial vulnerability in the current cycle. Households that have bought a home in a previous house price peak may become financially vulnerable only much later, in a subsequent house price peak, because they have consumed their financial buffer in the meantime. For this dissaving to happen, these households need positive net housing wealth and equity withdrawals, although I do not model the corresponding financial transaction explicitly. Financial

[1]The financial margin is defined as net income, less mortgage payments and some essential consumption. See also Equation (3) in Section 4.

vulnerability increases especially, once current house prices rise above previous house price peaks. Results suggest that when house prices are about to rise above previous house price peaks, policies to curb financial vulnerability should be employed. These could include an intervention in individual consumption choices, i.e. limiting the depletion of buffer stocks, which could be achieved by limiting housing equity withdrawals. Another policy could aim at dampening house price boom phases, for instance by implementing macroprudential credit restrictions.

This paper contributes to the existing literature by improving the agent-based housing market model by Tarne, Bezemer, and Theobald (2022) to include a more realistic housing wealth effect on consumption so that it is not active for all households, but only for those close to their borrowing constraint. The newly introduced parameters are then calibrated to match key stylized facts about the UK housing market and the characteristics of financially vulnerable households. Moreover, the paper contributes by examining in depth the impact of consumption on overall household financial vulnerability. This channel has hardly been studied so far.

2 Related Literature

This paper connects to the literature on the drivers of households' financial vulnerability as well as on the wider literature on housing wealth effects. Housing wealth can influence household consumption via an endowment effect or via a collateral channel. Rising house prices can make homeowners feel richer, leading them to increase their consumption. As housing can be used as collateral for credit, changes in house prices can influence homeowners' access to credit. Changes in credit access, however, should only affect the (real) consumption of households that are at their borrowing limit. When house prices rise, these households can finance their higher consumption by withdrawing equity. Moreover, if households have a precautionary savings motive (Carroll and Kimball 1996), their consumption may be sensitive to changes in the value of their properties, even if they are not directly at their borrowing limit (Aladangady 2017). For example, households that are close to their borrowing limit and see the value of their collateral falling may seek to hold more money to compensate for the reduced access to equity in an emergency.

Wealth effects can be strong. For instance, Mian, Rao, and Sufi (2013) find a collateral channel to be essential in explaining the drop in aggregate consumption in the US after the financial crisis of 2007/08. This finding has been supported by Kaplan, Violante, and Hall (2020), utilising alternative data sources. Cloyne et al. (2019) show that a collateral channel is important in explaining aggregate consumption fluctuations in the UK between 2005-15. Aladangady (2017) finds the overall housing wealth effect of 4.7% in the US to be exclusively driven by households above the median debt-service-to income ratio (DSR). Specifically, the housing wealth effect of these constrained households is estimated to be 12.7%, versus 0% for households below the average DSR. Similarly, Zhang (2019) finds a housing wealth effect for Dutch households above the median debt-to-income ratio (DTI) of 10.3% versus 4.1% for households below the median DTI. Guerrieri and Lorenzoni (2017) find that a precautionary channel can explain an economic recession with low interest rates after a credit crunch like that of 2008.

Most studies concerned with financial vulnerability focus on its effect on households' consumption. How consumption itself influences financial vulnerability remains mostly unexplored. Bartscher et al. (2020) estimate the impact of an income shock to all households on the share financial vulnerable households (debt-service-to-income ratio $>$ 40%) for the US from 1950 to 2016 based on household micro data. They find that the growth of debt through equity withdrawal played a crucial role in significantly increasing household financial vulnerability over time, especially among the middle class.

Other studies touch this relationship less directly. For instance, Brunetti, Giarda, and Torricelli (2016) estimate household financial vulnerability based on Italian household micro data between 1998 and 2012. They categorize households as vulnerable when they are not able to cover 1,500 € of unexpected expenses. This measure does therefore not necessarily aim to capture over-indebted households but households with poor portfolio allocation and generally poor households. They find that portfolios tend to become too illiquid in housing market boom phases, which might be explained by a wealth effect. Brunetti, Giarda, and Torricelli (2020) expand their previous analysis of financially vulnerable households to several European countries and the US (Brunetti, Giarda, and Torricelli 2016). They find that a one percentage point increase in the share of the household's housing wealth in total wealth increases its chances of being financially vulnerable

by 13 percentage points.

Kaplan, Violante, and Hall (2020) calculate the share of wealthy households living hand-to-mouth, i.e. households that spend all their disposable income and have significant amounts of illiquid but not liquid assets, based on micro-household data for various countries (US 1989-2010, UK 2008-10, Germany 2008-10 and others). They find that about 20% of households in the US and 22% of households in the UK qualify as wealthy households living hand-to-mouth. Again, this high proportion could be partly explained by a wealth effect.

Another strand of the literature is concerned about financial vulnerability with the timeliness of household microdata. Since household surveys are usually conducted only infrequently, these data must first be "nowcasted". This can be done by projecting developments in the national accounts onto the individual households in the micro data, or by explicitly modelling the behaviour of households. The nowcasted data can then be shocked with the aid of a model, e.g. by a positive interest rate or unemployment rate shock, and the impact on financial vulnerability is estimated.[2]

Ampudia et al. (2016) use the European Household Finance and Consumption Survey (HFCS) (European Central Bank 2020) to simulate consumption responses of households to changes in aggregate wealth with marginal propensities to consume (MPC), dependent on the households' income, following Mian, Rao, and Sufi (2013). They find that all income groups contribute, in real terms, equally to the observed slump in aggregate consumption, as high-income households experienced larger nominal losses in wealth than lower-income households but have lower MPCs. However, the authors only focus on aggregate consumption while not considering the effect on financial vulnerability of households.

[2]See for a brief literature overview Bańkowska et al. (2017)

3 The Model

The model used here follows Tarne, Bezemer, and Theobald (2022),[3] who adapted the agent-based model proposed by Baptista et al. (2016) and Carro et al. (2022). These models were calibrated on UK data, like the Wealth and Asset Survey and housing market data. The Baptista et al. (2016) model has also been applied to the Danish (Cokayne 2019), the Italian (Catapano et al. 2021), and the Spanish housing market (Carro 2022). The most important difference between Tarne, Bezemer, and Theobald (2022) and the present model is a more elaborated wealth effect, proxying precautionary savings, and an age limit on mortgage borrowing (section 3.2).

3.1 Overview

The model by Tarne, Bezemer, and Theobald (2022) is an agent-based housing market model, calibrated using UK data, with heterogeneous households and a commercial bank. With young households entering and old households exiting the simulation space, the demographic distribution is held stable to the UK distribution of 2011. The housing stock is fixed. Individual houses are characterized by a quality parameter serving as a proxy for their condition, size and location. Households can be renters in private housing or owner-occupiers, consisting of first-time-buyers (FTB), second-and-subsequent buyers (SSB), and buy-to-let investors (BTL). Investors purchase property that they rent out. Households that do not belong to one of these agent classes form a residual called 'social housing.'

Households can change between these types of housing. Households in the residual of social housing decide on renting privately or buying a home. They enter the ownership market with a bid price that is a function of their income, financial wealth and credit access, based on the bank's LTV policy. The LTV caps are household-specific and move procyclically with changes in house prices . BTL investors form a bid price depending on the projected yield of the property, considering current rental prices, house price expectations and mortgage costs.

[3] A list with all equations from Tarne, Bezemer, and Theobald (2022) can be found here: <https://github.com/RubenTarne/wealth-effect/blob/Tarne-BezemerTheobald/Equations%20-%20WP%20-%20Tarne%20Bezemer%20Theobald.pdf>.

On the supply-side, owner occupiers move on average every seventeen years[4] and investors' decision to sell property is determined by the expected yield. Ask prices are based on currently observed sale prices of houses of the same quality parameter.

All bids and offers are matched in a double auction until no offers and bids can be matched anymore and the auctioning process stops. The housing market generates boom-bust cycles with high turnover in the upswing and (very) low turnover in the house price downturn (see Figure 12 in the Appendix). The boom-bust dynamic is primarily driven by backward-looking price expectations.

Households labor income is determined exogenously according to the household's age and their randomly pre-set income percentile, according to UK micro data. There are no macro-economic feedback loops in the model. This implies that financial vulnerability is potentially under-estimated compared to the actual values.

3.2 Households' Consumption

As discussed previously, the housing wealth effect appears to be sensitive to households' collateral values. Therefore, I employ different parametrisations for the consumption function depending on the households debt-service-to income ratios (DSR). Following Aladangady (2017), households with DSRs above the median are classified as being close to their borrowing constraint and therefore their housing wealth affects their consumption. For those with DSRs below the median it does not. Households with above-median DSRs might consume all of their financial wealth, i.e. deposits in the model, when their net property wealth is sufficiently high for a certain time, but, crucially, the assumption is that they don't finance their consumption with debt.[5] The households' desired consumption is given by:

$$c^d_{i,t} = \alpha_i y^{disp}_{i,t} + \beta_i b_{i,t} + \gamma_{i,t}(w^h_{i,t} - q_{i,t}), \tag{1}$$

[4]The reason for moving can be due to employment, divorce, etc. which the model does not cover.

[5]This would require the modelling of explicit equity withdrawing, complicating the model significantly, while probably not overestimating the share of financially vulnerable households: when financial buffers fall below a certain threshold, households are already considered vulnerable. However, households financing their consumption with debt tend to lower their financial margin (see for the definition of financial vulnerability Chapter 4), which could even increase overall financial vulnerability.

where $y_{i,t}^{disp}$ is monthly disposable income (defined as $y_{i,t}^{net} - \sum_{k=1}^{n} m_{i,k}$),[6] with $y_{i,t}^{net}$ being post-tax income and $\sum_{k=1}^{n} m_{i,k}$ being the sum of the monthly mortgage payments (which remain constant over the repayment phase), k the house the mortgage is paid for and n the number of houses in the household's posession. $b_{i,t}$ constitute the household's deposits, $w_{i,t}^{h}$ gross housing wealth and $q_{i,t}$ mortgage debt. i is the households' individual index, t the simulation period (monthly steps). α_i is the marginal propensity to consume out of disposable income, ranging from 0.5 to 0.99, becoming weaker the higher the household's income (according to their income percentile Ξ_i assigned at "birth"), while first-time buyer agents have an extra saving motive to save up for a down payment.[7] β_i, like α_i is lower the higher the households' income (Dynan, Skinner, and Zeldes 2004; Arrondel, Lamarche, and Savignac 2019) and ranges from 0.025 to 0.0001.

$\gamma_{i,t}$ is the effect of net housing wealth on consumption. If the households' DSR[8] is above the median, then $\gamma_{i,t} = 0.01$ (which adds up to a yearly value of 12.7% reported by Aladangady (2017)), otherwise $\gamma_{i,t}$ is zero. This ensures that only households considered to be close to their borrowing constraint are sensitive to changes in their net property wealth. The desired consumption is subject to certain successively-applied constraints, so that actual consumption is given by:

$$c_{i,t} = \begin{cases} \alpha_i y_{i,t}^{disp} & \text{if } b_{i,t} + y_{i,t}^{disp} - c_{i,t}^{d} < \zeta_{i,t} y_{i,t}^{net} \\ c_0 & \text{if } c_{i,t}^{d} < c_0 \\ b_{i,t} + y_{i,t}^{disp} & \text{if } b_{i,t} + y_{i,t}^{disp} < c_0 \\ c_{i,t}^{d} & \text{else,} \end{cases} \tag{2}$$

where the first condition describes a buffer-stock: if the desired consumption would lead to deposits being lower than a certain multiple $\zeta_{i,t}$ of the household's monthly net income, the household limits its consumption to that induced by its disposable income. Crucially, $\zeta_{i,t}$ is set to zero for all households with DSRs above the median. These

[6] To be consistent with Ampudia, van Vlokhoven, and Żochowski (2016), I exclude mortgage and rental payments, i.e. housing consumption, from the calculation of desired consumption. Therefore, desired consumption only includes non-housing consumption.

[7] First-time buyers assigned to an income percentile $\Xi_i > 0.069$ have marginal propensity to consume out of disposable income (α_i) of 0.641. This diverges from Tarne, Bezemer, and Theobald (2022). See section 4 in the Appendix for the calibration of these values.

[8] The households' DSR is defined as the sum of monthly mortgage payments over its income, $\frac{\sum_{k=1}^{n} m_{i,k}}{y_{i,t}}$.

households might lower their money holdings to zero as long as their collateral is valuable enough. For all other households $\zeta_{i,t}$ is calibrated to 2.08. The second condition states that households consume at least c_0, set to 40% of median income, following Ampudia, van Vlokhoven, and Żochowski (2016).[9] As the conditions are applied successively, households with $\alpha_{i,t} y_{i,t}^{disp} < c_0$ consume c_0. The third condition states that households only consume less than c_0 if consuming c_0 would result in negative financial wealth. In this case, they consume all their disposable income and their deposits. As employment income is very stable, these cases are very rare and this condition allows us to simplify the model by abstracting from bankruptcies.[10]

4 Calibration

I introduce new parameters to the base model of Baptista et al. (2016), some of which have already been introduced in Tarne, Bezemer, and Theobald (2022). The new parameters that were estimated based on the literature are given in Table 6 in Appendix E. The propensities to consume out of disposable income and wealth are based on the estimates provided by Dynan, Skinner, and Zeldes (2004) and Arrondel, Lamarche, and Savignac (2019). This leaves eight parameters which need to be calibrated, shown in Table 7. To do so, I use the method of simulated moments (Gilli and Winker 2003; Franke 2009; Carro et al. 2022) to measure the distance between the model output and the calibration targets. I select twenty targets for this calibrating. The Bank of England's *Core Indicators for setting the LTV and DTI ratios* (Bank of England 2018, 68), shown in Table 1, and additional stylized facts of the wealth distribution and the characteristics of financially vulnerable households, reported in Table 2.

The calibration procedure is as follows. First, upper and lower limits for the parameter space of each variable were set (reported in Table 7). In a second step, a Latin hypercube was employed to efficiently sample 1000 different parameter combinations to run the

[9] In the model by Tarne, Bezemer, and Theobald (2022) c_0 is set lower and equal to the minimum monthly earnings a household could have, corresponding to the monthly income support of the UK government.

[10] In very rare cases, for instance for BTL investors with large mortgage payments and low rental income, households can have negative disposable incomes. These households then reduce their deposits to service their debt payments and finance their consumption. Once they go bankrupt, their deposits are set to zero—which represents a very rudimentary default mechanism.

Table 1: Comparison Model and Bank of England Core Indicators

	Model	Bank of England Core Indicators					
	Model Output	Average 1987-2006	Average 2006	Minimum since 1987	Maximum since 1987	Previous value (oya)	Latest value (November 2018)
Debt to income	0.865	0.687	1.013	0.493	1.096	0.985	0.978
OO debt to income	0.992	0.777	0.928	0.648	0.969	0.815	0.808
OO LTI ratio (mean above the median)	3.67	3.76	3.82	3.63	4.20	4.18	4.20
OO LTV ratio (mean above the median)	0.864	0.906	0.906	0.816	0.908	0.875	0.876
BTL LTV ratio	0.697	NA	NA	0.566	0.754	0.610	0.567
Monthly Housing Transactions	130823	129508	139039	51660	221978	101100	98400
Approvals of mortages	106413	97905	119041	26284	132709	65742	65269
Advances to homemovers	29628	48985	59342	14300	93500	32100	29400
Advances to FTB	30010	39179	33567	8500	55800	30800	29400
Advances to BTL	46775	10128	14113	3600	29100	6400	5200
House price to income ratio	2.89	2.89	4.31	2.12	4.57	4.48	4.57
Rental yield	0.165	0.058	0.051	0.048	0.076	0.048	0.048

Note:
The Core Indicators are taken from the Financial Stability Report (Bank of England 2018, 68); OO = Owner-Occupier, encompassing FTB and SSB; all values are means, except where stated otherwise; Model values are gained from 10 Monte-Carlo runs with an observation period of 1000 after a burn-in period of 1600.

model with (McKay, Beckman, and Conover 1979). Each run lasted for 2500 periods, where the first 1500 periods were omitted as a burn-in phase. The outputs of these model runs were rated with help of a weighted cost function, pricing the quadratic distance of the output from the target values. As there is no clear and universally accepted rule how to select these weights, I attributed stronger weights to those moments that I deemed most important for this analysis. For instance, I increased the weight of the characteristics of financially vulnerable households compared to the rental yield. Then I selected the model with the lowest overall distance to the targets.

None of the 1000 parameter combinations is able to get the model to match all target values in Table 1. However, most of the output of the model remains in bounds of the reported Bank of England's Core Indicators' values with the exception of the slightly too-high average debt-to-income ratio (DTI) of Owner-Occupiers, the too-high monthly purchases of buy-to-let (BTL) agents, and rental yield. As in the model BTL agents rarely become financially vulnerable, even with this higher turnover, this should not affect the analysis of financial vulnerability too much. However, as BTL agents' sales and purchases influence the house price cycle, they will indirectly influence purchasing and consumption decisions of other households.

Before turning to the other calibration targets in Table 2, financial vulnerability of the UK, the concept of financial vulnerability needs to be introduced. It follows Ampudia, van Vlokhoven, and Żochowski (2016) with a modification introduced with Equation (5).

First, the financial margin $FM_{i,t}$ of a household is calculated as its monthly net income, less its monthly mortgage payments and basic living expenses c_0:

$$FM_{i,t} = y_{i,t}^{\text{disp}} - c_0, \tag{3}$$

If a household has a negative financial margin, its disposable income is not enough to consume c_0. If the household holds debt[11] and cannot, from income or deposits, service its debt payments and basic consumption for more than eight months,[12] it is considered to be financially distressed (i.e. $d_{i,t} = 1$):

$$d_{i,t} = \begin{cases} 1 \iff FM_{i,t} < 0 \wedge |FM_{i,t}| \cdot 8 > b_{i,t} \wedge q_{i,t} > 0 \\ 0 \iff FM_{i,t} \geq 0 \vee |FM_{i,t}| \cdot 8 \leq b_{i,t} \vee q_{i,t} \leq 0 \end{cases} . \tag{4}$$

Directly calibrating the financially vulnerable households of the model to those of the Wealth and Asset Survey (WAS) of the UK is not possible as households' income in the model is relatively stable (households do not change their assigned income percentile). In the WAS financially distressed homeowners tend to have significantly lower income than in the model (see Figure 9 in Appendix D). This might be explained by negative income shocks after the house purchase, which are not present in the model (except when households retire). To bridge this gap between model and the WAS, the definition of distress in Equation (4) is modified for the model at hand by introducing a buffer of 20% of median income to the financial margin. The 20% resemble the distance between the mean income of vulnerable households in the model and the WAS. Indebted households, whose financial margin is lower than this extended margin, while their deposits are not sufficient to meet their payments for more than eight months (given their income were to

[11] At first stage Ampudia, van Vlokhoven, and Żochowski (2016) include households in their analysis, whether or not they are holding debt. However, as they are interested in conducting a stress test on the overall exposure at default, they ultimately consider only indebted households. As the model presented here features only mortgage debt and thereby excludes debt from other sources, in particular possible indebtedness of renters. For simplicity, I only include indebted households in this analysis. However, in Appendix C I re-do the main analysis of the paper with a simpler definition of financial vulnerability (all households with less than 1500 money units), including households without debt holdings.

[12] Following Ampudia, van Vlokhoven, and Żochowski (2016), the number of months considered, i.e. eight months, is chosen so that the exposure at default (EAD) of the commercial bank in the model is close to the share of non-performing mortgage loans to all mortgage loans in the UK, which was 2.4% between 2015-2019 (EBA 2019). As the model does not incorporate equity withdrawals and therefore features lower EAD, the value aimed at is below the aforementioned 2.4%. Specifically, the EAD of financially vulnerable households in the model is 1.5%.

Table 2: Other Stylized Facts to Match

	Model output	mean UK values	UK value range	Source
Wealth Inequality	0.481	0.449	0.407 - 0.474	ONS 2006-2016 (without pension wealth)
Deposits/Debt	1.977	1.57	1.3 - 1.84	ONS 2010-2016 (net finanical wealth / mortgage debt)
Average Deposit	73144	67000	54200 - 82000	ONS 2010-2016 (net financial wealth without pension wealth)
median DSR all indebted HH	0.137	0.136	-	Wealth and Asset Survey wave 5 (July 2014 - June 2016)
median DSR dis HH	0.311	0.356	-	as above
income adjusted median DSR dis HH	0.394	-	-	as above
share dis HH of all indebted HH	0.032	0.0353	-	-
median Age dis HH	49.65	48	-	as above
median Age non-dis HH	43.731	44	-	as above

Note:
Data by the ONS retrieved from https://www.ons.gov.uk/peoplepopulationandcommunity/ personalandhouseholdfinances/incomeandwealth/datasets/totalwealthwealthingreatbritain and for mortgage debt from https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/ datasets/householddebtwealthingreatbritain ; difference in periods covered by UK data due to data constraints; wealth inequality in the model is measured with the subset of periods with house prices between 98% and 121% of 2011-prices (UK price level range from 2006-2016); data from the fifth wave of the Wealth and Asset Survey is the subgroup of households with recorded mortgage payments; vul = financially vulnerable; HH = household; dis = financially distressed; DSR = Debt-Service-to-Income ratio; Model values are gained from 10 Monte-Carlo runs with an observation period of 1000 steps after a burn-in period of 1600 steps. Income shock adjusted DSRs come from lowering households' income by 20% of median income.

fall by 20% of median income), are considered to be financially distressed ($d_{i,t}^{adjusted} = 1$). The buffer is the same for every household, ensuring that low-income households, which are generally at higher risk of negative income shocks, are also at higher risk of becoming financially vulnerable (Ampudia et al. 2016). The definition is given by:

$$d_{i,t}^{adjusted} = \begin{cases} 1 \iff FM_{i,t} < 0.2y_t^{median} \wedge |FM_{i,t} - 0.2y_t^{median}| \cdot 8 > b_{i,t} \wedge q_{i,t} > 0 \\ 0 \iff FM_{i,t} \geq 0.2y_t^{median} \vee |FM_{i,t} - 0.2y_t^{median}| \cdot 8 \leq b_{i,t} \vee q_{i,t} \leq 0 \end{cases} \tag{5}$$

For the calibration I match households with $d_{i,t}^{adjusted} = 1$ in the model with households with $d_{i,t} = 1$ in the WAS.

The fit of the model to these calibration targets are shown in Table 2, togehter with the average wealth inequality, the average deposits-to-debt ratio and the average deposit per households. The wealth inequality and the deposits-to-debt ratio are slightly higher

in the model than found in the data. The median debt-service-to-income ratio for non-vulnerable households in the model and the WAS are very close together (0.137 to 0.136). The median DSR for financially distressed households in the model is reported twice, the first is calculated with their actual income, and the second including the hypothetical income shock of 20% of median income. As desired, both ratios enclose the reported DSR of households with $d_{i,t} = 1$ in the WAS. The rest of the empirical values presented in Table 2 are matched very well. Full distributions of DSRs, Income and Age of distressed and non-distressed households in the WAS and the model are shown in Appendix D. With the model calibration being able to match the empirical targets reasonably well we can look at the dynamics and drivers of financial vulnerability.

5 Results

5.1 Causes for Financial Vulnerability

For the present analysis, the focus will lie on households becoming financially vulnerable, i.e. households that would become financially distressed in the event of an income (or interest rate shock), not on households that actually are financially distressed. Davis and von Wachter (2011) find for the US that unemployment leads earning losses of 40% after one year in a recession. Following Bartscher et al. (2020) I use this result as a hypothetical stress-test on households' income.[13] As with the income buffer in Equation (5) (which could be interpreted as an income shock), I now define households as financially vulnerable that would become financially distressed *if* they experienced a 40% income shock. Note that the households' incomes in the simulation are not actually shocked,

[13]Specifically, the financial margin is calculated as follows:

$$FM_{i,t}^{shocked} = y_{i,t}^{\text{gross}} - 0.40 y_{i,t}^{\text{gross}} - T_{i,t} - Insurance_{i,t} - \sum_{j=1}^{k} m_{i,k} - c_0, \tag{6}$$

where $y_{i,t}^{\text{gross}}$ is the household's gross total income, $T_{i,t}$ and $Insurance_{i,t}$ are the taxes and insurance paid according to the lower gross income level. This implies the shock on net income is significantly lower than on gross income. The financial vulnerability of households is then calculated in line with Equation (5):

$$f_{i,t} = \begin{cases} 1 \iff FM_{i,t}^{shocked} < 0.2 y_t^{median} \wedge |FM_{i,t}^{shocked} - 0.2 y_t^{median}| \cdot 8 > b_{i,t} \wedge q_{i,t} > 0 \\ 0 \iff FM_{i,t}^{shocked} \geq 0.2 y_t^{median} \vee |FM_{i,t}^{shocked} - 0.2 y_t^{median}| \cdot 8 \leq b_{i,t} \vee q_{i,t} \leq 0 \end{cases} \tag{7}$$

i.e. the simulation is not actually affected.

Households in the model become financially vulnerable when two conditions are met simultaneously: first, their financial margin, calculated with a 40% shocked income, falls below 20% of median income[14] and, second, their deposits fall below the defined threshold. Purchasing property can reduce households' financial margin, as monthly mortgage payments increase, and reduce households' financial buffer, as down payments are made. When households become vulnerable due to a property purchase they are defined to be *vulnerable by purchase*.

Consumption on the other hand only affects the deposits of households, not their financial margin. Dissaving, i.e. consuming more than the disposable income, only occurs because of the wealth term in the consumption function as consumption induced by income (α_i in Equation (1)) is never larger than 0.99 $y_{i,t}^{disp}$. Households are defined as *vulnerable by dissaving* when they are dissaving the period they became vulnerable (and did not buy a house in the same period).[15] All other cases of households becoming vulnerable are defined as *by other*, including households experiencing a decline in their income (for instance when entering retirement, or when rental income decreases for BTL agents), which can also turn their financial margin negative.

Figure 1 shows the stock of financially vulnerable households over a representative house price cycle, according to the cause of their vulnerability.[16] The house price index (rhs) is measured in UK prices of 2011. The maximum share of financially vulnerable households in this cycle is around 7.5%. This is close to the share of 8.5% Bartscher et al. (2020) find for the US in 2007 when they stress households' income with a similar shock. Bartscher et al. (2020) measure financial vulnerability as households having debt-service-to-income ratios above 40%.[17]

[14] Median income is calculated by the actual, non-shocked, income of households in the model.

[15] Households can become financially vulnerable just a few months after buying a house. Due to this temporal closeness one might classify them as *vulnerable by purchase*, too. However, while the purchase may have decreased the households' financial margin and the down payments their financial buffer, dissaving induced by positive net wealth is the necessary condition to make the households financially vulnerable. Moreover, as will be discussed with Figure 4, this does not happen very often.

[16] The counterpart of Figure 1 but with the definition following Equation (4) and (5) is shown in Figure 11 in the Appendix.

[17] The overall share of vulnerable households in the model depends to a large extent on the definition of financial vulnerability used. For instance, the overall average of households financially vulnerable here is 4.5%, but when using a 20% income shock only, it is 1.9%. Without income shocks, i.e. following Equation (5), the overall average share is 1.1%.

While households becoming financially vulnerable by dissaving make up on average 60% of all vulnerable households, 37% become vulnerable by purchases. These magnitudes again relate to the findings by Bartscher et al. (2020). They estimate that about 50% of the increase in household mortgage debt between 1981 and 2007 is due to home equity extraction. At the same time, the number of financially vulnerable households almost quadrupled, before falling by around 40% until 2016.

It should be noted here that the importance of the dissaving channel depends on the definition of financial vulnerability employed here. When the threshold for how long a household has to be able to cover negative financial margin is reduced from eight months to one, the importance of the dissaving channel increases to 73%, while when increasing the months to 24, the importance of the dissaving channel falls to 45%.[18] Moreover, the calibration of the free parameters influences the relative strength of the dissaving channel. However, in the runs (1000) conducted for calibrating the model, it never falls below 49% while the average importance corresponds to 63% percent. This analysis is supplemented by the information given in Appendix B.1. With a simpler definition of financial vulnerability, namely all households with less than 1500 money units as financial buffer, the relative strengths of the vulnerability channels hold as well, see Appendix C.

In summary, the findings here suggest a major effect of consumption induced by housing wealth on financial vulnerability. Interestingly, this result is closely connected to the model calibration based on historical UK values. In UK, equity withdrawals played a significant role for consumption (Aron et al. 2012). Changing parameters in the definition of financial vulnerability, as well as changing the new parameters calibrated, changes the relative importance somewhat, but only to a limited extent.

The share of financially vulnerable households shows a clear cyclicality, again in line with Bartscher et al. (2020). While the overall share of financially vulnerable households follows the house price cycle with a small lag, both effects peak at different points of the house price cycle.[19] The share of households vulnerable by purchases increases strongly at the beginning of the price upswing, when turnover in the housing market is highest (see

[18] Appendix B.2 additionally shows the close fit of the calibration for the different thresholds.

[19] Calculated over the course 10 Monte-Carlo runs the maximum correlation of overall vulnerability is 0.94 at a lag of 11 months. For the dissaving channel, the maximum correlation is 0.92 at a lag of 14 months and for the purchasing channel 0.91 at a lag of 2 months. See also Figure 13 in the Appendix.

Figure 1: Share of Financially Vulnerable Households—by Cause of Financial Vulnerability (lhs) over the House Price Cycle (rhs)—averaged over 6 months

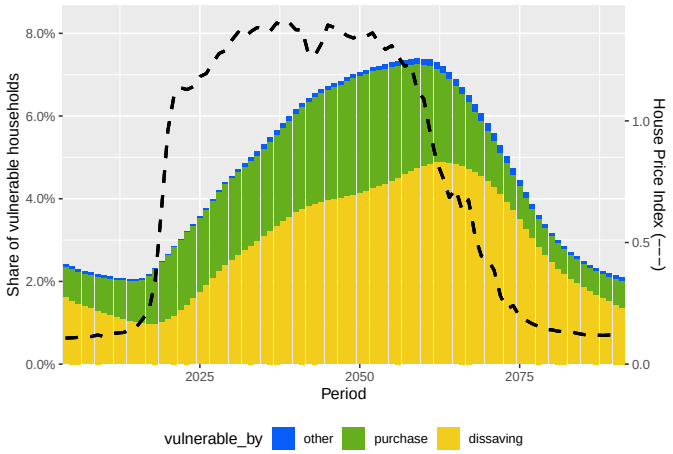


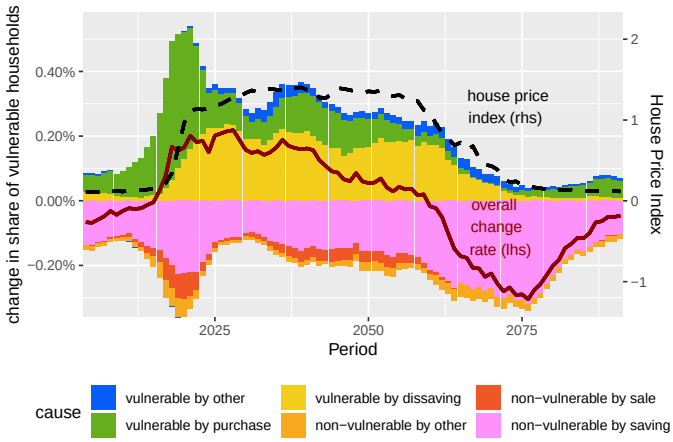
figure 12 in Appendix E) and then continues to rise. The share of households vulnerable by dissaving peaks around the midpoint of the house price downturn and then drops steadily. When house prices rise roughly above their long-term average, housing wealth-induced dissaving intensifies, steadily increasing the share of vulnerable households. When house prices fall back below their long-term average, the share of these vulnerable households falls again through deleveraging.[20]

Figure 2 shows the causes for increases and decreases in the share of financially vul-

[20]In this case, households that are 'underwater', i.e. they experience negative housing equity, tend to deleverage more than households with positive equity (following from Equation (1)). Such behaviour can be reflected against the findings of some recent studies (Ganong and Noel 2020; Berger et al. 2018; Guren et al. 2021). The authors find for the US quite insensitive housing wealth consumption elasticities for households that are 'underwater'. For the model used here, this would imply that underwater households would deleverage at most with $(1-\alpha)y_{i,t}^{m,disp}$ as they would not have a separate deleveraging motive sensitive to their net housing wealth. Deleveraging would take place more slowly. This slower deleveraging would reduce the number of households *non-vulnerable by saving* and thereby reduce the volatility of financial vulnerability.

However, this reduction in volatility might be neglected, as financially vulnerable households in the model already tend to be restricted in their saving response by the essential consumption c_0. They are squeezed by low incomes and high debt-service-to-income ratios. Moreover, the extra saving response in the model could be motivated with an increased income uncertainty in a house price bust—a mechanism that is not included in the model. Households with negative net housing wealth and low financial wealth—recall that in the model households with above-median DSRs have no precautionary savings buffer—might build up some financial wealth as buffer-stock as, empirically, house price busts tend to go together with higher income insecurity. This timely build-up of a buffer stock could decrease the share of households vulnerable, and, therefore, generate comparable dynamics of the share of households being financially vulnerable. Moreover, in the UK adjustable rate mortgages are more common (Aron and Muellbauer 2016), making refinancing a higher risk and thereby potentially inducing more precautionary saving.

Figure 2: Contributors to changes in the share of financially vulnerable households over the housing cycle - 6 months rolling averages



nerable households. The red line indicates the overall resulting change of the share of vulnerable households. Similar to the classification above, the economic actions of households reducing financial vulnerability are divided into *non-vulnerable by sales*—when they just sold property and ceased to be vulnerable—and *non-vulnerable by saving*—when they have a positive saving rate and did not just sell property. Other causes—death, regular repayment, inheritance and increases in income turning the financial margin positive, but not the saving rate—are subsumed under the label *other*.

The figure shows that the overall increase in financial vulnerability by purchase in the upswing is dampened by vulnerable households both selling properties and especially saving deposit buffers. The savings response comes mainly from households that have become vulnerable through purchases but have sufficiently high income to save quickly above their vulnerability threshold. Around the middle of the house price downturn, the saving channel is stronger than the dissaving channel, leading to a reduction in overall vulnerability. Here, not only the share of households vulnerable by purchases decreases, but also the share of households vulnerable by dissaving.

5.2 Characteristics of Financially Vulnerable Homeowners

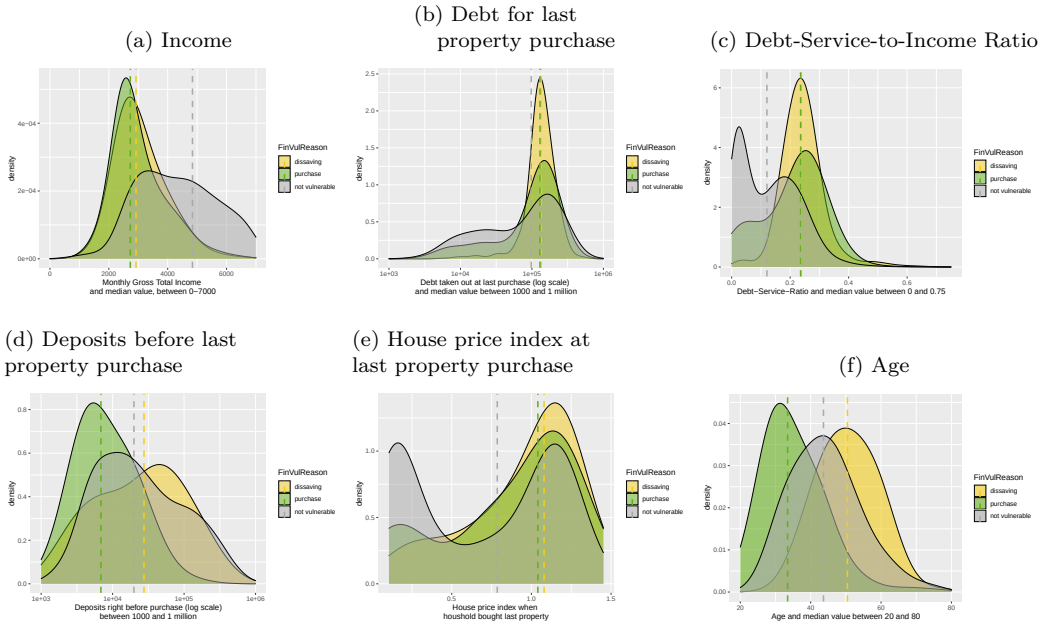
To understand what type of homeowners become financially vulnerable, Figure 3 compares different characteristics of homeowners by vulnerability status, i.e. if they have become financially vulnerable by purchase, by dissaving or why they are non-vulnerable with a mortgage. The plots consist of aggregated monthly data, implying that households that have been vulnerable for two months are double weighted compared to households that have been vulnerable for only one month.

What emerges are clear differences between vulnerable (green and yellow) and non-vulnerable homeowners (grey). As expected, financially vulnerable homeowners have lower income than non-vulnerable homeowners and tend to be more highly leveraged. While the credit volume taken out is similar between vulnerable and non-vulnerable homeowners, vulnerable homeowners have lower incomes, resulting in higher debt-service-to-income ratios (DSR). As the median DSR of all indebted households is on average 0.137 these households end up above the set threshold where housing wealth affects their consumption.

Between households vulnerable by purchase and vulnerable by dissaving the main difference is the amount of deposits held just before the latest home purchase (which can be used as down payments). These tend to be lower for households vulnerable by purchase (median value is 6857 and for households vulnerable by dissaving 2.7478×10^4). With comparable mortgage debt taken out to buy houses at comparable price levels (i.e. similar purchase prices), these lower deposits at purchase lead to lower deposits after purchase, and thus lower financial buffers. Households become vulnerable by dissaving significantly later in life.

As is shown in more detail in section A in the Appendix, households vulnerable by purchase are almost exclusively first-time buyers, because they have little financial buffers anyway, while households vulnerable by dissaving consist almost in equal parts of first-time buyers and movers. Buy-to-let investors on the other hand, due to their higher income, are unlikely to become vulnerable at all.

Figure 3: Densitiy curves and median values (striped lines) of central attributes of financially vulnerable and indebted non-vulnerable households



5.3 Path Dependency of Financial Vulnerability

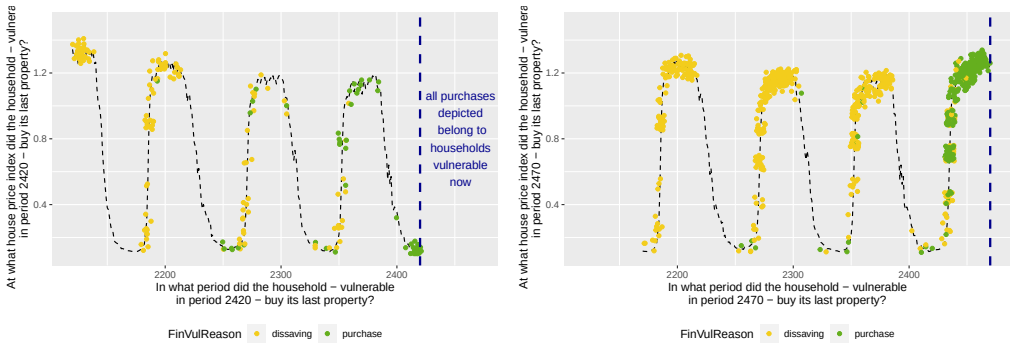
Due to their long contract maturity, debt-financed property purchases could influence the financial vulnerability of households for a long time (Drehmann, Juselius, and Korinek 2018). In the model, households become financially vulnerable at different points in time during the life of their mortgage contract and at different stages of the house price cycle.

To examine this further, in Figure 4, vulnerable households are compared at two specific points in the house price cycle with respect to their most recent real estate purchase. The left panel of Figure 4 maps the last real estate purchase of households vulnerable in a house price trough—which is where the blue striped line intercepts (period 2420). The right panel does the same for right after the subsequent house price upswing (marked again by the dotted line). The dots symbolize one household's last property purchase each. Each dot is positioned according to when (x-axis) and at what price levels (y-axis) the household bought this last property. The graph is looking back 25 years, which is the maturity of all mortgage contracts.

Figure 4: When did currently vulnerable households buy their last property?

(a) Last purchases of households vulnerable at trough
House price level at last purchase

(b) Last purchase of households vulnerable at peak
House price level at last purchase



The green dots in the left panel show that when house prices are currently low, only few households are vulnerable by purchase where some either just bought property (close to the striped blue line) or did so up to two house price cycles past. Households vulnerable by dissaving (yellows dots) have their last property purchases more equally distributed over the past three housing cycles.

The right panel of Figure 4 shows the financially vulnerable households 50 periods later than in the left panel, shortly after the house price peak (marked again by the dotted line). Most households that became newly vulnerable and bought their last property between period 2420 and 2470 (in other words, in the periods between the left and the right panel) became vulnerable by purchase. However, even more households becoming newly vulnerable bought their last property at a previous house price peak. This finding is replicated for a simpler definition of financial vulnerability, i.e. households holding fewer than 1500 money units as financial buffer, in Appendix C.

To understand the relationship between past house price cycle peaks and current vulnerability peaks (or current house price peaks and future vulnerability peaks), I perform an OLS, using all 10 Monte-Carlo runs. The time series is divided into individual cycles, as the idea is to understand what contributes to the level of peak financial vulnerability each cycle. The basic model specification is the following:

$$max\left(D_j^{adjusted}\right) = \alpha + \beta_1 HPI_j^{max} + \beta_2 HPI_{j-1}^{max} + \beta_3 HPI_{j-2}^{max} + \beta_4 HPI_{j-3}^{max} + \epsilon_j, \quad j = 1, ..., N \tag{8}$$

where $max\left(D_j^{adjusted}\right)$ is the peak share of financially vulnerable households in housing cycle j; HPI_j^{max} is the maximum house price index reached per cycle; HPI_{j-1}^{max} and HPI_{j-2}^{max} are the peak values of the previous cycles. The house prices peak in all cycles some months before the share of financial vulnerability peaks. Table 3 reports the corresponding results in column (I) for 85 cycles[21]. Upper and lower bounds of the 99.9% confidence intervals are shown in brackets.

In column (I) the coefficient of the level of the current house price peak is positive and significant, suggesting that higher current peaks go together with higher current financial vulnerability. The higher the previous peaks, the lower the vulnerability at the current peak. The estimation in column (II) includes the peak shares of financially vulnerable households of the previous three cycles, as well as the cycle duration, measured as the number of periods from the current vulnerability peak to the past vulnerability peak, the simulation period of the current peak and dummy variables for each Monte Carlo run. The effect of the house price level peaks remain relatively unchanged.

These results can be explained as follows: As soon as the current house price cycle reaches a peak that is roughly above the levels of the previous cycle, vulnerability increases particularly strongly. This is because households that bought at that earlier peak are still highly leveraged and only dissave when the price level has returned to its earlier level due to their positive net housing wealth. The longer a previous cycle peak lies back, the lower the leverage of households that bought their last property at that time, due to larger accumulated loan repayment. Following form the net housing wealth term in the consumption function, these households already dissave at lower house price levels. This could explain the smaller coefficients for the longer past cycles. Likewise, in Figure 4, the yellow dots appear at the price peaks three and four cycles ago in the left panel, when the current price level is still low.

[21] The first three cycles of every Monte-Carlo run are discarded, so that every selected cycle has a corresponding value HPI_{j-3}^{max}.

Table 3: Estimating the influence of house price peaks on peak vulnerability

	(I)	(II)
Intercept	0.1103 ***	0.1015 ***
	[0.0845, 0.1362]	[0.0462, 0.1568]
Max HPI current cylce	0.0188 ***	0.0134 ***
	[0.0065, 0.0312]	[0.0007, 0.0261]
Max HPI one cycle past	-0.0238 ***	-0.0260 ***
	[-0.0371, -0.0104]	[-0.0413, -0.0106]
Max HPI two cycles past	-0.0179 ***	-0.0186 ***
	[-0.0299, -0.0058]	[-0.0361, -0.0011]
Max HPI three cycles past	-0.0050	0.0004
	[-0.0167, 0.0068]	[-0.0162, 0.0169]
Max FinVul one cycle past		0.1495
		[-0.2624, 0.5614]
Max FinVul two cycle past		0.0601
		[-0.2763, 0.3965]
Max FinVul three cycle past		-0.1667 *
		[-0.4311, 0.0977]
Cycle duration		0.0001
		[-0.0002, 0.0004]
Simulation period of current peak		-0.0000
		[-0.0000, 0.0000]
Monte Carlo controls		x
N	85	85
R2	0.6481	0.7812
AIC	-760.3594	-772.7379

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

That past house price movements influence current consumption has previously been put forth by Berger et al. (2018). The findings here go further as they, first, show this for endogenous house boom-bust cycles, and second, demonstrate how this consumption in turn leads to long path dependencies of financial vulnerability with considerable volatility. This is important input both in theoretical models of financial vulnerability, and for macroeconomic policy purposes: price peaks matter not only to contemporaneous consumption and debt growth, but they have long-lasting effects on financial vulnerability. This is an additional and so far unexplored reason to manage house price cycles. Interestingly, higher house price peaks today could increase the threshold above which future

house prices would especially induce financial vulnerability by dissaving. Also, as soon as house prices rise above past house price peaks, financial vulnerability is about to increase significantly faster than before.

6 Conclusion

This paper analyses two important contributors to financial vulnerability of mortgage holders stemming from housing market dynamics, using an agent-based housing market model. House purchases, as well as consumption induced by a housing wealth effect have been found to be central to understanding households' financial vulnerability.

In the model, purchasing and dissaving impact financial vulnerability at different points along the house price cycle. The purchasing channel increases the share of vulnerable households mainly in the upswing when households buy properties. The dissaving channel on the other hand is more important at high price levels, where increases are rooted in the consumption of financial buffers, due to a housing wealth effect. Lower prices lead to a build-up of financial buffers, reducing financial vulnerability.

Financially vulnerable households tend to have lower income than non-vulnerable homeowners while being highly leveraged. Especially first-time-buyers become vulnerable by purchasing their first home. Households vulnerable by dissaving tend to be second-and-subsequent buyers, while buy-to-let agents become barely vulnerable at all. Finally, financial vulnerability showed strong path dependencies, in that property purchases from previous periods of high house prices affect the sensitivity of financial vulnerability to current house prices.

My results suggest that the wealth effect is essential for now- and forecasting household financial vulnerability, especially if financial buffers are included in the definition of financial vulnerability. See for instance Peterson and Roberts (2016) for the fact that current modelling approaches have not fully incorporated the transmission channels proposed here. The authors have developed a dynamic model currently used at the Bank of Canada, connecting micro-household data (from the Canadian Financial monitor) with macro data. While they model household behaviour and include financial assets in their definition of financial vulnerability, they do not consider a consumption response

to changes in wealth.

The results suggest that it may be difficult for policy makers to contain financial vulnerability when property prices are already high. After all, a high price alone can increase vulnerability because of the wealth effect. Policy makers should be especially worried when current prices rise above previous house price peaks. Many otherwise credit-constrained households then start experiencing positive net housing wealth because of valuation gains, inducing the dissaving of their financial buffers. The focus of policy makers can in such a situation be on limiting homeowner consumption, for example by limiting the possibility of equity withdrawals. Another policy approach would be to actively curb house price growth, for example by introducing macroprudential credit constraints on home buyers.

The agent-based model utilized here is able to match important empirical targets, most importantly most of the Bank of England Core Indicators, including indebtedness of agent-classes and average property turnover, and additionally the wealth distribution, the share of financially vulnerable households, their DSRs and age distributions, among others. However, the model also has some shortcomings. House prices tend to fall to unrealistically low levels, due to missing stabilizing mechanisms. This limitation could allow lower-income households to enter the housing market (earlier), thereby increasing the share of young, potentially financially vulnerable households. However, the age distributions of vulnerable households in the model and the UK in Figure 10 in Appendix D do not suggest that this is actually the case, as they are very close together. Too low troughs could also increase deleveraging of households due to the housing wealth effect. However, deleveraging is usually limited by households' income. Another limitation is the missing of macroeconomic feedback loops, implying that consumption behaviour does not feed back into households' income via aggregate demand, corporate sales and potentially unemployment. Considering an income buffer in the function defining households' financial vulnerability generally allows to take some general income risk into account. However, this kind of risk remains constant over the house price cycle, unlike in the real economy. Expanding the model to a wider macroeconomy is therefore a promising path for further research but out of scope for this paper.

Fixed mortgage interest rates can also lead to an underestimation of the financial vul-

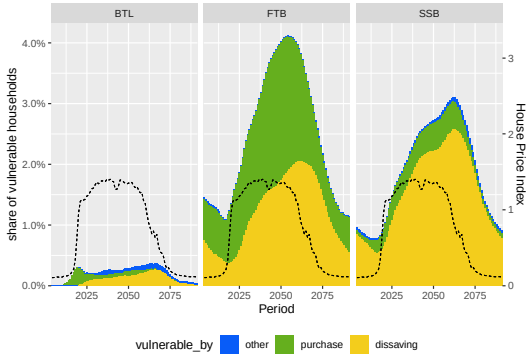
nerability dynamics. As central banks intervene in times of crises, incorporating flexible interest rates in the model will add considerable complexity, but this could be another promising path for future research. Finally, the omission of an explicit equity withdrawal channel leads to an overall underestimation of financial vulnerability, especially of higher-income households that would otherwise reduce their financial margin even more.

Appendix

A Financial Vulnerability by Agent-Class

Interestingly, the differences between both vulnerability channels purchases and dissaving are mirrored, to some extent, by the agent classes. Figure 5 shows that FTB agents are almost exclusively responsible for the purchasing channel. SSB agents usually hold higher deposits coming from the revenue of their previous home sale. BTL investors contribute almost nothing to the share of financially vulnerable households.

Figure 5: Share of financially vulnerable households by cause and agent-class - 6 months rolling averages



B Robustness Checks for the Strength of the Dissaving Channel

The strength of the dissaving channel could be sensitive to the parametrization selected from the calibration runs. Moreover, the setting of the financial vulnerability threshold of eight months (Equation (5)) could influence the model results.

B.1 Different Model Parametrization

To test if the strength of dissaving channel depends strongly on the choice of the free parameters, displayed in Table 7, the results of all 1000 calibration runs are compared. First, the importance of the dissaving channel in the best-fitting parametrization used does not seem to be an outlier from all these model runs. The average strength of the dissaving channel in all 1000 calibration runs was 63% with 49% being the smallest value and 75% the largest value, compared to the 60% of the parametrisation used here.

Comparing all the calibration runs with one another offers the opportunity to understand which of the free parameters most strongly influence the strength of the dissaving channel. To this end an OLS of the free parameters on the strength of the dissaving channel is performed.[22] The results are shown in Table 4 with the upper and lower 99.9% confidence interval bounds in brackets.

Most of the estimators seem to have a significant effect on the relative strength of the dissaving channel, while the estimators generally have the expected sign. For instance, the higher the income percentile for first-time-buyers (FTB), above which they have an extra saving motive, the fewer FTB agents increase their saving, the fewer enter the ownership market and the fewer become vulnerable by purchase. Therefore, the relative strength of the dissaving channel is higher. The same is true for the MPC of these FTB agents. By increasing maximum repayment age limit by one year, the importance of the dissaving channel increases on average by 0.7 percentage points. Increasing the maximum LTV for FTB agents by one percentage point reduces the importance of the dissaving channel by 0.6 percentage points.

[22] This regression does not account for the fit of the model results to the UK data.

Table 4: Estimating the influence of the free parameters on the relative importance of the dissaving channel to financial vulnerability

	I
Income Percentile	0.024 ***
	[0.017, 0.031]
MPC	0.059 ***
	[0.043, 0.074]
Payments / Income	-0.073 ***
	[-0.090, -0.056]
Precautionary Saving	-0.001
	[-0.003, 0.001]
Max. Age Repayment	0.007 ***
	[0.006, 0.008]
Max. LTV for FTB	-0.612 ***
	[-0.664, -0.559]
Max. LTV for SSB	0.067 ***
	[0.013, 0.120]
Max. LTV for BTL	-0.156 ***
	[-0.210, -0.103]
N	1000
R2	0.799

*** p < 0.001; ** p < 0.01; * p < 0.05.

B.2 Different Thresholds for Financial Vulnerability

The effect of different numbers for the months the households need to be able to cover their negative financial margins has been presented already in Chapter 5.1. This Appendix tests if changes in that parameters affect the calibration fit by much. Therefore, households are defined as being financially distressed for the model with Equation (5) and for the Wealth and Asset Survey (WAS) with Equation (4). I tested the calibration for three different parametrizations for the months of buffer: one, eight and 24. Table 5 shows the results, including the relative strengths of the dissaving and purchasing channel for this different definition of financially distressed households than in the main analysis of this paper. Here, too, the choice of the months of buffer parameter influences the dissaving channel significantly. Increasing the parameter leads to a decrease of the importance of the dissaving channel—from 59% to 74%. Increasing this parameter increases the share of households that are defined as financially vulnerable. These additional households seem

Table 5: Different parametrisation of the months to cover parameter

	vulnerability channels		% vul HH in indebted HH		median DSR vul HH		median DSR non-vul HH		median Age vul HH		median Age non-vul HH	
months of buffer	dissaving channel	purchasing channel	Model	WAS	Model	WAS	Model	WAS	Model	WAS	Model	WAS
1	0.744	0.237	0.0117	0.0123	0.270	0.393	0.137	0.135	49	50	44	44
8	0.658	0.306	0.0328	0.0353	0.259	0.356	0.133	0.134	47	48	44	44
24	0.592	0.351	0.0473	0.0548	0.257	0.356	0.131	0.132	46	48	44	44

Note:
Model values are calculated from single-run with 600 Periods. Median Age of non-vulnerable households includes only households with mortgage debt.

to become less vulnerable by dissaving and more so by purchases.

Overall, the distribution and characteristics of the financially vulnerable households in the model match the data from the WAS very well, even when increasing or lowering the months of buffer parameter—recall that the model has been calibrated to match these stylized facts only with the months of buffer set to eight.[23] The overall share of households being financially vulnerable holds well for all three specifications. The median DSR of financially vulnerable households increases when reducing the months-of-buffer in the model and the WAS. This increases the confidence that the financially vulnerable households in the model are similar to those in the WAS.

C Main Analysis With Simpler Definition of Financial Vulnerability

In this section the analysis of section 5.1 and section 5.3 is re-done, while using a different definition of financial vulnerability, namely including all households that have less than 1500 money units on their accounts. This measure has been popularised Lusardi, Schneider, and Tufano (2011) and used in an adapted form to research financial vulnerability of Italian (Brunetti, Giarda, and Torricelli 2016) and other European households (Brunetti, Giarda, and Torricelli 2020).

[23]The differences between the eight months parameter results in this Table and Table 2 emerge from their different aggregation. In Table 2 the basis for aggregation are monthly averages (or medians). This means that the characteristics of households that are vulnerable in periods where overall financial vulnerability is low, are weighted higher than that of households that are vulnerable when overall vulnerability is high. In this Table each households' characteristic is equally counted, like in the distributions in Figure 3.

The left panel of Figure 6 shows the share of households with less than 1500 money units on their bank account over the course of a housing cycle. This share rises to about 25% in the housing market upswing. However, this includes renters, explaining the majority of households being vulnerable by "other". The share of vulnerable renters is very stable as they have no housing wealth effect influencing their financial buffers and as rents remain relatively stable over the house price cycle.

The right panel shows only owner-occupiers, including buy-to-let investors with deposits lower than 1500 money units. Compared to the main analysis, these households do not necessarily hold mortgage debt. The effects of purchases and dissaving on financial vulnerability are quite similar to the analysis in the main paper. Financial vulnerability by dissaving is highest when there has been a period of high prices, like in the main analysis, only purchases increase vulnerability earlier in the house price upswing than in the main analysis, when housing market turnover is highest.

Figure 7, similarly, confirms the long path dependencies of financial vulnerability. Households that bought their home at high prices one or two house price cycles past become vulnerable by dissaving when house prices have been high for a long period of time. In conclusion, the importance of a housing wealth effect on the dynamics of financial vulnerability seems to be robust to changing to this simpler definition of financial vulnerability.

Figure 6: Share of households with less than 1500 money units – by cause of this financial vulnerability over the house price cycle

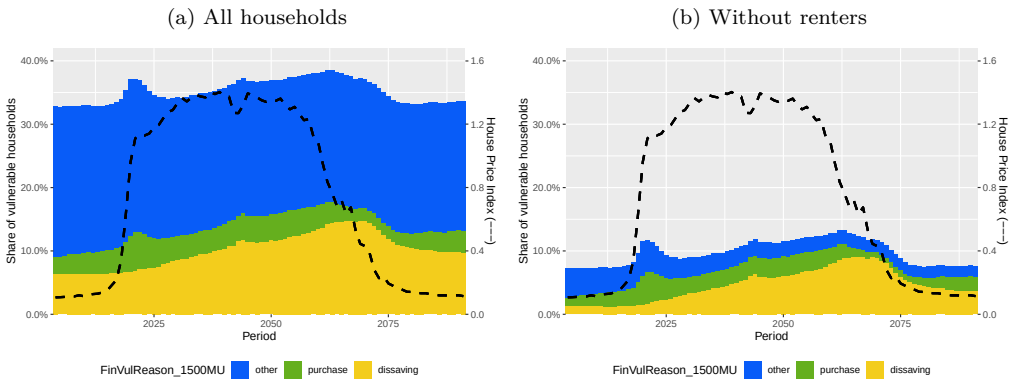
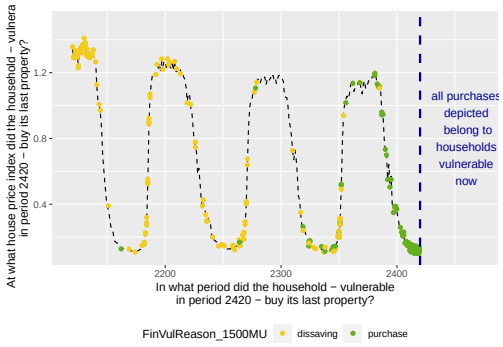
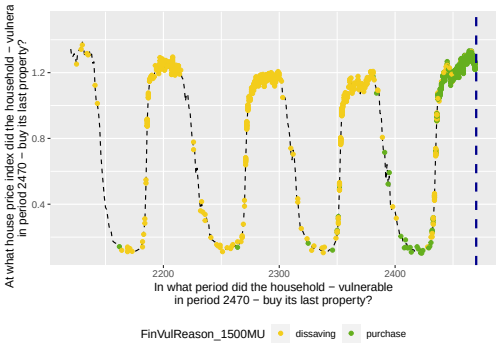


Figure 7: When did owner-occupiers with less than 1500 money units buy their last property?

(a) Owner-occupiers vulnerable at at low prices



(b) Owner-occupiers vulnerable at at high prices



D Additional Calibration Results

This section provides a more detailed comparison of the debt-service-to-income ratios, gross income and age structures of financially distressed and non-distressed households between the model and the Wealth and Asset Survey (WAS). Figure 8 shows the debt-service-to-income ratio distributions (density curves) for financially vulnerable and non-vulnerable indebted homeowners in the WAS (left panel) and model (right panel). As the figure consists of density curves, the share of financially vulnerable households in all households with mortgage debt is hidden.[24] The median DSR of non-vulnerable indebted homeowners is 13.4% in the WAS and 13.3% in the model. Financially vulnerable indebted homeowners' DSR is 34.7% in the WAS and 25.9% in the model.[25] While median DSRs of the non-vulnerable households of the model and WAS are very close together, the median DSRs of the vulnerable households diverge due to the near absence of negative income

[24] More specifically, due to data limitations I only take the sub-group of interviewed households with recorded mortgage payments into account, as I need those to calculate their financial margin. They make up 53% of all indebted households interviewed. Both sub-groups seem to be quite similar, while those reporting specific monthly mortgage payments tend to be a bit younger (median age is 43.5 instead of 45.5). Assuming the share of vulnerable households would be the same in the sub-group with and without recorded mortgage payments, the share of financially vulnerable households of *all* households would be 1.1%—in the model this share is 1.1%.

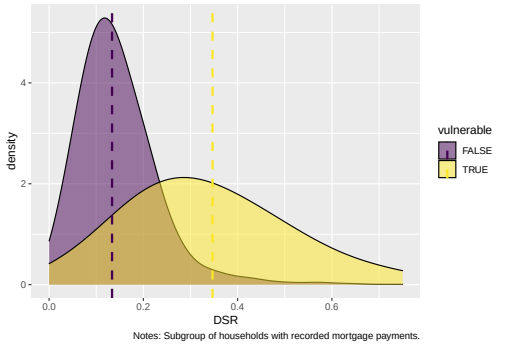
[25] A alternative measurement for the model is the mean of the median DSR in each period - not the overall median of the DSR distribution of all financially vulnerable households over all periods (i.e. each households is recorded once per period). The median DSR of vulnerable households is then 26.0%. This measurement is also used in table 2.

risk in the model, as is more discussed in section 4.

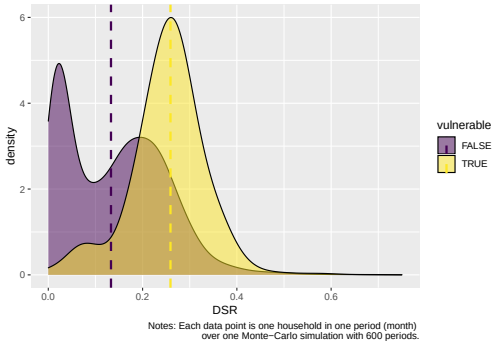
The DSR distributions in the the model have a higher density at very low values, possibly due to the house prices falling to lower levels in the model than observed in reality. The density of DSRs at the right tail is lower in the model than in the WAS, which is probably due to the higher stability of households' wages in the model than observed in reality. For the WAS the share of vulnerable households of all households with mortgage debt is 3.5% and for the model, using the same definition as introduced above, this share is 3.2%. Figure 9 shows the different income distributions of the WAS and the model, discussed in section 4.

Figure 8: Histogram and median value of debt-service-ratios of finanically distressed and non-distressed households in the Wealth and Asset Survey (left) and the model (right)

(a) Wealth and Asset Survey



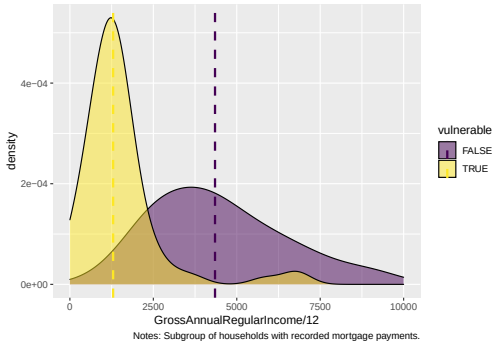
(b) Model output



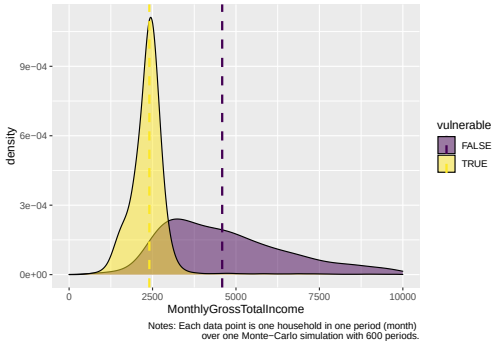
Another important stylized fact is to match the age distribution of distressed and non-distressed households. Since with retirement the households' in the model income falls significantly at age 65, a higher share of distressed households here (as opposed to the WAS) could imply an overestimation of dissaving on financial vulnerability (i.e. the adjusted definition used in Section 5), driven by drops in income. In the model, the age of financially distressed households is driven by both the saving motive for first-time buyers (stronger motive leads to younger households entering the market) and the maximum age by which a household has to repay its mortgages (the higher the maximum age, the older financially vulnerable households tend to be). In the WAS the median age for financially non-distressed households is 44 years and 43.7 years in the model. For

Figure 9: Histogram and median value of Monthly Gross Total Income of finanically distressed and non-distressed households in the Wealth and Asset Survey (left) and the model (right)

(a) Wealth and Asset Survey



(b) Model output

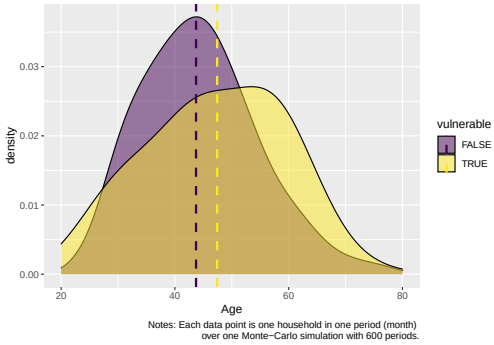


distressed households the median age is 48 years in the WAS and 47.4 in the model. The age distributions of both household groups from the model are remarkably similar to those of the WAS, but with lower densities at both tails.

Figure 10: Histogram of the age of finanically distressed and non-distressed households in the Wealth and Asset Survey (left) and the model (right)

(a) Wealth and Asset Survey

(b) Model output



E Supplemental Figures and Tables

Table 6: New parameters estimated from the literature

Parameter	Description	Value	Source
$\alpha_{\Xi\leq 0.25}$	Monthly propensity to consume out of disposable income for households in income percentile ≤ 0.25	0.99	Dynan, Skinner, and Zeldes (2004) PSID and SCF Data
$\alpha_{\Xi>0.25\leq 0.5}$	Monthly propensity to consume out of disposable income for households in income percentile $> 0.25 \leq 0.5$	0.96	Dynan, Skinner, and Zeldes (2004) PSID and SCF Data
$\alpha_{\Xi>0.5\leq 0.75}$	Monthly propensity to consume out of disposable income for households in income percentile $> 0.5 \leq 0.75$	0.93	Dynan, Skinner, and Zeldes (2004) PSID and SCF Data
$\alpha_{\Xi>0.75\leq 0.9}$	Monthly propensity to consume out of disposable income for households in income percentile $> 0.75 \leq 0.9$	0.9	Dynan, Skinner, and Zeldes (2004) PSID and SCF Data
$\alpha_{\Xi>0.9\leq 0.99}$	Monthly propensity to consume out of disposable income for households in income percentile $> 0.9 \leq 0.99$	0.75	Dynan, Skinner, and Zeldes (2004) PSID and SCF Data
$\alpha_{\Xi>0.99}$	Monthly propensity to consume out of disposable income for households in income percentile > 0.99	0.5	Dynan, Skinner, and Zeldes (2004) PSID and SCF Data
$\beta_{\Xi\leq 0.25}$	Monthly propensity to consume induced by finanical wealth for households in income percentile ≤ 0.25	0.025	Arrondel, Lamarche, and Savignac (2019)
$\beta_{\Xi>0.25\leq 0.5}$	Monthly propensity to consume induced by finanical wealth for households in income percentile $> 0.25 \leq 0.5$	0.0225	Arrondel, Lamarche, and Savignac (2019)
$\beta_{\Xi>0.5\leq 0.75}$	Monthly propensity to consume induced by finanical wealth for households in income percentile $> 0.5 \leq 0.75$	0.0175	Arrondel, Lamarche, and Savignac (2019)
$\beta_{\Xi>0.75\leq 0.9}$	Monthly propensity to consume induced by finanical wealth for households in income percentile $> 0.75 \leq 0.9$	0.0125	Arrondel, Lamarche, and Savignac (2019)
$\beta_{\Xi>0.9}$	Monthly propensity to consume induced by finanical wealth for households in income percentile > 0.9	1e-04	Arrondel, Lamarche, and Savignac (2019)

Note:
The marginal propensities to consume, based on Dynan, Skinner, and Zeldes (2004) and Arrondel, Lamarche, and Savignac (2019), are each slightly adjusted to match the wealth inequality and debt-to-deposit ratio.

Table 7: New parameters estimated by calibration

Parameter	Description	Value	Range for calibration
$\alpha_{FTB,i}$	Propensity to consume out of disposable income for FTB agents above specific income percentile	0.641	[0 - 1.0]
Ξ_i	Income percentile value above which FTB agents save for a downpayment via $\alpha_{FTB,i}$	0.069	[0.5 - 1.0]
$\zeta_{i,t}$	Precautionary buffer (multple of monthly net income) for households with DSRs below the median, for households with DSRs above the median $\zeta_{i,t} = 0$	2.08	[0 - 4.0]
σ	Maximum share of posttax income that investors spend on mortgage payments	0.496	[0.33 - 0.75]
$Age^{OO}_{repayment}$	Maximum age by which mortgages for owner-occupiers have to be repaid	70	[65 - 75]
LTV^{cap}_{FTB}	Maximum LTV of FTB mortgage contracts	0.985	[0.75 - 0.99]
LTV^{cap}_{SSB}	Maximum LTV of SSB mortgage contracts	0.916	[0.75 - 0.99]
LTV^{cap}_{BTL}	Maximum LTV of BTL mortgage contracts	0.753	[0.75 - 0.99]

Note:
The commercial bank's internal LTV caps for the different agent classes have been re-calibrated to match the stylized facts. To the author's knowledge, there is no publicly available data on these caps and the Bank of England is currently not enforcing LTV caps themselves. As LTV caps have strong effects on the housing market dynamics (Tarne, Bezemer, and Theobald 2022) they are included in the calibration.

Figure 11: Share of financially distressed households by cause of financial distress over the house price cycle - 6 months rolling averages

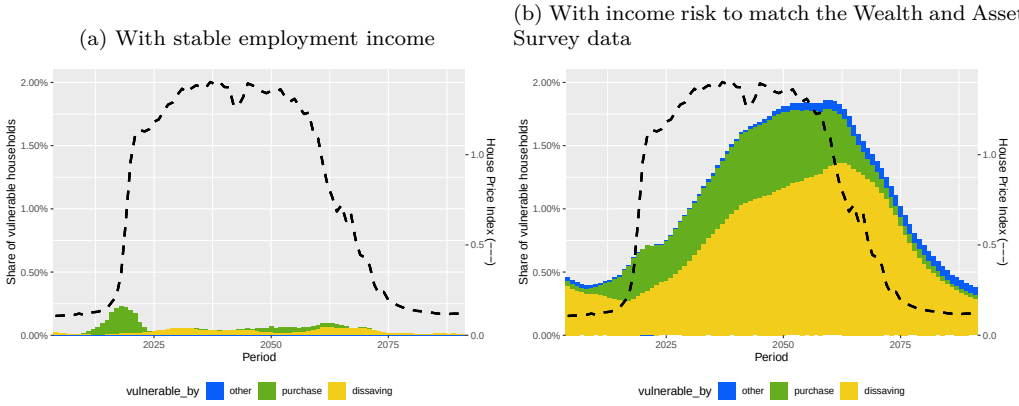


Figure 12: Housing market turnover (percentages of all houses transacted per months) - 12 months rolling averages

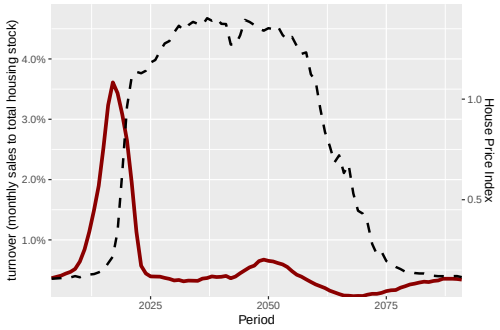
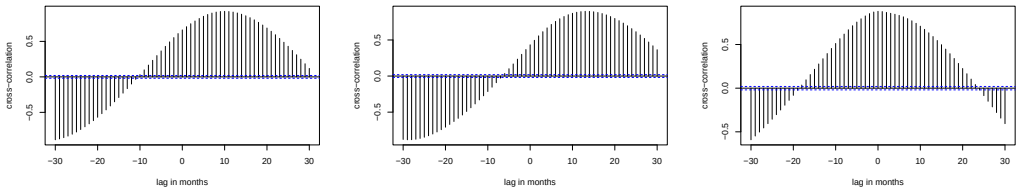


Figure 13: Cross-Correlation of Financially Vulnerable Households and the House Price Index

(a) Overall Vulnerability (b) Vulnerable by Dissaving (c) Vulnerable by Purchase



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