Heterogeneity in Expectations and the Level of House Prices*

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Abstract

Expectations are central for housing decisions and heterogeneity in expectations is a robust feature of survey data. We study the implications of heterogeneity in house price growth expectations for the level of house prices. We feed the joint empirical distributions of income, wealth and expectations into a calibrated heterogeneous agents housing model. We find that eliminating heterogeneity in house price growth expectations would raise average house prices and amplify house price fluctuations thereby reducing the fit of the model. Without heterogeneity, average house prices would be about 7 percent and the boom-bust cycle would be about 25 percent larger.

JEL Classification: D14,D84,D31,E21,E30,G21, R21

Keywords: Housing, survey expectations, house price cycles, life-cycle model

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1 Introduction

Much of the recent literature on macroeconomics and housing is motivated by the international housing boom-bust episode of the early 2000's and the ensuing economic recession. One of the key questions is to identify the forces behind the increase and subsequent collapse in housing. The existing literature provides two alternative views on this question. While Justiniano, Primiceri, and Tambalotti (2015) and Favilukis, Ludvigson, and Van Nieuwerburgh (2017) find that shocks to credit conditions are the determining factor in explaining the housing boom and bust, Landvoigt (2017) and Kaplan, Mitman, and Violante (2020) stress the role played by expectations/beliefs about future house prices. Thus, in these papers, as in Bailey, Dávila, Kuchler, and Stroebel (2019), expectations or beliefs about future prices developments are central.

Our paper contributes to this literature by investigating how measured subjective house price growth expectations and their heterogeneity influence equilibrium house prices in a structural housing model. As the main difference to the existing literature, we explore explicit measures of expectations at the individual household level and do not rely on implicit measures derived from a particular economic model. We find that the house price growth expectations elicited in the survey data and their heterogeneity play an important role for the level and the dynamics of equilibrium house prices.

As a first step we measure subjective house price growth expectations in a sample of Dutch households from the Dutch National Bank (DNB) Household Survey. Our sample spans the years 2003 to 2018 and in these years we observe a pronounced housing boom-bust-boom cycle with the national real house price growth index exhibiting a growth of about $+3\%$ in the years prior to 2008, then a sharp drop to a trough with a shrinkage by -10% in 2013, followed by a reversal with real house price growth reaching more than $+5\%$ in 2018. We show that average house price growth expectations feature the same timing of the boom-bust cycle as the nation wide house price index, but with a smaller amplitude. We next note that a significant number of household heads reports zero house price expectations. Conditioning the sample on household heads who report non-zero expectations we show that their expectations track the nationwide house price growth very well.

Note that we observe the realized house price growth from period $t-1$ to t and measure expectations from t to $t+1$. One plausible interpretation of the measured house price growth expectations of those households that provide a non-zero answer to the survey question is therefore that those households simply pay attention to the aggregate house price index and state backward looking expectations. Such an interpretation is supported by the observation that the average expectations track the actual house price growth index well. Importantly, however, we do not model any such expectations formation process but rather feed in the distribution of observed expectations into our structural household model.

The model entails an expected capital gains mechanism through which expectations affect economic decisions and through this equilibrium house prices. For our research question it is therefore of key relevance whether the subjective house price growth expectations correlate with decisions in the data—and whether our model gives rise to similar patterns. To address such correlations in the data, we, first, estimate how the probability to move houses depends on observed household characteristics. From this regression we define as a "likely mover" a household that has a predicted moving probability larger than the average moving probability in the sample of 2 percent. We show that systematically over the sample period likely hovers on average hold higher house price growth expectations than the average of the rest of the population. Second, we investigate in more detail how house price growth expectations correlate with housing market decisions. Specifically, we show that households that hold higher house price growth expectations report higher values of housing adjustments conditional adjusting the value of their houses.

To investigate the quantitative role of house price expectations for observed movements in house prices, we proceed by employing a structural macroeconomic model of the Dutch housing market. Our model features many elements that are standard in the quantitative macroeconomics housing literature such as a home ownership and a rental markets, idiosyncratic income shocks, a warm glow bequest motive, and long-term mortgage contracts, cf., e.g., Berger, Guerrieri, Lorenzoni, and Vavra (2015) and Kaplan, Mitman, and Violante (2020). We abstract from default as this option is essentially not observed in the Netherlands. The main feature of the model is heterogeneity in expectations according to household types with a fixed and exogenous expectations process.

We calibrate the model to the Dutch housing market. To solve the calibrated model along the transition of the observed house price boom-bust-boom cylce, we adopt the concept of a *temporary equilibrium* approach suggested by Piazzesi and Schneider (2016).[1] Accordingly, going from period $t-1$ to t we feed into the model in period t the observed joint distribution of short-term house price growth expectations, incomes and wealth—financial wealth and housing wealth—, compute decisions, aggregate and clear the housing market in period t. To compute decisions, households of all ages j in a period t solve a dynamic consumption-savings-housing choice model over their (remaining) life-cycle at ages $j, j+1, \ldots, J$. Going forward from model period t, age j, their house price growth expectations at all remaining ages $j+1, \ldots$ are specified such that at each age $j+1, j+2, \ldots$ a household stochastically becomes a long-term house price

[1] Piazzesi and Schneider (2016) base this notion on early work by Grandmont (1977), Grandmont (1978), also see Hicks (1939) and Lindahl (1939).

growth expectations household.[2] In contrast to short-term house price growth expectations, we assume that long-term house price growth expectations are constant at the respective mode in the data of 2%. We then move on to the next period $t+1$, again feed the joint distribution of house price growth expectations, incomes and wealth exogenously into the model, solve the household model and compute the equilibrium. We thereby overwrite in each period t the model generated distribution across household characteristics with the actual distribution as measured from the data. Implicitly, when going from any period $t-1$ to period t, households thus draw shocks to their incomes, the value of their wealth and their expectations.[3] Importantly, for their remaining life-cycle, households act fully rationally based on their expectations. However, as implied by the concept of a temporary equilibrium, we do not impose that these expectations are consistent with the equilibrium house prices computed from the model.

We then employ the calibrated model to conduct two main experiments along the sequence of temporary equilibria. First, we investigate the role that the heterogenous house price growth expectations as measured from the data play for the level of equilibrium house prices. We show that a model with homogenous expectations—where we feed into the model the per period t average short term house price growth expectation—consistently over the entire sample period generates a higher level of house prices. As we further show, this pattern comes from a concavity of housing demand in house price growth expectations. This concavity in turn is mainly determined by the debt-to-income (DTI) constraint in the model. Intuitively, model households with very high house price growth expectations would like to buy large houses but the DTI constraint—according to which the total amount of borrowing cannot exceed a certain multiple of current period income—holds them back. Removing this constraint from the model leads to an almost linear housing demand function in short-term house price growth expectations and moves the level of equilibrium house prices in the two model variants—with heterogenous and homogenous house price growth expectations—close to each other.

Second, we show that the model with heterogenous expectations better matches the salient features in the data on the boom-bust-boom house price cycle. We look at two summary statistics, the overall fit of the model to the data and the amplitude of equilibrium house prices—the distance between peak and trough. According to both measuring rods, the model with heterogenous house price growth expectations performs better than the model with homogenous expectations. This holds with respect to both, house prices as well as the rental rate.

[2]Long-term house price growth expectations are modeled as an "absorbing" state.

[3]While the implicit income shocks are consistent with the stochastic process we estimate for the income process, the implicit shocks to wealth and expectations have zero ex-ante probability.

Related Literature Our paper is related to several strands of the literature on house price dynamics[4]. While a few papers attribute the boom-bust episode in the US at the beginning of this century mainly to financial factors (Justiniano, Primiceri, and Tambalotti 2015; Favilukis, Ludvigson, and Van Nieuwerburgh 2017), several others, however, show that some form of deviation from rational expectations is necessary to explain the large swing in prices in such a relatively short period of time. For example, Kaplan, Mitman, and Violante (2020) show that shocks to the income process and financing conditions alone are not enough to explain the observed change in house prices. Instead, additional shocks to beliefs about housing demand are needed. Garriga, Manuelli, and Peralta-Alva (2019) develop a model with segmented markets in which lower mortgages rates lead to an increase in prices. However, to match the data, they need to add shocks to expectations about future financing conditions. Landvoigt (2017) estimates a life-cycle model using Survey of Consumer Finances data to infer house price expectations of households. He finds that even though the mean of the expectations was not particularly high, the subjective volatility of the expectations was high during the boom-bust cycle. Piazzesi and Schneider (2009) document that even though only 20% of households in the Michigan Survey of Consumers expected house prices to increase further in 2004-2005, that was twice as high as before. They then develop a search model to show that optimism of such a relatively small group can have a significant effect on prices. The fact that our data set includes household's expectations—in addition to standard variables such as age, income and wealth—allows us to use each household's house price expectations directly to compute household housing demand.

Our paper is also related to Bailey, Cao, Kuchler, and Stroebel (2018) who show that individuals' housing market expectations are partially driven by the house price experiences of distant friends. Individuals whose distant friends live in areas with high house price growth expect higher house price growth relative to otherwise similar individuals whose friends live in areas of low house price growth. They, like us, find that individuals act on these expectations and buy, for example, larger houses. Using data for Germany, Kindermann, Blanc, Piazzesi, and Schneider (2022) show that renters on average have more accurate house price growth expectations than home owners but their forecasts are also more dispersed. While we do not investigate peer effects in house price growth expectations and do also not ask whether renters have more accurate expectations than home owners, we would implicitly take such features into account by feeding into the model the distribution of measured expectations should survey respondents in our sample also form their expectations alike.

Our paper further connects to the literature on the role of expectations for the determination of asset prices. As we document, households' house price growth expectations in the following

[4]See Griffin, Kruger, and Maturana (2021) for a recent overview of the boom-bust episode in the U.S and Duca, Muellbauer, and Murphy (2021) for cross country evidence.

year on average depend on recent house price growth, which is consistent with extrapolative expectations. Barberis, Greenwood, Jin, and Shleifer (2018) develop a theoretical model in which such expectations can lead to bubbles in asset prices.

Extrapolative subjective beliefs about expected capital gains in the stock market are also central in Adam, Marcet, and Beutel (2017). They introduce subjective stock price beliefs into an otherwise standard Lucas asset pricing model. Their model generates quantitatively significant boom-bust cycles and is consistent with the observed positive correlation between realized capital gains and capital gains expectations measured in surveys. Adam, Beutel, Marcet, and Merkel (2015) develop a heterogeneous agent version of this model, which generates very similar stock price moments and additionally explains the observed patterns in trading volumes.

Subjective expectations and the expected capital gains mechanism are also important elements in our paper. Our focus, however, is on the role of belief heterogeneity, in conjunction with frictions, for market prices. The debt-to-income and the loan-to-value constraint limit demand by the most optimistic agents, thereby dampening a boom. The no short-selling constraint prevents pessimistic agents from selling, thereby dampening the bust. Therefore, we find significantly smaller boom-bust cycles in the model with heterogeneous expectations than in the model with homogenous expectations. Since these frictions are likely to be more relevant for the housing market than the stock market, our results do not really contradict Adam, Marcet, and Beutel (2017). Adam, Pfäuti, and Reinelt (2022) embed extrapolative house price expectations into an otherwise standard New Keynesian model. They show that in such an environment a decline in the natural rate of interest makes the lower bound on nominal interest rates problem more severe compared to a model with full-information rational expectations.

Glaeser and Nathanson (2017) use a variant of extrapolative expectation formation of otherwise rational households to explain the observed momentum at one-year horizons, mean reversion at five-year horizons, and excess longer-term volatility of housing markets.[5] Chodorow-Reich, Guren, and McQuade (2022) build a model with diagnostic expectations, which lead to overoptimism to not only explain the boom-bust cycle in the U.S. but also the subsequent rebound. Our paper relates to these in so far as that we use measured expectations of households to explain the observed cycle in the Netherlands, which also features a rebound at the end.

More broadly, our work relates to a growing literature on subjective expectations and economic decisions. This work originates in the seminal contribution by Dominitz and Manski (1997), which started an economic field studying subjective probabilistic expectations as reviewed in Manski (2004) and, more recently, in Bachmann, Topa, and van der Klaauw (2023).

[5] Kuchler, Piazzesi, and Stroebel (2023) provide an overview of the empirical literature on housing market expectations.

Our paper also related to the literature on belief disagreement driven speculation. In an overview of the macroeconomic effects of such speculation, Simsek (2021) develops a simplified model to analyze the effects of short selling constraints and leverage constraints. Under plausible conditions, a short-selling (loan to value) constraint prevents pessimistic (optimistic) investors from acting on their beliefs and therefore leads to overvaluations (undervaluations). We show that the consequences of belief (expectations) heterogeneity in the presence of these constraints depend somewhat on the location of expectations. If most agents are optimistic (pessimistic) , but the majority of agents is not constrained, exogenously reducing heterogeneity in expectations while keeping the mean constant, will lead to higher (lower) prices. This is behind our finding that a counter-factual economy with homogenous expectations would feature more fluctuations in house prices.

The remainder of this paper is structured as follows. Section 2 motivates our analysis by presenting a simple two period lived household model to show that housing demand is convex-concave in house price growth expectations. Section 3 describes our data and summarizes the main results of our data analysis. We proceed in Section 4 by developing the quantitative life-cycle model of the Dutch housing market and by defining the temporary equilibrium approach in Section 5. Section 6 describes our choices of functional forms and our calibration. Section 7 documents the results from our first experiments and provides an outlook on future experiments we aim at conducting in the future. Finally, Section 8 concludes the paper.

2 Housing Demand in a Two-Period Model

2.1 Setup

Consider a two-period lived household i with preferences over consumption c_j in the two periods of live $j \in \{0, 1\}$

$$u(c_0, c_1) = \ln(c_0) + \beta \ln(c_1),$$

where β is the discount factor.

The household is endowed with some initial assets $a_0 \geq 0$ and earns a fixed exogenous income of y in both periods. Households may invest in financial assets or housing. Housing is subject to a no short-selling constraint $h_1 \geq 0$, while financial assets are subject to a debt-to-income (DTI) constraint $a_1 \geq -\gamma y$.[6] Consumption is the numeraire good and houses are traded in the initial period at price p_0. Each household i has some expectation p_1^i over next period's housing price,

[6] In our quantitative model of Section 4, there will also be a loan-to-value constraint and housing will be part of the utility function.

which we take as a given number and thus ignore any uncertainty that there might exist around these expectations. Since there is no bequest motive, the household sells the house in the second period at the expected price $p_1^i = p_0 (1 + \Delta p_1^i)$. Likewise, the household consumes all assets in the period 1. Under these expectations and for an inter-temporal price $q \leq 1$ of financial savings the (perceived) budget constraints in the two periods of life are

$$c_0 + qa_1 + p_0 h_1 \leq y + a_0, \qquad c_1 \leq y + a_1 + p_1^i h_1$$

Finally, there is an exogenous supply of houses H in the economy, which, without loss of generality, we normalize to $H = 1$.

2.2 Analysis

Given the simple structure of the two-asset model, the household's portfolio decision depends on the expected returns on housing and the financial asset, incomes, initial wealth and the constraints. In Appendix A we show that the short-selling constraint on housing and the debt to income constraint imply that there are four relevant cases:

$$1.)\, a_1 = -\gamma y, h_1 = 0, \;\; 2.)\, a_1 > -\gamma y, h_1 = 0, \;\; 3.)\, a_1 = -\gamma y, h_1 > 0, \;\; 4.)\, a_1 > -\gamma y, h_1 > 0$$

for which we derive the consumption, savings and housing choices. Here we show only housing demand, which is

$$h_1 = \begin{cases} 0 & \text{if} \quad \Delta P_1^i \leq R \quad \vee \\ & \qquad a_0 \leq \left[\frac{(1-\gamma)-(1+q\gamma)\beta\Delta P_1^i}{\beta \Delta P_1^i}\right] y \\ \frac{1}{p_0}\frac{1}{1+\beta}\left[\beta(y + a_0 + \gamma y) - \frac{1}{\Delta P_1^i}(1 - R\gamma)y\right] & \text{if} \quad \Delta P_1^i > R \quad \wedge \\ & \qquad a_0 > \left[\frac{(1-\gamma)-(1+q\gamma)\beta\Delta P_1^i}{\beta \Delta P_1^i}\right] y \end{cases} \tag{1}$$

where $\Delta P_1^i \equiv \frac{p_1^i}{p_0}$ are individual's gross house price change expectations and $q = 1/R$.[7] The first line shows that housing demand is zero for households with relatively pessimistic house price growth expectations, where pessimistic means that the household expects house price growth being lower than the return on the financial asset, i.e. $\Delta P_1^i \leq R$.[8] Housing demand is also zero in case the household is relatively poor. This is the second line in the first case of (1).

The second case shows that housing demand is positive for households who are sufficiently wealthy and have relatively optimistic expectations, where optimistic means that the household

[7] The details of these derivations are shown in the appendix.

[8] For simplicity, we assume that if the two returns are equal, the household invests only in the financial asset.

expects house price growth being larger than the return on the financial asset, i.e. $\Delta P_1^i > R$. The equation also shows that housing demand in this case is concave in house price expectations. This is a result of the interplay of the utility function and the debt to income constraint. A household that expects $\Delta P_1^i > R$ would like to borrow as much as possible to invest into housing since he effectively expects an arbitrage opportunity. Due to the DTI borrowing is limited and any additional housing investment must be financed by lower consumption which gets, in utility terms, ever more costly.[9]

Thus, our simple framework can be summarized by the following housing demand function

$$h_1\left(p_0, \Delta P_1^i\right) = \max\left\{0, \frac{1}{p_0}\left(\phi - \psi\frac{1}{\Delta P_1^i}\right)\right\}, \tag{2}$$

where $\phi \equiv \frac{\beta}{1+\beta}\left((1+q\gamma)y + a_0\right)$, and $\psi \equiv \frac{1-\gamma}{1+\beta}y$. Equation (2) shows that housing demand is an increasing function in the individual house price growth expectation ΔP_1^i and a decreasing function of the current period market price p_0. The min operator implies that housing demand has a convex region for low house price growth expectations. The demand function (1) implies a concave regions for higher house price growth expectations. Thus, housing demand features a convex-concave schedule.

Given distribution $\Phi(\Delta P_1^i)$ of house price growth expectations such that $\int_R^\infty d\Phi(\Delta P_1^i) > 0$ and the assumed exogenous supply of houses of $H = 1$, the equilibrium price $p_0 > 0$ in the housing market is thus

$$p_0 = \int \max\left\{0, \phi - \psi\frac{1}{\Delta P_1^i}\right\} d\Phi(\Delta P_1^i).$$

2.3 An Illustrative Example

The important insight from equation (2) is the convex-concave schedule of housing demand in house price growth expectations. We now develop an example to illustrate how this feature of the demand schedule may give rise to house price dynamics such that in a "regime" with $l$ow average house price growth expectations the equilibrium house price in a "scenario" with homogeneous house price growth expectations is below the equilibrium price of a scenario with heterogenous expectations and vice versa for a regime with $h$igh average house price growth expectations. An implication is that the amplitude of house price movements is higher in the economy with homogenous house price growth expectations.

[9]We show concavity formally in the appendix. But it is apparent in equation (1) since ΔP_1^i enters the denominator with a negative sign so that $\frac{\partial h}{\partial(\Delta P_1^i)} > 0$ and $\frac{\partial^2 h}{\partial(\Delta P_1^i)^2} < 0$.

To derive this result, we assume that within each expectations regime, there are two degenerate expected house price distribution scenarios. In the homogeneous expectations scenario house price expectations for all individuals are given by $\bar{\Delta}P_1^h > \bar{\Delta}P_1^l$, respectively, where $\bar{\Delta}P_1^j = \int \Delta P_{t+1}^i d\Phi^j(\Delta P_{t+1}^i)$. In the heterogeneous expectations scenario, we assume that a fraction $\frac{1}{2}$ in the population holds low and a fraction $\frac{1}{2}$ holds high house price growth expectations relative to the respective mean expectations $\bar{\Delta}P_1^j$, $j \in \{l, h\}$. We parameterize these expectations by a symmetric spread κ such that heterogenous expectations in the respective regime are given by $\left[\bar{\Delta}P_1^j - \kappa, \bar{\Delta}P_1^j + \kappa; \frac{1}{2}, \frac{1}{2}\right]$, for $j \in \{l, h\}$.

If $\bar{\Delta}P_1^l$ is only somewhat larger then R, housing demand with homogenous expectations will be relatively small. In such a case, the corresponding heterogenous expectations case will feature higher demand and therefore a higher price. The additional demand of the 50% of households with expectations $\bar{\Delta}P_1^l + \kappa$ will more than compensate the zero demand from the households with expectations $\bar{\Delta}P_1^l - \kappa < R$ for whom the short-selling constraint is binding. Such a case is shown in the illustrative example in Panel (a) of Figure 1, where $\bar{\Delta}P_1^l = 1.1$ and $R = 1$. For a sufficiently large spread, demand will be higher under heterogenous expectations.

Since the demand function is concave for high house price growth expectations, Jensen's inequality immediately implies that demand with homogenous expectations will be larger than demand in the corresponding heterogenous expectations case. This is, for example, the case for $\bar{\Delta}P_1^h = 2$ in Panel (a) of Figure 1, where a mean preserving spread in expectations implies lower demand and therefore lower prices.

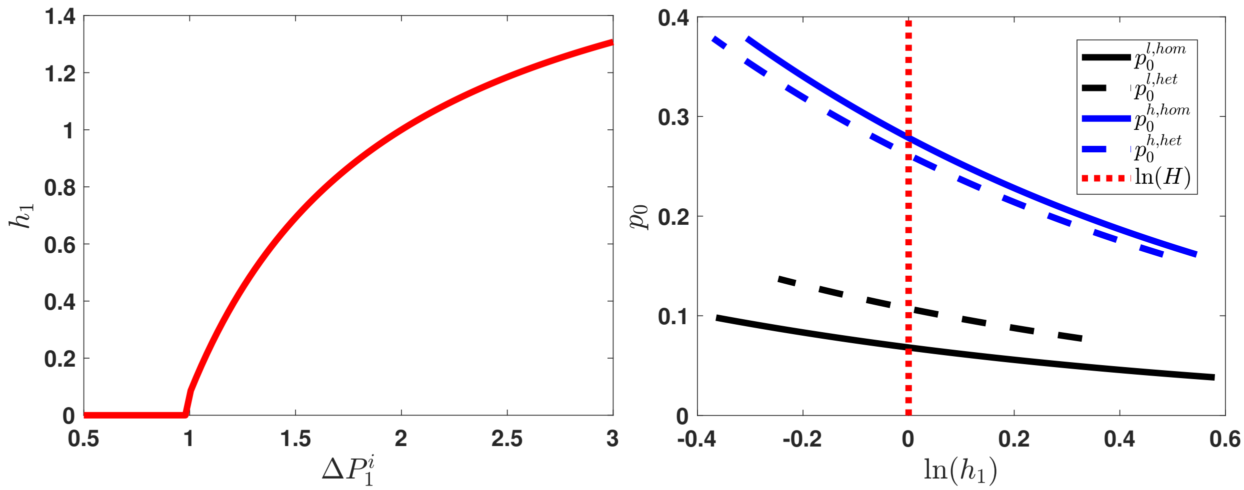
This implies equilibrium house prices in the homogeneous and the heterogeneous expectations scenario relate as

$$p_t^{l,hom} < p_t^{l,het}, \qquad p_t^{h,hom} > p_t^{h,het}, \qquad \Leftrightarrow \qquad p_t^{h,hom} - p_t^{l,hom} > p_t^{h,het} - p_t^{l,het}. \tag{3}$$

Panel (b) displays the associated inverse demand functions in regimes $j \in l, h$ and scenarios $s \in \{hom, het\}$, plotted against log housing, $\ln(h_1)$ and the log housing supply $\ln(H) = 0$. The equilibrium house prices feature exactly the schedule in (3).

The take-away from this analysis is that under sufficient movement of house price growth expectations across "regimes" and an according distribution of these expectations, equilibrium house prices may relate as a in (3). On the basis of these insights the main quantitative questions we pose in our subsequent data analysis in Section 3 as well as in our development and analysis of the structural model in Sections 4 through 7 are, first, whether subjective house price growth expectations elicited in the survey data are in line with these features and give rise to equilibrium house price movements in line with (3); second, whether differences between a quantitative model with heterogeneous and homogeneous house price growth expectations are quantitatively

Figure 1: Illustration: Housing Demand and Housing Market Equilibrium



(a) Housing Demand in Expectations

(b) Housing Market Equilibrium

Notes: Parametrization: $R = 1, y = 1, a_0 = 0.15, \beta = 0.75, \gamma = 0.1, \bar{\Delta} P_1^l = 1.1, \bar{\Delta} P_1^h = 2, \kappa = 0.5$. Panel (a): Housing demand as a function of house price growth expectations evaluated at $p_0^{h,hom} = 0.28$. Panel (b): Inverse housing demand as function of $ln(h_1)$. Equilibrium house prices: $p_0^{l,hom} = 0.07 < p_0^{l,het} = 0.11, \quad p_0^{h,hom} = 0.28 > p_0^{h,het} = 0.26$.

relevant; third, whether a model with heterogeneous house price growth expectations moves us closer to the data; fourth, as a subsidiary quantitative question, which constraint is the relevant one to generate concavity in the demand schedule, the DTI constraint—which we looked at in the two-period model—or the loan-to-value constraint—which we will introduce in the quantitative model.

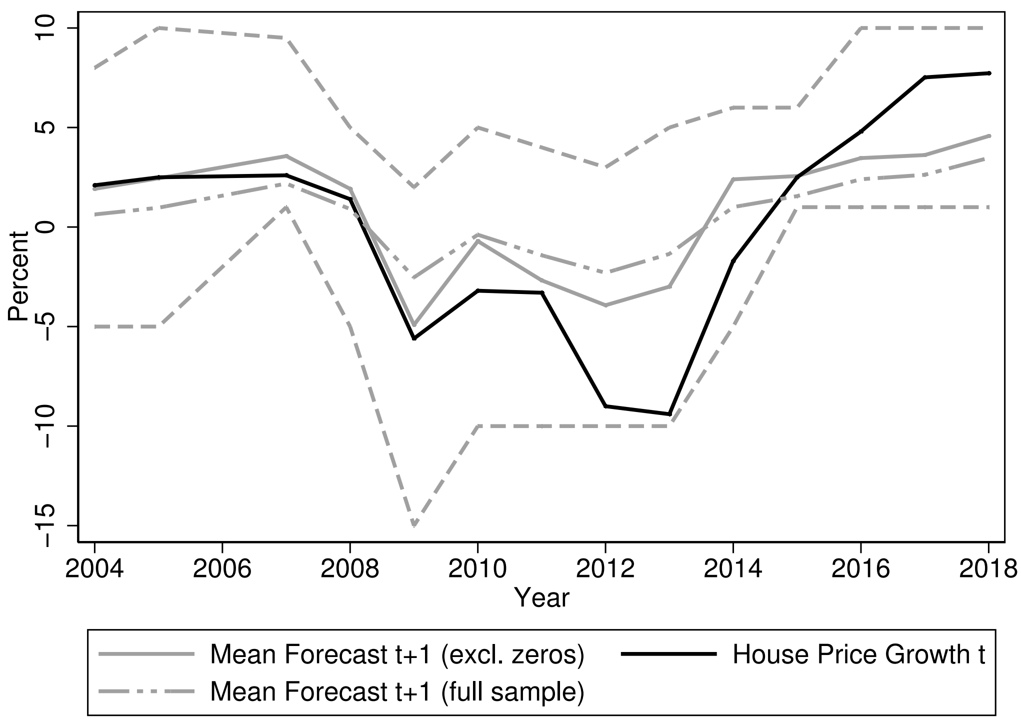
3 House Price Growth Expectations and Housing Decisions

In this section, we explore the panel data on household house price growth expectations and how those relate to house-adjustment decisions.

The Netherlands experienced a boom-bust-boom cycle over the sample period. Figure 2 shows the time series for house price growth, in real terms. The Netherlands experienced very fast house price growth in the early 2000s, monotonically declining but positive house price growth until 2008, negative house price growth between 2009 and 2014, and positive house price growth since 2015. House prices increased by about 0.3% per year in real terms on average over the entire period.

Figure 2 also shows expectations of house price growth by households. This data is generated based on households' responses to the two following questions in the Dutch National Bank (DNB) Household Survey: "What kind of price movement do you expect on the housing market **in the**

Figure 2: House Price Growth and House Price Growth Expectations



Notes: This figure shows the national house price index net of HIPC inflation in the Netherlands (black solid line) and average expected short-term house price growth for the full sample (gray dashed-dotted line) and a sample excluding focal point answers at 0 house price growth (gray solid line). Error bands shown in dotted lines contain 90% of the cross-sectional distribution of house price growth expectations in the full sample.
Source: Own calculations based on DNB Household Survey and ECB Statistical Data Warehouse.

next two years? Will housing prices increase, decrease or remain about the same?"[10] and "How much percentage points a year will they increase/decrease on average?"[11] Preceding questions in the survey do not reveal whether households are nudged to think about this as a real or a nominal question. Since the average answer over the sample roughly equals the time series average of realized *real* house price growth over this period, we interpret their answers as the answers to a question about real house price growth. We note that the average forecast of short-term house price growth is about zero in year 2004, slightly positive in the period 2005-2009, slightly negative in the period 2010-2014, and slightly positive since 2015.

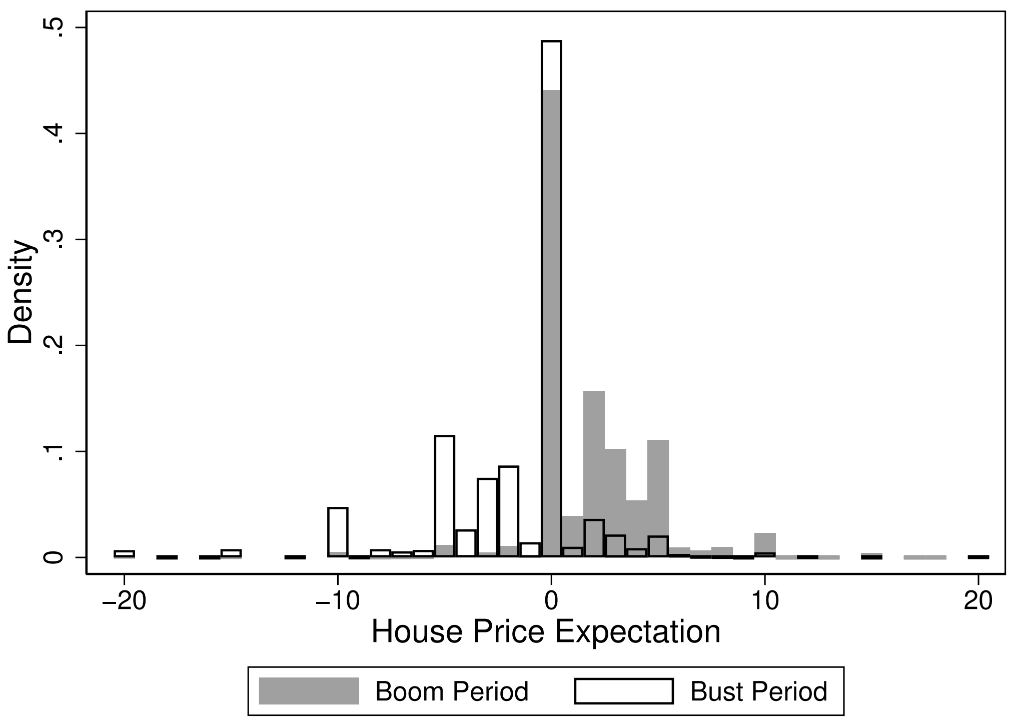
The average forecast masks a lot of heterogeneity. The dotted lines in Figure 2 contain 90% of the cross-sectional distribution of house price growth expectations. There is large heterogeneity in house price growth expectations at any given point in time. To further describe the data on house price growth expectations we plot in Figure 3 the distribution of the forecast of aggregate house price growth for the two phases of the boom-bust-boom cycle. Specifically we define as boom periods the years when realized house price growth was positive, i.e. years 2003 to 2008 and years 2014 to 2018, and as bust period the years in which it was negative, i.e., years 2009 to 2013. The graph shows that the distribution of households stating non-zero house price growth is shifted to the right, relative to zero, during the boom phase and to the left during the bust phase, and that there is large heterogeneity in boom and in bust periods.

House price growth expectations are very different in the boom periods than in the bust period. Figure 2 already showed that short-term house price growth expectations were higher during the boom period than during the bust period. When one excludes households who give the focal point anwer of zero, this pattern becomes even more clearly visible. From Figure 2 we see that for this subsample of households who report non-zero house price growth expectations, the average house price growth expectation moves closely with realized aggregate house price growth. Table 1 provides the corresponding summary statistics by reporting the means and the standard deviations of the distribution of house price growth expectations. Excluding focal point answers of 0, the average short-term house price growth expectation during boom periods is 3.0 and during the bust period it is -2.69. In Table 2 we further provide results on a regression of the short-term house price growth expectations on a constant and a dummy variable for the bust period. This shows that the difference between the boom periods and the bust period is significant.

[10] Bold in the survey.

[11] We trim the expectations data by dropping the top 2.5% and the bottom 2.5% to delete observations with very extreme house price growth expectations.

Figure 3: Distribution of Short-Term House Price Growth Expectations



Notes: This figure shows household short-term expected house prices for the full sample, divided into two periods. Boom periods are identified as years with positive house price growth (2003-2008 and 2014 to 2018); bust periods are years with negative house-price growth (2009-2013).
Source: Own calculations based on DNB Household Survey.

Table 1: Summary Statistics on House Price Growth Expectations

	Mean	St. Dev.
	Entire Sample Period	
Short Term		
Full Sample	0.60	3.17
Excluding Focal Point at 0	1.11	4.23
Long Term		
Full Sample	2.85	3.44
Excluding Focal Point at 0	2.97	3.46
	Boom Periods	
Short Term		
Full Sample	1.71	2.59
Excluding Focal Point at 0	3.00	2.81
Long Term		
Full Sample	2.92	3.14
Excluding Focal Point at 0	3.01	3.15
	Bust Period	
Short Term		
Full Sample	-1.34	3.15
Excluding Focal Point at 0	-2.69	4.03
Long Term		
Full Sample	2.77	3.78
Excluding Focal Point at 0	2.92	3.82

Notes: Boom periods are identified as years with positive house price growth (2003-2008 and 2014 to 2018); bust periods are years with negative house-price growth (2009-2013). All variables are measured in percent.
Source: Own calculations based on DNB Household Survey.

Table 2: Expectations During Booms and Bust

	Short-Term Expectations	Long-Term Expectations
Constant	1.7977***	3.2228***
	(0.0321)	(0.0580)
Bust Period Dummy	-3.3708***	-0.2280**
	(0.0721)	(0.1017)
Observations	16061	10956
R^2	0.1458	0.0005

Notes: Independent variables are short-term expected house-price growth and long-term expected house-price growth; both variables are in percent. Boom periods are identified as years with positive house price growth (2003-2008 and 2014 to 2018); bust periods are years with negative house-price growth (2009-2013). All variables are measured in percent. Robust standard errors in parentheses with $^{*}p < 0.10,^{**} p < 0.05,^{***} p < 0.01$.
Source: Own calculations based on DNB Household Survey.

In addition to the question on short-term house price growth expectations, the survey contains a question on long-term house price growth expectations: "In about a period of 10 years what do you think is a normal increase or decrease for property prices **per year**?" As for the short-term expectations, Table 1 reports the according summary statistics for the long-term house price growth expectations suggesting that there is no difference between boom and bust periods. The regression results in Table 2 confirm this. While the dummy variable on the bust periods is significant (at the 5 percent level), the magnitude of the point estimate is small. We can therefore conclude that short-term house price growth expectations are negative in a bust and positive in a boom period, whereas long-term house price growth expectations are on average relatively stable over the cycle.

Likely vs. Unlikely Movers To investigate how subjective house price growth expectations translate into housing choices, we start by identifying "likely" or "unlikely" movers in the data and ask whether likely movers hold different house price growth expectations than unlikely movers. We identify these households on the basis of the predicted moving probability from a linear probability model, see Table 3 below. This linear probability model regresses a moving indicator variable on the state variables of the households, as well as year fixed effects.[12] If a household-year observation has a predicted likelihood of moving larger than the average moving rate in the sample of 0.02, they are labeled as "likely movers"; otherwise, they are labeled as "unlikely movers."

Figure 4 plots the average house price growth expectations conditional on belonging to either of the two groups, likely and unlikely movers. We find that likely movers hold higher house price growth expectations than unlikely movers until about 2012 when average house price growth

[12] The moving indicator is constructed as a dummy variable from the survey question "WOD35B: In which year did you buy your current house?"

Table 3: Moving Propensity Linear Probability Model

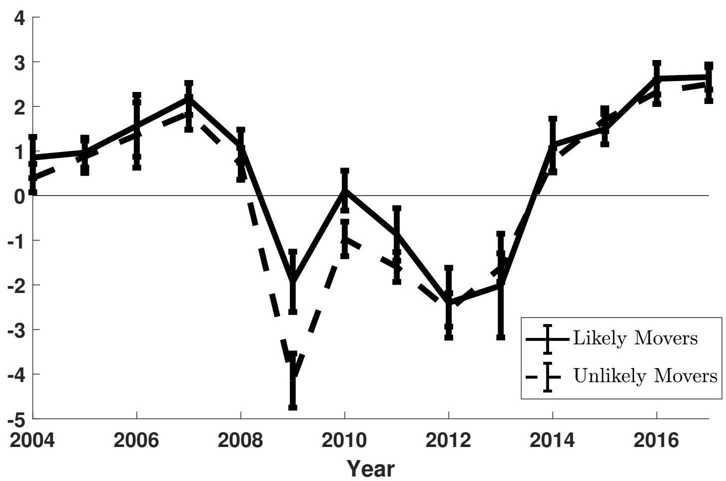
	House Adjustment Indicator
Net Financial Assets	0.0000
	(0.0004)
House Value	0.0005
	(0.0005)
Net Income	0.0136***
	(0.0033)
Age	-0.0057***
	(0.0011)
Age squared	0.0000***
	(0.0000)
Renter	0.0165**
	(0.0068)
Constant	0.1769***
	(0.0323)
Year Fixed Effects	Yes
Observations	10352
R^2	0.0200

Notes: Independent variables is an indicator function for house-adjustment. Net income and household portfolio items are in thousands of euros. Renter is a dummy variable for renting households. Robust standard errors in parentheses with $^{*}p < 0.10,^{**}p < 0.05,^{***}p < 0.01$.

Source: Own calculations based on DNB Household Survey.

expectations started to increase strongly and the conditional average expectations of the two groups of households are closely aligned. While this difference is insignificant for most survey years, it is significant in the bust year of 2009 and the following year. Until (and including) year 2012 the pattern is also fairly robust so that we conclude from this analysis that households that are more likely to move hold on average higher house price growth expectations until 2012.

Figure 4: House Price Growth Expectations by Likelihood of Moving, Data



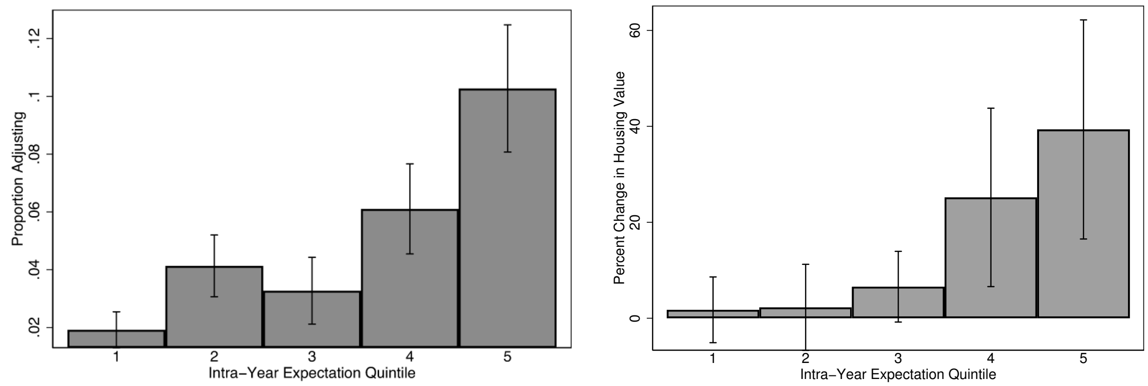
Notes: Likelihood of moving is in percent. Likely movers identified as households with a likelihood of moving higher than 2%. Yearly confidence bands are shown for 95% confidence.
Source: Own calculations based on DNB Household Survey.

Expectations and the Size of Housing Adjustments Based on Quintana (2023) we finally look in Figure 5 at the relationship between house price growth expectations and the percent of adjusting (resp. moving[13]) households in Panel (a) of the figure and the percent increase of reported housing adjustments relative to the value of existing houses, conditional on owning a house in Panel (b).[14] We pool across all sample years and group households by quintiles of their short-term house price growth expectations. The graph shows that the fraction of adjusting households and the size of housing adjustments increase in short-term house price growth expectations. Specifically, households in the lowest expectations quintile on average do not adjust the value of their houses whereas households in the highest quintile on average adjust it by 40%.

[13]We use the terms "moving" and "adjusting" interchangeably.

[14]The "reported housing value" is given in the survey as "B26OGB" and is based on the question "WOD44S: In order to calculate for example the deemed home ownership value (eigenwoningforfait) and the immovable property tax (OZB) the government uses the WOZ-value of your house (the official value of your house determined by the municipality). What is the determined WOZ-value for your home?"

Figure 5: Adjusting Households by Expectations Quintiles



(a) Fraction of Adjusting Households

(b) Size of Housing Adjustments

Notes: This figure shows the fraction of the population adjusting in Panel (a) and the percent of housing value adjustments (in 2002 prices) conditional on owning a house in Panel (b) by intra-year short-term expectations quintile. Only home-owning households that report well-defined expectations are included in the graphs.
Source: Quintana (2023).

Summary of Data Insights The main takeaway from our data exercise is thus threefold. First, households display substantial heterogeneity in their expectations with respect to short-term and long-term house price growth. Second, mean short-term house price growth expectations correlate with the observed boom-bust-boom cycle in the Dutch housing market. Third, short-term expectations are also correlated with housing decisions in an expected manner: households that hold higher house price growth expectations are more likely to move and the higher the expected house price growth, the higher are housing adjustments. Our next objective is to develop a quantitative model to investigate how subjective expectations, through the lens of the model, translate into house price dynamics, both in terms of the level as well as changes over time.

4 A Structural Housing Model with Subjective House Price Growth Expectations

In order to study the potential for observed variations in house-price growth expectations to account for the boom-bust-boom cycle in house prices, we turn to a structural model. The model features idiosyncratic income shocks, warm glow bequests, home-ownership and rental markets for housing services, and long-term mortgage contracts. We abstract from default as this option is essentially not observed in the Dutch data set. The model is standard and very close to those of Kaplan, Mitman, and Violante (2020) and Berger, Guerrieri, Lorenzoni, and Vavra (2015), but we allow for heterogeneity in house price growth expectations.[15]

We model households in discrete time and denote each period by $t = 0, \ldots, T$. Our model is cast in partial equilibrium. Interest rates on savings and borrowing are exogenous objects and so are tax instruments.[16]

4.1 Endowments, State and Choice Variables

The model economy is populated by a continuum of households indexed by i. They live with certainty for a fixed number of periods, $j \in \{0, 1, ..., J\}$. During the working period until the fixed retirement age $0 < j_r < J$, households receive a stochastic net labor income with three components: a deterministic and age-specific earnings component $g(j) > 0$, a persistent income state $\eta' = \eta^{\rho}\nu$, where $\rho \in (0,1)$ is the autocorrelation parameter and $\nu \sim_{i.i.d.} \Psi_{\nu}$ is the current period persistent income shock, and a transitory income shock $\epsilon \sim_{i.i.d.} \Psi_{\epsilon}$. Thus, income during the working period is $y(j;\eta,\epsilon) = g(j)\eta\epsilon$. Retirement income, which in our model encompasses all non-interest old-age income, is related to the income received in the period before entering retirement, that is income for all ages $j \in \{j_r, \ldots, J\}$ is $y(j;\eta_{j_r-1},\epsilon_{j_r-1}) = \varrho \cdot y(j_r-1,\eta_{j_r-1},\epsilon_{j_r-1})$.

Households can save in risk-free bonds that pay a net return, r. Households may also save in discrete housing units, $h' \in \mathcal{H} = \{h_0, ..., h_{n_h}\}, 0 < h_0 < ... < h_{n_h}$, that sell at current period unit price p_t. Since we denote by h the beginning of period housing stock, h' is the housing stock households held during a given period and transfered to the next period forming beginning of next period's housing stock. When purchasing housing units, households have the option to finance part of the purchase through a loan contract at a fixed rate, r_m, that is subject to an intermediation spread such that $r_m = r + \zeta$, where $\zeta > 0$ denotes the spread. As an alternative to owning—importantly, we do not allow for owning and renting at the same time—, households may choose to live for rent $b \in \mathcal{B} = \{b_0, ..., b_{n_b}\}, 0 < b_0 < ... < b_{n_b}$, where discrete renting units sell at price q_t. It is understood that the elements in $\mathcal{H}$ and $\mathcal{B}$ represent both the size and the quality of houses, respectively apartments, traded in the market.

Housing units depreciate at rate δ and the value of a house owned at the beginning of period t is thus $(1-\delta)p_t h$. If a household decides to adjust the size of the house it owns or decides to change from owning to renting or from renting to owning, it must incur a housing transaction cost linked to the size of the beginning-of-period house, $\theta\,(1-\delta)\,p_t h$ for $\theta > 0$. At the beginning of each period, homeowners are also subject to a moving shock, $\xi \in \{0, 1\}$, where $\xi = 1$ with

[15] The model is stationary. We show in the appendix how to derive this stationary model from a growth model.

[16] We directly model net income of households.

probability $0 < \pi < 1$, that if realized, i.e., for $\xi = 1$, forces them to sell their house so that their financial wealth position at the beginning of period t changes to $(1-\theta)(1-\delta)p_t h$.[17]

As in Landvoigt (2017), given the positive spread $\zeta > 0$, households will never choose to take out a mortgage and save in bonds at the same time. We therefore only need to keep track of a households' net non-housing (liquid) asset position, which we denote by a. Mortgage contracts are such that at origination, a house *adjusting* and *non-adjusting* households are subject to a maximum debt-to-income (DTI) constraint, $a' \geq -\lambda_y y(j;\eta,\epsilon)$, and a home equity lines of credit (HELOCs) constraint, which we also refer to as a loan-to-value (LTV) borrowing constraint. We follow Kaplan, Mitman, and Violante (2020) by assuming that HELOCs are one-period non-defaultable contracts. Hence, we assume that $a' \geq -\lambda_h p_t h'$. Taking both constraints together we thus have $a' \geq -\min\{\lambda_h p_t h', \lambda_y y(j;\eta,\epsilon)\}$. That is, homeowners are allowed to borrow up to a proportion λ_h of the value of their home, as long as they pay back the loan before they die—there is no possibility to default in the model—, and up to a multiple λ_y of their income.

Renting households are subject to a zero borrowing constraint $a' \geq 0$. We also assume that all households begin their economic life with no housing and no financial assets, thus $a(j=0) = h(j=0) = 0$.

To summarize, the budget constraint of a household is

$$c + a' + x(d'; h', b, p_t, q_t) = w_t(j; a, h; \eta, \epsilon),$$

where $w_t(i, j; a, h; \eta, \epsilon)$ is beginning of period total wealth

$$w_t(j; a, h; \eta, \epsilon) \equiv y(j; \eta, \epsilon) + \left(1 + r + \mathbb{1}_{\{a<0\}}\zeta\right) a + (1-\delta)\, p_t h \tag{4}$$

and $x(d'; h', b, p_t, q_t)$ are the period t housing expenditures

$$x(d'; h', b, p_t, q_t) = \begin{cases} p_t h' + \theta\,(1-\delta)\, p_t h & \text{if } d' = adj, \text{ i.e., } b = 0, h' > 0, h' \neq h \\ p_t h' & \text{if } d' = nadj, \text{, i.e., } b = 0, h' = h > 0 \\ q_t b + \theta\,(1-\delta)\, p_t h & \text{if } d' = rnt, \text{ i.e., } b > 0, h' = 0. \end{cases}$$

Here $d' = adj$ if a household owns and adjusts during the period, $d' = nadj$ if a household owns and does not adjust during the period, and $r' = rnt$ if a household rents during the period. The

[17]After retirement, the moving shock is the only source of risk that households face. This risk facilitates to calibrate the model to generate a hump-shaped housing demand, see Section 6.

borrowing constraint is

$$a' \geq \bar{a} \equiv \begin{cases} -\min\left\{\lambda_h p_t h', \lambda_y y(j;\eta,\epsilon)\right\} & \text{if} \quad h' > 0 \\ 0 & \text{otherwise.} \end{cases}$$

4.2 Preferences

Households derive utility from non-durable consumption, c, and the service flow from housing units owned during the period, h', or from renting an apartment, b. We denote this service flow by $s(h', b, j)$. This service flow $s(\cdot)$ also depends on the age j of the household reflecting that the relative utility of owning versus renting plausibly varies with age. Households discount the future at rate β and the per period utility function $u\left(c, s\left(h', b, j\right)\right)$ satisfies $u_c > 0, u_s > 0, u_{cc} < 0, u_{ss} < 0, u_{cs} = u_{sc} \geq 0$. In the terminal period J, households also value wealth w' they leave behind according to a warm glow bequest utility function $v(w')$ with $v_{w'} > 0$ and $v_{w'w'} < 0$.

4.3 Objective and Subjective Expectations

In each period, households hold *objective* expectations with respect to the transitory and persistent income shocks ϵ, ν and the moving shock ξ. They are agnostic about aggregate risk—or, are risk-neutral with regard to it—and thus assume that their incomes $y(j;\cdot)$ are not affected by aggregate shocks, the interest rate r is constant and house prices do not fluctuate. Households hold *subjective* expectations with respect to the per period house price growth rate $\Delta p_{t+s} = \frac{p_{t+s}}{p_{t+s-1}} - 1$, $s \geq 1$. Since households abstract from aggregate uncertainty, they take their central forecast for house price growth to be a certain outcome. We denote these expectations formed in period t by $\mathbb{E}_t^i\left[\Delta p_{t+s}\right]$ for all future periods $s \in \{t+1, \ldots, t+J-j\}$. Specifically, household i's house price growth expectations obey a two state Markov process with state vector $e = [S, L]$ for $s$hort-term and $l$ong-term house price growth expectation, respectively, and associated transition matrix $\pi(e' \mid e)$. The short term house price growth expectation is Δ_i—which in our calibration is directly extracted from the survey data—and the long-term house price growth expectation is constant at house price growth rate Δ_L—which in our calibration is equal to the average expected long-term house price growth rate. Each period, the transition probability from short- to long-term expectations is constant, $\pi(e' = L \mid e = S) = \lambda$, where L is an absorbing state, i.e. $\pi(e' = L \mid e = L) = 1$. The initial probability vector in period t for the house price growth from period t to period $t+1$ is $\Pi_t = [1-\lambda, \lambda]'$. With this stochastic transition of expectation types we reduce the complexity of the model that would otherwise arise if we were to consider all potential combinations of short- and long-term expectations.[18] Thus, the

[18]This modeling choice is similar to the notions of "stochastic aging" or "stochastic retirement" often encountered in the literature.

individual i's specific house price growth expectation in period t for a future period $t+s$, $s \geq 1$, is $\mathbb{E}_t^i\left[\Delta p_{t+s}\right] = (1-\lambda)^s \Delta_i + \frac{1}{\lambda}\left(1-(1-\lambda)^s\right)\Delta_L$.

4.4 The Housing Capital Gains Mechanism

In the presence of movements in the house price, the household must account for potential housing capital gains. Equation (4) implies that next period's beginning-of-period total wealth is

$$\begin{aligned} w' &= y(j+1;\eta',\epsilon') + \left(1+r+\mathbb{1}_{\{a'<0\}}\zeta\right)a' + (1-\delta)\,p_{t+1}h' \\ &= y(j+1;\eta',\epsilon') + \left(1+r+\mathbb{1}_{\{a'<0\}}\zeta\right)a' + (1-\delta)\,p_t h' + \underbrace{(1-\delta)\,p_t\Delta p_{t+1}h'}_{\text{Housing Capital Gains}} \end{aligned} \tag{5}$$

Hence, conditional on current-period saving and housing choices, the household expectation of its future beginning-of-period resources is:

$$\begin{aligned} \mathbb{E}_t^i\left[w' \mid \eta, p_t, a', h'\right] = \mathbb{E}\left[y(j+1;\eta',\epsilon') \mid \eta\right] + \left(1+r+\mathbb{1}_{\{a'<0\}}\zeta\right)a' \\ + (1-\delta)\,p_t h' + \underbrace{(1-\delta)\,p_t h'\mathbb{E}_t^i\left[\Delta p_{t+1} \mid p_t\right]}_{\text{Expected Housing Capital Gains}} \end{aligned} \tag{6}$$

where $\mathbb{E}_t^i\left[\Delta p_{t+1} \mid p_t\right]$ denotes the period t expectation of household i of house price growth between t and $t+1$. We allow for heterogeneity in this expectation.

Importantly, whether or not the household receives next-period housing capital gains depends on its current-period housing choice. Hence, the mechanism through which subjective expectations about future house price growth affect consumption, savings and housing decisions works through a wealth/endowment effect due to expected future capital gains.

4.5 Dynamic Programming Problems

We describe the dynamic programming problem of households holding long-term house price growth expectations, $e = L$, followed by households with short-term house price growth expectations, $e = S$. Throughout, it is convenient to collect state variables as $z = \left[\mathbb{E}_t^i\left[\Delta p_{t+1} \mid p_t\right], j; a, h, \eta, \epsilon\right]$. All state variables are summarized in Table 4. Notice that for both expectations types $e \in \{S, L\}$ the terminal value function from the perspective of a period t age j household is

$$V_{t+J-j+1}(z_{t+J-j+1}, e) = v(w'(J))$$

where $w'(J) = \left(1+r+\mathbb{1}_{\{a'(J)<0\}}\zeta\right)a'(J) + (1-\delta)p_{t+J-j+1}h'(J)$.

Households with Long-Term House Price Growth Expectations. At all ages $j \in \{0,\ldots,J\}$ a household may choose between the three alternatives "owning", "adjusting" and "renting", $d \in \{own, adj, rnt\}$. "Owning" means that the household owns a house at the beginning of the pe-

Table 4: State Variables

State Var.	Values	Interpretation
$\mathbb{E}_t^i\left[\Delta p_{t+1} \mid p_t\right]$	$\in \mathbb{R}$	Short-Term House Price Growth Expectation
j	$j \in \{0, \ldots, J\}$	Age of household
t	$t \in \{0, \ldots, T\}$	Time
e	$e \in \{S, L\}$	Expectations type
h	$h \in \{h_0, \ldots, h_{n_h}\}$	Beginning of period housing wealth
a	$a \geq \bar{a}$	Beginning of period financial assets
η	$\eta \sim \Psi_\eta$	Persistent income state
ϵ	$\epsilon \sim \Psi_\epsilon$	Transitory income shock

Notes: This table summarizes the state variables of the quantitative model.

riod and attempts to non-adjust the house during the period. The household is then hit by the moving shock, ξ, with probability π. In case the moving shock realizes ($\xi = 1$), the household is forced to sell the house and can purchase a new house or rent. "Adjusting" means that the household adjusts the size of the house or becomes a homeowner during the period. In this case, the moving shock is irrelevant. "Renting" means that the household rents a house during the period. With this notation, we can define the current-period value function as the upper envelope of the choice-d-specific value functions:

$$V_t\left(z, e = L\right) = \max_{d \in \{own, adj, rnt\}} \left\{V_t\left(z, e = L; d\right)\right\},$$

where the choice-d-specific value functions and dynamic problems are

$$V_t(z, e = L; d = own) = \pi \max_{d' \in \{adj, rnt\}} \{V_t(z, e = L; d')\} + (1 - \pi) V_t(z, e = L; d' = nadj) \tag{7a}$$

$$V_t(z, e = L; d' = adj) = \max_{\{c, a', h'\}} \{u(c, s(h', b = 0, j)) + \beta \mathbb{E}_t[V_{t+1}(z', e = L)]\} \tag{7b}$$

$$s.t. \quad c + a' + p_t h' = y(j; \eta, \epsilon) + \left(1 + r + \mathbb{1}_{\{a<0\}} \zeta\right) a + (1 - \theta)(1 - \delta) p_t h$$

$$a' \geq -min\{\lambda_h p_t h', \lambda_y y(j; \eta, \epsilon)\}$$

$$V_t(z, e = L; d' = nadj) = \max_{\{c, a'\}} \{u(c, s(h' = h, b = 0, j)) + \beta \mathbb{E}_t[V_{t+1}(z', e = L)]\} \tag{7c}$$

$$s.t. \quad c + a' + \delta p_t h' = y(j; \eta, \epsilon) + \left(1 + r + \mathbb{1}_{\{a<0\}} \zeta\right) a$$

$$a' \geq -\min\{\lambda_h p_t h', \lambda_y y(j; \eta, \epsilon)\} \tag{7d}$$

$$V_t(z, e = L, d = rnt) = \max_{\{c, a', b\}} \{u(c, s(h' = 0, b, j)) + \beta \mathbb{E}_t[V_{t+1}(z', e = L)]\} \tag{7e}$$

$$s.t. \quad c + a' + q_t b = y(j; \eta, \epsilon) + \left(1 + r + \mathbb{1}_{\{a<0\}} \zeta\right) a + (1 - \theta)(1 - \delta) p_t h$$

$$a' \geq 0.$$

Since households that are forced to move are in the same position as households who move voluntarily, $V_t(z, e = L; d' = adj) = V_t(z, e = L; d = adj)$.

Households with Short-Term House Price Growth Expectations. Households with short-term house price growth expectations solve almost identical dynamic programming problems. The only difference is that their continuation value is

$$V_{t+1}(z') = \sum_{e' \in \{S, L\}} \pi(e' \mid e = S) V_{t+1}(z', e').$$

4.6 Solution Method

The household model is solved using the discrete-continuous endogenous grid method (DC-EGM) as in Iskhakov, Jørgensen, Rust, and Schjerning (2017). This procedure builds on the EGM of Carroll (2006) and consists of using an exogenous end-of-period (i.e., post-decision) savings grid and the household's Euler equation to back out an endogenous grid for beginning-of-period net financial assets. Secondary kinks in choice-specific value functions are handled by eliminating segments that fall below the upper envelope of the correspondence.

5 Temporary Equilibria and Price Dynamics

In order to study the implications of household expectations heterogeneity for aggregate price dynamics, we use the structural housing model to look at a sequence of temporary equilibria—in the spirit of Hicks (1939), Lindahl (1939) and Grandmont (1977, 1978)—generated by the observed distribution of household income, wealth, demographics and expectations. Following Piazzesi and Schneider (2016, p. 1587), a temporary equilibrium for date t, is defined as "a collection of prices and allocations such that markets clear given beliefs and agents' preferences and endowments".[19] More specifically, a *temporary equilibrium with measured expectations* is a quasi-static concept where the cross-sectional distribution of expectations and total wealth w is kept exogenous, and market-clearing is imposed. Further, again following Piazzesi and Schneider (2016, p. 1589), "a sequence of temporary equilibria"—again, in our context, with measured expectations—"is a collection of date t temporary equilibria that are connected via the updating of endowments".

By modeling the dynamic fluctuations of aggregate prices as a sequence of temporary equilibria with measured expectations, we account for the effects of distributional changes—including changes in expectations—within the household sector on aggregate prices, while remaining agnostic about the source of such changes. In particular, we are agnostic about any specific expectation-formation process that is behind the observed joint distribution of households. Further, by taking the supply of assets—i.e., the aggregate stocks of financial assets and housing wealth—directly from the data, we do not need to explicitly model the supply side of the economy.[20] In this way, the sequence of temporary equilibria generated by the model allows us to map the *observed* sequence of distributions over expectation types and states, $\{\Phi_t\}_{t=2004}^{t=2017}$, to a sequence of price vectors, $\{[p_t, q_t]\}_{t=2004}^{t=2017}$, which includes the boom-bust cycle in the housing market in the Netherlands.

5.1 A Sequence of Temporary Equilibria with Measured Expectations

This section provides a formal definition of a date t temporary equilibrium (with measured expectations) and the sequence of temporary equilibria.

Let $\mathcal{G} = \mathbb{R}$ be the set of all possible house price growth expectations, $\mathcal{J}$ be the set of possible ages, $\mathcal{A} = \mathbb{R}$ be the set of possible non-housing assets held by the household, $\mathcal{H}$ be the set

[19] Also see Farhi and Werning (2019) and Molavi (2019) for recent examples using the concept, as well as the review article by Brunnermeier et al. (2021), which discusses the usefulness of the concept in studies with survey beliefs.

[20] Since our results arise from an exogenous sequence of joint distributions, they continue to hold for any model that delivers an identical sequence of equilibrium distributions—regardless of the source of fluctuations and supply-side dynamics. Finally, note that we do not need to treat the distribution of households as a state variable in the household's dynamic programming problem since this would only be relevant—in the presence of aggregate risk—if it informed household's price expectations, which we already directly observe.

of possible housing assets, $\mathcal{N}$ be the set of possible persistent income state realizations, and $\mathcal{E}$ be the set of possible transitory income shock realizations. Let $z = [\mathbb{E}_t^i [\Delta p_{t+1} \mid p_t], j; a, h, \eta, \epsilon]$ and $\mathcal{Z} = \mathcal{G} \times \mathcal{J} \times \mathcal{A} \times \mathcal{H} \times \mathcal{N} \times \mathcal{E}$. Further, let $\mathcal{P}(\iota)$ and $\mathcal{B}(\iota)$ denote the power set and the Borel σ-algebra of ι, respectively. Finally, let $\mathcal{M}$ be the set of all probability measures on the measurable space $(\mathcal{Z}, \mathcal{B}(\mathcal{Z}))$, where $\mathcal{B}(\mathcal{Z}) = \mathcal{B}(\mathcal{G}) \times \mathcal{P}(\mathcal{J}) \times \mathcal{B}(\mathcal{A}) \times \mathcal{P}(\mathcal{H}) \times \mathcal{B}(\mathcal{N}) \times \mathcal{B}(\mathcal{E})$.

Definition 1 (Temporary Equilibrium)**.** *Given the interest rate r, the loan spread ζ, the supply of owner-occupied housing H_t, the supply of rental housing B_t, and a cross-sectional measure $\Phi_t(z)$, a period t temporary equilibrium is a set of functions $V_t : \mathcal{Z} \to \mathbb{R}$, $c_t : \mathcal{Z} \to \mathbb{R}_+$, $a_t' : \mathcal{Z} \to \mathcal{A}$, $h_t' : \mathcal{Z} \to \mathcal{H}$, and $b_t : \mathcal{Z} \to \mathbb{R}_+^0$, as well as prices $[p_t, q_t]$ such that*

1. *The functions V_t, c_t, a_t', h_t', and b_t are measurable with respect to $\mathcal{B}(\mathcal{Z})$, the function V_t satisfies the households' Bellman equation and the functions c_t, a_t', h_t' and b_t are the associated policy functions.*

2. *Markets clear*

$$H_t = \int h_t'(z) d\Phi_t(z), \qquad B_t = \int b_t(z)\, d\Phi_t(z), \qquad A_t = \int a_t'(z) d\Phi_t(z). \tag{8}$$

The concept of a period t temporary equilibrium is a generalization of the concept of a rational expectations equilibrium. A period t temporary equilibrium gives the allocations and prices for any given beliefs, a special case are the beliefs that are given some model of belief formation (e.g., full-information rational expectations).

A sequence of temporary equilibria is next defined as follows:

Definition 2 (Sequence of Temporary Equilibria)**.** *A sequence of temporary equilibria is a collection of date t temporary equilibria with a sequence of cross-sectional distributions, $\Phi_t(z)$.*

We take the sequence of $\Phi_t(z)$ from the data and remain agnostic about how the sequence of short-term house price growth expectations have been formed. For income and wealth, we thus overwrite in each period t the model generated distribution with the actual distribution as measured from the data. While the implicit income shocks are consistent with the stochastic process we estimated, the implicit shocks to wealth have zero ex-ante probability.

5.2 Computational Implementation

To compute a date t temporary equilibrium we, first, feed into the model from the data the cross-sectional joint distribution of short-term house price growth expectations, age, assets, the owned housing value, the rental housing value, and income. Second, we compute the solution to the household model as described in Subsection 4.6. Third, for given value and policy functions and a given cross-sectional distribution, we solve the market clearing on the housing and rental market, cf. equation (8), as a bivariate rootfinding problem in $[p_t, q_t]$.

6 Functional Forms and Calibration

In this section, we specify the functional forms relating to households' preferences and discuss calibration.

6.1 Functional Forms

Households' instantaneous utility function, following Landvoigt (2017) and Berger, Guerrieri, Lorenzoni, and Vavra (2015), is given by

$$u\left(c, s\left(h', b, j\right)\right) = \frac{\left[c^{1-\sigma} s\left(h', b, j\right)^{\sigma}\right]^{1-\gamma} - 1}{1-\gamma},$$

where the service flow of utility from owned houses, respectively from rented apartments, $s\left(\cdot\right)$, is linear in its first two arguments and given by

$$s\left(h', b, j\right) = \omega_j h' + b + \varpi \text{ where } \varpi \geq 0 \text{ and } \omega_j = 1 + e^{\omega_0 + \omega_1 j + \omega_2 j^2} \geq 1$$

In the above, parameter ϖ measures the value of social housing as in, e.g., Kaas, Kocharkov, Preugschat, and Siassi (2021), and age dependency of the relative weight parameters ω_j is assumed to match the hump-shaped home ownership profile in the data, see below.

Our specification of the utility from bequests follows De Nardi (2004) and is given by

$$v\left(w\right) = \vartheta_1 \frac{\left(w + \vartheta_2\right)^{1-\gamma} - 1}{1-\gamma}$$

here parameters $\vartheta_1 > 0$ measures the level utility derived from intended bequests and parameter $\vartheta_2 \geq 0$ the "luxury goods" motive.

6.2 Calibration

We pursue a standard calibration strategy distinguishing between parameters measured from the data (first-stage parameters) and those that are identified using the model (second-stage parameters). We calibrate an initial temporary equilibrium of the model using moments obtained as averages over the entire period of analysis, from 2003 to 2017. All variables are measured in terms of the median real net annual income.

Values of first-stage parameters are reported in table 6. The model is specified at an annual frequency, with households starting their working life at age 25 ($j = 0$), retiring at age 65 ($j = 40$) and dying at age 80 ($j = 55$). There is no stochastic death between periods. The share of housing services is set to $\sigma = 0.3$ to match the empirical average rental expenditure of 30% of income. The risk aversion parameter is fixed at $\gamma = 2$, in line with much of the macroeconomic literature. The estimation of the income process follows Storesletten, Telmer, and Yaron (2000,2004). We estimate an autocorrelation of the persistent income component of $\rho = 0.97$, and a variance of the persistent shock of $\sigma_\nu^2 = 0.09$ and of the transitory shock of $\sigma_\epsilon^2 = 0.29$. In our model, pension income is all non-interest income households receive in retirement and not just pension income. We therefore focus on the ratio of average old age to working age income in the data, and accordingly set the old age income replacement rate to 0.85. The risk-free rate is set to $r[\%] = 3$ percent. The mortgage loan mark up is set to the period average of $\zeta[\%] = 1$ percent p.a.. The maximum DTI and LTV ratios are set to the estimated averages in the data of $\lambda_y = 5$ and $\lambda_h = 0.9$, respectively. We normalize the rental rate to one and fix the rent-to-price ratio at 0.07 as in Nijskens, Heeringa, et al. (2017). We follow Kaplan, Mitman, and Violante (2020) by fixing log-linear housing grids with four and six points for rental and owner-occupied housing, respectively. The minimum and maximum owner-occupied housing grid points correspond to the 10^{th} and 80^{th} percentile of the empirical distributions, with the minimum rental grid point set according to the 10^{th} percentile of the rental housing distribution, and all other points overlapping with the owner-occupied housing grid. Specifically,

$$\begin{aligned}\mathcal{H} &= \{0.243, 0.373, 0.571, 0.874, 1.338, 2.048\} \\ \mathcal{B} &= \{0.098, 0.243, 0.373, 0.571\}\end{aligned}$$

Following Fernandez-Villaverde and Krueger (2011), the value of social housing is treated like a computational parameter and set to a level low enough so that it does not have a noticeable impact on the implications of the model, $\varpi = 0.00001$. The house depreciation rate, $\delta = 0.04$, and the house sales transaction cost, $\theta = 0.07$, are taken from the literature.

Values of second-stage parameters are reported in table 7. The discount factor is determined to match the average level of net worth of households, giving $\beta = 0.965$. The hazard rate of the moving shock is set to target the average moving rate of homeowners, yielding $\pi = 0.018$.[21] The parameters governing the utility premium due to home-ownership $\{\omega_j\}_{j=0}^2$ are chosen to match the model-implied age polynomial of home ownership rates with its empirical counterpart after controlling for time and cohort effects. The parameter governing the strength of bequests, ϑ_1, is set targeting the median net worth ratio of 50-80 year-old households. The luxuriousness of bequests parameter, ϑ_2, is calibrated to match the fraction of eighty year-old households in the bottom half of the net wealth distribution that are bequeathing a positive amount of wealth.

[21] Since our model abstracts from moving costs for renters, we do not target the average moving rate of renters. With respect to homeowners, the moving shock is necessary in order to add additional ownership risk, which remains even after retirement.

We feed in the cross-sectional distribution over short-term subjective house price growth expectations, income, assets and housing wealth as well as the demographic distribution directly from the data (see Section 5). To determine the second-stage parameters, we focus on the temporary equilibrium in the year 2004.

Targeted moments and corresponding model moments are reported in table 8. Notice that in our model we face a tension between the average bequest motive—to match home ownership rates—and the percent of households intending to bequeath in the bottom half of the net wealth distribution. The latter pushes net wealth up, the former pushes it down. For this reason, we do not achieve exact identification; calibrated data and model moments deviate from each other and the largest error concerns the deviation of average net wealth.

We relate long-term expectations elicited in the data by respondent (household) i to the same household's short-term expectations according to the relationship

$$\mathbb{E}_{i,t}(\pi^h_{t+10}) = \alpha_0 + \alpha_i + \beta_0 \mathbb{E}_{i,t}(\pi^h_{t+1}) + \beta_1 \pi^h_t \tag{9}$$

where α_i is a time-invariant household component, $\mathbb{E}_{i,t}(\pi^h_{t+10})$ is the household's long-term house price growth expectation and $\mathbb{E}_{i,t}(\pi^h_{t+1})$ is the household's short-term house-price growth expectation, respectively, and π^h_t is the realized house-price growth.

Table 5: Long-Term Expectations

	(1)	(2)	(3)	(4)	(5)
Constant	2.8422***	2.7566***	2.7918***	2.3357***	2.3333***
	(0.0499)	(0.0527)	(0.0556)	(0.5996)	(0.6062)
$E_{i,t}(\pi^h_{t+1})$		0.0976***	0.1255***	0.1129***	0.0883***
		(0.0141)	(0.0189)	(0.0246)	(0.0179)
House-Price Growth, π^h_t			-0.0343**	-0.0274*	
			(0.0135)	(0.0165)	
Household Fixed Effects	No	No	No	Yes	Yes
Observations	4741	4741	4741	4741	4741
R^2	0.0000	0.0146	0.0161	0.4182	0.4176

Notes: Independent variable is long-term expected house-price growth, in percent. House-price growth is in percent. Robust standard errors in parentheses with $^{*}p < 0.10, ^{**}p < 0.05, ^{***}p < 0.01$.
Source: Own calculations based on DNB Household Survey.

Results of the regression are contained in Table 5. As we observe from the table by comparing specifications (4) and (5), once controlling for household fixed effects, the realized house price growth π^h_t only has a relatively mild impact on long-term house price growth expectations and is estimated with low significance. The "reversion" coefficient between short-term and long-term house price growth expectations is about 0.1, which is estimated with a high degree of statistical significance. Based on these estimates we calibrate the probability to transit from a short- to a long-term expectations household to $\pi(e' = L \mid e = S) = 0.1$.

Expected short-term house-price growth expectations are essentially treated as a state variable. It is a continuous variable that is "discretized" on a grid with seven gridpoints.[22] To calculate the model-implied housing demand of a household with given short-term house price growth expectations $\mathbb{E}_{i,t}[\pi^h_{t+1}]$ from the survey, we linearly interpolate between gridpoints. Long-term house price growth expectations are instead restricted to be homogeneous at an expected long-term house price growth rate of 2%, which is the mode (and the median) of the distribution, cf. Figure **??**.

Table 6: First-Stage Parameters

Parameter	Interpretation	Value
	Demographics	
j	Period length in years	1
J	Length of life 80	55
jr	Retirement age 65	40
	Preferences	
σ	Weight on housing services	0.3
γ	Risk aversion	2
	Expectations	
$\mathbb{E}^i t[\Delta p_{t+1}]$	Short-term house price growth expectations	Data
Δ_L	Long-term house price growth expectations	Data
$\pi(e' = L \mid e = S)$	Expectations transition probability	0.1
	Income Process	
$\{g(j)\}$	Deterministic age profile polynomial	P(4)
ϱ	Replacement rate	0.85
ρ	Autocorrelation of persistent component	0.97
σ^2_ν	Variance of persistent shock	0.09
σ^2_ε	Variance of transitory shock	0.29
	Housing Sector	
p/q	Owner-occupied housing price	$1/0.07$
n_h	No. Owner-occupied house sizes	6
n_b	No. rental house sizes	4
ϖ	Value of social housing	0.00001
δ	House depreciation rate	0.04
θ	House sales transaction cost	0.07
	Financial Instruments	
r	Risk-free rate	0.03
ζ	Mortgage loan markup	0.01
λ_y	Maximum DTI ratio on mortgage loans	5
λ_h	Maximum LTV ratio on mortgage loans	0.90

Note: This table lists the parameters calibrated using only the data, as well as their economic interpretation and their value.
Source: Own calculations based on DNB Household Survey.

6.3 Life-Cycle Profiles

The life-cycle profiles of the baseline calibration are presented in figure 6. The takeaway from the top-left panel of the figure is that the model does a decent job in matching the data on homeownership rates and housing expenditures on owned housing.

[22] The values of the grid are $[-0.05, -0.03, 0.0, 0.02, 0.03, 0.05, 0.10]$.

Table 7: Second-Stage Parameters

Parameter	Interpretation	Targeted Moment	Value
β	Discount factor	Average net worth	0.965
ω_0	Additional utility from owning	Homeownership rate	-0.927
ω_1	Additional utility from owning	Polynomial coefficient 1	-0.030
ω_2	Additional utility from owning	Polynomial coefficient 2	-0.00005
ϑ_1	Strength of bequest motive	Median $NW_{j=80}$ / Median $NW_{j=50}$	1915.104
ϑ_2	Luxuriousness of bequests	Share of age 80 bequ. HH in bottom half of NW distr.	30.945
π	Moving shock hazard rate	Annual percent of moving homeowners	0.018

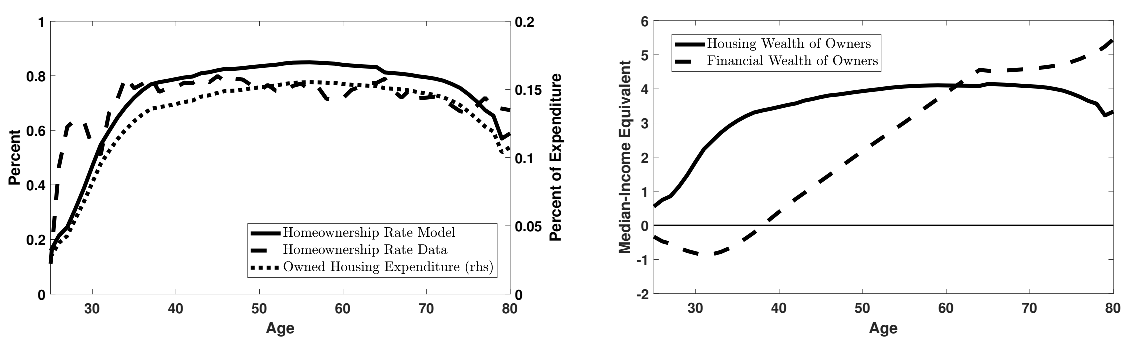
Note: This table lists the parameters calibrated using the model, as well as their economic interpretation, the empirical concept which they target, and their value.

Table 8: Calibration Targets and Model Moments

Targeted Moments	Data	Model
Average net worth	7.254	6.722
Homeownership rate	0.731	0.782
Polynomial coefficient 1	0.031	0.067
Polynomial coefficient 2	-0.0002	-0.0006
Median $NW_{j=80}$ / Median $NW_{j=50}$	1.391	1.320
Share of age 80 bequ. HH in bottom half of NW distr.	0.354	0.580
Annual percent of moving homeowners	0.019	0.018

Note: This table lists the moments targeted in calibration, as well as the values in the data and values implied by the model. Household assets are expressed in terms of median annual income.
Source: Own calculations based on DNB Household Survey.

Figure 6: Life-Cycle Profiles



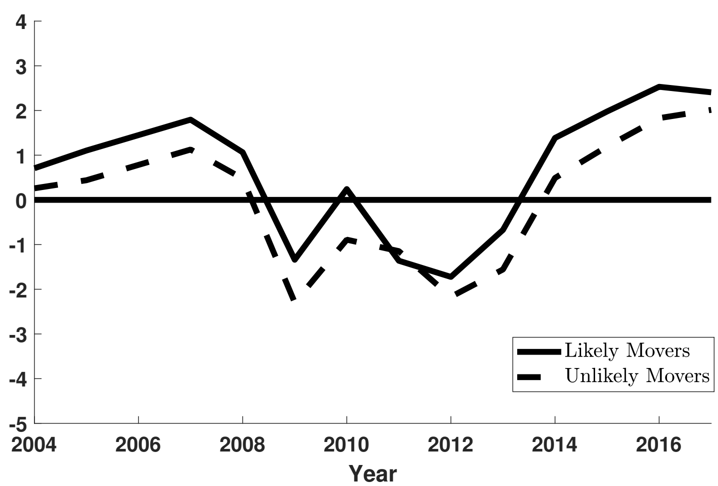
(a) Housing Expenditures and Homeownership Rate (b) Housing and Financial Wealth of Owners

Notes: This figure shows the model-implied age profiles for homeownership, owned hounding expenditures, housing wealth for owners, and financial wealth for owners. The empirical age profile for homeownership is also shown.
Source: Own calculations based on DNB Household Survey.

6.4 Likelihood of Moving

We compare the model's performance in terms of the likelihood of moving, as documented in section 3, cf. Figure 4. As we documented there, respondents (respectively, households) that hold higher house price growth expectations tend to move more likely. We investigate whether the model replicates this feature in the data. To this purpose, we run the same regression as in Section 3 on the model generated data to predict the likelihood of moving within the model for each household i. As in the data exercise we define households as likely movers for whom the predicted likelihood to move exceeds 2%. Importantly, these statistics were not directly targeted in the calibration. The result for all years is shown in Figure 7, where the same qualitative patterns as in the data exercise of Figure 4 emerge: Model households that hold higher house price growth expectations are more likely to move houses. The house price growth expectations gap between likely and unlikely movers, however, is somewhat more pronounced in the model than it is in the data.

Figure 7: House Price Growth Expectations by Likelihood of Moving, Model

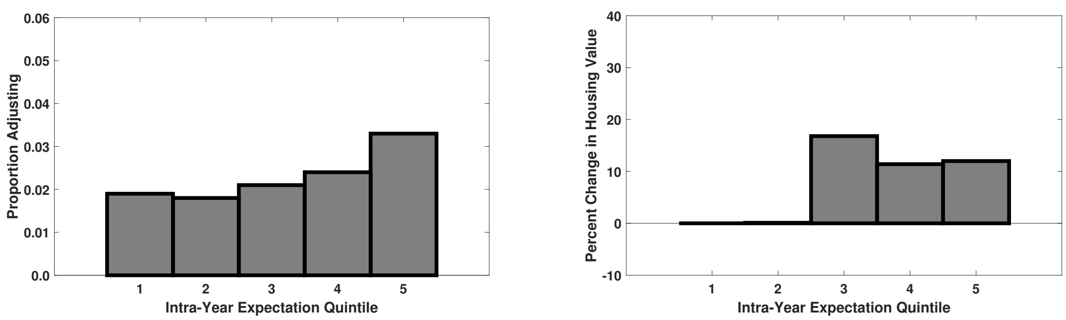


Notes: Likelihood of moving in percent. Likely movers identified as households with a likelihood of moving higher than 0.02. See Figure 4 for corresponding graph in the data.
Source: Own calculations based on DNB Household Survey.

6.5 Adjusting Households by Expectations Quintiles

It is further useful to compare the model's performance in terms of the adjustment behavior of households, as documented in Section 3, cf Figure 5. To this end, we present in Figure 8 the fraction of adjusting homeowners and the size of house-adjustment by expectation quintile. Again, these statistics were not directly targeted in the calibration. Nonetheless, the model does a fair job of replicating the main pattern identified in the data and is within an acceptable level of accuracy from a quantitative perspective. This lends some degree of external validation that the model adequately captures the mechanism at work in producing the empirical relationship between house-adjusting behavior and house price expectations.

Figure 8: Adjusting Households by Expectations Quintiles



(a) Fraction of Adjusting Households

(b) Size of Housing Adjustments

Notes: This figure shows the model-implied fraction of the home-owning population adjusting in Panel (a) and the size (in percent) of housing value adjustments conditional on owning a house in Panel (b) by short-term expectations quintile.
Source: Own calculations based on DNB Household Survey.

7 The Role of Heterogeneous House Price Growth Expectations for Equilibrium House Prices

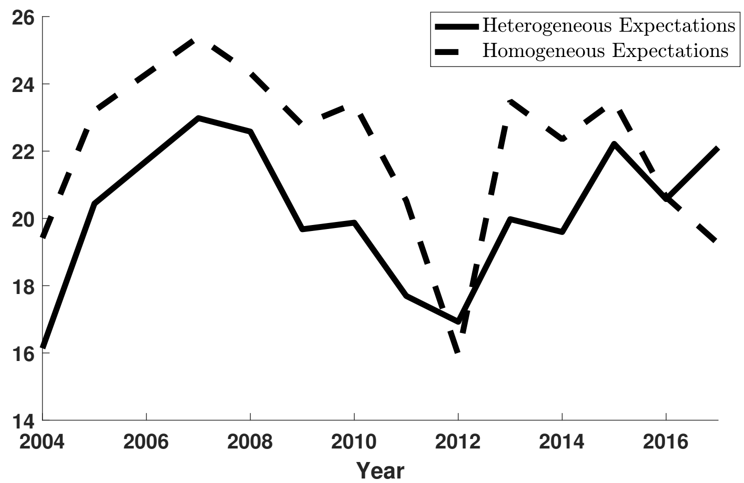
Our main objective is to investigate the effects of heterogenous house price growth expectations on the level and the dynamics of house prices. For this purpose, we evaluate the model first in its baseline specification with heterogeneous expectations as described in the previous section. That is, we feed into the model in each year t the measured house price growth expectations of household i for period $t+1$. We label this model as "heterogenous expectations". As an alternative model, we assume "homogeneous expectations". In this alternative calibration, we assume that in each period t the short-term house price growth expectations are equal to the average short-term house price growth expectations of the DNB survey respondents in that period, as shown in Figure 2. Thus, by construction, the cross-sectional average expectation is the same between the two versions of the model.

Figure 9 shows the time path of the equilibrium house price in the two model variants. We make two important observations. First, both model variants generate a house price boom until 2007, followed by a bust lasting until 2012, which is succeeded by another house price boom. This pattern is broadly consistent with the data, cf. Figure 2.[23] Second, the model with

[23] See the last paragraph of this section for a further discussion of the model fit to the data in the two variants of the model.

heterogenous house price growth expectations features a lower level of house prices, apart from in a trough year 2012, and a lower amplitude of house price fluctuations.

Figure 9: Owner-Occupied House Prices

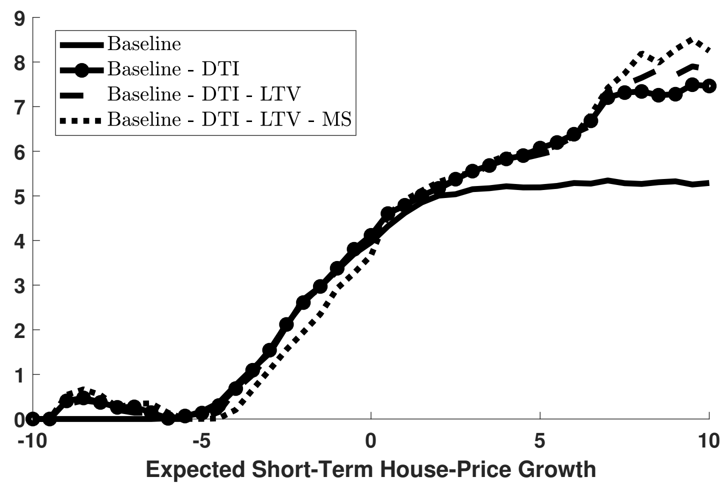


Notes: This figure shows the times series of the model-implied house price under heterogeneous expectations and homogeneous expectations. All expectations and state variables correspond to the data.
Source: Own calculations based on DNB Household Survey.

These findings on how the level and the dynamics of house prices are affected by heterogeneity in expectations may have many reasons. It could be that **[TBC]** We next demonstrate that the major reason is the convex-concave shape of housing demand in house price growth expectations.

We first show that housing demand is a convex-concave function of the short-term house price growth expectations. For this purpose we compute the average demand for houses for different values of short-term expectations by aggregating over all other state variables in the model. Results are shown in Figure 10. We observe that for households with house price growth expectations below -4%, demand for housing in the model is basically zero. Demand increases in house price growth expectations and, as conjectured above, beyond the convexity of housing demand in expectations for values of house price growth expectations around -4%, housing demand is a concave function in these short-term expectations. Households in the heterogeneous expectations version of the model that have high or low expectations might both experience a significant change in their expectations as a result of the homogenization, but the effect of this homogenization on their demand for housing will be asymmetric. As in our illustrative model of Section 2, if heterogeneous house price growth expectations of households are relatively low, then homogenization will reduce housing demand and thus equilibrium house prices. In contrast, if heterogeneous house price growth expectations are relatively high, then homogenization will increase housing demand thereby pushing equilibrium house prices up.

Figure 10: Concavity of Housing Demand in Expectations

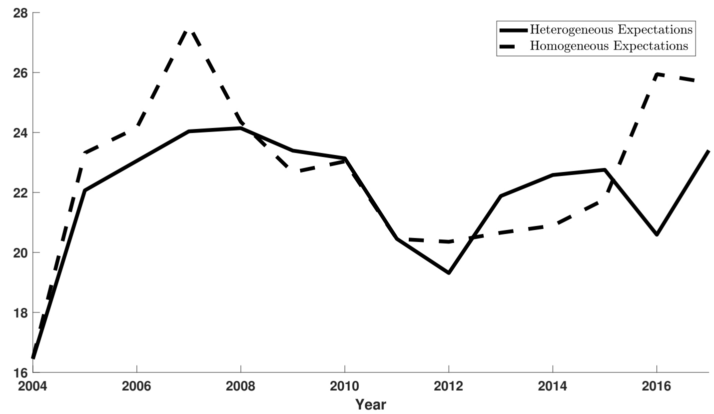


Notes: This figure shows the aggregate housing demand (in median income units) for home-owners by short-term expected house-price growth, in percent. The graphs represent the baseline model of Section 4 and three additional lines that cumulatively shut off the debt-to-income restriction, the loan-to-value restriction, and the moving shock.
Source: Own calculations based on DNB Household Survey.

To understand the source of the concavity, we next turn off various features of the model, the debt-to-income constraint (DTI), the loan-to-value constraint (LTV), and the moving shock (MS). With each model element switched off, the housing demand stays concave. However, switching off the DTI constraint, leads to a strong reduction in the concavity. Economically, households with very high house price growth expectations would like to buy very valuable houses on the market to the point where the DTI becomes binding, which suppresses demand relative to a model in which the DTI constraint does not apply.

We now further develop the implications of the concavity of housing demand as a function of house price growth expectations by computing the same sequences of temporary equilibria as in Figure 9 but with the DTI constraint switched off. Results shown in Figure 11 confirm the relevance of the concavity of demand in house price growth expectations driven by the DTI constraint. Without it, the level of house prices over the observation period in the heterogeneous and the homogenous expectations variants of the model are essentially the same, apart from in the boom years around 2007 and 2016. The reason is the approximate linearity of housing demand in short-term house price growth expectations above -4% in this exercise. As a consequence of this linearity, changes due to the reallocation of expectations—with high-expectation households in the heterogeneous model featuring lower expectations in the homogeneous model, and vice versa—are roughly canceled out throughout the cycle. The fact that the equilibrium house price is still higher in the boom years around 2007 and 2016 may be that housing demand is still somewhat concave for positive house price growth expectations and especially concave at very high house price growth expectations, cf. Figure 9. When households who already own a very large house have even higher house price growth expectations, their demand for housing does not increase. Relocating these expectations to households with lower house price growth expectations through homogenization will instead lead to an increase of housing demand.

Figure 11: House Prices without Debt-to-Income Constraint



Notes: This figure shows the times series of the model-implied house price under heterogeneous expectations and homogeneous expectations, whilst shutting off the debt-to-income restriction in both versions of the model. All expectations and state variables correspond to the data.
Source: Own calculations based on DNB Household Survey.

We finally investigate how close the model comes to matching the boom-bust-boom cycle shown in Figure 2. We centralize the sequence of house prices in model and data and compute two summary statistics on the basis of the centralized data. First, we define as the fit of the model of any variable ν—precisely, of house prices and rental rates—the sum norm of differences between model and data, $\sum_{t=t_0}^{T} \|\nu_t^{Data} - \nu_t^{TE}\|$. Second, we define as the amplitude the distance from the peak to the trough of the cycle. Table 9 presents the results. As the table shows, the model with heterogenous expectations brings us closer to the data and (the measure of fit is lowest for both the house price and the rental rate) and the model also generates a more reasonable amplitude than the other model variants. We also note that for both summary statistics (fit and amplitude) the model with constant (short-term) house price growth expectations better matches the data than the model with homogenous expectations.

TBC: delete fit, only present amplitude in the table. Rental rates raus. Also replace figure 10 again with the one including the outlier correction.

Table 9: Measure of Fit and Amplitude

		House Prices	
Measure	Data	Heterogeneous Expectations	Homogeneous Expectations
Fit	0.0000	1.1464	1.1097
Amplitude	0.2161	0.3393	0.4223
		Rental Rates	
Measure	Data	Heterogeneous Expectations	Homogeneous Expectations
Fit	0.0000	0.9736	1.1729
Amplitude	0.3173	0.2422	0.1219

Notes: We define the fit of variable ν as the sum norm of differences between model and data, $\sum_{t=t_0}^{T} \|\nu_t^{Data} - \nu_t^{TE}\|$. The amplitude is measured as the distance from the peak to the trough of the cycle.
Source: Own calculations based on DNB Household Survey.

8 Conclusion

We employ a structural model of household consumption and savings featuring a housing market with the availability of rental housing to study the influence of expectations on aggregate house prices in the recent boom-bust episode in the Netherlands. To do so, we measure expectations on real house price growth in survey data for the Netherlands and compute a sequence of temporary equilibria by feeding into the model the distribution of measured expectations jointly with the distribution of income and wealth. We find that over the Dutch 2004-2018 boom-bust-boom house price cycle, our model with measured generates a lower level of house prices than a model with homogeneous expectations. We show that this is due to the debt-to-income constraint which constrains households with high house price growth expectations in their housing demand. We further find that the model with heterogenous expectations gives a better fit to the dynamics of house prices than one with time varying homogenous or constant expectations.

Our finding on the relevance of the debt-to-income constraint suggests that the interaction between subjective house price growth expectations and institutional features of the housing market play a decisive role for equilibrium house prices. Since subjective house price growth expectations also move with the housing cycle, this finding may have important implications for the design of countercyclical regulatory housing market policies.

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Appendix

A Analytical Derivations in Two-Period Model

A.1 Problem, FOCs and CS

Household i lives for two periods and has preferences

$$u(c_0, c_1) = u(c_0) + \beta u(c_1),$$

where β is the discount factor and c consumption. The household is endowed with some initial assets $a_0 \geq 0$ and earns a fixed exogenous income of y in both periods. The household can invest either in a financial asset a at price $q \equiv \frac{1}{R}$ or housing h at price p_0 and has some initial endowment of the liquid asset a_0. The period budget constraints are

$$c_0 + qa_1 + p_0 h_1 = y + a_0, \qquad c_1 \leq a_1 + p_1^i h_1 + y$$

We assume that the household can not short housing, i.e. we have $h_1 \geq 0$. Moreover, we also have a debt to income (DTI) constraint

$$-a_1 \leq \gamma y = \Gamma.$$

Thus, in total there are 4 constraints: 2 period budget constraints, which we know will be binding and the following non-negativity and debt to income constraints:

1. $a_1 \geq -\gamma y$
2. $p_0 h_1 \geq 0$

Lagrangian

$$\begin{aligned} \mathcal{L} &= \max_{c_0, c_1, a_1, h_1} u(c_0) + \beta u(c_1) + \lambda_0[y + a_0 - c_0 - qa_1 - p_0 h_1] && (10) \\ &+ \lambda_1[y + a_1 + p_1^i h_1 - c_1] + \lambda_2[a_1 + \gamma y] + \lambda_3 p_0 h_1 && (11) \end{aligned}$$

FOCs

$$\begin{aligned}
c_0 &: \quad u'(c_0) = \lambda_0 && (12)\\
c_1 &: \quad \beta u'(c_1) = \lambda_1 && (13)\\
a_1 &: \quad -\lambda_0 q + \lambda_1 + \lambda_2 = 0 && (14)\\
h_1 &: \quad -\lambda_0 p_t + \lambda_1 p_1^i + \lambda_3 p_0 = 0 && (15)
\end{aligned}$$

Rearranging (14) and (15) and dividing the latter by p_0

$$\begin{aligned}
-\lambda_0 q + \lambda_1 &= -\lambda_2 && (16)\\
-\lambda_0 + \lambda_1 \frac{p_1^i}{p_t} &= -\lambda_3 && (17)
\end{aligned}$$

We know that budget constraints will bind and therefore λ_0 and λ_1 will be positive. Remaining CS conditions:

$$\begin{aligned}
\lambda_2 &: \quad \lambda_2[a_1 + \gamma y] = 0 && (18)\\
\lambda_3 &: \quad \lambda_3 p_0 h_1 = 0 && (19)
\end{aligned}$$

A.1.1 Solution

We have 4 cases to consider. Foreshadowing a bit the results, we will sort them according to first whether or not saving in the financial asset happen in equilibrium or not. This is essentially a condition relating the interest rate to endowments and the discount factor. The focus of our paper is on the effect of house price expectations, therefore we sort the cases then in increasing order of house price expectations. Since housing in this simplified model is essentially just a second asset, households demand no (a positive amount of) housing if they expect its return to be below (above) that of the financial asset.

Case 1: a_1 interior and $h_1 = 0$

Here $\lambda_2 = 0$ but $\lambda_3 > 0$ and $a_1 > -\gamma y$, $h_1 = 0$. Rewrite (16)

$$\lambda_0 = \frac{\lambda_1}{q} \tag{20}$$

into (17)

$$\begin{aligned} -\frac{\lambda_1}{q} + \lambda_1 \frac{p_1^i}{p_t} &= -\lambda_3 \\ \lambda_1 \left(-R + \Delta P_1^i\right) &= -\lambda_3 \end{aligned}$$

Sine the RHS is negative, it must be the case that

$$\Rightarrow R > \Delta P_1^i \tag{21}$$

Thus, if the return on financial assets exceeds the (expected) return on housing, the household invests only in the financial asset. (16) also implies Euler equation in terms of financial assets.

$$\begin{aligned} u'(c_0) = \beta R u'(c_1) \\ c_1 = \beta R c_0 \end{aligned} \tag{22}$$

where the latter follows from log utility. Use this in the present value budget constraint

$$c_0 + q c_1 = a_0 + (1+q) y$$

to obtain, after some transformations, the equilibrium consumption decisions

$$c_0 = \frac{1}{1+\beta} \left(a_0 + y\left(1+q\right)\right) \tag{23}$$

$$c_1 = \frac{\beta}{1+\beta} R \left(a_0 + y\right) + \frac{\beta}{1+\beta} y. \tag{24}$$

This solution requires $a_1 > -\gamma y$. Inserting the solution for c_0 into the period budget constraint (recall $h_1 = 0$) yields

$$\begin{aligned} a_1 &= R\left[y + a_0 - c_0\right] = R\left[y + a_0 - \frac{1}{1+\beta}\left(a_0 + y\left(1+q\right)\right)\right] \\ &= \frac{R}{1+\beta}\left[\beta(y + a_0) - q y\right] \end{aligned}$$

$$\begin{aligned} a_1 \geq -\gamma y \Leftrightarrow \frac{R}{1+\beta}\left[\beta(y+a_0) - q y\right] &\geq -\gamma y \\ \beta a_0 &\geq [-q(1+\beta)\gamma + q - \beta] y \\ a_0 &\geq \frac{1}{\beta}\left[-q(1+\beta)\gamma + q - \beta\right] y \end{aligned} \tag{25}$$

If $R\beta = 1$ and $\gamma = 0$, no borrowing allowed, this boils down to $a_0 \geq 0$ which is intuitive since $R\beta = 1$ implies perfect consumption smoothing and period incomes are identical. Savings in period 1 are only positive if initial wealth is positive. If (25) does not hold, savings would be at the lower bound $a_1 = -\gamma y$, which is analyzed in case 3 below. Condition (25) can also be written as a requirement on the interest rate

$$R \geq \frac{1-(1+\beta)\gamma}{\beta}\frac{y}{y+a_0}$$

Case 2: both interior

Suppose $\lambda_2 = \lambda_3 = 0$, i.e. $a_1 > -\gamma y$ and $h_1 > 0$, then (16) and (17) imply

$$\begin{aligned} -\lambda_0 q + \lambda_1 &= 0 && (26)\\ -\lambda_0 + \lambda_1 \frac{p_1^i}{p_t} &= 0 && (27)\\ &\Rightarrow \frac{1}{q} = \frac{p_1^i}{p_0} && (28)\\ &\Leftrightarrow R = \Delta P_1^i && (29) \end{aligned}$$

Thus, an interior solution where the household invests in both can only occur if the rate of returns are equal. In this case, consumptions are determined but portfolio choice is (within the bounds of the constraints) indeterminate. Euler equation is standard

$$u'(c_0) = \beta R u'(c_1) = \beta \Delta P_1^i u'(c_1) \tag{30}$$

Inserting this into the intertemporal budget constraint yields the same allocations for consumption as (23) and (24). Housing $h_1 > 0$ and financial assets $a_1 > -\gamma y$ on the other hand are indeterminate, only the sum of the two $a_1 + p_0 h_1$ is determinate. (25) is still the relevant requirement for the lower bound on initial wealth for this equilibrium to occur. For simplicity, we assume that the household invests only in the financial asset when the returns are equal so that housing demand is

$$h_1\left(R, \Delta P_1^i\right) = 0 \Leftrightarrow \Delta P_1^i \leq R \tag{31}$$

Case 3: both at lower constraint $h_1 = 0$ and $a_1 = -\gamma y$

Suppose $\lambda_2 > 0$ and $\lambda_3 > 0$, i.e. $h_1 = 0$ and $a_1 = -\gamma y$, then (16) and (17) become

$$\lambda_0 q = \lambda_1 + \lambda_2 \quad (32)$$
$$\lambda_0 = \lambda_1 \frac{p_1^i}{p_t} + \lambda_3 \quad (33)$$

Inserting marginal utilities, we get as Euler equations

$$u'(c_0) = \frac{1}{q}\beta u'(c_1) + \frac{\lambda_2}{q} \quad (34)$$
$$u'(c_0) = \frac{p_1^i}{p_t}\beta u'(c_1) + \lambda_3 \quad (35)$$

Since the last terms in both rows are positive and $c_0 = y + a_0 + \gamma y$ and $c_1 = y - R\gamma y$ implies that $u'(c_0) < u'(c_1)$, it must be that

$$\beta < \max\left[R, \Delta P_1^i\right] \quad (36)$$

From case 1, we know that in addition the initial wealth can not be too large, to be precise

$$a_0 < \frac{1}{\beta}[-q(1+\beta)\gamma + q - \beta]y \quad (37)$$

Since the returns are low and initial wealth not large, the household would like to borrow at the going rates in either the financial asset or housing but can't.

Case 4: h_1 interior but $a_1 = -\gamma y$

Suppose $\lambda_2 > 0$ but $\lambda_3 = 0$, i.e. $a_1 = -\gamma y$ and $0 < h_1$, then (17) implies

$$\lambda_0 = \lambda_1 \Delta P_1^i \quad (38)$$

combining with the FOCs for consumption, we get the Euler equation

$$u'(c_0) = \beta \Delta P_1^i u'(c_1) \quad (39)$$

with the return on housing as interest rate factor. This happens because (16) and (17) imply

$$\lambda_0 q = \lambda_1 + \lambda_2 \quad (40)$$
$$\lambda_0 \frac{p_t}{p_1^i} = \lambda_1 \quad (41)$$

Since $\lambda_2 > 0$ it must be that

$$\begin{aligned} q &< \frac{p_t}{p_1^i} && (42) \\ &\Rightarrow \Delta P_1^i > R, && (43) \end{aligned}$$

the return on housing exceeds the return on financial assets.

Since borrowing is at its maximum, let's first derive c_0, c_1 as a function of h_1:

$$c_0 = y + a_0 + q\gamma y - p_0 h_1 \quad (44)$$

$$c_1 = y - \gamma y + p_1^i h_1 \quad (45)$$

Inserting into EE with log utility

$$\begin{aligned} c_1 &= \beta \Delta P_1^i c_0 && (46) \\ y - \gamma y + p_1^i h_1 &= \beta \Delta P_1^i (y + a_0 + q\gamma y - p_0 h_1) && (47) \\ p_1^i h_1 + \beta \Delta P_1^i p_0 h_1 &= \beta \Delta P_1^i (y + a_0 + q\gamma y) - y + \gamma y && (48) \\ p_1^i h_1 &= \frac{1}{1+\beta} [\beta \Delta P_1^i (y + a_0 + q\gamma y) + (\gamma - 1) y] && (49) \\ h_1 &= \frac{1}{1+\beta} \left[\frac{1}{p_0} \beta (y + a_0 + q\gamma y) + \frac{1}{p_1^i} (\gamma - 1) y \right] && (50) \end{aligned}$$

$$h_1 = \frac{1}{p_0} \frac{1}{1+\beta} \left[\beta (y + a_0 + q\gamma y) - \frac{1}{\Delta P_1^i} (1 - \gamma) y \right] \quad (51)$$

This implies that

$$c_0 = y + a_0 + \gamma y - p_0 h_1 = y + a_0 + \gamma y - \frac{1}{1+\beta} \left[\beta (y + a_0 + q\gamma y) - \frac{1}{\Delta P_1^i} (1 - \gamma) y \right] \quad (52)$$

Now housing has to be positive, this requires the term in brackets in (51) to be positive

$$\beta (y + a_0 + q\gamma y) - \frac{1}{\Delta P_1^i} (1 - \gamma) y \geq 0 \quad (53)$$

which implies

$$\begin{aligned}
\beta(y + a_0 + q\gamma y) &\geq \frac{1}{\Delta P_1^i}(1-\gamma)y \\
a_0 &\geq \frac{(1-\gamma)}{\beta \Delta P_1^i} y - (1+q\gamma)y \\
a_0 &\geq \left[\frac{(1-\gamma)}{\beta \Delta P_1^i} - (1+q\gamma)\right] y \\
a_0 &\geq \left[\frac{(1-\gamma) - (1+q\gamma)\beta \Delta P_1^i}{\beta \Delta P_1^i}\right] y
\end{aligned} \tag{54}$$

(51) is also concave in house price expectations since (ignoring the constant in front)

$$\frac{\partial h}{\partial \Delta P_1^i} = -(-1)\frac{(1-\gamma)y}{[\Delta P_1^i]}^2 > 0 \tag{55}$$

and

$$\frac{\partial^2 h}{\partial (\Delta P_1^i)^2} = -2\frac{(1-\gamma)y}{[\Delta P_1^i]}^3 < 0 \tag{56}$$

B Data Description and Sources

All data is aggregated at the household level and defined in annual terms unless otherwise stated. The main sample is from 2004 to 2017; The year 2004 is the first year in which questions on households' expectations of house prices were included in the sample. Households with negative net worth are dropped from the sample. The sample is further selected by dropping the bottom and top one percent of all expectations questions in order to eliminate extreme values. The household responses on the year in which the current accommodation was purchased and the year in which it was moved into underwent an error-correction phase to ensure they are weekly increasing and complete for the period of household participation; when the correct response is not obvious the observation has been dropped. Regarding the temporary equilibrium simulations, only households for which there is data on all state variables and who participated in at least two surveys are included in the analysis.

- Short-term Market House Price Expectations: Expected average change in house prices in the next two years; in annual percent. Source: DNB Household Survey (WOD205,WOD206, WOD44P,WOD44Q).

- Long-term House Price Expectations: Expected average increase in house prices over a period of ten years; in annual percent. Source: DNB Household Survey (WOD207,WOD44RA).

- Consumer Price Expectations: Expected change in consumer prices over the next twelve months; in annual percent. Source: DNB Household Survey (PR0,PR1a,PR2a,PR3a,PR4a).
- Net income: Total net income minus income from interest and real estate income; specified in thousands of 2002 euros. Source: DNB Household Survey.
- Assets: Total assets excluding primary owned house; specified in thousands of 2002 euros. Source: DNB Household Survey.
- Housing: Value of primary owned house; specified in thousands of 2002 euros. Source: DNB Household Survey.
- Mortgage: Total value outstanding mortgages; specified in thousands of 2002 euros. Source: DNB Household Survey.
- Rent: Total rental expenditure; specified in thousands of 2002 euros. Source: DNB Household Survey (WOD205,WOD206).
- Age: Age of the household head. Source: DNB Household Survey.
- Household size: Number of household members. Source: DNB Household Survey.
- College: Dummy variable indicating if head of household has attended college. Source: DNB Household Survey.
- Retired: Dummy variable indicating if head of household is retired. Source: DNB Household Survey.
- Rural: Dummy variable indicating if household is in a rural region. Source: DNB Household Survey.
- Province: Variable denoting the province where the household is located. Source: DNB Household Survey.
- Home Adjustment Indicator: Dummy variable indicating if the household moved in the period; it is constructed using the variables indicating when the current accommodation was purchased or moved into. Source: DNB Household Survey.
- House Prices: Price index for housing in the Netherlands. Source: ECB's *Statistical Data Warehouse*.