Housing Consumption and Bubble Size

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Abstract

This paper identifies a novel determinant of the magnitude of house price bubbles: the demand for housing consumption. We provide a theoretical framework and investigate the role of this factor with an innovative experimental design that allows modeling of the consumption side and the investment side of housing. The overlapping generation structure, as well as the endogenous nature of the dividend (rental income) and, thus, the endogenous fundamental value of the housing asset make our experimental design a credible framework for studying house price bubbles. The results show that the lower the demand for housing consumption, the smaller the fundamental value of housing and the larger the size of the house price bubble.

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1 Introduction

House price fluctuations have a substantial impact on economic performance. Empirical studies show that recessions associated with house price busts are not only twice as long but also twice as deep compared to normal recessions or recessions associated with equity price busts (Claessens et al. (2012); Claessens et al. (2009); IMF (2003)). Understanding which factors determine the magnitude of housing bubbles is therefore essential. In this paper, we investigate whether the consumption side of the housing asset is a driving factor for the house price bubble size.[1]

Housing is a particular asset given its dual nature. The housing asset has a consumption side (it provides housing services) and an investment side. Conceptually, it is crucial to separate the consumption from the investment side as housing consumption and housing investment combine to determine housing market outcomes. Both housing investment and housing consumption are economically important from a household perspective. Typically, investing in a housing asset constitutes the most significant investment of a household within its lifetime. Households consume housing services independently of whether they own or rent the property they are living in. The larger the property and/or the better its quality, the more housing services are consumed and the higher the utility from housing consumption. Housing consumption constitutes the single-highest household expenditure item in all OECD and EU countries (Eurostat, 2020). However, the relative importance of housing consumption varies however greatly across countries.

We shed new light on the role of housing consumption as a potential determinant of the magnitude of house price bubbles by testing Huber (2018)'s model prediction empirically. Comparative statics show that a weak (strong) preferences for housing services relative to other consumption goods lead to a low (high) demand for housing consumption, resulting in a low (high) share of consumption expenditure being spent on housing consumption as a model equilibrium outcome. Consequently, the dividend of the housing asset (i.e., price for housing services) and the fundamental value (FV) are expected to be smaller the weaker the preference for housing services. This in turn has crucial implications for the maximum bubble size: In equilibrium, every asset needs to be affordable. It follows from the resource constraint of the economy that an economy with a weak aggregate preference for housing services will have more room for larger bubbles.

The theoretical prediction that the demand for housing consumption (relative to other

[1] Throughout the paper, we use "housing consumption" and "housing services" interchangeably. If not noted otherwise, we refer to "bubbles" as the differences between the trading price and the fundamental value of the asset (i.e., overpricing).

consumption goods) is a driving factor for the magnitude of housing bubbles needs to be validated empirically. In a cross-country comparison and over the period of 1970–2019, Huber (2018) shows for a sample of 18 OECD countries that countries characterized by lower housing consumption experience bubbles of significantly larger magnitude.[2] While this observational data has the advantage of providing realistic, real–world information, this data also has its limitations due to measurement problems and allows only for a correlational interpretation.[3] A laboratory experiment can overcome both the measurement issues and the data limitations: In the lab, housing services, the fundamental value and traded house prices are known. Hence, one key advantage is that the bubble size can be measured without error. Further, the controlled environment allows us to establish a causal relationship.

To test the hypothesis that the demand for housing consumption (relative to other consumption goods) is a driving factor for the magnitude of housing bubbles, two treatments are implemented—one with a weak preference for housing services and one with a strong preference for housing services relative to other consumption goods. The weak and the strong preferences for housing services are randomly and exogenously induced across sessions by varying the corresponding parameter in the household's utility function. The key parameter, the preference for housing services, is calibrated to match the observational data (CPI weight on housing services, incl. imputed rents).

The design of the laboratory experiment is closely related to the overlapping generation (OLG) model of rational housing bubbles of Huber (2018), which extends the framework of Galí (2014). Following the main model features, the investment and consumption side of the housing asset is explicitly (and separately) modeled. Households live for two periods in the

[2]Housing consumption is measured by the CPI weight on housing services, including imputed rents. This aggregate indicator presents information on the final consumption expenditure of households on housing (incl. side costs such as water, electricity, gas, and other fuels), as a percentage of their overall final consumption expenditure. This indicator highlights the relative importance of housing-related expenditures within consumer spending and facilitates comparison with other household budget items across countries. In 2019, the country with the lowest relative housing expenditure was Malta, with 12% of overall household consumption expenditure on housing. In other countries (e.g., Finland), housing consumption constitutes over a quarter of overall household consumption expenditure (OECD, 2021). Huber (2018) measures bubbles by independent house price booms (and boom–bust cycles).

[3]The measurement of house price bubbles using observational data is prone to measurement errors. A further challenge is measuring the quantity and quality of housing consumption (housing services): Cross-country data on average size (square meters) and housing quality is scarce. See Piazzesi et al. (2007) for a more in-depth discussion. For example, the NIPA real housing quantities only reflect one input into the production of housing services and are often criticized for being grossly mismeasured. Similarly, Ozimek (2014) challenges the measure of housing services provided by the Bureau of Labor Statistics (the CPI weight on housing services) due to their method for measuring imputed rents. In addition, conclusions on the causal effect cannot be easily drawn because of, among others, omitted variable problems.

experimental setup and, in each period, young and old households exist. Households decide how much *housing services* and how much of all other consumption goods to consume, how much to invest in the *housing asset*, and how much to save in riskless bonds.[4] In the subsequent period, households receive the return from their housing investment and savings. The dividend from investing in the housing asset is given by the rental income the house generates (which is determined by the current demand for housing services). As standard in the asset price literature, we define the fundamental value of a housing asset by the expected discounted flow of future dividends that the asset generates. Hence, the demand for housing consumption determines both the dividend and the fundamental value of the housing asset *endogenously*.

Our results confirm that housing bubbles are substantially and significantly larger in an economy with a weaker preference for housing services and, consequently, higher relative demand for housing services. This result holds for a wide range of bubble measures and the price–to–rent ratio. Our results survive a number of robustness checks; among them alternative explanations for housing bubbles such as liquidity constraints and differences in cash-to-asset ratios: The significantly larger bubbles in the treatment with a weak preference for housing services are driven by the endogenously resulting differences in both the dividend and fundamental value of the housing asset. We therefore can conclude that preferences and thereby demand for housing services relative to other consumption goods causally and negatively affect the size of housing bubbles and that they do so through the fundamental value.

Our study contributes to the existing literature on housing markets in three ways. First, this study highlights a novel factor that may determine the size of house price bubbles: the consumption side of housing assets.[5] This 'consumption channel' is universally valid as long as the asset under consideration is a consumption good at the same time. Examples of other assets that entail a consumption and an investment side include artwork, classic cars, and jewelry. However, the consumption channel for bubble formation is arguably most relevant for the housing asset, given that housing consumption expenditure constitutes the largest consumption expenditure share for most economies in the world. The existing theoretical and empirical literature focuses exclusively on the investment side of housing

[4] In our context, consuming housing services when young can be best understood in terms of renting the housing asset.

[5] Studying the impact of the consumption side of the house price bubble size is different from investigating the effect of an asset on aggregate consumption. Crockett et al. (2018) and Fenig et al. (2018) show experimentally that investing in an asset allows the transfer of resources from one period to the next (consumption smoothing). In our environment, the asset itself provides consumption utility to individuals, and we investigate its impact on the size of bubbles.

and shows that intensive housing investment (e.g., measured by turnover rates) is often associated with the emergence of housing bubbles.[6] The literature thereby establishes two key determinants for house price fluctuations; mortgage market conditions and housing supply play a key role for the magnitude of housing booms and busts.[7]

Second, this paper—one of the first laboratory experiments regarding housing markets—contributes to the experimental (housing market) literature on bubble formation by pointing towards a novel channel, namely the consumption side of the asset. To our knowledge, Ikromov and Yavas (2012) and Bao and Hommes (2019) are the only experimental studies that analyze housing market features and their impact on house price bubbles. Both studies ignore the consumption side of housing, and focus on channels for house price formation that work either through the demand for housing investment or through housing supply. Ikromov and Yavas (2012) find that transaction costs and the divisibility of assets reduce the magnitude of experimental housing bubbles. Bao and Hommes (2019) show that an increase in the housing supply elasticity may stabilize speculative asset bubbles. Our paper also contributes to the vast experimental asset market literature on bubble formation. The seminal paper of Smith et al. (1988), is characterized by a finite horizon with an exogenous and decreasing FV over time. Several follow-up studies replicate and modify the experimental setting in Smith et al. (1988) to study different drivers of bubble formation. Examples include experiments that study the impact on bubble formation of: short-selling restrictions; transaction costs; and the divisibility of assets; future markets; cash availability in the economy; the nature of the fundamental value (constant versus decreasing or increasing); the impact of experience; confusion and certainty about the dividend process.[8] These studies assume that the asset is a pure investment good, ignoring that some assets, particularly housing, have an additional consumption side.

Third, we contribute methodologically to the experimental asset market literature. Our design provides a framework in which both a market for the traded asset (the house) and a market for the dividend of that traded asset (the price of housing services) exist. In the related literature, most experiments assume an exogenous dividend for the traded asset (e.g., Marimon and Sunder (1993); Noussair et al. (2001); Ikromov and Yavas (2012)). No-

[6] The strong relationship between prices and turnover rates was first illustrated by Stein (1995). Leung (2004), Andrew and Meen (2003), Hort (2000), and Berkovec and Goodman (1996) confirmed this result. Nowadays, policy makers use turnover rates as a warning indicator for bubble formation.

[7] Local and global credit aggregates, short- and long-term interest rates matter for house price fluctuations (Claessens et al. (2009); Agnello and Schuknecht (2011); Igan and Loungani (2012)).

[8] See for example Porter and Smith (1995), Smith et al. (2000), Noussair and Tucker (2016), Noussair et al. (2001), Dufwenberg et al. (2005), Haruvy and Noussair (2006), Lei and Vesely (2009), Kirchler et al. (2012), Ikromov and Yavas (2012), or Weitzel et al. (2019). For a literature review, see chapters 29–30 of Plott and Smith (2008).

table exceptions are Jaworski and Kimbrough (2016), Weber et al. (2018), and Bao et al. (2018). Unlike these studies, in our design the dividend of the bubbly asset is determined endogenously by the demand of the *market* participants. The preferences for housing services and thus the demand for housing consumption determine the dividend of the housing asset, and hence the fundamental value of the housing asset, endogenously. The endogenous, *market*-driven dividend is a crucial and novel feature for the analysis of experimental (housing) bubbles in asset markets. Beyond this endogeneity aspect, a special feature of our model-based design is that it allows for rational bubbles. Most asset market experiments use finite horizon environments, and hence rational theoretical bubbles are ruled out by construction.[9] Furthermore, the OLG structure allows interesting potential extensions for future research, namely, analysis of housing market interventions and changes in population dynamics.

The remainder of the paper is structured as follows: Section 2 summarizes the OLG model. Section 3 describes the design and implementation of the lab experiment as well as the treatments and the hypotheses. Section 4 explains how we measure experimental bubbles and presents the results. We also discuss potential alternative explanations for our key result and address them with corresponding robustness checks. Section 5 concludes.

2 The OLG Model

The model of Huber (2018) builds on Galí (2014), and provides an explanation of why countries with a *lower* preference for housing services experienced significantly *larger* housing bubbles during 1970–2019. We take the model framework to the laboratory and provide empirical evidence for the causal impact of the preference for housing services on the bubble size. In this section, we first illustrate the underlying mechanisms driving the theoretical result intuitively. Second, we briefly present the relevant model ingredients using simplified notation. Finally, we highlight three model predictions that we test in the laboratory.

2.1 Illustration of the Model Mechanism

Suppose that total consumption in an economy can be divided into two categories: Housing consumption, hence housing services, S, and all other types of consumption, C. Households consume housing services independent of whether they own or rent the house they live in. The larger the house and the better the quality, the more housing services a household con-

[9] Our experimental design draws upon seminal theoretical work on rational bubbles by Samuelson (1958) and Tirole (1985) and is based on an overlapping generations structure.

sumes. Further, suppose that there are two identical countries: country *High* and country *Low*. These two countries differ in one aspect only—which is the aggregate preference for housing services relative to other consumption goods. Households in country *High* have a stronger preference for housing services relative to other consumption goods. One can think of this as a country full of individuals who want to live in big and/or high-quality houses, but do not care if they can go to restaurants or the theatre very often. Hence the relative demand for housing services is strong in country *High*. This leads to a high price of housing services relative to other consumption goods in country *High*, and hence a larger consumption expenditure share is spent on housing services. In contrast, in country *Low*, households do not care that much about housing services because they prefer other types of consumption goods. The demand for housing services is low. And hence the price for housing services relative to other consumption goods as well as the consumption expenditure share spent on housing services is lower in country *Low*.[10]

This has important implications for the FV of the housing stock in each economy. Suppose that the FV of an asset is calculated by the expected discounted stream of dividends that the asset generates. What is the dividend of a housing asset? It is the rental income that a housing asset could generate, hence the price of housing services. Thus, the FV is the expected discounted stream of the price of housing services. It follows that in country *High*, where the aggregate preference for housing services is stronger and the relative price for housing services is higher, the FV of the housing stock will thus be higher as well—compared to country *Low*.

This in turn has crucial implications for the maximum bubble size: In equilibrium, every asset needs to be affordable. It follows from the resource constraint of the economy that country *High*, where the FV of the housing stock is larger, will only have room for smaller bubbles. In country *Low*, where the FV of the housing stock is lower, there is room for larger bubbles. These predictions will be discussed more formally in Section 2.3.

2.2 Model Setup

In this exposition we focus on the household sector, as subjects play the role of households in the experiment. Without loss of generality, we simplify the notation and explain the differences to allow the reader to go back and forth between the full-fetched model and the simplified version implemented in the laboratory. The model is based on an overlapping

[10] Observational data shows that the aggregate consumption expenditure shares spent on housing services vary a lot across countries (e.g., OECD and Eurostat). The aggregate expenditure on housing services is calculated as the sum of actual rents (what the renters pay) and the imputed rents (the rent homeowners would pay would they rent the house they are living in).

generations structure, where a continuum of households lives for two periods (*young* and *old*). The size of each generation (*young* and *old*) is normalized to unity. In each period, a *young* and an *old* generation exist; the total population thus remains constant. Households born at time t maximize the expected utility over the lifecycle

$$u(C_{y,t}) + \xi^k v(S_t) + \gamma E_t\{u(C_{o,t+1})\}, \tag{2.1}$$

where $C_{y,t}$ and $C_{o,t+1}$ denote the consumption level of the non-durable composite consumption good in period t when *young* and in period $t+1$ when *old*. Consuming housing stock of size S_t yields housing service utility $v(S_t)$. The preference for housing services in country k relative to *all other* consumption when *young* $C_{y,t}$ is denoted by ξ^k. The discount factor is denoted by γ and $u(\cdot) = v(\cdot) = log(\cdot)$.[11]

Young households receive an endowment E_t, which they allocate between consuming the bundle $C_{y,t}$, consuming housing services of size S_t, investing in housing assets of size H_t, and investing in a one-period riskless bond of value Z_t; see Equation (2.2).[12] Investing in housing assets is equivalent to purchasing housing stock of size H_t. The return on bond investments, Z_t, is given by the interest rate R_t.

The dual motives of housing are disentangled by modeling the consumption aspect (consuming housing services S_t) and the investment aspect (investing in housing assets H_t) separately. This assumption distinguishes this model from existing models of rational housing bubbles and allows to isolate the impact of the demand for housing services on the house price bubble size. This model provides the simplest framework to investigate the research question—does the demand for housing consumption drive the size of housing bubbles? All *young* households consume housing services S_t by renting housing stock from the *old* generation, and invest in housing by buying housing stock H_t from the *old* generation. We thus do not distinguish explicitly between renters and homeowners.[13] Given

[11]Housing services and *all other* composite consumption goods are assumed to be separable (as e.g., in Iacoviello (2005)). The log specification over S and C is based on findings of Davis and Ortalo-Magne (2011), who show that the expenditure share on housing services is constant (over time and across US cities). Also, Huber (2018) finds for a sample of 18 OECD countries that cross-country differences in consumption expenditure shares on housing services are constant over time.

[12]The full-fledged model of Huber (2018) follows Galí (2014), where firms produce the composite consumption good under the assumption that *young* households supply their labor services inelastically for a wage W_t. In both models, the "financial wealth" of the *young* consists of two elements: the wage W_t and an endowment U_t (that follows an exogenous i.i.d stochastic process), hence $E_t = W_t + U_t$. In the experiment we are interested in comparative statics of the deterministic steady state, hence the model boils down to an endowment economy, where households receive a constant endowment $E = W + U$ at the beginning of the lifecycle.

[13]Theoretically, the model allows for the possibility that some households consume more housing than they own $S > H$ (i.e, they would be renters and landlords at the same time—renting a larger property to live in while investing/renting out a smaller housing asset). Or vice-versa, they may

our research question, such a differentiation is not of interest and also in the real–world households consume housing services independently of whether they own or rent the house they are living in.[14]

Investing in the housing asset H_t yields a dividend payment in the subsequent period—a rental income when *old*. Before *old* households die, they sell their housing stock to the new *young* generation. The budget constraint of the *young* household at time t is given by

$$P_t C_{y,t} + P_t^r S_t + Q_t H_t + Z_t \leq E_t, \tag{2.2}$$

where P_t denotes the price of the composite consumption good and P_t^r the price for housing services. The purchasing price of one unit of housing stock is denoted by Q_t, and is defined as a sum of the fundamental part FV_t and a bubble component B_t:

$$Q_t \equiv FV_t + B_t, \tag{2.3}$$

where the fundamental part is defined as the expected discounted stream of dividends (rental income) the housing asset H_t generates:

$$FV_t \equiv E_t \left\{ \sum_{j=1}^{\infty} \left(\frac{1-\delta}{R_{t+j}} \right)^j P_{t+j}^r \right\}. \tag{2.4}$$

The budget constraint when *old* is given by Equation (2.5). By purchasing the consumption bundle $C_{o,t+1}$, the *old* household consumes all its financial wealth. The *old* household's wealth consists of (1) the rental income from renting its housing stock to the *young* generation $P_{t+1}^r H_t$, (2) the reselling value of its housing stock $Q_{t+1} H_t$, and (3) the payoff from its maturing bond holding $R_t Z_t$. Formally, for each *old* household we have

$$P_{t+1} C_{o,t+1} \leq (1-\delta) \left(P_{t+1}^r + Q_{t+1} \right) H_t + R_t Z_t. \tag{2.5}$$

Equation (2.5) shows that the value of the housing asset depreciates by the fraction $\delta \in [0, 1)$ at the end of each period. However, this depreciation is compensated by the endowment of the *young* such that the total value of the housing stock in the economy remains constant.[15] To implement the original model in the laboratory, we make one

consume less housing than they own $S < H$ (i.e., they would be homeowners and landlords—living in and hence consuming housing of size S and being landlord of the remaining fraction $H - S$).

[14]The motivation to not distinguish between renting and owning goes back to Henderson and Ioannides (1983): "[...]before the introduction of institutional considerations there is no reason for people to actually owner-occupy their consumption–investment demands, as opposed to being landlords of their asset holdings and renting their consumption demand from some other landlords".

[15]When born in t, *young* households receive an endowment E_t. A part of this endowment is

additional assumption: the dividend payment that the *old* household receives is also subject to depreciation. Note that this modification does not change the model's qualitative predictions. However, this assumption leads to a simplified FV_t calculation as shown in (2.4)—which is equal to the implemented FV_t calculation in the experiment where we have an indefinite horizon by construction. In the experiment, we assume a constant continuation probability $(1-x)$ and no depreciation of the housing which leads to an identical FV_t calculation; i.e., $FV_t \equiv E_t \left\{ \sum_{j=1}^{\infty} \left(\frac{1-x}{R_{t+j}} \right)^j P^r_{t+j} \right\}$.[16]

2.3 Model Predictions

This section presents the model predictions that result from comparative statics of the steady state when varying the model parameter of interest ξ. We test these model predictions in the laboratory experiment. Comparative statics of the steady state show that an increase in ξ (capturing a rise in households' preference for housing services relative to other consumption goods) induces an *intra*-temporal reallocation: a substitution from other consumption goods C_y toward housing services S when *young*. This leads to an increase in the consumption expenditure share spent on housing services S and to a decrease in the consumption expenditure share spent on other consumption goods C_y when *young*[17]:

$$\begin{aligned} \text{Share}_S &= \frac{\text{spending on housing services S}}{\text{total spending on consumption}} \\ &= \frac{P^r_t S_t}{P^r_t S_t + P_t C_{y,t}} = \frac{\xi}{1+\xi}, \end{aligned} \tag{2.6}$$

This change in the consumption composition (i.e., consumption expenditure shares) is also reflected in the relative price $p^r_t = P^r_t / P_t$, the price for housing services relative to other consumption goods. The increase in the demand for housing services S_t leads to a higher absolute P^r_t and relative price p^r_t. It follows that the fundamental value FV_t, the expected discounted stream of the price for housing services, increases.

Prediction 1: *The Absolute Bubble Size B_t decreases in ξ.* In equilibrium it must hold

equal to the value of δ units of housing stock, whose price is $Q_t > 0$. Formally, $U_t = \delta Q_t H_t$.

[16]Hence, the actual discount factor $[(1-x)/R_{t+j}]^j$ is identical with $\delta = x$. Note that the assumption of a zero depreciation rate in the experiment comes without loss of generality, but simplifies the information subjects need to process. With a positive depreciation rate, the actual discount factor in the experiment would be given by $[(1-\phi)/R_{t+j}]^j$, where $\phi \equiv \delta + x$.

[17]$\text{Share}_C = \frac{\text{spending on C}}{\text{total spending on consumption}} = \frac{1}{1+\xi}$; note that these shares are equal to CPI weights. The official CPI weight on housing services of a country includes both, the spending on housing services of renters (the actual rent they pay) and the spending on housing services of homeowners (the imputed rent, what they would pay if they would rent the house they are living in).

that

$$B_t \in [0,\ E - FV_t] \quad \forall \quad t. \tag{2.7}$$

Equation (2.7) states the condition for bubble existence and the theoretical upper bound for the housing bubble defined by overpricing of the housing stock $Q_t - FV_t$. This condition is derived from the budget constraint of the *young*, Equation (2.2). The larger the preference for housing services, the larger the fundamental value FV_t of the housing stock today ($\partial FV_t/\partial\xi > 0$). It follows from Equation (2.7), that the theoretical maximum of the aggregate bubble size is smaller; i.e. ($\partial B_t/\partial\xi < 0$). In other words, countries that are characterized by a larger fundamental value of real estate (potentially because the demand for housing consumption is stronger) have less room for large bubbles—that is to say, cannot experience large bubbles—compared to countries where the fundamental value of real estate is lower (i.e., the demand for housing consumption is weaker).

Prediction 2: *The Relative Bubble Size B_t/FV_t decreases in ξ.* The model predicts that the realized relative bubble size B_t/FV_t, that is the overpricing $Q_t - FV_t$ divided by the fundamental value FV_t, is larger the weaker the preference for housing services relative to other consumption goods ξ, i.e. ($\partial(B_t/FV_t)/\partial\xi < 0$).

Prediction 3: *The Price–to–Rent Ratio PRR_t decreases in ξ.* In reality, it is challenging to detect a housing bubble $B_t = Q_t - FV_t$ given the difficulty of measuring the fundamental value FV_t of a housing asset correctly. In policy and public debates, the price–to–rent ratio is often referred to as an indicator to detect whether housing markets are fairly valued, or in a "bubble." This indicator is provided to the public on a country–level, but also for large cities. For example the UBS Global Real Estate Bubble Index uses this metric to determine which cities are at the greatest risk of a bubble—the higher the PRR, the greater the risk. In the model, the PRR is given by Q_t/P_t^r and decreases in ξ, i.e. ($\partial PRR_t/\partial\xi < 0$).

3 Experimental Design

This section describes how we take the OLG model to the laboratory. First, we present the treatments. Second, we explain the decisions that subjects, who assume the role of households, make in a lifecycle. Third, we describe the assignment to markets and the overall structure of the experiment. Finally, we present the procedure and the subject pool. The instructions—including the decision screens—are provided in Appendix D.

3.1 Treatment Variation and Calibration

In order to test the aforementioned predictions, we implement the following two treatments in a between-subject design (subjects are randomly assigned to either treatment):

Treatment ($\xi = 2$)**.** *Households have weak preferences for housing services (low ξ). The utility from consuming housing services S relative to the consumption good C is low.*

Treatment ($\xi = 6$)**.** *Households have strong preferences for housing services (high ξ). The utility from consuming housing services S relative to the consumption good C is high.*

In the model, the preference parameter ξ determines the consumption expenditure spent on housing services as a fraction of the total consumption expenditure in equilibrium, see Equation (2.6). Hence, we can calibrate the parameter ξ using observational data for the housing services expenditure shares. These shares vary from 12% to 30% (sample of 18 OECD countries).[18] The implied parameter ξ is roughly three times larger for countries with the highest expenditure share compared to countries with the lowest expenditure share. In our experiment, we match this relative difference in magnitude of parameter ξ. In the treatment ($\xi = 6$), the preference parameter ξ is three times larger than in the treatment ($\xi = 2$). Appendix Table A1 summarizes the remaining parameter choices.

3.2 Decisions in a Lifecycle (Young and Old)

The seminal OLG laboratory experiment is that of Marimon and Sunder (1993)—who address questions of equilibrium selection and sunspots in the presence of multiple equilibria.[19] In our overlapping generation design, a household's lifecycle consists of two periods (*young* and *old*) and each subject in the experiment assumes the role of a household: In the first period, subjects make decisions as a *young* household. In the second period, subjects make decisions as an *old* household and receive payments that are based on their decisions when *young* and *old*, as well as aggregate outcomes. Figure 1 shows the lifecycle and the transactions that take place when *young* and *old*.

[18] Rewriting Equation (2.6) gives $\xi = Share_S/(1 - Share_S)$, the parameter ξ is uniquely pinned down for each country. Appendix Table shows the observational country data for $Share_S$.

[19] Our experimental design differs in three aspects. First and as Camera et al. (2003), we use a continuous double auction design. Second, we construct 'generations' by randomly assigning subjects to one of two markets after each life cycle instead of having them wait to be reassigned to participate in the one market. Third, only one randomly chosen lifecycle forms the basis of payments. To implement an infinite time horizon in the laboratory, we follow Crockett et al. (2018) and implement an indefinite horizon. These features are discussed in detail in this section. Other OLG laboratory experiments include: Lim et al. (1994) to study price dynamics and the use of money as a store of value, Bernasconi and Kirchkamp (2000) to investigate how inflation is determined by monetary policy and average savings, and Camera et al. (2003) to study characteristics of economies that encourage the use of fiat money (a dominated asset).

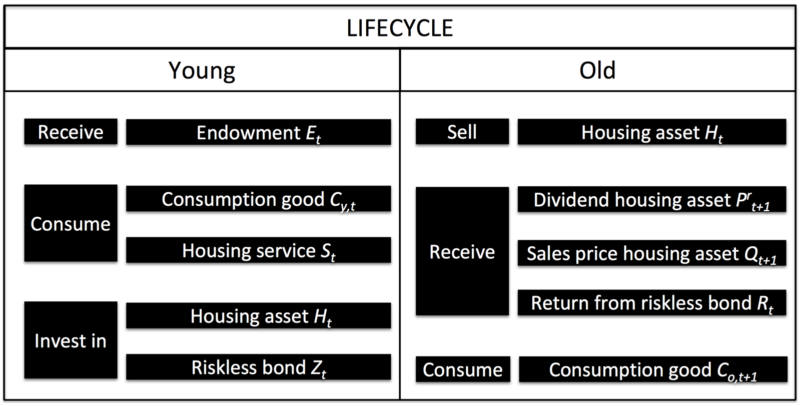


Figure 1: Lifecycle and Transactions when Young and Old.

At the beginning of a lifecycle, each household receives an endowment E_t. In accordance with the budget constraint in Equation 2.2, households can spend the endowment E_t by consuming the composite consumption good $C_{y,t}$ and housing services S_t, and by investing in the housing asset H_t and in the riskless bond Z_t.

Young households decide how many units of the consumption good $C_{y,t}$ and how many units of housing services S_t they want to purchase. Following a similar design as in Fenig and Petersen (2017) and Fenig et al. (2018), subjects do so by clicking on a combination of $C_{y,t}$ and S_t in a graph on the decision screen. *Young* subjects get utility as defined by the first two elements in Equation (2.1). The utility level for all possible combinations of $C_{y,t}$ and S_t is shown in a colored heat map and, for the selected combination, the number is displayed next to the heat map. The preference for housing service relative to other consumption goods (denoted by the parameter ξ) affects the utility a household gets from consuming a certain combination of $C_{y,t}$ and S_t.

Our treatment variations exogenously induce varying preferences for housing services. As explained in Section 3.1, preferences for housing services S_t relative to other consumption goods $C_{y,t}$ are either low ($\xi = 2$) or high ($\xi = 6$), depending on the random treatment assignment. It is crucial that subjects understand the consequences of their consumption decisions for their household utility. The heat maps visualize the treatment variations and the displayed numeric utility further enhances subjects' comprehension (see screenshots in Appendix D).

The general equilibrium model entails a market for housing consumption S_t and one for housing investment H_t. The price for housing consumption P_t^r defines the dividend of the current *old* households' housing asset holdings H_t. The dividend of the housing asset H_t is thus endogenous. In most experimental asset markets, the dividend process is exogenous and common knowledge. Our experimental design's critical and novel feature is the endogenous nature of the dividend of the housing asset H_t. Our design thereby contributes to the nascent but notable literature on endogenous dividends.[20] In our setup, households' demand for housing services relative to other consumption goods determines the dividend. Hence, the price for one unit of S_t, $p_t^r = P_t^r/P_t$, depends on all *young* household's purchases of $C_{y,t}$ and S_t in the market. The price for one unit of the consumption good $C_{y,t}$, P_t, is set to the numeraire (and equal to one).

The market price, P_t^r, can only be determined once all *young* households in the market have submitted their purchase decisions for $C_{y,t}$ and S_t (subject to the budget constraint in Equation (2.2) and the exogenously available supply; i.e. C^{supply} and S^{supply}). We therefore provide a graphical tool on which subjects can simulate the purchase decision with regard to $C_{y,t}$ and S_t of other *young* households in the market. Together with the own chosen combination of $C_{y,t}$ and S_t, the price for one unit of S_t, P_t^r, is calculated and displayed on the screen.[21] We ask *young* households to submit the maximum number of units of $C_{y,t}$ and S_t they want to purchase. The price P_t^r is fully flexible and can take values between 0 and infinity. The exact calculation of P_t^r is shown in Appendix Table A1.[22] Once all *young* households in the market have submitted their demands, the resulting market price for one unit of S_t, P_t^r, as well as the finally purchased units of the consumption good $C_{y,t}$ and housing service S_t are displayed on the screen.

Young households also purchase units of housing asset H_t in a continuous double auction (for instance, Camera et al. (2003)) from the current *old* in the market. Before the *young* households get to the double auction, they learn how the dividend of the housing asset H_t will be determined—that is, that it will depend on the choices with regard to $C_{y,t+1}$ and S_{t+1} by the *future young* (the generation born in $t + 1$). Young subjects can simulate the average purchase of $C_{y,t+1}$ and S_{t+1} by the *future young* using a graphical tool.[23] Remember that the dividend is determined endogenously by the rental price in the

[20] Weber et al. (2018) study assets with endogenous, price-dependent default probabilities. In contrast to our study, the asset has no consumption side, and the dividend payment (the interest rate) is fixed and known. However, the default probability of the asset's issuer is endogenous, and hence the realized dividend (and FV) is endogenous. In Bao et al. (2018) and Jaworski and Kimbrough (2016), the dividend is endogenously determined by the CEO's effort and the monopolist's decision, respectively. In the latter work, the dividend is also determined by selling a good to demand–revealing robot buyers.

[21] Subjects can try as many combinations as they wish (without time restriction). This step helps subjects learn how aggregate decisions affect prices and dividends in the economy and their payoffs. Once they decide on a combination $(C_{y,t}, S_t)$, they click the "Submit" button.

[22] Alternative procedures to determine the market demand and market price for housing services S_t include the elicitation of full demand schedules or call markets. In our setup, *young* households demand *two* consumption goods simultaneously, which complicates their implementation substantially. In Appendix A, we provide evidence that our setup allowed subjects to form adequate point estimates about P_t^r.

[23] As a help device, the same heat map is depicted because the *future young* will make the exact

subsequent period, P^r_{t+1}. To help households form expectations about the rental return of housing asset H_t, the dividend from each simulated combination of $C_{y,t+1}$ and S_{t+1} is calculated and displayed on the screen. We implement a standard experimental double auction with the only exception that *young* households can only *purchase* and *old* households can only *sell* housing assets H_t. *Young* subjects can initiate a purchase of an asset by submitting an offer to buy (a price for which they want to buy one unit of housing asset H_t) or by accepting an offer to sell submitted by *old* households (a price for one unit of housing asset H_t). The duration of the double auction is three minutes.[24] After the double auction is over, the remaining budget remains automatically in the bank account (= is invested into a riskless bond Z_t) and earns a fixed interest payment of 5%.

When *old*, households learn about their investment return from asset H_t—that is, they receive a dividend payment for each housing asset H_t they bought when *young*.[25] Subsequently, the *old* households enter a double auction in which they can sell housing assets H_t to the current *young* households in the market. *Old* households can initiate a sale of an asset by submitting an offer to sell (a price for which they want to sell one unit of housing asset H_t) or by accepting an offer to buy from the *young* households (a price for one unit of housing asset H_t). The dividend from the sold housing assets H_t, the sales price of housing assets H_t, and the return from the riskless bond Z_t are automatically spent on consumption good $C_{o,t+1}$. The utility from consuming $C_{o,t+1}$ is defined by the third element of the utility function in Equation (2.1).

To facilitate decisions and ensure that decisions are as well–informed as possible, subjects play four practice periods before the actual experiment starts and can access a history screen from any decision or feedback screen (and go back to the decision or feedback screen).[26] At the end of a lifecycle—subjects receive summary information on their decisions in the corresponding lifecycle: the number of units $C_{y,t}$ and S_t purchased when *young* and the respective prices, P_t and P^r_t, as well as the number of units of H_t purchased. Subjects receive information on the dividend of each purchased housing asset H_t, the price for

same decision on purchasing $C_{y,t+1}$ and S_{t+1} as the *current young* households in period t.

[24] There is no depreciation of the housing stock; thus the stock of housing assets H_t remains constant from period to period. Therefore, unsold units of the housing asset H_t are assigned randomly to the current *young* households in the market at a punishment price. The punishment price is 50% less (more) than the median trading price for the current *old* (*young*) in the market. This incentivizes subjects to trade the existing housing stock H_t, such that the market clears. On average, less than one unit of housing stock H_t remains unsold per experimental market and period (no significant treatment differences) suggesting that it does not affect the experimental results.

[25] The dividend of the housing asset H_t is given by the price for housing services P^r_{t+1}, which is determined by the demand for C_{t+1} and S_{t+1} of the current *young* households in that period.

[26] The history screen shows for all previous periods a summary of (1) the subject's decisions on C_t, S_t, H_t; (2) the corresponding utilities; (3) the return from investing in the riskless bond Z_t; (4) the median price for all traded housing assets; and (5) the average dividend per housing asset.

which they sold the purchased assets H_t, the median price of all sold housing assets, Q_t, the return from the riskless bond Z_t, and the total lifecycle utility (Equation (2.1)).

3.3 Market Assignment and Experimental Procedure

In the model, infinitely many households exist, which—for obvious reasons—is not feasible in the laboratory. Therefore subjects, who represent households, play several lifecycles as in Marimon and Sunder (1993). Each session is composed of 16 subjects and two markets A and B. At the beginning of the experiment, 50% of all subjects are randomly assigned to Cohort I and the remaining 50% of subjects to Cohort II (eight in Cohort I and eight in Cohort II). All subjects are informed that they will remain in the assigned cohort for all periods of the experiment.

At the beginning of period 1, four members of each cohort are randomly assigned to market A and the other four members to market B. Cohort I (II) starts as *young* (*old*) households in period 1 and subjects make decisions accordingly. Appendix Figure A1 presents an overview over each cohort's lifecycles. From period 2 onwards, cohorts switch between generations in each period. That means that Cohort I (II) takes the role of *old* (*young*) households in period 2 and takes the role of *young* (*old*) households in period 3, etc. Cohort I's lifecycle 1 consists of periods 1 and 2; its lifecycle 2 consists of periods 3 and 4, etc. Cohort II's lifecycle 1 consists of periods 2 and 3; its lifecycle 2 consists of periods 4 and 5, etc.

Our incentive structure differs from existing OLG asset market experiments. Only one completed lifecycle (chosen randomly) forms the basis for the payment. We pay only one completed lifecycle because this most closely aligns incentives with the infinite–horizon OLG model where the death probability when young is zero and households only live for one lifecycle. This design choice prevents subjects from hedging risk by playing different strategies in different lifecycles.

As an important design feature, subjects are randomly assigned to either market A or market B at the beginning of a lifecycle and remain in the same market throughout a lifecycle. That means that the formerly *young* households remain in the *same* market when turning *old*, while the formerly *old* households are *randomly* assigned to either market A or market B before a new lifecycle starts. Subjects know in which market they are (A or B), but do not know the other market participants' identity. In comparison to the existing literature on OLG market experiments,[27] the way we assign subjects to markets keeps the

[27] In Marimon and Sunder (1993)'s design, each subject plays during two periods (i.e., a lifecycle) as young and old in the first and second period, respectively. After the second period, (old) subjects

design close to the OLG model and has the advantages of gathering more observations, providing the subjects with experience, reducing repeated interaction with the same subjects and collusive behavior in small markets, as well as simplifying the complex setup. The instruction handouts illustrate the assignment to cohorts and markets (Appendix D).

To implement an infinite time horizon in the lab, we follow Crockett et al. (2018) and implement an indefinite horizon by assuming a constant probability of continuation in each period. As Duffy (2016) points out, "infinite horizons are not operational in the lab, but indefinite horizons are". The probability of continuation is set to 80%. As discussed in Section 2.2, the stopping probability captures for instance the depreciation rate in the theoretical model.[28] Before running the sessions, we threw a ten-sided dice repeatedly until the number 0 or 1 turned up to determine the number of periods in the experimental session. Thus, the length of each session is the same and equal to nine periods. Both the theoretical and the actual length of a session remains the same across treatments. Before the experiment starts, subjects have four trial periods to get familiar with the experimental environment.

3.4 Procedure and Subject Pool

At the beginning of each experimental session, the instructions, illustrating screenshots, graphs, and tables, are handed out to the subjects on paper and read aloud by one experimenter. The beginning of the trial periods and the start of the incentivized periods are also announced aloud. Appendix D shows the material handed out to the subjects. The instructions and materials are identical for treatment ($\xi = 2$) and treatment ($\xi = 6$) except for one variation: The formula for the lifetime utility differs depending on the treatment: $u(C_{y,t}) + 2 * v(S_t) + E_t\{u(C_{o,t+1})\}$ for treatment ($\xi = 2$) and $u(C_{y,t}) + 6 * v(S_t) + E_t\{u(C_{o,t+1})\}$ for treatment ($\xi = 6$). The heat maps—illustrating households' utility from consumption goods $C_{y,t}$ and housing services S_t—and screenshots are adjusted accordingly.

The sessions were conducted at the BEElab at Maastricht University in April, May, and September 2016, and the programming was done with the software z-Tree (Fischbacher, 2007). Participants were mainly Maastricht University undergraduate students, recruited using the online recruitment system ORSEE (Greiner et al., 2004). We sent invitations to students from the following study fields: Econometrics and Operations Research, Economics and Business Economics, Fiscal Economics, and International Business.

are randomly assigned to restart as young participants or to wait until being reassigned.

[28] Duffy (2016) argues that a continuation probability has the advantage that future payoffs are discounted at a certain rate (discount factor with infinite horizon) and the stationarity of an infinite horizon is induced.

In total 256 subjects took part in 16 experimental sessions (eight sessions per treatment) composed of 53% women and 47% men (the share of women per session varied between 37.5% and 62.5%).[29] The average age was 21 years. The conversion rate was 1 utility unit to 3 euros, and the average earnings per subject were 27.27 euros (SD = 4.63 euros).[30] This includes a show-up fee of 5 euros, a finishing fee of 5 euros, and the converted utility units of one completed lifecycle that was randomly selected at the end of the experiment. The average duration of a session was 2.5 hours. After the experiment had finished, subjects were asked to fill out a questionnaire and were paid their earnings in private.

4 Data Analysis and Results

This section presents the test results of the model predictions in Section 2.3. Section 4.1 explains how we measure experimental house price bubbles. Section 4.2 presents the descriptive statistics and the experimental results on the impact of housing consumption on the bubble size. Section 4.3 shows that the bubble size is constant over time as predicted by the OLG model. Sections 4.4 and 4.5 describe robustness checks that rule out two alternative explanations for the treatment effect, namely liquidity constraints and (small endogenous) differences in cash–to–asset ratios. We refer to Appendix C for additional robustness checks (e.g., on expectation formation, alternative bubble measures and trading prices (median instead of mean), reaction to the treatment variation).

4.1 Measuring the Experimental Bubble Size

To measure the housing bubble in the experiment, we need to compute the fundamental value—that is, the *expected* discounted stream of dividends. We thus need to take a stance on subjects' expectation formation about the future stream of dividends in the experiment. We could do so by—consistent with the OLG model—assuming that households are rational as in Equation (2.4). Given that the OLG model has no information frictions, the agents will forecast the future stream of dividends correctly in the deterministic steady state. In the steady state of the model, where P^{r*} denotes the steady state value of the dividend, Equation (2.4) simplifies to $FV_t = \frac{(1-\delta)}{R-(1-\delta)} P^{r*} \quad \forall t$. Using the same calibration of parameters as in the experiment ($R = 1.05, \delta = 0.2, S = H = 20$) gives a FV of 19.2

[29]Eckel and Füllbrunn (2015) and Holt et al. (2017) show that asset markets with a declining dividend and a higher share of male participants produce larger bubbles. Though Holt et al. (2017) show no gender differences in markets with a constant dividend, we invited the same number of male and female students to each session.

[30]The average earnings were 23.12 euros (SD = 1.81 euros) in treatment ($\xi = 2$) and 31.42 euros (SD = 2.25 euros) in treatment ($\xi = 6$).

for the treatment ($\xi = 6$), and a FV of 6.4 for the treatment ($\xi = 2$). All the results that follow, are robust to assuming the model–consistent rational expectation formation.[31]

The empirical literature on expectation formation has however shown that households are to a large degree backward looking; that is, they adapt their expectations to past observations. Adaptive expectations seem to match survey and experimental data rather well.[32] We therefore assume that subjects recognize all realized dividends of the past and update their beliefs accordingly.[33] Hence, in period one, we assume that households expect all future dividends to be equal to the current and first realization. In all future periods, households update their belief and expect that all future dividends will be equal to the average of all realized dividends to date. Hence, households expect the following fundamental value:

$$FV_t \equiv E_t \left\{ \sum_{j=1}^{\infty} \left(\frac{1-x}{R} \right)^j P^r_{t+j} \right\}, \tag{4.1}$$

where $(1-x)$ denotes the common-knowledge continuation probability, R the interest rate, and $E_t \left\{ P^r_{t+j} \right\} \equiv \sum_{k=1}^{t} \frac{P^r_k}{t} \equiv \bar{P}^r_t$ the average of the realized dividends in period t.

Having defined the expectation formation and hence the fundamental value FV as in Equation (4.1), we can compute the bubble measures. We use both theoretical and experimental bubble measures to analyze the treatment differences. The theoretical bubble measures are derived from the OLG model in section 2: the absolute bubble size $B_t = Q_t - FV_t$, where Q_t denotes the realized trading price in the experiment in period t (prediction 1), the relative bubble size B_t/FV_t (prediction 2), and the price–to–rent ratio $PRR_t = Q_t/P^r_t$ (prediction 3). In the experimental asset price literature, there seems to be a converging consensus on the suitability of the bubble measures proposed by Stöckl et al. (2010)—the relative absolute deviation RAD and the relative deviation RD. We use these two experimental indicators for measuring the bubble size. Doing so facilitates the comparison of our results with the results (and bubble sizes) of other asset market experiments.

The Relative Absolute Deviation, $RAD = \frac{1}{N} \sum_{t=1}^{N} \frac{|Q_t - FV_t|}{|\bar{FV}|}$, measures the average level of "mispricing". N denotes the total number of realized periods in the experiment and $\bar{FV}$ the absolute value of the average fundamental value of the market, with $\bar{FV} = \frac{1}{N} \sum_{t=1}^{N} FV_t$.

[31] Results are available upon request.

[32] Hommes (2020)'s survey of the (behavioral macro and experimental) literature shows that individuals use simple, backward-looking expectation rules such as adaptive expectations or trend-following rules. Specifically in the context of housing markets, the recent empirical literature on expectation formation shows that households update their expectations by extrapolating past information about aggregate variables (e.g., Armona et al. (2019)).

[33] Appendix C presents two alternative types of adaptive expectation formation. Our results are robust to these variations.

The Relative Deviation, $RD = \frac{1}{N}\sum_{t=1}^{N}\frac{(Q_t - FV_t)}{|\bar{FV}|}$, measures "overvaluation". While RAD averages the absolute difference between the mean price and the fundamental value, RD averages the difference between the mean price and the fundamental value.[34]

4.2 Impact of Preference for Housing Services on Bubble Size

This section presents our main experimental results comparing the bubble size in treatment ($\xi = 2$) and treatment ($\xi = 6$). Recall that we use three bubble–magnitude measures derived from the theoretical model ($B_t = Q_t - FV_t$, B_t/FV_t, and PRR_t) and two experimental bubble–magnitude measures (RAD and RD). Figures 2–4 show the time series of the respective three theoretical bubble–magnitude measures disaggregated by treatment.[35] Table 1 shows the results of non-parametric tests and regression analysis of treatment differences; thus, testing the model predictions in Section 2.3. Here, the results for the three theoretical and the two experimental bubble–size measures are depicted.

To determine whether treatment differences are statistically significant, we conduct pairwise Mann–Whitney U tests for each bubble size indicator. The first two rows of Panel A in Table 1 show the average value of the five (theoretical and experimental) measures of bubble magnitude for each treatment.[36] The last row of Panel A presents the corresponding Z-value and significance level. We consider conservatively each session as an independent observation because, within one session, subjects go back and forth between the two markets A and B. Session–level measures are constructed by taking the average of the measures of the two simultaneous markets resulting in eight independent observations per treatment. Panel B in Table 1 Panel B reports Ordinary Least Square regression results on treatment differences for all five bubble measures. The dependent variable are the five bubble–size measures, respectively, and the explanatory variable of interest is the treatment dummy ξ that is equal to one for the treatment ($\xi = 2$), and zero otherwise. The standard errors are (conservatively) clustered at the session–level. We control for the gender composition of the session and for the period of the experiment to account for potential time trends that could result from learning by experience.[37]

[34]Appendix C shows that our results are robust to using three alternative bubble indicators: the Price Amplitude (PA), first proposed by King et al. (1991); the Total Dispersion (TD) and the Average Bias (AB), both first introduced by Haruvy and Noussair (2006). Also, the results are robust to using the median trading price Q_t^m instead of the mean Q_t to compute the bubble sizes.

[35]Appendix Figures B1 and B2 show the time series of the fundamental value FV_t and the mean trading price Q_t for each session and market separately.

[36]Appendix Table B1 provides descriptive statistics at *a session level* for all five bubble measures.

[37]We use periodic observations for the three theoretical measures and session–level observations for the two experimental measures. The results are robust to using the averages of each session ($N = 16$). None of the controls is statistically significant; the results are robust to their exclusion.

Result 1 (The Absolute Housing Bubble Size decreases in ξ)**.** *Households' preference for housing services affects the absolute bubble size B_t negatively: B_t is significantly smaller in treatment ($\xi = 6$) than in treatment ($\xi = 2$).*

The first model prediction states that the absolute bubble size B_t—the difference between the trading price Q_t and the fundamental value FV_t—is smaller, the stronger the preference for housing services (relative to other consumption goods). Figure 2 provides the corresponding comparative statics and shows the average mean trading housing price Q_t (solid line with squares) and its fundamental value FV_t (dashed line with circles) for each period and for both treatments. The left panel shows the averages over sessions in treatment ($\xi = 2$), the right panel the averages over sessions in treatment ($\xi = 6$). Inducing a strong preference for housing services (relative to other consumption goods) leads to a statistically significantly higher FV (18.37) compared to the treatment with a weak preference for housing services (6.31) ($z = -3.363$, $p = 0.0002$). These values closely match the model's predicted steady state values (19.2 and 6.4), according to Equation (2.4).

Figure 2 shows that the housing asset is overvalued in both treatments and illustrates our key result: The absolute bubble size B_t is much smaller in the right panel—when the preference for housing services is strong. To highlight this key result, we add two point-dotted lines to Figure 2 indicating the range $[(1 - 60\%) \cdot FV_t, (1 + 60\%) \cdot FV_t]$. We choose this particular range because for treatment ($\xi = 6$), the trading price Q_t just lies in between these bounds, whereas for treatment ($\xi = 2$), the trading price Q_t is far outside of this range.[38] The first column of Table 1 reports that the treatment difference in the absolute bubble size B_t (22.03 versus 10.61) is statistically significant at the 1% level.

Figure 2 reveals that the fundamental value FV_t and the average mean trading price Q_t, and thus the absolute bubble size B_t, are relatively constant over time in both treatments.[39] Similarly, Figure 3 illustrates that the relative bubble size B_t/FV_t is relatively stable over time in both treatments. Recall that we implemented two deterministic steady states of the model in the lab, one with the key model parameter $\xi = 2$ and one with $\xi = 6$. In each deterministic steady state, the absolute and relative bubble size are constant and larger in the steady state with a weaker preference for housing services ($\xi = 2$). And this is exactly

[38] Figure 2 reveals that the price Q_t is similar across treatments. Q_t^{max} denotes the maximally feasible average trading price that would prevail if participants would invest—after the consumption decisions (S_t and C_t)—all their remaining budget into the housing asset (i.e., no saving via riskless bond). Figure 2 shows that Q_t is much smaller than Q_t^{max} in both treatments.

[39] The roughly constant trading price Q_t may trigger concerns that the participants did not react to the treatment differences. This is not the case as our robustness check 6 in Appendix C shows. The slight decrease in the trading price over time in treatment ($\xi = 2$) is driven by one outlier, session 12 (Appendix Figure B1).

what we find. This paper provides a thorough discussion of "flat experimental bubbles" and on how our results contribute to this related literature by Hoshihata et al. (2017) and Kopanyi-Peuker and Weber (2021) in Appendix B.

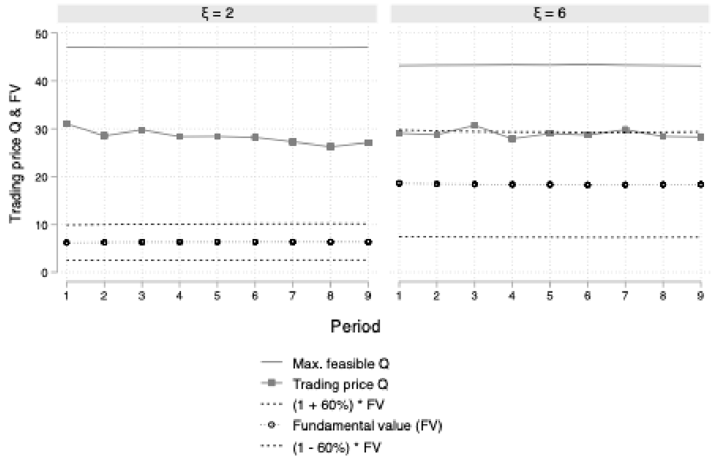


Figure 2: Average Mean Trading Price Q and FV (by Treatment). *Notes*: ξ denotes the preference for housing services S_t (relative to consumption goods C_t).

Result 2 (The Relative Housing Bubble Size decreases in ξ). *Households' preference for housing services affects the relative bubble size B_t/FV_t negatively: B_t/FV_t is significantly smaller in treatment ($\xi = 6$) than in treatment ($\xi = 2$).*

The second model prediction states that the relative bubble size is smaller the stronger the preference for housings services (relative to other consumption goods). For each session, Figure 3 shows the time series of the bubble relative to the fundamental value B_t/FV_t. Comparing the left ($\xi = 2$) and right ($\xi = 6$) panels shows that the relative bubble size is substantially smaller when the preference for housing services is strong. The second column of Table 1 shows that this treatment difference in the average relative bubble size B_t/FV_t (3.50 versus 0.58) is statistically significant ($p < 0.01$).

Result 3 (The Price–to–Rent Ratio decreases in ξ). *Households' preference for housing services affects the Price–to–Rent Ratio (PRR) Q_t/P_t^r negatively: Q_t/P_t^r is significantly smaller in treatment ($\xi = 6$) than in treatment ($\xi = 2$).*

The third prediction, derived from the OLG model, concerns the Price–to–Rent Ratio. Comparative statics of the deterministic OLG model show that the stronger the preference for housings services (relative to other consumption goods), the smaller the PRR. Figure 4 plots the Price–to–Rent Ratio at a session–level for each treatment and shows that the PRR is consistently smaller in the treatment ($\xi = 6$) compared to the treatment ($\xi = 2$).

The third column of Table 1 reports that this treatment difference in the average Price–to–Rent Ratio (14.28 versus 5.07) is also statistically significant at the 1% level.

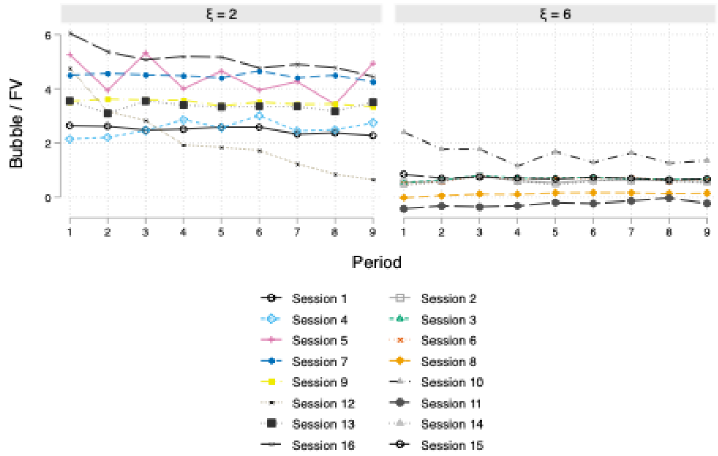


Figure 3: Relative Bubble Size B_t/FV_t (by Treatment and Session). *Notes*: ξ denotes the preference for housing services S_t (relative to consumption goods C_t).

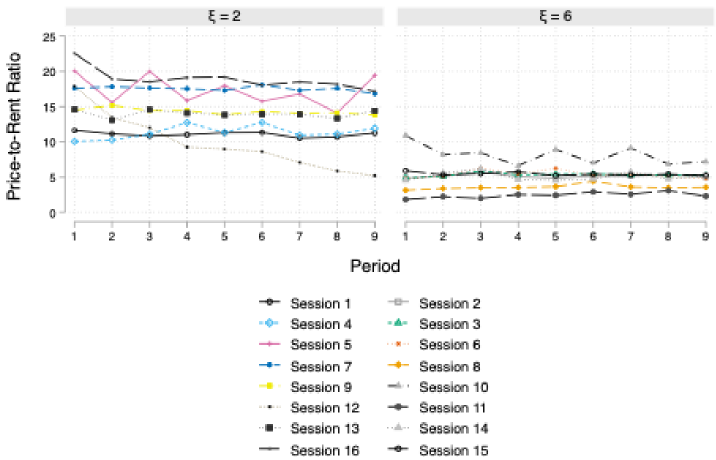


Figure 4: Price-to-Rent Ratio PRR_t (by Treatment and Session). *Notes*: ξ denotes the preference for housing services S_t (relative to consumption goods C_t).

To facilitate a comparison of our results with other asset market experiments, we use two well-established bubble indicators in the experimental asset price literature (RAD and RD). Table 1 shows the average values of both indicators in the last two columns and compares the distribution of values across treatments. For the treatment ($\xi = 2$), RAD indicates that the periodic trading price is on average 349% larger than the FV in the market. This compares to 65% in the treatment ($\xi = 6$). According to the RD indicator, the average trading price per period is 349% above the average FV when the preference for housing services is weak. This compares to 58% when the preference for housing services is strong—a large difference. Table 1 confirms that these treatment differences are significant for both indicators ($p < 0.01$).

Result 4 (RAD and RD decreases in ξ)**.** *Households' preference for housing services affects the experimental bubble measures (RAD and RD) negatively: RAD and RD are significantly smaller in treatment ($\xi = 6$) than in treatment ($\xi = 2$).*

Table 1: Bubble size indicators across treatments

	B_t	B_t/FV_t	PRR_t	RAD	RD
Panel A: MWU tests					
Treatment ($\xi = 2$)	22.03	3.50	14.28	3.493	3.493
Treatment ($\xi = 6$)	10.61	0.582	5.070	0.651	0.581
Z	2.626***	3.361***	3.361***	2.731***	3.361***
Panel B: OLS regressions					
Treatment dummy ($\xi = 6$)	-11.04***	-2.929***	-9.253***	-2.873***	-2.926***
	(3.663)	(0.409)	(1.280)	(0.422)	(0.434)
Constant	31.79*	3.431*	14.07**	2.831*	3.193*
	(16.46)	(1.630)	(5.099)	(1.502)	(1.685)
N	144	144	144	16	16
R^2	0.345	0.736	0.739	0.776	0.771
adj. R^2	0.331	0.730	0.733	0.742	0.735

Notes: * p<0.1, ** p<0.05, *** p<0.01. The indicators in the first three columns are derived from the model. The standard bubble indicators used in the experimental literature are shown in the last two columns. $B_t = Q_t - FV_t$ denotes the absolute bubble size (mean trading price minus fundamental value), B_t/FV_t the relative bubble size, $PRR_t = Q_t/P_t^r$ the Price–to–Rent Ratio. $RAD = \frac{1}{N}\sum_{t=1}^{N} \mid Q_t - FV_t \mid \ / \mid \bar{FV} \mid$ denotes the Relative Absolute Deviation and $RD = \frac{1}{N}\sum_{t=1}^{N} (Q_t - FV_t) \ / \mid \bar{FV} \mid$, where $\bar{FV} = \frac{1}{N}\sum_{t=1}^{N} FV_t$, the Relative Deviation; (Stöckl et al., 2010). **Panel A:** The first two rows show the mean values for both treatments, the third row the Z-values from a Mann–Whitney U test. The sample size of each test is $N = 16$. **Panel B:** Ordinary Least Square regression with standard errors in parentheses (clustered at session level where appropriate, robust otherwise). The dummy variable ξ takes the value one for the treatment ($\xi = 6$), and zero otherwise. Controls are period and gender composition in the first three columns and gender composition in the last two columns.

4.3 Robustness Check 1: Liquidity Constraint

Figure 2 illustrates that the average mean trading price Q_t of the housing asset H_t is similar in both treatments; 28.58 for treatment ($\xi = 2$) and 28.85 for treatment ($\xi = 6$). This section investigates the possibility that this realized trading price results from a binding liquidity constraint. Such an endowment mechanism does not exist in the theoretical model of Huber (2018) where the equilibrium is an interior solution but could, in principle, exist in the experiment. The theoretical maximum absolute bubble size B_t^{max} is limited from below by the fundamental value and from above by the liquidity in the market; see Equation (2.7). Since the endogenously realized price for housing service P_t^r, and thus the fundamental value, are higher in the treatment ($\xi = 6$), the difference in the realized bubble size across treatments could result as a consequence of a binding liquidity constraint.

To investigate this possibility, we compute the maximum possible trading price Q_t^{max} for both treatments—the house price that would prevail if all households (after purchasing the consumption good C_t and housing services S_t) would have zero savings in the riskless bond Z_t, and instead, would spend all their remaining budget on housing assets H_t. The calculation is detailed in Appendix C.

Households could have spent maximally $Q_t^{max} = 47.01$ and $Q_t^{max} = 43.26$ experimental currency units per unit of housing asset H_t in treatment ($\xi = 2$) and ($\xi = 6$), respectively. The difference between the upper bound Q_t^{max} and the realized market price Q_t amounts to 18.67 and 14.28 experimental currency units in treatment ($\xi = 2$) and ($\xi = 6$), respectively. The difference between the upper bound Q_t^{max} and the realized trading price Q_t is at least 30% in either treatment. Figure 2 illustrates this difference visually. This gap is too large to be considered a binding liquidity constraint for the realized trading price Q_t. We therefore conclude that the variation in the realized bubble sizes across treatments is attributed to the different exogenous preferences for housing services (and hence the different endogenous fundamental values).

4.4 Robustness Check 2: Cash–to–Asset Ratio (CAR)

Mortgage market conditions and credit availability played an important role for the formation of house price bubbles in the aftermath of the Great Recession (for instance, (Claessens et al., 2009), (Agnello and Schuknecht, 2011), (Igan and Loungani, 2012), and (Schularick and Taylor, 2012)). A number of asset market experiments support this view by providing evidence that the level of cash and consequently the cash–to–asset ratio (CAR) matter for the magnitude of asset prices and bubble formation (for instance, (Smith et al., 1988), (Haruvy and Noussair, 2006), (Caginalp et al., 2001), (Caginalp et al., 1998), (Kirchler et al., 2012), (Noussair and Tucker, 2016), (Weitzel et al., 2019), (Kirchler et al., 2015), (Razen et al., 2017), (Hens and Steude, 2009), and (Kose, 2015)). However, reviewing this literature suggests that the impact of cash holdings depends crucially on the setup of the experimental asset market. A comparison of design differences and similarities between these experimental asset markets and ours is presented in Appendix C. Although our experimental design is somewhat closer to market settings with null results (relatively constant FV and CAR over time, small cash differences across treatments), we nevertheless perform a robustness check. It addresses the concern that slight *endogenously* emerging budget differences drive the treatment effect—instead of differences in the preference for housing services affecting the bubble size through the fundamental value.

Recall that the *initial* cash holdings are identical across treatments. Participants take their consumption decisions (consumption good C_t and housing services S_t), which determines the FV_t of the housing asset and the remaining budget for the investment decisions. Households also make investment decisions (housing asset H_t and riskless bound Z_t), which determines the housing price Q_t. Hence, if endogenous cash holding differences (that emerge through the consumption decisions C_t and S_t) would drive the treatment effect (the different bubble sizes), then this liquidity effect has to go via the housing price Q_t. The FV_t is already determined by the young households' S_t purchases and is hence not affected. The *endogenous* differences in cash holdings do not translate into different trading prices in our experiment. Figure 2 shows that the realized trading price Q_t is very similar across treatments and not statistically significantly different (p = 0.574). This result is not surprising, given that the initial cash holdings are identical and the resulting endogenous difference in available cash before the double auction is small on an experimental scale (approximately 9% in our experiment compared to approximately 900% in (Weitzel et al., 2019)).

To further address the concern that the small differences in cash holdings drive the treatment effect, we adjust the trading price in treatment ($\xi = 2$) for the nine percent greater liquidity in the market. We do so by reducing the realized trading price Q_t in the treatment ($\xi = 2$) by 2.7 experimental currency units ($= 0.674 \cdot 4$). The figure 67.4% corresponds to the share of the cash holdings (= 865.20; after purchasing C_t and S_t) that the average household invests in H_t in treatment ($\xi = 6$).[40] The number 4 is the theoretical price difference of asset H_t due to cash differences (= 80 remaining budget/ 20 units of H_t).[41] Alternatively, one could adjust the trading price in the treatment ($\xi = 6$), arguing that, if the young households had had the same cash holdings (i.e., 80 experimental currency units more), then they might have spent it on the housing asset. The results are robust to this alternative.

Table 2 presents the same tests for the bubble indicators as in subsection 4.2 but calculated with the adjusted trading price Q^{adj} for the treatment ($\xi = 2$). As can be seen from the non-parametric test results in Panel A and the regression results in Panel B, each bubble measure remains significantly different across treatments. The results confirm that the housing bubble size is significantly smaller in the treatment with a strong preference for

[40] Alternatively, we could take the share of the cash holdings of 940.20 invested in H_t in treatment $\xi = 2$ (60.3%), but we decided on the more conservative robustness test.

[41] In equilibrium, the cash difference when entering the double auction would be 80 (= 940 - 860) experimental currency units. The endogenously determined steady state price for one unit of S_t is 2 in treatment ($\xi = 2$), and it is 6 in treatment ($\xi = 6$). Since all parameters and the experimental setup are otherwise identical, the remaining budget when entering the double auction for H_t is larger in treatment ($\xi = 2$) by maximally $(6 - 2) \cdot 20 = 80$ experimental currency units.

housing services. This large difference cannot be explained by an endogenously resulting nine percent larger liquidity in treatment ($\xi = 2$).

Table 2: Bubble size indicators controlling for CAR

	B_t^{adj}	$(B_t/FV_t)^{adj}$	PRR^{adj}	RAD^{adj}	RD^{adj}
Panel A: MWU tests					
Treatment ($\xi = 2$)	19.34	3.071	12.93	3.066	3.066
Treatment ($\xi = 6$)	10.61	0.582	5.070	0.553	0.442
Z	2.100**	3.361***	3.361***	3.361***	3.361***
Panel B: OLS regressions					
Treatment dummy ($\xi = 6$)	-8.347**	-2.503***	-7.899***	-2.513***	-2.624***
	(3.663)	(0.408)	(1.280)	(0.406)	(0.425)
Constant	29.10*	3.003*	12.71**	2.194	2.773
	(16.46)	(1.626)	(5.095)	(1.410)	(1.684)
N	144	144	144	16	16
R^2	0.241	0.672	0.674	0.733	0.732
adj. R^2	0.225	0.665	0.667	0.714	0.713

Notes: * p<0.1, ** p<0.05, *** p<0.01. The indicators in the first three columns are derived from the model. The standard bubble indicators used in the experimental literature are shown in the last two columns. $B_t^{adj} = Q_t^{adj} - FV_t$ denotes the absolute bubble size (mean trading price minus fundamental value), B_t^{adj}/FV_t the relative bubble size, $PRR_t^{adj} = Q_t^{adj}/P_t^r$ the Price–to–Rent Ratio. $RAD^{adj} = \frac{1}{N}\sum_{t=1}^{N} \mid Q_t^{adj} - FV_t \mid \; / \mid \bar{FV} \mid$ denotes the Relative Absolute Deviation and $RD^{adj} = \frac{1}{N}\sum_{t=1}^{N} \left(Q_t^{adj} - FV_t\right) \; / \mid \bar{FV} \mid$, where $\bar{FV} = \frac{1}{N}\sum_{t=1}^{N} FV_t$, the Relative Deviation; (Stöckl et al., 2010). The superscript adj refers to an adjustment of the trading price in treatment $\xi = 2$ to control for endogenously resulting small differences in market liquidity. **Panel A:** The first two rows show the mean values for each treatments, the third row the Z-values from a Mann–Whitney U test. The sample size of each test is $N = 16$. **Panel B:** Ordinary Least Square regression with standard errors in parentheses (clustered at session level where appropriate, robust otherwise). The dummy variable ξ takes the value one for the treatment ($\xi = 6$), and zero otherwise. Controls are period and gender composition in the first three columns and gender composition in the last two columns.

5 Conclusion

The dual nature of housing makes it a particular asset. Housing entails a consumption and an investment side, and both are economically relevant from a household perspective. Housing represents a large share of the wealth of private households, and households spend the largest share of their monthly consumption expenses on housing, in all OECD countries. However, the relative importance of housing consumption varies greatly across countries—as does the magnitude of housing bubbles—resulting in a significant negative relationship between housing consumption expenditures and housing bubble sizes. While the existing literature studying determinants for house price volatility and the bubble size focuses exclusively on aspects that work through the investment side of the housing asset, the role of housing consumption has not been explored to the best of our knowledge. This paper aims to fill this gap.

The 'consumption channel' is universally valid as long as the asset under consideration is a consumption good at the same time. For example, artwork, classic cars, and jewelry are simultaneously consumption and investment goods. However, given that housing consumption constitutes the largest consumption expenditure share for most economies, this 'consumption channel' is particularly relevant for housing bubbles.

In our theoretical framework and laboratory experiment, the economy is modeled as an OLG world and the investment and consumption side of housing are explicitly and separately modeled. Furthermore, a market for the traded asset (the house) and a market for the traded asset's dividend (price for housing services) exists, particularly essential for assets that entail a consumption and an investment component. The asset's dividend is thus determined *endogenously* by the consumption demand of households. This framework and a number of novel features (among them, subjects' assignment to markets, the OLG incentive structure) make our experimental design a credible starting point for follow-up studies on experimental (housing) asset markets.

Consistent with the model predictions, our results confirm that housing bubbles are substantially and significantly larger when the demand for housing services (i.e., housing consumption) is weak. The bubble size (both absolute and relative) and the price–to–rent ratio are larger in the treatment with weaker preferences for housing services. Several well-established experimental bubble indicators draw the same conclusion. Weak preferences for housing services lead to a significantly lower demand for housing services (relative to other consumption goods), and consequently, a significantly lower dividend and fundamental value for the housing asset; eventually resulting in larger housing bubbles. We can rule out a number of potential alternative channels—including, differences in liquidity or cash–to–asset ratios—and are confident in concluding that differences in the dividend and thus fundamental value drive the treatment effect. Furthermore, the bubble size is relatively stable over time, as would be expected in an overlapping generation world.

As mentioned earlier, our design provides an adequate starting point for follow-up studies. For instance, competing policy interventions in the housing market to manage bubbles can be analyzed in our OLG design. Follow-up work may also compare the relative merits of policy interventions that aim to foster housing affordability (e.g., rental subsidies, rental caps, help-to-buy schemes) and their implications for economies' vulnerability to housing bubbles. Furthermore, the OLG structure allows the analysis of how policy interventions affect the young and the old generation (differentially) and how changes in population dynamics (resulting from aging or migration) affect housing bubbles.[42]

[42]For ethical reasons, it can be challenging to test the causal effect of policy interventions in the field. A laboratory setup provides a credible alternative. Note that our two-period OLG design can be easily modified to an OLG environment with several periods per lifecycle if needed.

Appendix A: Design features

We ask *young* households to submit the maximum number of units of $C_{y,t}$ and S_t they want to purchase. Once all *young* households in the market have submitted their demands, the algorithm checks for availability of the demanded number of units, and the resulting market price for one unit of S_t, P_t^r, as well as the finally purchased units of the consumption good $C_{y,t}$ and housing service S_t are displayed on the screen.

In the case of excess demand, the number of units demanded by each *young* household is reduced proportionately until it matches the supply of units of $C_{y,t}$ and S_t. Excess demand existed for $C_{y,t}$ and S_t in 234 and 284 out of a total of 288 market encounters, respectively. Note that only relative demand for $C_{y,t}$ and S_t matter for price formation, and there is no reason to believe that the proportional assignment (in the case of excess demand) matters differently for $C_{y,t}$ versus S_t.

Table A1: Parameter choices

Parameter	Calibration	Explanation
Supply		
C_t^{supply}	= 20 units of consumption good	In each market (A & B) and period
S_t^{supply}	= 20 units of housing services	In each market (A & B) and period
H_t^{supply}	= 20 units of housing asset	In each market (A & B) and period
Endowment		
E_t	250 experimental currency units	*Young* household at beginning of lifecycle
$E_{o,1}$	50 experimental currency units in Z_1	*Old* household in period 1
	5 units of H_1	*Old* household in period 1
Prices		
P_t	$= 1$	Price for one unit of C_t (numeraire)
P_t^r	$= \xi * \frac{C^{demanded}}{S^{demanded}}$	Relative price for one unit of S_t
Q_t	determined in a double auction	Average price for one unit of H_t
R	$= 1.05$	Interest rate on riskless bond holding Z_t
Dividend	$= P_t^r$ if $S_t^{demand} = S_t^{supply}$	Rental income generated by asset H_t
	$= P_t^r$ if $S_t^{demand} > S_t^{supply}$	
	$= P_t^r * \frac{S_t^{demand}}{S_t^{supply}}$ if $S_t^{demand} < S_t^{supply}$	
Utility		
U($\xi = 2$)	$= log(C_{y,t}) + 2log(S_t) + log(C_{o,t+1})$	Utility in treatment $\xi = 2$
U($\xi = 6$)	$= log(C_{y,t}) + 6log(S_t) + log(C_{o,t+1})$	Utility in treatment $\xi = 6$
Demanded units		
$X_{i,t}$	$= X_{i,t}$ if $\sum_{i=1}^{4} X_i^{demand} \leq X^{supply}$	No aggregate excess demand
$X_{i,t}$	$= X_{i,t}^{adj}$ if $\sum_{i=1}^{4} X_{i,t}^{demand} > X_t^{supply}$	Aggregate excess demand

Notes: $X_{i,t}$ denotes the *actual* individual demand of subject i in period t of variable $X \in \{C_t, S_t, H_t\}$, while X_t^{supply} denotes aggregate supply of X_t. $X_{i,t}^{adj}$ denotes the individual *adjusted* demand of subject i in period t in case of aggregate excess demand and is given by $X_{i,t}^{adj} = X_{i,t} \frac{X_t^{supply}}{\sum_{i=1}^{4} X_{i,t}^{demand}}$, hence individual demand gets proportionally adjusted.

Young households purchase consumption goods $C_{y,t}$ and housing services S_t in a graph on the decision screen and can simulate other *young* households' purchase decisions. Alternative procedures to determine the market demand and market price for housing services

S_t include the elicitation of full demand schedules or call markets. Ideally, we would have employed demand schedules where households are price–takers. Note however that—in the model and in our design—*young* households demand *two* consumption goods simultaneously, $C_{y,t}$ and S_t, which *both* affect the price of housing services P_t^r.[43] This complicates the implementation of full demand schedules and call markets substantially. Due to time constraints (the experiment lasted 2.5 hours on average) and the importance of the consumption utility, we decided for the described procedure, which we believe was a good feasible solution. Our setup allowed subjects to form adequate point estimates about P_t^r: Subjects first performed four practice periods, and during the incentivized periods, more than 75% of subjects revealed a stable relative demand for $C_{y,t}/S_t$.[44]

<table>
<tr><th>Period</th><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th rowspan="7">Etc.</th></tr>
<tr><td rowspan="3">Cohort I
(8 subjects)</td><td></td><td>young</td><td>old</td><td>young</td><td>old</td><td>young</td><td>old</td><td>young</td></tr>
<tr><td>Lifecycle</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">3</td><td>.......</td></tr>
<tr><td>Market</td><td colspan="2">A or B
(random)</td><td colspan="2">A or B
(random)</td><td colspan="2">A or B
(random)</td><td>.......</td></tr>
<tr><td rowspan="3">Cohort II
(8 subjects)</td><td></td><td>old</td><td>young</td><td>old</td><td>young</td><td>old</td><td>young</td><td>old</td></tr>
<tr><td>Lifecycle</td><td></td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">3</td></tr>
<tr><td>Market</td><td>A or B</td><td colspan="2">A or B
(random)</td><td colspan="2">A or B
(random)</td><td colspan="2">A or B
(random)</td></tr>
</table>

Figure A1: Chronological order of the experiment

[43] $P_t^r = p_t^r$, since the price for C_t, $P_t = 1$, is the numeraire.
[44] We eye-balled the individual time trends of each subject. Figures are available upon request.

Appendix B: Additional Results

Table B1 provides the average bubble size (for all five bubble size indicators) at a session level. Figure B1 plots the mean trading price and the fundamental value for each session separately. Figure B2 provides an even more detailed view and illustrates mean trading price and the fundamental value for each of the two markets within one session.

Constant Bubble Size

In the OLG model, households live for two periods and only buy and sell the housing asset H_t once in their lifetime. We compare two deterministic steady states of the model, one with the key model parameter $\xi = 2$ and one with $\xi = 6$. In each deterministic steady state, the absolute and relative bubble size and the price–to–rent ratio are constant and larger in the steady state with a weaker preference for housing services ($\xi = 2$). In the experiment, subjects play several lifecycles but are incentivized to treat each lifecycle as if it was the only one they live: only one lifecycle is chosen randomly and paid out. If subjects are correctly incentivized (as if they live for one lifecycle only), one would not expect any boom–bust cycles in the trading price or the bubble size. Subjects would decide what the optimal decision is and replay this decision in every lifecycle.

As predicted by the OLG model, the absolute and relative bubble size as well as the trading price Q_t do not display any boom–bust cycles over time. This finding relates to Hoshihata et al. (2017), who refer to such bubbles of constant magnitude as "flat bubbles". Empirical work often measures bubbles in asset prices by boom–bust cycles. Many experimental asset markets display boom–bust cycles as well. The large majority of these experiments are based on finite horizons—in contrast to the indefinite two-period overlapping generation design that we use in our experiment. In the experimental asset price literature, flat bubbles are a rare event. Aside from Hoshihata et al. (2017), Kopanyi-Peuker and Weber (2021) also observe flat bubbles that continue until the market terminates. The underlying asset market designs of both aforementioned studies differ from our OLG structure. However, both market designs share a key characteristic with our design: a long time horizon. In contrast to typical asset market experiments, the time horizon in Kopanyi-Peuker and Weber (2021) and our study is indefinite, while the time horizon is very long but fixed to 100 periods in Hoshihata et al. (2017).

Table B1: Bubble Size Indicators on Session Level

Session	B_t	B_t/FV_t	PRR_t	RAD	RD
S1 Average	15.51	2.49	11.09	2.49	2.49
S4 Average	16.21	2.55	11.35	2.55	2.55
S5 Average	27.96	4.42	17.28	4.41	4.41
S7 Average	28.66	4.48	17.53	4.48	4.48
S9 Average	22.90	3.49	14.30	3.49	3.49
S12 Average	13.24	2.11	9.81	2.10	2.10
S13 Average	21.53	3.36	13.97	3.36	3.36
S16 Average	31.00	5.09	18.92	5.07	5.07
Treatment $\xi = 2$ Average	**22.03**	**3.50**	**14.28**	**3.49**	**3.49**
S2 Average	11.55	0.60	5.15	0.60	0.60
S3 Average	12.78	0.68	5.32	0.68	0.68
S6 Average	11.32	0.64	5.38	0.64	0.64
S8 Average	2.11	0.11	3.58	0.14	0.11
S10 Average	28.21	1.59	8.13	1.58	1.58
S11 Average	-4.68	-0.25	2.42	0.27	-0.26
S14 Average	10.28	0.58	5.11	0.59	0.59
S15 Average	13.30	0.71	5.45	0.71	0.71
Treatment $\xi = 6$ Average	**10.61**	**0.58**	**5.07**	**0.65**	**0.58**

Notes: The indicators in the first three columns are derived from the model. The standard bubble indicators used in the experimental literature are shown in the last two columns. $B_t = Q_t - FV_t$ denotes the absolute bubble size (mean trading price minus fundamental value), B_t/FV_t the relative bubble size, $PRR_t = Q_t/P_t^r$ the Price–to–Rent Ratio. $RAD = \frac{1}{N}\sum_{t=1}^{N} \mid Q_t - FV_t \mid \; / \mid \bar{FV} \mid$ denotes the Relative Absolute Deviation and $RD = \frac{1}{N}\sum_{t=1}^{N} (Q_t - FV_t) \; / \mid \bar{FV} \mid$, where $\bar{FV} = \frac{1}{N}\sum_{t=1}^{N} FV_t$, the Relative Deviation; (Stöckl et al., 2010).

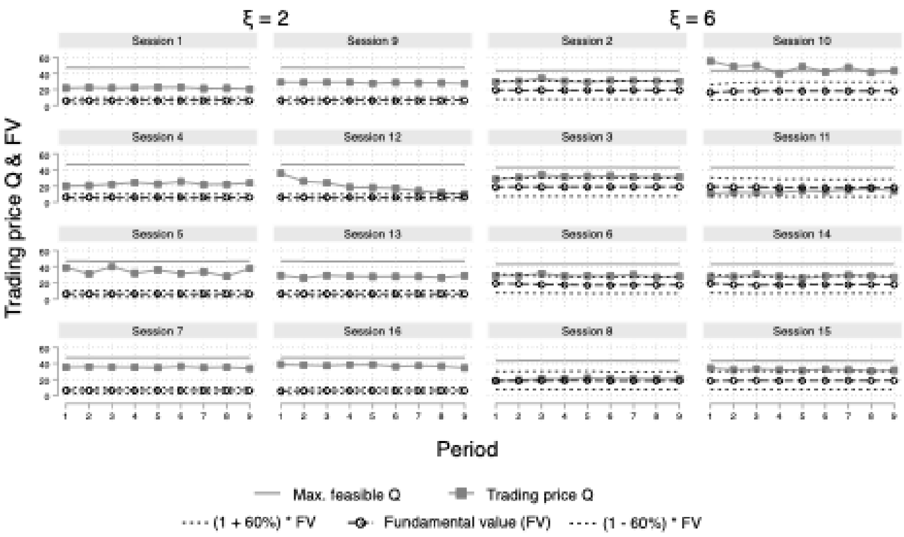


Figure B1: Mean Trading Price Q and FV (by Session Average). Notes: ξ denotes the treatment parameter; the preference for housing services S_t (relative to other consumption goods C_t).

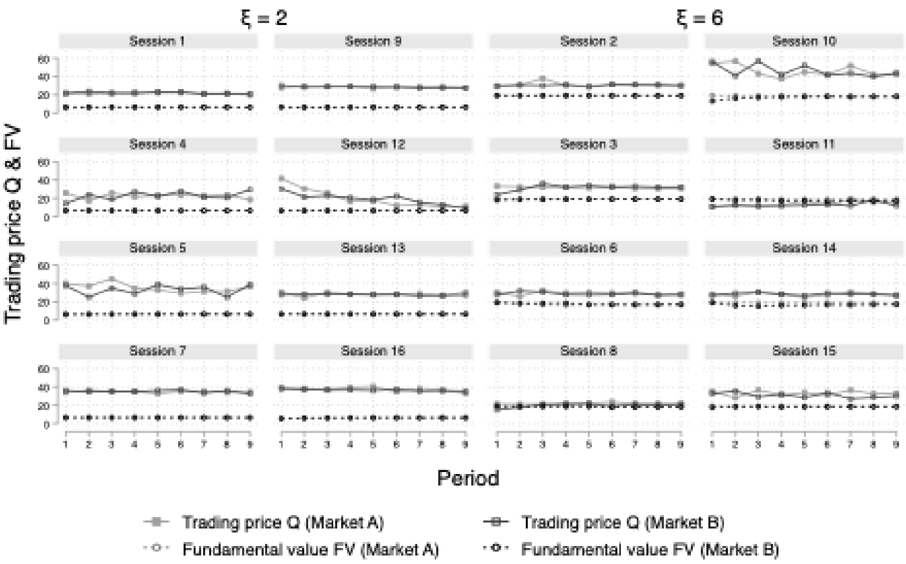


Figure B2: Mean Trading Price Q and FV (by Market and Session). Notes: ξ denotes the treatment parameter; the preference for housing services S_t (relative to other consumption goods C_t).

Appendix C: Robustness Checks

Robustness Check 1: Liquidity Constraint

The maximum possible trading price Q_t^{max} in each treatment is calculated as follows. To compute the available budget when entering the double auction for housing assets H_t, we first need to subtract aggregate consumption spending on C_t $(= P_t{\cdot}20)$ and S_t $(= P_t^r{\cdot}20)$ from the market liquidity E_t $(= 4{\cdot}250)$. Households have an average remaining budget of 940.20 and 865.20 experimental currency units in treatment $(\xi = 2)$ and $(\xi = 6)$, respectively.[45] This budget difference is small on an experimental scale. We obtain the maximum price Q_t^{max} that households could spend on the housing asset H_t by dividing the remaining budget in the economy by the available housing assets H_t $(= 20$ units).

Robustness Check 2: Cash–to–Asset Ratio (CAR)

A finite–horizon with a decreasing FV over time characterizes the experimental asset market of the seminal paper by Smith et al. (1988) (denoted by SSW). The dividend payments each period increase the cash in the economy, which—coupled with the decreasing FV—increases the CAR over time by construction. SSW find that experimental asset prices deviate strongly from fundamental values.[46] In finite–horizon setups with constant FV, Noussair and Tucker (2016) and Weitzel et al. (2019) find that high initial cash holdings and a high constant CAR are associated with higher prices and bubbles.[47]

In contrast to the aforementioned studies, our experimental design consists of an indefinite horizon and an endogenous, relatively constant FV of the housing asset. For indefinite–horizon asset markets with constant FV, the evidence on the impact of cash holdings on asset prices is rather scarce and mixed. The setup of Hens and Steude (2009) is characterized by an increasing CAR over time; interestingly three out of four markets do not display any over-evaluation of the asset. More generally, Kose (2015) finds that overpricing depends on the existence of a redemption value in such a context. They document higher prices and larger overpricing when the constant FV does not include a redemption value. Our experimental design is similar in that the horizon is indefinite, the (endoge-

[45] The average price for housing services S_t is 1.99 and 5.74 experimental currency units in treatment $(\xi = 2)$ and $(\xi = 6)$, respectively.

[46] Haruvy and Noussair (2006), Caginalp et al. (2001), and Caginalp et al. (1998) show that high initial cash–to–asset ratios increase asset prices strongly in such a SSW–settings and lead to larger asset bubbles. Kirchler et al. (2012) find that bubbles emerge when a decreasing fundamental value is coupled with an increasing CAR (as in the SSW setup). However, when the FV follows a constant time trajectory, they find no effect of cash holding levels or the CAR on asset prices.

[47] Also the inflow of new traders with new cash and a consequently increasing CAR can trigger large asset price increases (Kirchler et al., 2015), but not always (Razen et al., 2017).

nous) FV is constant (without redemption value), and cash holdings (as well as the CAR) are constant. Differences include the endogenous nature of the FV and the overlapping–generation design. We contribute to this literature by showing that an indefinite–horizon asset market with an OLG structure and endogenous constant FV (without redemption value) features consistently overpricing.

In our experiment, the *initial* cash is the same for both treatments (and constant over time). However, we observe that the young's remaining budget after purchasing C_t and S_t and before entering the double auction for H_t differs slightly across treatments. We investigate the impact of the endogenously emerging difference in cash holdings on the trading price Q_t. As explained in the previous subsection, households have an average remaining budget of 940.20 and 865.20 experimental currency units in treatment ($\xi = 2$) and ($\xi = 6$), respectively. In our setup, the cash difference on the asset market across treatments is rather small (approximately 9%) compared to Weitzel et al. (2019) where liquidity across treatments differs by approximately 900%.

Robustness Check 3: Assumptions about Expectations

For robustness purposes, we measure the *expected* fundamental value as in Equation (4.1) using two alternative adaptive expectation formations. Our results are robust to these alternative types of expectation formation and are available upon request.

We call the first alternative *naive* households. We assume that naive households expect the dividend to be constant and equal to the first realization. The naive households calculate and expect the following fundamental value:

$$\begin{aligned} FV_t^{naive} &\equiv E_t \left\{ \sum_{j=1}^{\infty} \left(\frac{1-x}{R} \right)^j p_{t+j}^r \right\} \\ &= \frac{1}{R}(1-x)p_{t=1}^r + \frac{1}{R^2}(1-x)^2 p_{t=1}^r + \frac{1}{R^3}(1-x)^3 p_{t=1}^r + \ldots \\ &= p_{t=1}^r \left(\frac{1-x}{R-(1-x)} \right) \quad \forall \quad t. \end{aligned} \tag{C1}$$

The second alternative are *myopic* households. We assume that myopic households observe the dividend payment in each period and expect all future dividends to be equal to the current realization. In all periods, myopic households update their belief and expect that all future dividends will be equal to the currently realized dividend. The myopic households calculate and expect the following fundamental value:

$$FV_t^{myopic} \equiv E_t \left\{ \sum_{j=1}^{\infty} \left(\frac{1-x}{R} \right)^j p_t^r \right\}. \tag{C2}$$

Robustness Check 4: Median (instead of Mean) Trading Price

Figures C1–C4 replicate our key findings when we use the median trading price of the housing asset instead of the mean trading price. The treatment effect is statistically significant for all five bubble indicators.

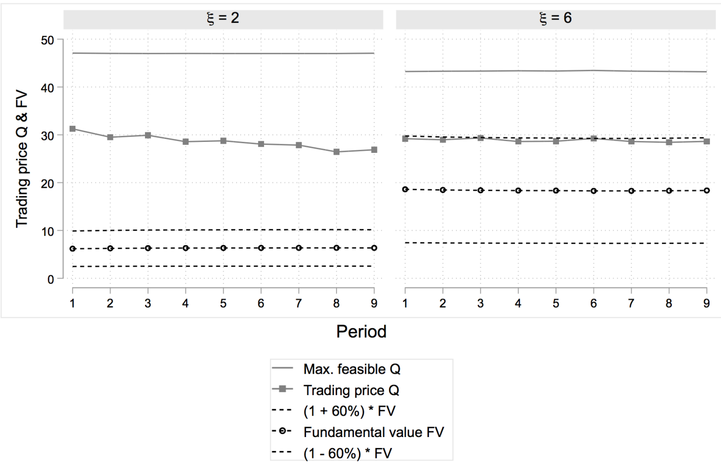


Figure C1: Average Median Trading Q_t^m Price and FV (by Treatment). Notes: ξ denotes the preference for housing services S_t (relative to consumption C_t).

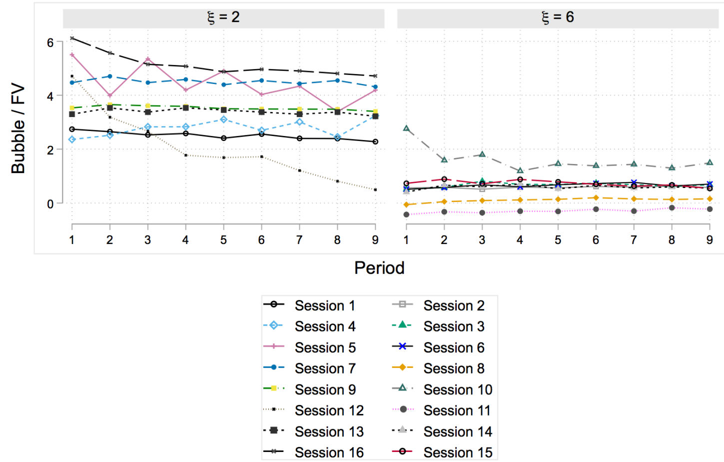


Figure C2: Relative Bubble Size B_t^m/FV_t (by Treatment and Session). Notes: ξ denotes the preference for housing services S_t (relative to consumption C_t); $B_t^m = Q_t^m - FV_t$, where Q_t^m denotes the median trading price.

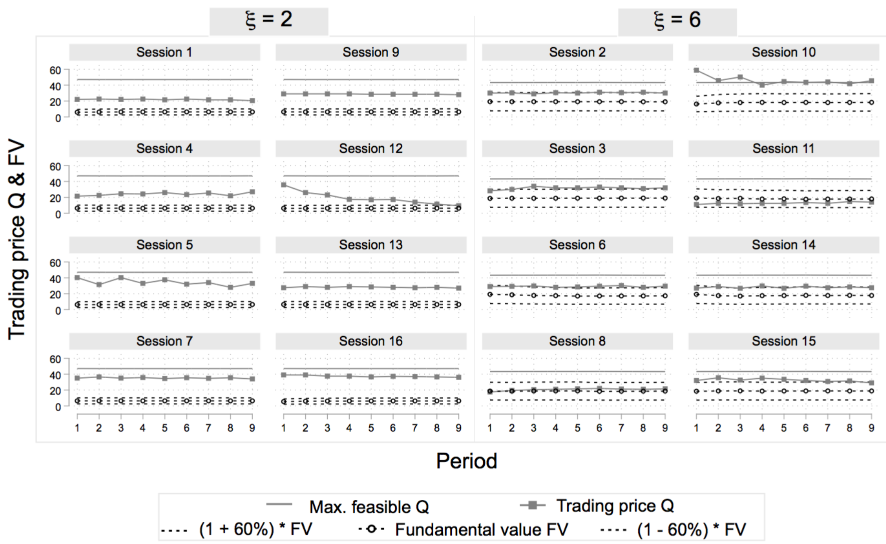


Figure C3: Median Trading Price Q_t^m and FV (by Treatment and Session). Notes: ξ denotes the preference for housing services S_t (relative to consumption C_t).

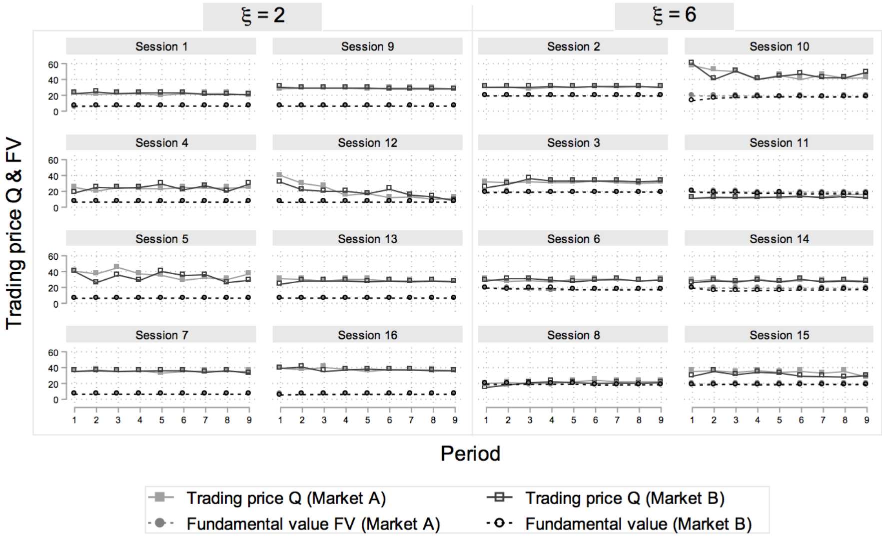


Figure C4: Median Trading Price Q_t^m and FV (by Market and Session). Notes: ξ denotes the preference for housing services S_t (relative to consumption C_t).

Robustness Check 5: Experimental Bubble Indicators

We employ a number of alternative experimental bubble indicators, namely the following:

Price Amplitude (PA)

$$PA_{King} = \frac{max_t(Q_t - FV_t) - min_t(Q_t - FV_t)}{FV_1} \tag{C3}$$

is defined as the difference between the peak and the trough of the period trading price relative to the fundamental value, normalized by the initial fundamental value in period one. A high PA suggests large price swings relative to the fundamental value. This measure was first proposed by King et al. (1991).

Total Dispersion (TD)

$$TD = \sum_t |Q_t - FV_t| \tag{C4}$$

is the sum of all period absolute deviations of median prices from the fundamental value and thus a measure of the magnitude of overall mispricing. This measure was first introduced by Haruvy and Noussair (2006). The TD measures the difference between the trading price and the fundamental value, and is hence similar to the PA measure. However, the TD measure is more complete in the sense that it does not only measure the difference between the maximum and minimum deviation from the fundamental value.

Average Bias (AB)

$$AB = \frac{\sum_t (Q_t - FV_t)}{T} \tag{C5}$$

was first introduced by Haruvy and Noussair (2006) and is calculated by the sum of all period absolute deviations of median trading prices from fundamental value, normalized by the total number of periods T. Hence, it is an indicator of the average per-period deviation of trading prices from the fundamental value.

The first column of Table (C1) shows the Price Amplitude (PA). According to this measure, the bubble in the treatment "Weak preference for housing services ($\xi = 2$)" is on average almost three times as large. The second column of Table (C1) shows the Total Dispersion (TD) measured by the sum of all period absolute deviations of median trading prices from the FV. According to this measure, the bubble is significantly larger in the treatment "Weak preference for housing services ($\xi = 2$)". The third column of Table (C1) shows the indicator Average Bias (AB); AB averages the sum of all median price deviations from the FV. These three additional experimental bubble indicators each reveal that the bubble size is substantially larger for the treatment "Weak preference for housing services ($\xi = 2$)". Table C2 and C3 show that this difference between the two treatments is statistically significant.

Table C1: Additional Experimental Bubble Indicators

Session	PA	TD	AB
S1 Average	0.48	140.34	15.59
S4 Average	1.82	159.42	17.71
S5 Average	2.41	252.50	28.06
S7 Average	0.59	258.90	28.77
S9 Average	0.42	200.99	22.33
S12 Average	4.21	114.72	12.75
S13 Average	0.64	194.90	21.66
S16 Average	0.96	281.23	31.25
Treatment $\xi = 2$ Average	**1.44**	**200.38**	**22.26**
S2 Average	0.31	99.99	11.11
S3 Average	0.38	113.89	12.65
S6 Average	0.37	103.05	11.45
S8 Average	0.27	18.16	2.02
S10 Average	1.29	252.76	28.08
S11 Average	0.47	-48.62	-5.40
S14 Average	0.36	92.29	10.25
S15 Average	0.46	122.79	13.64
Treatment $\xi = 6$ Average	**0.49**	**94.29**	**10.48**

PA (Price Amplitude)= $max(Q_t - FV_t)/FV_1 - min(Q_t - FV_t)/FV_1$; (Porter and Smith, 1995). TD (Total Dispersion)= $\sum_{t=1}^{N} \mid Q_t^m - FV_t \mid$; (Haruvy and Noussair, 2006). AB (Average Bias)= $\frac{1}{N}\sum_{t=1}^{N}(Q_t^m - FV_t)$; (Haruvy and Noussair, 2006). FV_t denotes the fundamental value, Q_t the mean trading price and Q_t^m denotes the median trading price.

Table C2: Difference of Bubble Size Indicators between Treatments

	PA	TD	AB
Δ mean	0.95***	106.09***	11.79***
Z	3.361	2.626	2.626
N	16	16	16

Notes: The values represent the difference in means of the two treatments and Z-values from a Mann–Whitney U test. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. PA (Price Amplitude)= $max(Q_t - FV_t)/FV_1 - min(Q_t - FV_t)/FV_1$; (Porter and Smith, 1995). TD (Total Dispersion)= $\sum_{t=1}^{N} \mid Q_t^m - FV_t \mid$ and AB (Average Bias)= $\frac{1}{N}\sum_{t=1}^{N}(Q_t^m - FV_t)$; (Haruvy and Noussair, 2006). FV_t denotes the fundamental value, Q_t the mean trading price and Q_t^m denotes the median trading price.

Table C3: Impact of ξ on Bubble Size Indicators

	PA	TD	AB
	(1)	(2)	(3)
ξ	-1.021*	-101.8**	-11.31*
	(0.524)	(35.50)	(3.945)
Constant	-0.086	295.4*	32.82*
	(1.511)	(154.48)	(17.16)
N	16	16	16
R^2	0.253	0.385	0.385
adj. R^2	0.138	0.290	0.290

Notes: Ordinary Least Square regressions (robust std. errors in parentheses). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The dummy ξ is equal to one for the treatment "Strong preference for housing services ($\xi = 6$)", and zero otherwise. We control for the session's gender composition. PA (Price Amplitude)= $max(Q_t - FV_t)/FV_1 - min(Q_t - FV_t)/FV_1$; (Porter and Smith, 1995). TD (Total Dispersion)= $\sum_{t=1}^{N} \mid Q_t^m - FV_t \mid$ and AB (Average Bias)= $\frac{1}{N}\sum_{t=1}^{N}(Q_t^m - FV_t)$; (Haruvy and Noussair, 2006). FV_t denotes the fundamental value, Q_t the mean trading price and Q_t^m denotes the median trading price.

Robustness Check 6: Reaction to the Treatment Parameter ξ

In the main text of the paper, we focus on the impact of the preference parameter ξ on the house price bubble size. In this section, we investigate the reaction to the treatment parameter ξ on the consumption decisions C and S in further detail. We find that the purchase decisions for the consumption good C, and thus the ratio of housing services over consumption S/C, differ significantly across treatments. As the model predicts, households purchase significantly fewer units of C in treatment ($\xi = 6$) compared to the treatment ($\xi = 2$) ($z = 3.123$ and $p = 0.0018$; two-sided Mann–Whitney U test). The difference in the ratio of housing services over consumption S/C is significantly larger with $\xi = 6$ compared to the treatment ($\xi = 2$) ($z = -3.123$, $p = 0.0018$, two-sided Mann–Whitney U test).

Note that, to achieve market clearing, we require the total demand of C and S to be equal to or smaller than the exogenous supply of 20 units, respectively. We observe excess demand in most market encounters. When looking at the actually requested units of C and S, before adjusting for excess demand, we find that the difference in the ratio S/C is highly significant across treatments ($z = -2.71$, $p = 0.0063$; two-sided Mann–Whitney U test).[48]

Recall that the price of C is the numeraire and is set equal to one. The relative price of housing services S is determined endogenously by the relative consumption choices C and S of the households, and determines in turn the dividend of housing asset H (the steady state model prediction is $P^r = 2$ in the case of $\xi = 2$, and $P^r = 6$ for the treatment $\xi = 6$). Our experimental data is very close to the model's predictions; the realized price for housing services is $P^r_{\xi=2} = 1.99$ and $P^r_{\xi=6} = 5.74$, respectively. The relative price for housing services P^r is significantly different across treatments ($z = 3.363$ and $p = 0.0008$; two-sided Mann–Whitney U test). Therefore, we conclude that the participants do react to the treatment parameter ξ.

[48]For the raw data, the difference across treatments becomes larger and remains in line with the model's prediction. The treatment differences are slightly significant for C ($z = 1.785$, $p = 0.0742$ for C and $z = -1.5$, $p = 0.1152$ for S; two-sided Mann–Whitney U test).

Appendix D: Instructions & Screenshots

Written Instructions

Welcome and General Instructions

Thank you for participating in this experiment. You are taking part in an experiment involving decisions on experimental groups.

Please read these instructions carefully; they will help you make appropriate decisions. You will receive 5 euros for participating in this experiment and another 5 euros for finishing the experiment. Furthermore, you will earn money depending on your decisions and the decisions of other participants during the experiment. Depending on your own and other participants' decisions you may earn a considerable amount of money.

At the end of the experiment, your earnings will be immediately paid out in cash.

Questions

Please feel free to raise your hand and ask the experimenter(s) any question you may have at any time during the experiment.

Please do not talk to other participants until the experiment is over. During the experiment, the use of cell phones is prohibited.

Overview over the Experiment

In this experiment, you will play several "**lifecycles**". A lifecycle consists of two periods: In the **first period** of a lifecycle, you are "**Young**". In the **second period** of a lifecycle, you are "**Old**".

In each lifecycle, you can earn Happiness Points, which will depend on your consumption and investment decisions when "Young" and "Old" as well as on other participants' decisions.

You will play several **independent** lifecycles. In each lifecycle, the decisions when "Young" and "Old" will be the same.

Objective in each lifecycle

Your **objective in each lifecycle** is to earn **as many Happiness Points as possible** with your available budget. You earn Happiness Points by purchasing consumption good C and housing service S. Your final budget at the end of the lifecycle will also be transformed into Happiness Points. The number of Happiness Points will be transformed into euros at the exchange rate of 1 Happiness Point = 3 euros.

When "Young," you can use your budget to purchase consumption good C and housing service S. You can also invest in the housing asset H. In case you do not spend all your money on S, C and H, your remaining budget will remain in your bank account B and receive automatically an interest rate payment. Your purchase of consumption good C and housing service S gives you immediately Happiness Points.

When "Old," your housing asset H (you bought when "young") provides a dividend (= return) and a potential profit from reselling it at a higher price to the next young generation. The remaining budget in your bank account B provides a fixed interest. After the period of being "Old," your total returns from housing asset H and bank account B will be transformed into Happiness Points.

Decisions in a lifecycle

Remember: A **lifecycle** consists of two periods: In the **first period** of a lifecycle, you are "**Young**". In the **second period** of a lifecycle, you are "**Old**". **Each period** is split into **two stages**, respectively.

When you are "Young": In stage (1), you decide how many units of consumption good C and how many units of housing service S you want to purchase. In stage (2), you can ask for units of the housing assets H with the remaining budget in a double auction.

When you are "Old": In stage (1), you can sell your purchased units of the housing assets H (if you have purchased any) in a double auction to the new "Young". In stage (2), you will be informed of your total returns from housing assets H and your bank account B and you will receive a summary of your lifecycle decisions and the corresponding Happiness Points.

Decisions when being "Young"

You will receive a budget of 250 EURUX, which will be deposited in your bank account. You can use this money to buy consumption good C, housing services S, and housing assets H.

Stage (1) when young

At the top of the screen you'll see a **graph** with the different combinations of consumption good C (x-axis) and housing services S (y-axis) that you can buy. The graph shows different colors for each combination of consumption C and housing services S chosen. The color map goes from red to yellow to green. The **greener the color** the **more Happiness Points** you receive for the specific **combination of C and S**. The more red the area, the fewer Happiness Points you receive for the corresponding combination of C and S. The formula behind this is: **Happiness Points (from C and S) = log(C) + 2*log(S)**.

You can move the red point in the upper graph to the left. The red point represents your choice of C and S. On the right, you see how many Happiness Points you would receive for this particular combination of C and S. You can try any combination of C and S units and as many combinations as you wish.

The price for one unit of C is fixed and equal to 1 EURUX. Each of the different **combinations of C and S** defines a **price for housing services S**. The price will depend on the combination-choice of all "Young" participants in your group.

The graph with the blue point on the left of the screen helps you to understand what the relative price of housing services might be. The blue point represents the (simulated!) average choice by the other "Young" participants in your group. Note that this is just a simulation and not the final choice of the other "Young" in your group. The simulated price will be displayed on the right side of the screen. Notice that this information is only a potential (simulated) price. The actual price will be computed based on all group members' choices.

You will receive information on the total number of Happiness Points and your remaining bank account balance for the chosen combination of C and S units.

Once you have decided on a combination of C and S units on the graph, you submit your final decision by clicking on the button "Submit".

Note that, for **all Young** in your group, **the total available amount of C and S is 20 units, respectively**. You input the very maximum amount you would like to purchase. You may end up purchasing less than your desired amount. If the total demand for consumption good C and housing services S in the group is in excess of what is available, you may find yourself able to purchase only a fraction of the units you requested. Each Young's purchased units of C and S will be reduced proportionally to the requested amounts.

After all participants have submitted their consumption and housing services decisions, the price for S will be computed. Your spending on C and S will be debited from your bank account.

The computer will check that every Young is able to pay the purchased units of C and S at the calculated price of C and S. Once everybody is set, you continue to Stage (2).

Stage (2) when young

In Stage (2) when "Young," you have to decide how many assets H you want to buy. The dividend will depend on the decisions with regard to the purchase of C and S made by the future "Young"—that is, the "Young" when you will be "Old". Before buying the housing assets H when "Young," you will find a screen where you can choose different combinations of C and S to simulate the choice made by the future "Young" and its implications for the dividend. The graph will help you get an idea about the dividend.

You can buy as many housing assets H as you wish and as your available budget allows. Your available bank account balance (after having purchased C and S) will be displayed in the upper part of the screen. Below that information, you will see the current number of housing assets H that you hold. Both are instantly updated each time you buy an asset. You will have 3 minutes to buy the assets H.

When you are "Young," you will only be able to **buy** assets H. You will not be able to sell them. You can buy assets H from the current "Old" in your group. You will be able to do so in two ways.

First, you can **initiate a purchase** of an asset by **submitting an offer to buy (a price for which you want to buy a unit of asset H)**. If you have money (EURUX) in your bank account and would like to buy an asset, you can initiate the purchase by submitting an offer to buy. Note that the offer cannot be larger than your available budget.

After entering a number in the text area "Enter offer to buy" click on the red button labeled "Submit offer to buy". Immediately, in the column labeled "Offers to buy", you will see a list of numbers ranked from low to high. These numbers are the prices at which all "Young" in your group are willing to buy an asset in this period. The offers to buy will be executed once they are accepted by one of the current "Old" in your group.

On the trading screen, your own offers are marked in blue; others' offers are in black. If you want to buy more assets H, repeat this process.

Second, you can **realize a purchase** of assets by **accepting an offer to sell (accepting a price for one unit of H)** submitted by a participant who is currently "Old".

If you have enough money in your bank account, you can buy an asset at one of the prices listed in the "Offers to sell" column, which contains all the offers submitted by participants in the Old role. You buy an asset by selecting one of the others' offers and then clicking on the red button "Buy". The best offer is highlighted in deep blue.

Whenever an offer is accepted, a transaction is executed. Immediately when you accept an offer to sell, you realize a purchase and the number of EURUX in your bank account goes down by the trading price. At the same time, your trading partner realizes a sale and the balance of his/her bank account increases by the trading price. Similarly, your number of assets H goes up by one unit and your trading partner's number of assets H goes down by one unit.

In each group, there will be **20 units of housing assets H** (owned by the "Old" in your group). Assets not sold in the double auction are distributed equally among all "Young" in your group (or until the budget of all "Young" is zero) at a punishment price equal to 1.5 times the median price. To calculate the median price in your group you order all sale prices from lowest to highest and pick the price that is in the middle.

Your remaining bank account balance—that is, the budget that you did not spend on consumption good C, housing service S, and housing asset H—will stay in your bank account B and you will receive an interest rate payment of 5%.

Decision when being "Old"

At the beginning of the "Old" phase of the lifecycle, you receive the interest rate payment in your bank account B; it will be deposited in your bank account.

You will receive a dividend for the housing assets H that you bought when "Young" (if any) and the selling price for your housing assets H. How the dividend and the selling price for H are determined is explained below.

Stage (1) when old

When you are "Old," you will only be able to **sell** the assets H that you purchased when you were "Young" in the same lifecycle. You can sell assets H to the current "Young" in your group. Note that you can only sell as many assets H as you hold. You will have 3 minutes to sell all your assets H. Note that you should sell all your assets H, otherwise you will be punished. You will be able to sell assets H in two ways:

First, you can **initiate a sale** of assets by **submitting an offer to sell (you propose a price for which you want to sell one unit of asset H)**.

You can enter a number (integer) in the text area labeled "Enter offer to sell" in the first column and then click on the button "Submit offer to sell". A set of numbers will appear in the column labeled "Offers to sell". Each number corresponds to an offer from one of the participants who is currently "Old" in your group. Your own offers are shown in blue; others' offers are shown in black. The offers to sell are ranked from high to low. Each offer introduced corresponds to **one single asset**. Note that by submitting an offer to sell, you initiate a sale, but the sale will not be executed until someone accepts it.

If you want to sell more of your assets H, repeat this process.

Second, you can **realize a sale** of an asset H by **accepting an offer to buy (accepting a price a "Young" is willing to buy an asset H for)**.

The highest (best) price currently listed in the column of "Offers to buy" is highlighted in deep blue.

Again, a transaction is executed whenever an offer to buy is accepted. If you accept an offer to buy posted by an other participant, you realize a sale and as a result the amount of EURUX in your bank account increases by the trading price. At the same time, your trading partner realizes a purchase and the balance of his/her bank account decreases by the trading price. Similarly, your number of assets H goes down by one unit and your trading partner's number of assets H goes up by one unit.

For all housing assets H that you do not sell you will be punished. You lose your unsold assets H and you will only receive 50% of the median price that was realized during this period in your group. To calculate the median price you order all sale prices from lowest to highest and pick the price in the middle.

Stage (2) when old

Your total budget when being "Old" includes the remaining bank account balance B plus interest payments, as well as the dividend for your housing assets H and the price at which you sell the housing assets H that you had purchased when being "Young".

Summary of the Lifecycle

You will see a summary of your decisions in the corresponding lifecycle on the screen:

- How many units of C and S you bought in that lifecycle and the respective prices;
- How many units of H you bought;
- The median price of housing asset H of all sold H;

- The dividend of asset H you received when "Old";
- The price for which you have sold the purchased assets H;
- The return on your bank account B;
- The number of Happiness Points you received for this lifecycle.

From this information, your **final budget when "Old"** will be calculated (in EURUX) and transformed into Happiness Points at the following exchange rate: **Happiness Points (from H and B) = log (EURUX)**.

History screen

To help you with the decisions, you will find on the decision screens when "Young" a button labeled "History". If you click this button, you move to a history screen but can return at any time to the decision screen. On this new screen you will find a summary of your decisions concerning C, S, H, and B as well as the corresponding Happiness Points you received in all previous periods of this experiment. Furthermore, you will find a summary of the median price per housing asset H and the average dividend per housing asset H in all previous periods of this experiment.

Assignment to group A or B

In total, 16 participants participate in this experiment including yourself. All 16 participants will be assigned randomly to Cohort I or Cohort II at the beginning of the experiment—that is, before period 1 starts. You will be informed whether you belong to Cohort I or Cohort II. All participants will remain in the assigned cohort for the entire experiment. A total of 8 participants will form Cohort I and 8 participants will form Cohort II.

At the beginning of period 1, 4 members of each cohort will be randomly assigned to Group A and the other 4 members of each cohort will be assigned to Group B.

In period 1, Cohort I will be "Young" and Cohort II will be "Old", and will make decisions accordingly. To start, each member of Cohort II will be endowed with 5 units of housing assets H and 50 EURUX in their bank account.

In period 2, Cohort I will be "Old" and Cohort II will be "Young". Cohort I will remain in the *same* group (A or B) as in period 1. A total of 4 members of Cohort II will be randomly assigned to Group A and the other 4 members will be assigned to Group B.

In period 3, Cohort I will be "Young" and Cohort II will be "Old". Cohort II will remain in the *same* group (A or B) as in period 2. A total of 4 members of Cohort I will be randomly assigned to Group A and the other 4 members will be assigned to Group B.

Etc.

Chronological order of the experiment

Remember that one lifecycle will be chosen randomly and you will be paid according to your Happiness Points in **that** lifecycle. Cohort I's lifecycle 1 consists of periods 1 and 2, its lifecycle 2 consists of periods 3 and 4, etc. Cohort II's lifecycle 1 consists of periods 2 and 3, its lifecycle 2 consists of periods 4 and 5, etc.

If a cohort is "Old" in the last period of the experiment, that lifecycle is complete and enters the lottery of the randomly selected lifecycle for payment. If a cohort is "Young" in the last period of the experiment, that lifecycle is not complete and does not enter the lottery of the randomly selected lifecycle for payment.

In the graphs and tables attached, you find a summary of the experiment.

There will be two sequences of the just described experiment: One trial sequence with four periods, which does not enter the lottery for payment. It is there to help you get familiar with the experiment. Then there will be a sequence out of which one lifecycle will be chosen randomly at the end of the experiment and paid out.

The experiment ends after each period with a probability of 20%. We have thrown a ten-sided dice to determine the number of periods, whereby the numbers 0 and 1 indicated ending the experiment and the numbers 2 through 9 indicated continuing the experiment.

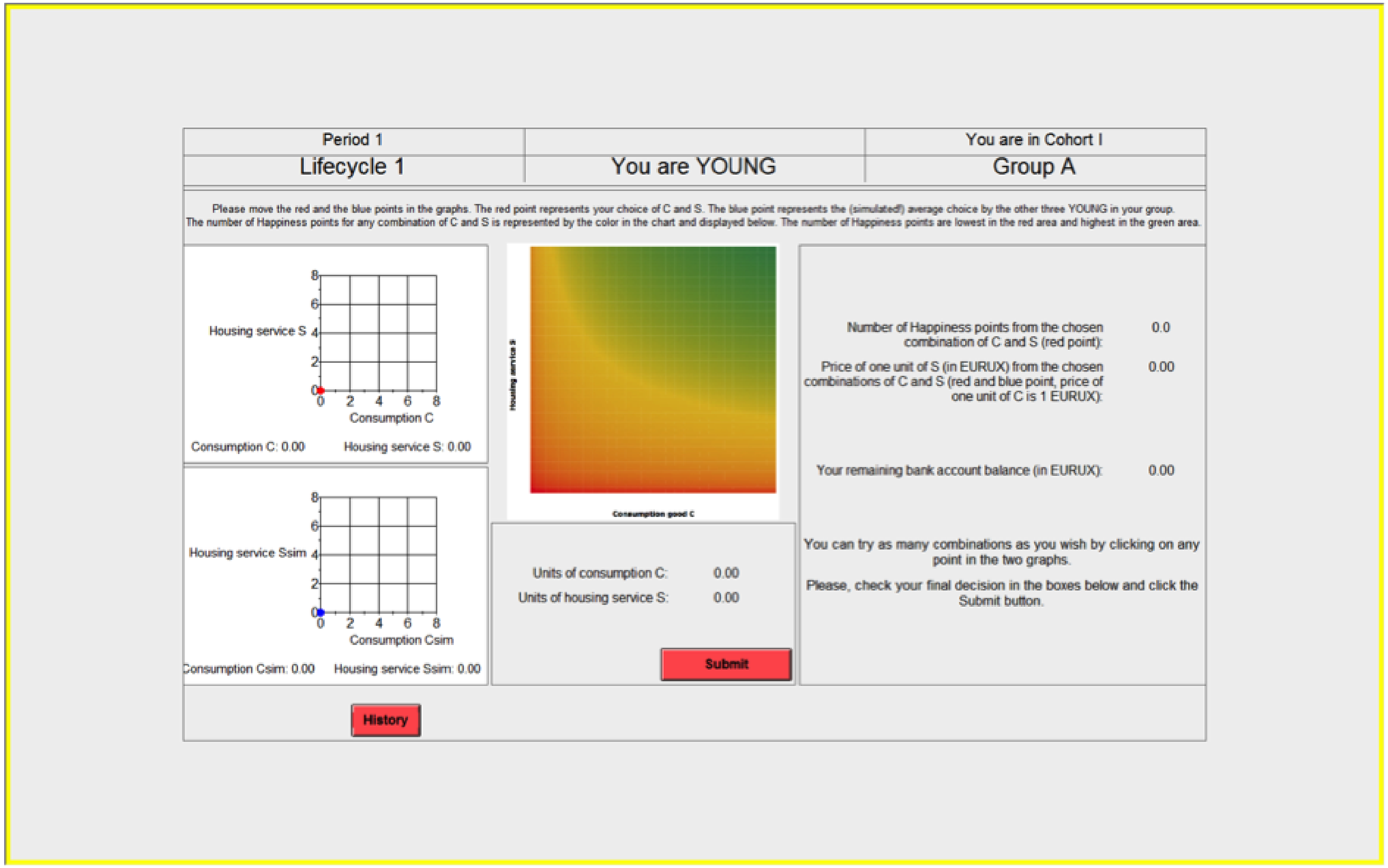


Figure C5: Decision screen when "Young": Stage 1 (consumption C and housing services S).

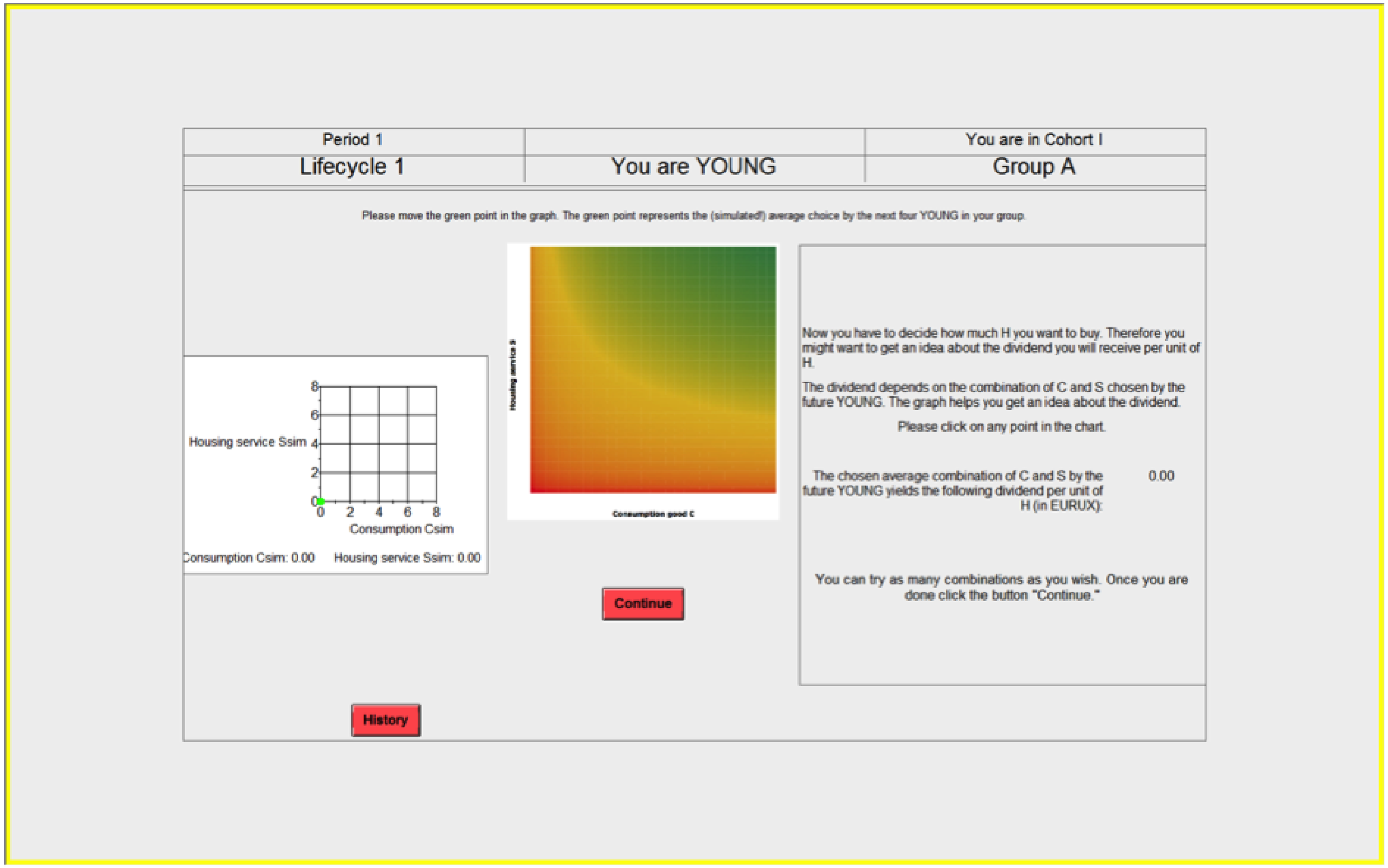


Figure C6: Screen when "Young": Stage 2 (simulation of dividend).

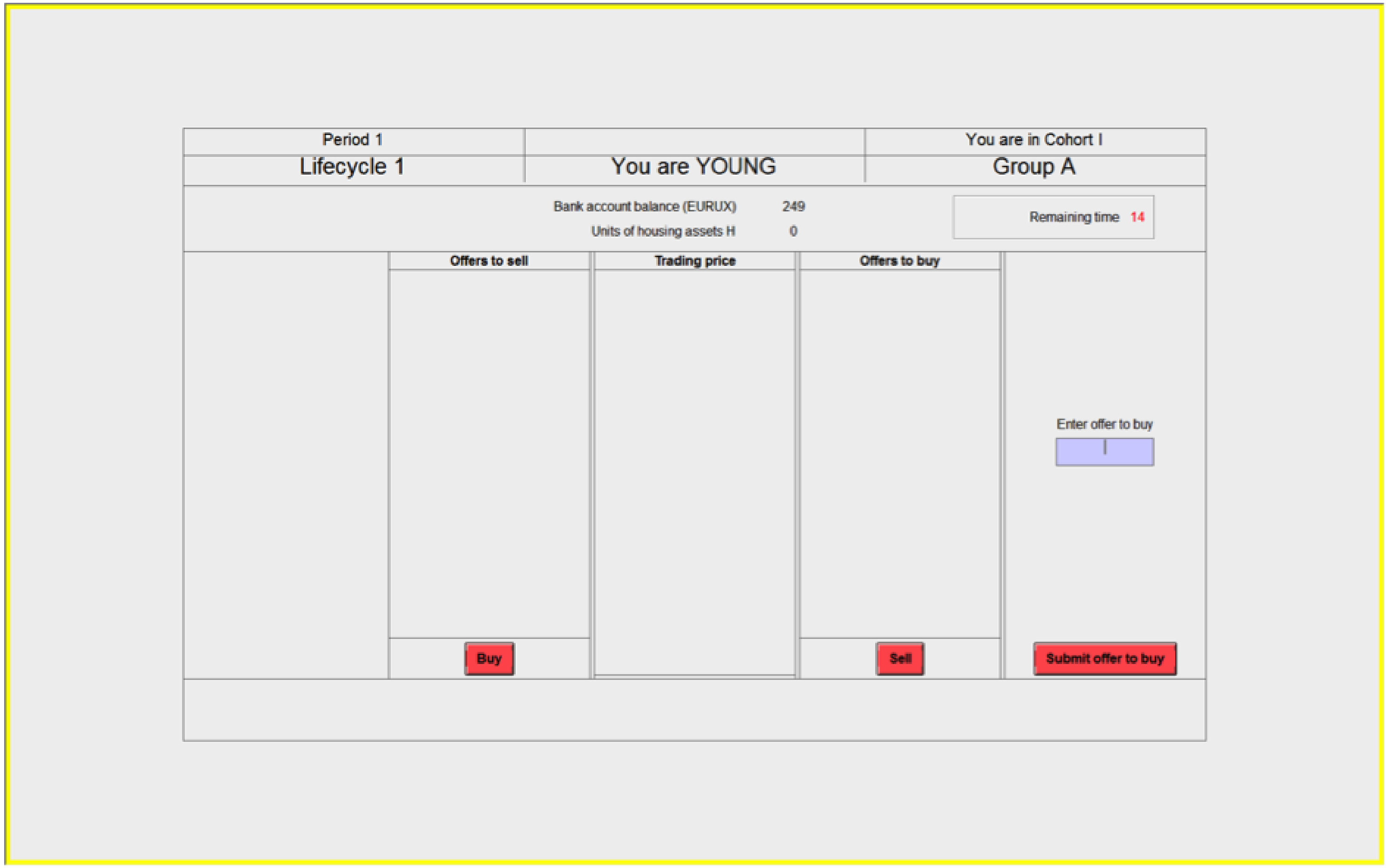


Figure C7: Decision screen when "Young": Stage 2 (housing asset H).

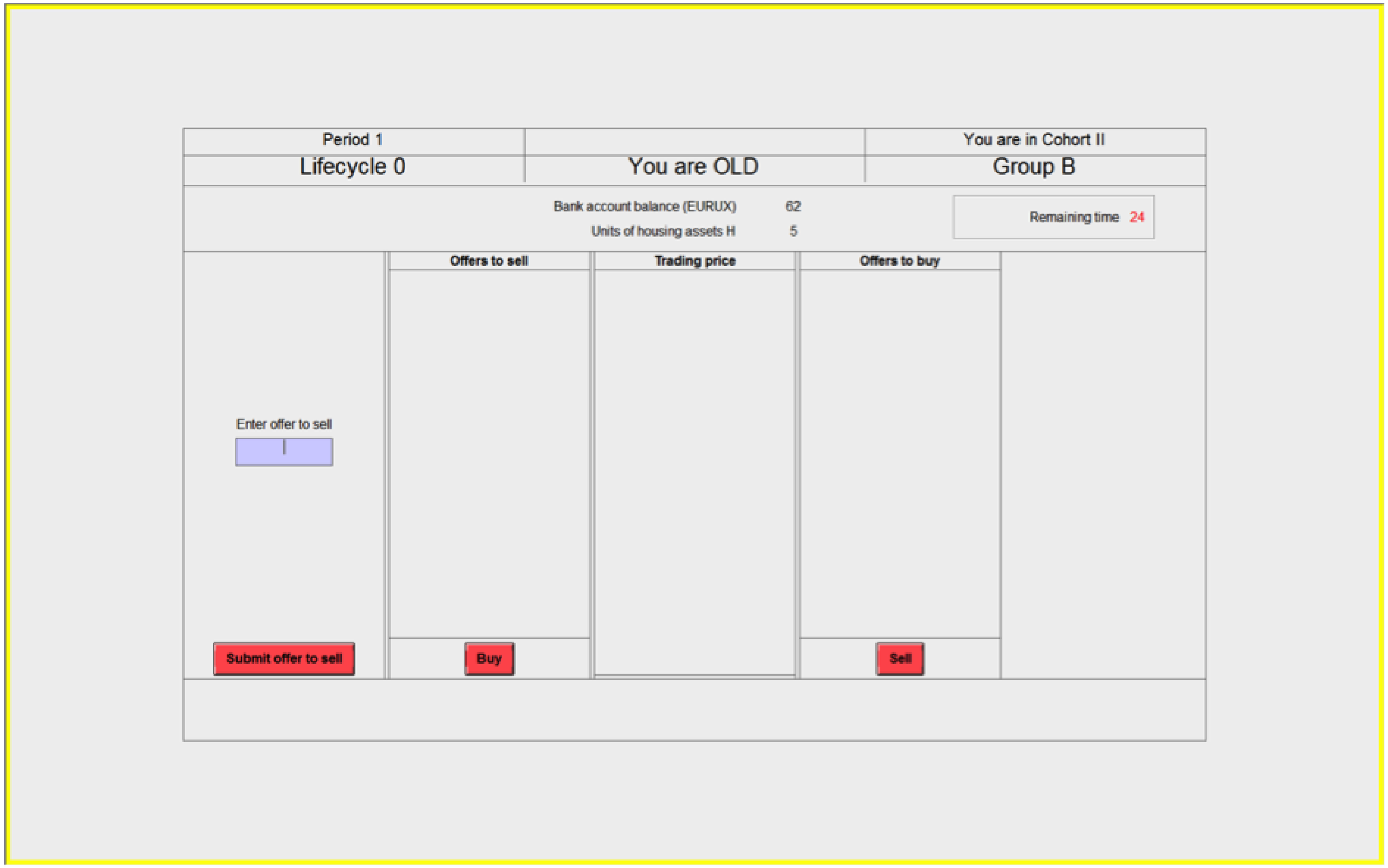
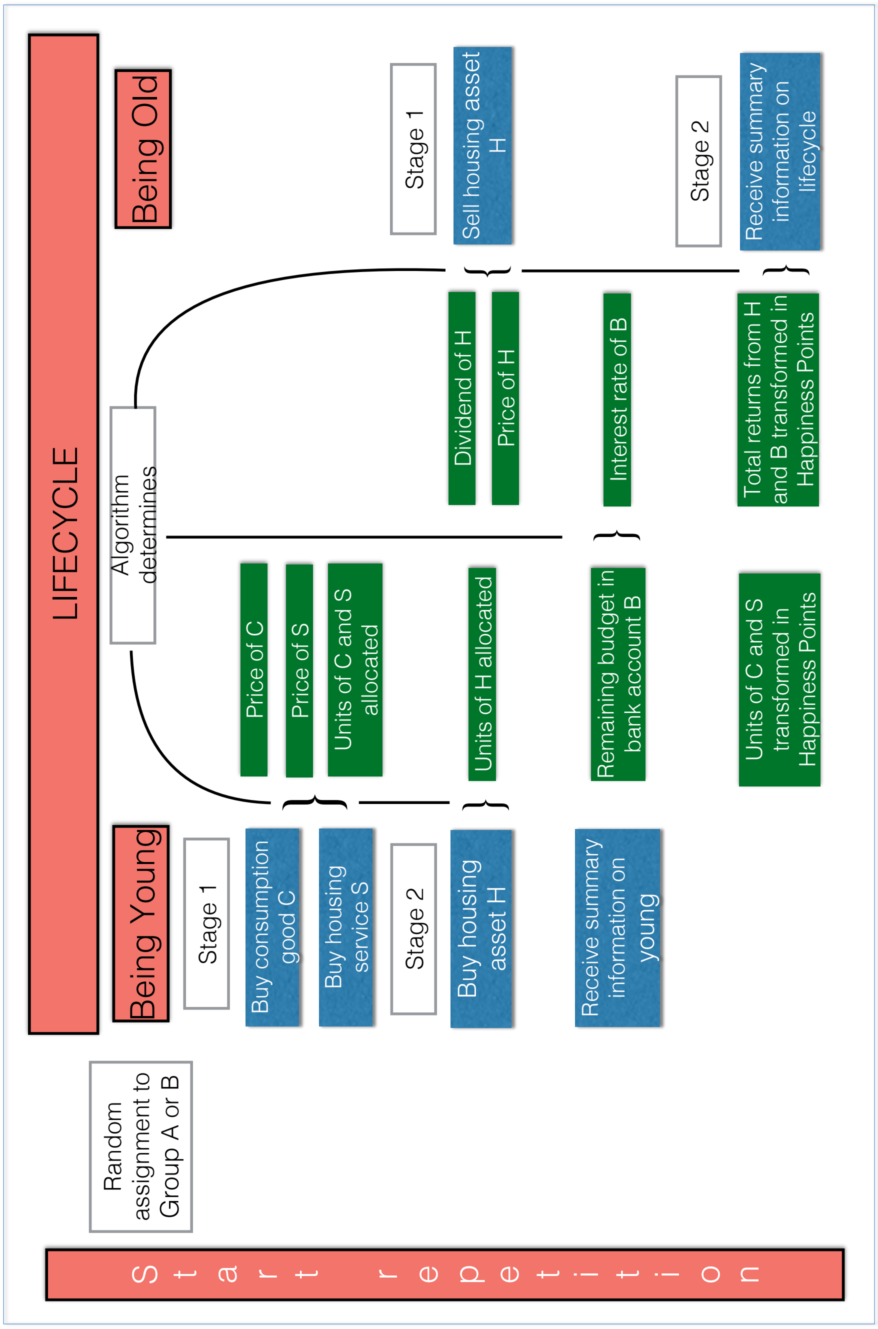


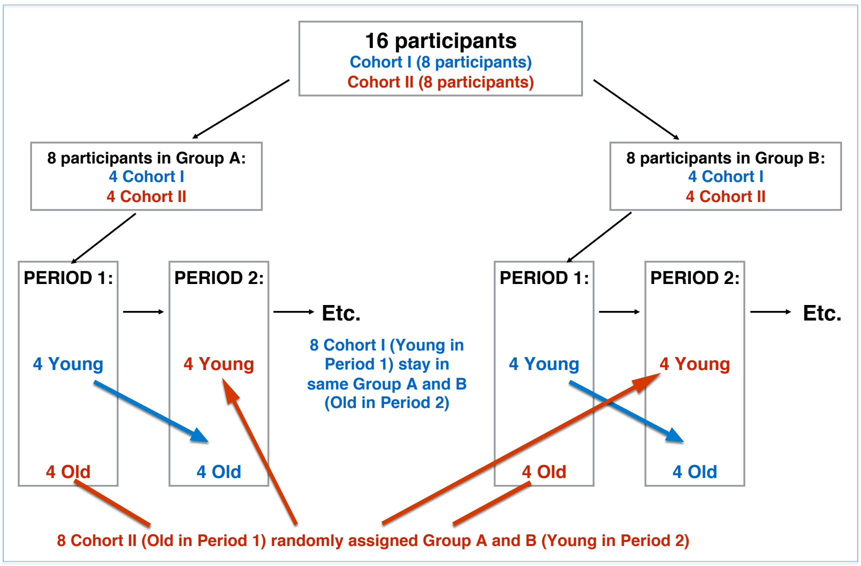
Figure C8: Decision screen when "Old": Stage 1 (housing asset H)

Handouts: Graphs and Table

Decisions in a lifecycle



Assignment and chronological order



Period		1	2	3	4	5	6	7	
Cohort I (8 subjects)		young	old	young	old	young	old	young	
	Lifecycle	1		2		3		....	
	Group	A or B (random)		A or B (random)		A or B (random)		....	Etc.
Cohort II (8 subjects)		old	young	old	young	old	young	old	
	Lifecycle		1		2		3		
	Group	A or B	A or B (random)		A or B (random)		A or B (random)		

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