Preference for Housing Services and House Price Bubble Occurrence
Evidence from a Macro-Experiment

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Abstract

Large house price bubbles can be devastating for the real economy. Therefore, understanding the conditions under which large house price bubbles occur is fundamental. We shed new light on this issue in a laboratory setting. We find that endowing subjects with a lower preference for housing services creates larger experimental house price bubbles. This is in line with the theoretical model mechanism proposed by Huber (2017). The experimental result also speaks to the empirical cross-country regularity found in Huber (2017): countries that spend a lower share of total consumption on housing services, experienced significantly larger house price bubbles during 1970-2014. This paper also contributes to the literature on experimental asset markets more generally. The paper provides a new experimental framework within which a market for the dividend of a traded asset exists. In addition, this paper provides novel design features for bringing OLG models to the laboratory.

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1 Introduction

Housing market fluctuations have a strong impact on overall economic performance. Recent empirical studies show that recessions associated with house price busts are not only longer but also much deeper than normal recessions or recessions associated with equity price busts.[1] Therefore, understanding the conditions under which large house price bubbles occur is fundamental.

Housing is very different to other assets given its dual nature - the consumption and investment demand for housing. Empirical studies have shown that times of intensive housing investment are often associated with bubbly episodes.[2] The existing empirical and experimental literature explores channels that work through the investment demand for housing. The role housing consumption plays in generating housing bubbles, however, remains under-explored.

We shed new light on this issue in a laboratory setting by exploring the relevance of preferences for housing services as a potential driver for house price bubbles. We find that endowing subjects with a weaker preference for housing services generates larger house price bubbles. This experimental result is in line with the empirical cross-country regularities found in Huber (2017). That paper shows that countries characterized with a weaker preference for housing services experienced significantly larger, more volatile, and a larger number of independent house price booms (and boom-bust cycles) during 1970-2014.[3] However, conclusions on the causal effect cannot be easily drawn. Huber (2017) proposes a theoretical overlapping generation (OLG) model that provides an explanation for why housing consumption might determine the vulnerability of an economy to housing bubbles.

The proposed model mechanism in Huber (2017) is tested in a laboratory experiment. The model allows for rational bubbles, given it's overlapping generation structure. The strong assumption of rationality is removed in the laboratory and

[1] Recessions that are associated with house price busts (four years) are much longer than recessions associated with equity busts (two and a half years). Following e.g. Claessens *et al.* (2012), Claessens, Kose, and Terrones (2009) and IMF (2003), house price busts have larger effects on consumption and investment and therefore GDP. The GDP drops by 8% on average when house prices burst compared to 4% when equity prices burst.

[2] Housing investment e.g. measured by turnover rates. The strong relationship between turnover and prices was first illustrated in Stein (1995). Subsequently, papers by Leung (2004), Andrew and Meen (2003), Hort (2000), and Berkovec and Goodman (1996) have confirmed the results.

[3] The preference for housing services relative to other consumption goods is measured empirically by (1) expenditure for housing services as a share of disposable income, and (2) by the CPI weight on housing services. Both measures include imputed rents. In the model, the preference for housing services determines the consumption expenditure share for housing services.

the theoretical mechanism is tested without it. Households live for two periods and decide how much *housing services* and how much of *all other* consumption goods to consume, how much to invest in the real estate asset *house*, and how much to save in riskless bonds. The dividend from investing in the asset house is given by the rental income a house generates.[4]

Two treatments are implemented - one with a weak and one with a strong preference for housing services. The results show that housing bubbles are substantially larger in the treatment with weak preferences for housing service. This results holds for a wide range of bubble measures, as well as for established experimental bubble indicators: the absolute bubble size, the bubble size relative to the fundamental value, the relative absolute deviation (RAD), the relative deviation (RD), the price amplitude (PA), the total dispersion (TD), and for the average bias (AB). Further, the difference in the magnitude of housing bubbles across treatments is robust to adjusting realized trading prices for endogenously resulting differences in the cash-to-asset ratio. Since the weak and strong preferences for housing services are randomly induced across sessions, we can conclude that the preference for housing services causally and negatively affects the size of housing bubbles in our setup.

The present paper's contribution to the existing literature on experimental asset markets is twofold.

This study highlights a new channel that determines the size of house price bubbles: the preference for housing services. The existing literature shows that the magnitude and duration of experimental bubbles vary with market conditions that affect the investment demand of housing. Ikromov and Yavas (2012), for instance, show experimentally that asset and market characteristics such as transaction costs, short selling restrictions and divisibility of the asset affect the magnitude of the boom and bust cycles. The role housing consumption plays in generating experimental housing bubbles, has not been explored. This paper aims to fill this gap.

This paper - one of the first laboratory experiments on housing markets - contributes to the existing literature on experimental asset markets also methodologically.[5] We implement several novel design features for OLG market experiments and believe that the experimental design provides a good starting point for the study of policy interventions in an OLG environment.

[4]The rental income is determined by the next young generation's demand for housing services.

[5]To our knowledge, Ikromov and Yavas (2012) and Bao and Hommes (2015) are the only experimental studies that analyze housing market features and their impact on house price bubbles.

First, our design provides a framework where both a market for the traded asset and a market for the dividend of that traded asset 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) or Ikromov and Yavas (2012). In contrast, in our design, the dividend of the bubbly asset is determined endogenously by the choices of the market participants. As mentioned before housing is a special asset given its dual nature. The fundamental value of a real estate asset is determined by the expected flow of future dividends that the asset generates. The dividend is given by the price for housing services. Hence, the demand for housing consumption determines the fundamental value of the real estate asset. It is therefore important to consider both the demand for housing consumption and the demand for housing investment simultaneously. The endogeneity of the dividend in the housing market is a crucial and novel feature for the analysis of experimental (housing) bubbles on asset markets.

Second, we provide new design features concerning the assignment of subjects to markets. In comparison to the existing literature, our assignment keeps the design close to the model structure and has the advantage of gathering more observations, providing the participants with experience, and simplifying the complex setup.

Third, our incentive structure is novel and important for overlapping generations market experiments. As is common in the literature, subjects play several life-cycles in the experiment. However, in the theoretical model subjects live one lifecycle only. To address this issue in the experiment, only one lifecycle is chosen randomly and paid out.[6] This design feature prevents subjects from hedging risk by playing different strategies in different life-cycles. We also find very stable patterns over the different life-cycles of a subject - which indicates that our incentive structure is aligned with the theoretical setup.

The remainder of the paper is structured as follows: Section 2 provides an overview of the related experimental literature and briefly summarizes the empirical regularities across countries. Section 3 shows the key equations of theoretical overlapping generation model.[7] Section 4 describes the design and implementation of the lab experiment including the experimental market design, and experimen-

[6]Duffy and Lafky (2016) explore the effect of fixed versus dynamic group membership on public good provision in an OLG setup. They also chose one lifecycle randomly for payment, however their study does not fall into the category of experimental OLG asset markets.

[7]Please refer to Huber (2017) for a detailed presentation of the overlapping generation model, and the empirical regularities across countries.

tal treatments. Section 5 explains carefully how we measure experimental bubbles, and presents the results from the experiment. In section 6 we address alternative explanations and provide corresponding robustness checks. Section 7 concludes.

2 Related Literature

2.1 Experimental studies

Our paper is related to the literature that studies the occurrences and underlying causes of experimental bubble formation. This literature is large. However, most of the experimental designs are very different to ours. In contrast to our design, most experimental papers assume an exogenous and finite dividend process. The seminal paper of Smith *et al.* (1988) (hereafter SSW) assumes a four-state iid. dividend process that is public knowledge. As the fundamental value (FV) of an asset is assumed to be its expected future dividend stream, it follows that the FV is deterministically declining. SSW find that experimental asset prices deviate strongly from fundamental values.

This setting was replicated and modified by many researchers, studying different treatments in similar designed experiments as SSW. Examples include experiments that study the impact of experience, short selling restrictions, constant fundamental values, transaction costs, and the divisibility of assets on bubble formation, e.g. Porter and Smith (1995), Noussair *et al.* (2001), Dufwenberg *et al.* (2005), Haruvy and Noussair (2006), Lei and Vesely (2009), Kirchler *et al.* (2012), Ikromov and Yavas (2012). These studies have in common that they design a tradable asset that has a finite lifetime. The asset pays a common-knowledge dividend distribution every period, which is the only source of value.[8]

[8] Porter and Smith (1995) study whether bubbles are less likely or smaller if the dividend is certain compared to an uncertain dividend. The authors do not find significant differences between the two treatments. A further result is that future markets help reduce the magnitude of bubbles but cannot eliminate them. Noussair *et al.* (2001) study whether bubbles are eliminated when the fundamental value is constant over the finite lifetime of the asset (instead of decreasing as in SSW). They find that bubbles are not eliminated. This finding is in line with Vernon L. Smith (2000). Dufwenberg *et al.* (2005) find that bubbles are reduced when the assets are traded by experienced traders, while Lei and Vesely (2009) show that bubble formation is reduced when the dividend process is explained very thoroughly to the participating subjects. Kirchler *et al.* (2012) show that confusion about the fundamental value plays a crucial role in experimental bubble formation. Haruvy and Noussair (2006) analyze the impact of short selling restrictions on bubble formation. They find that trading prices are reduced when short selling restrictions are relaxed, however negative bubbles persist. Ikromov and Yavas (2012) investigates the impact of transaction costs, short selling restrictions and the divisibility of assets on bubble formation. They find that

One main difference to our design is that all aforementioned papers assume a finite horizon (declining fundamental value). By contrast, our design captures an infinite horizon OLG model to allow for rational bubbles. The seminal paper of an OLG laboratory experiment is Marimon and Sunder (1993). Marimon and Sunder (1993)'s experimental design consists of assigning a fixed number of subjects to each session. Each subject plays during two periods (i.e. a lifecycle) as young and old in the first and second period respectively. After playing in the second period (old) subjects are randomly assigned to restart as young participant or waiting until being reassigned. Marimon and Sunder (1993) constructed this experimental environment to address questions of equilibrium selection and sunspots in the presence of multiple equilibria. Following Marimon and Sunder (1993), Lim *et al.* (1994) implemented an OLG model with money in a laboratory setting with the objective of studying price dynamics and the use of money as a store of value. Bernasconi and Kirchkamp (2000) use a slightly different environment to Marimon and Sunder (1993) in order to investigate how inflation is determined by monetary policy and by the amount of average saving within each period. Camera *et al.* (2003) use an OLG environment built on Marimon and Sunder (1993) with the difference of adopting a double auction environment instead of a supply schedule as the market institution to determine prices and quantities. They investigate how fiat money is used in transactions when an identically marketable, dividend-bearing asset, is also present.

Our OLG environment is based on Marimon and Sunder (1993), however it differs in three aspects. First and as in Camera et al. (2003), we use a continuous double auction environment. Second, we use a different way to construct 'generations' as we opted for pooling subjects randomly after each life cycle instead of having them waiting to be reassigned. This different assignment strategy has two advantages. First, it allows us to gather more observations. Second, we manage to stay closer to the theoretical model by mixing over a larger pool of subjects to reassign subjects to new generations. Recall that in the model a pair of subjects meets just once for an transaction. A further difference is the incentive structure. Our subjects know that only one life cycle will be paid out, this life cycle is chosen randomly. This design feature helps us to prevent subjects from hedging risk by playing different extremes in different life cycles. We think this incentive structure is very important to align

transaction costs as well as an increase in the divisibility of assets reduce the magnitude of bubbles. Short-selling restrictions lead to prolonged bubbles. For a review of the literature see chapters 29 and 30 in Plott and Smith (2008).

the experiment with the theoretical model, where subjects live for one life cycle only. To implement an infinite horizon environment in the laboratory, we follow Crockett and Duffy (2015) by implementing an indefinite horizon by assuming a constant probability of continuation each period.

2.2 Empirical Evidence

In this paper we highlight Huber (2017)'s novel empirical regularities identified across 18 OECD countries: First, the share of consumption spend on housing services is highly and negatively correlated with the number of independent house price booms and the number of boom-bust cycles that have occurred during 1970-2014.[9] Second, the share of consumption spend on housing services is highly and negatively correlated with the amplitude and the intensity of independent house price booms and boom-bust cycles across countries. Thus, countries where housing consumption is low as a proportion of overall consumption experienced not only more frequent, but also larger and more violent independent house price booms as well as boom-bust cycles during 1970 to 2014.[10]

3 The OLG Model

This section briefly summarizes the - for our purpose - most relevant model ingredients of Huber (2017). We focus in particular on the household sector. In the experiment, subjects play the role of households.[11] In addition, we highlight in this section the testable model predictions.

This model framework allows to study why countries with a *lower preference for housing services* experienced significantly larger, and a larger number of housing bubbles during 1970-2014. We take the model to the laboratory for the qualitative analysis of the impact of the preference for housing services on the bubble size.

[9]For instance, the number of completed independent house price booms (boom-bust cycles) that are associated with at least a 80% price increase, displays a cross-country correlation with the expenditure share for housing services of -0.72 (-0.30).

[10]The preference for housing services relative to other consumption goods is measured empirically by the CPI weight on housing services (including imputed rents). In the model (we base the experiment on), the preference for housing services determines the share of consumption on housing services as an equilibrium outcome.

[11]The firms are simulated by the computer, and hence we skip the firm side in this presentation.

3.1 Households

An overlapping generations structure is assumed where a continuum of households lives for two periods. The size of each generation (young and old) is normalized to unity. After dying, the old generation is replaced by a new, young one. Hence total population remains constant. Households born at time t maximize the expected lifetime utility

$$u(C_{1,t}) + \xi^k v(S_t) + \gamma E_t\{u(C_{2,t+1})\} \tag{3.1}$$

where C_t denotes the non-durable composite consumption good.[12] Consuming housing stock of size S_t yields housing service utility $v(S_t)$. ξ^k denotes the aggregate preference for housing service of country k relative to *all other* consumption $C_{1,t}$ when young, and $u(\cdot) = v(\cdot) = log(\cdot)$.[13]

Young households supply their labor service inelastically for a real wage W_t, and allocate their net wealth between consuming the bundle $C_{1,t}$, housing services of size S_t, save/invest in an one period riskless bond of value Z_t and purchasing housing stock of size H_t. The return to saving Z_t is given by the nominal interest rate $(1+i_t)$. For future reference, the real interest rate is defined as

$$R_t \equiv (1 + i_t)E_t \left\{ \frac{P_t}{P_{t+1}} \right\}. \tag{3.2}$$

Huber (2017) considers the two-dimensional aspect of housing, the demand for consumption and the investment demand. The dual motives of housing behavior is disentangled by modelling the consumption aspect (consuming housing services) and investment aspect (investing in housing) separately. This assumption distinguishes this model from existing models of rational housing bubbles, and allows the separate analysis of the impact of the demand for housing services on house price

[12] $C_{1,t} \equiv \left(\int_0^1 C_{1,t}^{1-\frac{1}{\varepsilon}}(i)di\right)^{\frac{\varepsilon}{\varepsilon-1}}$ and $C_{2,t+1} \equiv \left(\int_0^1 C_{2,t+1}^{1-\frac{1}{\varepsilon}}(i)di\right)^{\frac{\varepsilon}{\varepsilon-1}}$ are the bundles consumed when young and old, respectively. In each period, there exists a continuum of differentiated goods, each produced by a different firm, and with a constant elasticity of substitution denoted by ε, with $\varepsilon > 1$. Differentiated consumption goods (and the firms producing them) are indexed by $i \in [0, 1]$.

[13] As in Iacoviello (2005), I assume that housing service and *all other* composite consumption are separable. The decision of choosing a log specification over housing service and composite consumption is based e.g. on Davis and Ortalo-Magne (2011), who find that the expenditure share on housing is constant (over time and across U.S. cities). Further, I find that cross-country differences in the expenditure share on housing services are constant over time (for a sample of 18 OECD countries). Bernanke (1984) studies the joint behavior of the consumption of durable and non-durable goods, and finds that a separable log specification is a good approximation. Note the functions $u(\cdot), v(\cdot)$ are continuous and twice differentiable, with $\lim_{C\to 0} u(C) = -\infty$ and $\lim_{C\to 0} u'(C) = \infty$, $\lim_{S\to 0} v(S) = -\infty$ and $\lim_{S\to 0} v'(S) = \infty$.

bubble occurrence and bubble size.

For concreteness, when young households buy housing services S_t, they do so by renting housing stock S_t from the old generation. Young households that invest in housing buy housing stock H_t when young from the old generation. The housing asset yields a dividend payment next period - a rental income when old. Before the old household dies, he sells the remaining housing stock to the new young generation.[14]

When born, households are endowed with $\delta \in [0, 1)$ units of housing stock whose price is $Q_{t|t} > 0$. Households can buy and trade houses.[15] Each period, the housing stock depreciates by the fraction δ; it follows that the total housing stock in the economy remains constant.[16]

Accordingly, the budget constraint of the young household at time t is given by

$$C_{1,t} + \frac{Z_t}{P_t} + \sum_{k=0}^{\infty} q_{t|t-k} H_{t|t-k} + p_t^r S_t \leq W_t + \delta q_{t|t}, \tag{3.3}$$

where P_t is the price of the composite consumption good in period t. The rental and purchasing price of one unit of housing stock is denoted by P_t^r and Q_t, respectively. With prices written in lowercase letters, I define prices relative to the consumption bundle, so $q_t = \frac{Q_t}{P_t}$ and $p_t^r = \frac{P_t^r}{P_t}$. Further, $H_{t|t-k}$ denotes the quantity of the housing stock purchased in t, introduced by the cohort born in period $t-k$, and whose relative current price is $q_{t|t-k}$ for $k = 0, 1, 2, ...$

The budget constraint when old is given by equation (3.4). By purchasing the consumption bundle $C_{2,t+1}$, the old household consumes all his wealth. The household's wealth consists of (1) the rental income from renting his housing stock to the young generation, which is given by $\sum_{k=0}^{\infty} p_{t+1}^r H_{t|t-k}$, (2) the re-selling value of his housing stock[17], (3) the payoff from his maturing bond holding, and (4) real profits

[14] As ?) argued, "...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] Assuming that housing is a partially bubbly asset, it follows that households are endowed with a partially bubbly asset as in Galí (2014). With the difference that in Galí (2014) households are endowed with a pure bubbly asset, that is intrinsically useless.

[16] Young households are endowed with the know-how to set up a new firm producing a differentiated consumption good. That firm only becomes productive after one and for one period only (i.e. when the founder is old), generating profits, D_t, for the owner when old.

[17] At the end of the period the old household sells his remaining housing stock, i.e. $(1-\delta)\sum_{k=0}^{\infty} q_{t+1|t-k} H_{t|t-k}$, to the young generation.

generated by his intermediate firm, D_{t+1}. Formally, for each old household we have

$$C_{2,t+1} \leq \frac{(1+i_t)Z_t}{P_{t+1}} + \sum_{k=0}^{\infty} p^r_{t+1} H_{t|t-k} + (1-\delta) \sum_{k=0}^{\infty} q_{t+1|t-k} H_{t|t-k} + D_{t+1}, \tag{3.4}$$

where $H_t = \sum_{k=0}^{\infty} H_{t|t-k}$.

3.2 Price of Housing: Definitions

The house price q_t is defined as a sum of the fundamental part q_t^F and a bubble component q_t^B

$$q_t \equiv q_t^F + q_t^B \tag{3.5}$$

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

$$q_t^F \equiv E_t \left\{ \sum_{k=1}^{\infty} \prod_{j=0}^{k-1} \frac{1}{R_{t+j}} (1-\delta)^{k-1} p^r_{t+k} \right\} \tag{3.6}$$

3.3 Testable Predictions of the Model

In a bubbly equilibrium it must hold that

$$B_t \in \left[0; W - q_t^f\right] \quad \forall \quad t. \tag{3.7}$$

Huber (2017) refers to (3.7) as condition 1 for Bubble Existence. The larger the fundamental value of the real estate stock today, the smaller the maximum theoretically possible aggregate bubble value today. In other words, countries that are characterized by a larger fundamental value of real estate (potentially because the aggregate preference for housing services is stronger), have less room for large bubbles, i.e. cannot experience large bubbles - in comparison to countries where the fundamental value of real estate is lower (i.e. the aggregate preference for housing services is weaker).

Comparative Statics of the Steady State show that an increase in ξ (capturing a rise in household's preference for housing services relative to other consumption goods) induces a decrease in the fraction of income spend on other consumption goods when young (hence C_1 decreases) and an increase in the fraction of income spend on housing services, hence the rental price p^r increases. Consumption when old, C_2, increases. The fundamental price q^F, the discounted stream of rental prices, increases. The price-rent-ratio (PRR) decreases. The bubble component q^B decreases. In policy debates the PRR is often referred to as a good indicator for the detection of house price bubbles.

In section 5, we discuss our experimental result. Our results are in line and hence support each of the above discussed comparative statics.

4 Experimental Design

This section outlines the experimental design using overlapping generations. First, we explain the decisions that subjects take in a lifecycle. Second, we describe the assignment to groups (= markets) and the overall structure of the experiment. Third, we present the treatments and the parameters (chosen based on the theoretical model) and, finally, the procedure and the subject pool. The instructions are provided in the appendix.

Our objective to run a macro lab experiment was two-fold: First, we focus in the lab-experiment on the novel empirical stylized fact identified across 18 OECD countries. Countries that spent a lower share of consumption expenditure on housing services experienced larger house price bubbles during 1970-2014. However, conclusions on the causal effect cannot be easily drawn given data availability issues, potential measurement errors especially for the bubble and the preference for housing services, and the problem of reversed causality. As conclusions on the causal effect of the preference of housing services on housing bubbles cannot be drawn from the empirical data, **?**) develops a theoretical model that provides a causal link, an explanation why the preference for housing services might determine the vulnerability of an economy to housing bubbles. The proposed model mechanism is tested in a laboratory setting.

Second, this paper contributes to the literature on experimental asset markets more generally. It provides an experimental framework where also a market for the dividend of a traded asset exists. Most experiments in the related literature assume exogenously a dividend for the traded asset. Our design is one of the first where a market for the dividend of a bubbly asset exists and where the dividend is determined endogenously in the laboratory setting by the choices of the market participants. Furthermore, we implement novel design features with respect to the

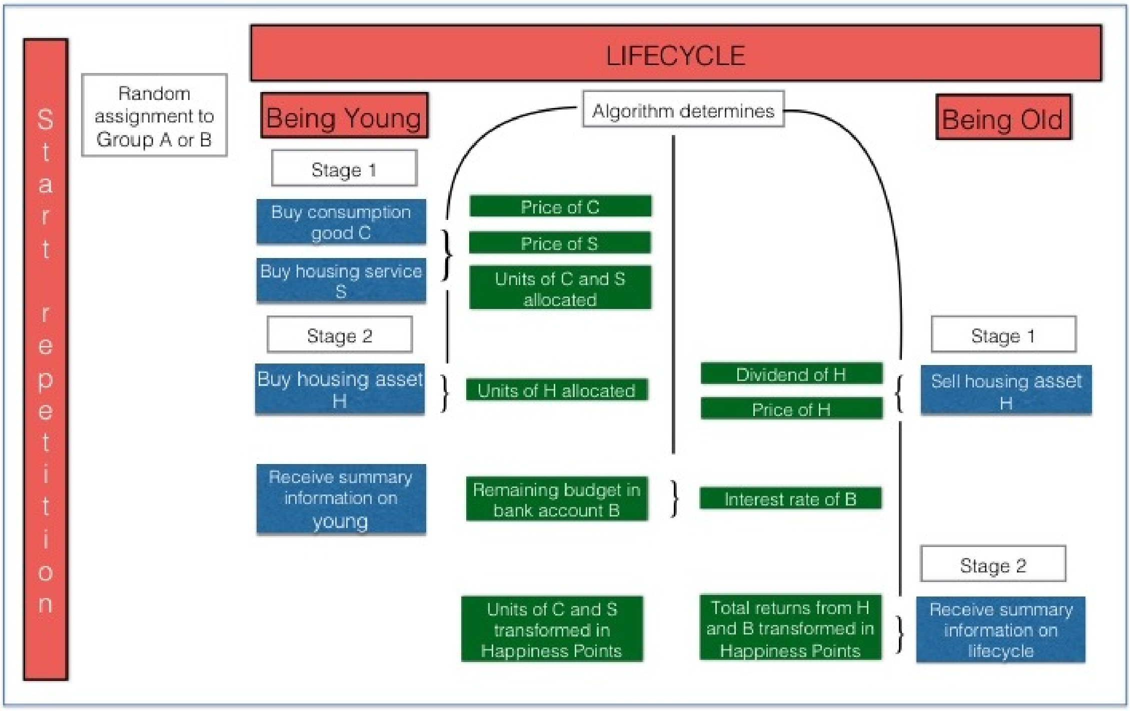


Figure 1: Lifecycle and decisions when young and old

assignment to markets, and the incentive structure in an OLG setup. These features will be discussed in more detail in the next sections.

4.1 Decisions in a lifecycle (young and old)

As mentioned earlier, we implement an experimental design using overlapping generations. For feasibility reasons, subjects play several lifecycles, but only one completed lifecycle (chosen randomly) forms the basis for the payment. We decided to pay only one completed lifecycle because it most closely aligns incentives with the idea of independent overlapping generations. Figure (1) shows the timing of the decisions subjects take within each lifecycle. A lifecycle consists of two periods: In the first period of a lifecycle, subjects take decisions as a *young* household. In the second period of a lifecycle, subjects take decisions as an *old* household and receive payments that are based on their decisions when young and old, as well as aggregate outcomes. The decision screens of a lifecycle can be found in the appendix.

Each period (*young* and *old*) is divided into two stages. In the theoretical model, young households make decisions on the consumption good C, housing services S, the housing asset H and the riskless bond B simultaneously. For practical reasons (screen overload, remaining budget calculation, dividend calculation), this is not feasible in the lab. We, therefore, split decisions into two stages. At the beginning of a lifecycle, subjects receive an endowment (= budget) that they can spend on the consumption good C, housing service S, the housing asset H, and the riskless bond B.

When *young*, subjects first decide how many units of the consumption good C and how many units of housing service S they want to purchase (young, stage 1). They do so by clicking on a combination of C and S in a graph on the decision screen. Next to the graph where they make their choices, a colored heat map is displayed on the screen. The colors go from red to yellow to green. The greener the color the more happiness points (utility) subjects receive for the specific combination of C and S. The price for one unit of C is set to the numeraire (and equal to one). The (relative) price for one unit of S, p_t^r, depends on all young's purchases of C and S in the market. The price p_t^r can only be calculated once all young in the group have submitted their purchase decisions (subject to budget constraints and available supply of C and S). We therefore provide a graph on which subjects can simulate the purchase decision of C and S of other young subjects in the group. Together with the own chosen combination of C and S, the relative price for one unit of S, p_t^r, is calculated and displayed on the screen. Subjects can try as many combinations as they wish (without time restriction). Once they decide for a combination of C and S, they press a "Submit" button, and their decision is submitted. We tell subjects to submit the very maximum number of units of C and S they want to purchase. Once all young in the group have submitted their demands, the algorithm checks for availability of the demanded number of units. In the case of excess demand, each young subject's demanded units are reduced proportionally to the requested amounts.

In the second stage when *young*, subjects purchase units of housing asset H in a double auction from the current *old* in the group (young, stage 2). Before the *young* subjects get to the double auction, they learn how the dividend of the housing investment H will be determined. They understand that the dividend will depend on the choices of C and S by the *future young*. They can simulate the average purchase of C and S by the future *young* on a graph.[18] The dividend resulting from each simulated combination of C and S is calculated and displayed on the screen. We

[18]As a helping device, the same heat map as in stage 1 when *young* is depicted because the future *young* will make the exactly same decision on purchasing C and S as the current *young* generation.

implement a standard experimental double auction with the only exception that *young* subjects can only *purchase* and *old* subjects can only *sell* housing assets H. Currently *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) or by accepting an offer to sell submitted by *old* subjects (a price for one unit of housing asset H). The duration of the double auction is three minutes. After the double auction, the remaining budget is automatically invested into a riskless bond B (= remains in the bank account) and earns a fixed interest payment.

When *old*, subjects learn about their investment return in asset H. They receive a dividend payment for each housing asset H they bought when young. The *old* subjects enter a double auction, where they can sell housing assets H to the current *young* generation in the group (old, stage 1). Currently *old* subjects 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) or by accepting an offer to buy from the *young* subjects (a price for one unit of housing asset H). The duration of the double auction is three minutes. The stock of housing assets H has to remain constant from generation to generation, we assume no depreciation of the housing stock. Unsold units of the housing asset H are assigned randomly to the current *young* in the group at a punishment price. The punishment price is lower than the median trading price for the current *old* and it is higher for the current *young* in the group. This incentivizes subjects to trade the existing housing stock H, such that the market clears.

At the end of a lifecycle, subjects receive summary information on their decisions in the corresponding lifecycle: the number of units C and S purchased in that lifecycle and the respective prices, units of H purchased, and the median price of H of all sold assets H. Furthermore, subjects receive information on the dividend of each purchased housing asset H, the price for which they sold the purchased assets H, the return from the riskless bond B, and the total lifecycle utility.

To facilitate decisions and ensure that decisions are as well-informed as possible, subjects can get to a history screen from any decision screen or feedback screen (and back to the decision or feedback screen). On the history screen, they find a summary of their decisions on C, S, H, and B as well as the corresponding utility in all previous periods of the experiment. Furthermore, the history table shows the median price for all traded housing assets H and the average dividend per housing asset H in all previous periods of the experiment.

4.2 Markets Assignment and Experimental Structure

In the beginning of the experiment, 50% of all subjects are randomly assigned to Cohort I and the remaining 50% of subjects to Cohort II. All subjects are informed that they will remain in the assigned cohort for all periods of the experiment.

In 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 a *young* (*old*) generation in period 1 and subjects make decisions accordingly. Figure (2) summarizes the assignment to Cohorts and Markets.

From period 2 onwards, cohorts switch between generation in each period. That means that Cohort I (II) takes the role of the *old* (*young*) generation in period 2, the role of *young* (*old*) generation in period 3, etc. As an important design feature, the *old* subjects remain in the *same* Market as in the previous period (when they were *young*), while the *young* subjects are *randomly* assigned to either Market A or Market B. Through this assignment, we control for colluding behavior in small markets and repeatedly interacting agents.

Cohort I's lifecycle 1 consists of periods 1 and 2, lifecycle 2 consists of periods 3 and 4, etc. Cohort II's lifecycle 1 consists of periods 2 and 3, lifecycle 2 consists of periods 4 and 5, etc. Figure (3) presents an overview over each cohort's lifecycles.

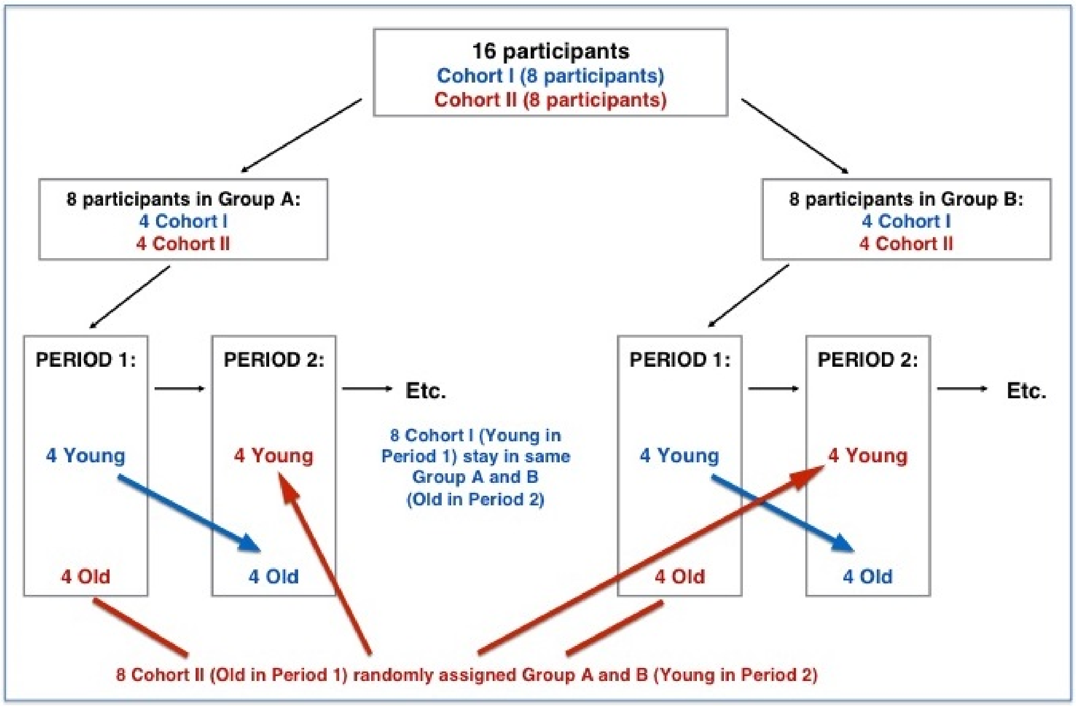


Figure 2: Assignment of subjects to Market A and B

As mentioned earlier, one completed lifecycle is chosen randomly and paid out at the end of the experiment. If a cohort is *old* (*young*) in the last period of the experiment that lifecycle is complete (incomplete) and enters (does not enter) the lottery of the randomly selected lifecycle for payment.

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)		

Figure 3: Chronological order of the experiment

To implement an infinite horizon environment in the lab, we follow Crockett and Duffy (2015) and implement an indefinite horizon by assuming a constant probability of continuation each period. This probability is set to 80%. Before running the sessions, we threw a ten-sided dice to determine the number of periods. Thus the length of each session is the same and equal to nine periods. Before the experiment starts, subjects have four trial periods to get familiar with the experiment and the decisions they are expected to make.

Conservatively, we consider each session as an independent observation because subjects go back and forth between the two Markets A and B. We thus interpret one session as a "super-Market" and the aggregate behavior in one session as the behavior in a "super-Market."

4.3 Treatments and Parameter Choices

The treatments are derived from **?**)'s theoretical model. We implement the following two treatments in a between-subject design:

- Treatment *"Weak preference for housing service"*: subjects have a weak preference for housing services (low ξ), the utility from consuming housing services S relative to the consumption good C is low.
- Treatment *"Strong preference for housing service"*: subjects have a strong preference for housing services (high ξ), the utility from consuming housing services S relative to the consumption good C is high.

The main hypothesis concerning the effect of preference for housing service on the size of housing bubbles on the housing asset market is:

> *Housing Bubbles are larger in the treatment "Weak preference for housing service" with low ξ compared to the treatment "Strong preference for housing service" with high ξ.*
> *We expect the deviation of the asset price from the fundamental value to be larger in treatment "Weak preference for housing service" compared to the treatment "Strong preference for housing service".*

The treatment variable ξ takes the following values: $\xi = 2$ in the treatment *"Weak preference for housing service"* and $\xi = 6$ in the treatment *"Strong preference for housing service"*. In the treatment Strong preference for housing service the relative preference parameter is 300% larger.

We calibrated these values to match cross-country stylized facts presented in Chapter 1. More concretely, for the sample of 18 OECD countries, the lowest share of total consumption spent on housing services is around 11%, while the largest is slightly above 30%. In the model, data on the aggregate consumption expenditure share spent on housing services pins down the model parameter ξ for each country uniquely. We match the distance between the lowest and largest ξ implied by the aggregate consumption expenditure shares spent on housing services across countries.

The remaining parameter choice are derived from the theoretical model and are summarized below

- 16 subjects in each session (8 in Cohort I, and 8 in Cohort II)
- Four trial periods and nine periods in the experiment (number of periods determined by throwing a ten-sided dice before the sessions started)
- Supply: In each market (A and B), 20 units of consumption good C, housing service S, and housing asset H, respectively
- Excess demand for S and/or H:
  proportional cut of the demand for all *young* subjects until demands equals supply
- Endowment at the beginning of each lifecycle (when being *young*):
  250 EURUX
- Endowment of initial Cohort II members in period 1 (*old subjects*):
  five units of housing asset H and 50 EURUX invested in bond B.
- Price for one unit of C: numeraire and equal to one
- Price for one unit of S: relative price $p^r = \xi * \frac{C^{demanded}}{S^{demanded}}$
- Price for one unit of H: determined in a double auction
- Punishment price for unsold H: 0.5 of median price in the respective market for sellers (currently *old*); 1.5 of median price in the respective market for buyers (currently *young*).
- In each period, the dividend of the Housing asset H is determined by the current *young* and given by p^r if $S^{demand} = S^{supply}$; Dividend $= p^r * \frac{S^{demand}}{S^{supply}}$ if $S^{demand} < S^{supply}$
- After purchase of C, S, and H, remaining budget invested in riskless bond B at an interest rate of 5%.
- Happiness Points (from C and S) $= log(C) + \xi log(S)$
- Happiness Points (from H and B) = log(return from selling the previously purchased H + divided per purchased H + 1.05*investment in bond B)

4.4 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 then read aloud by one of the experimenters. The material handed out to the subjects can be found in the appendix. The instructions and materials are the same for treatment *"Weak preference for housing service"* and treatment *"Strong preference for housing service"* with two exceptions: First, the formula for the utility from C and S differs depending on the treatment ("Happiness Points (from C and S) $= log(C) + 2 * log(S)$" for treatment *"Weak preference for housing service"*; "Happiness Points (from C and S) $= log(C) + 6 * log(S)$" for treatment *"Strong preference for housing service"*). Second, the heat map and screenshots are adjusted accordingly. The beginning of the trail sequence, as well as the start of the main sequence, are announced aloud by one of the experimenters.

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

In total 256 subjects took part in 16 experimental sessions (eight sessions per treatment) composed by 53% women and 47% men (the share of women per session varied between 37.5% and 62.5%). Eckel and Füllbrunn (2015) show that asset markets with a higher share of male participants produce larger price bubbles. To control to some extend for the gender composition, we invited the same number of male and female students to each session. The average age was 21 years. The conversion rate was 1 Happiness Point (= utility) to 3 Euro and the average earnings per subject were 27.27 Euro (including a show-up fee of 5.00 Euro and a finishing fee of 5.00 Euro). The average duration of a session was 2 hours 30 minutes. After the experiment had finished, subjects were asked to fill out a questionnaire and were paid their earnings in private.

5 Data Analysis and Main Results

In this section, we first explain how we measure house price bubbles. As in the model, we define a bubble as the difference between the realized median trading price q and the fundamental value q^F. For robustness purposes, we measure the expected fundamental value by four alternative methods, leading to four different bubble measures. For each alternative, we show the difference and similarities of the raw data in the trading price, fundamental value and bubble formation across treatments. Our results are robust to these variations.
Second, we employ and describe a wide range of indicators for measuring experimental bubbles. These indicators are widely used in the experimental asset price literature, and we study their differences across the two treatments (strong versus weak preference of housing services). All employed indicators reveal the same pictures; bubbles are significantly larger in the treatment *"Weak preference for housing service"*.

In addition, we provide statistical inference. Conservatively, we consider a session as an independent observation (resulting in 16 independent observations) and use the non-parametric Mann-Whitney U test to test the difference in the distribution of housing bubbles between the two treatments. Complementary regression analysis allows controlling for the gender composition in a session, age, and a time trend.

5.1 Experimental Bubble Measures

As in the model, the experimental bubble is computed by $q_t^B = q_t - q_t^F$, where q_t denotes the realized trading price in the experiment in period t, and q_t^F the fundamental value, i.e. the discounted stream of expected dividends. Next, we assume four different expectation formations, leading to four different measures for the fundamental value, and hence bubble sizes.

Fundamental Value

Each period ends with a probability $x = 20\%$. In our baseline, we assume *sophisticated traders.* We assume that they recognize all realized dividends of the past and update their beliefs accordingly. Hence, in period one sophisticated traders expect all future dividends to be equal to the current and first realization. In all future periods, sophisticated traders update their belief and expect that all future dividends will be equal to the average of all up to date realized dividends. The sophisticated traders calculate and expect the following fundamental value:

$$\begin{aligned}
q^F_{t=1,sophisticated} &= \left(\frac{1-x}{R}\right) p^r_1 \\
q^F_{t=2,sophisticated} &= \left(\frac{1-x}{R}\right)^2 \frac{p^r_1 + p^r_2}{2} \\
&... \\
q^F_{t,sophisticated} &\equiv E_t \left\{ \sum_{j=1}^{\infty} \left(\frac{1-x}{R}\right)^j \sum_{k=1}^{t} \frac{p^r_k}{t} \right\} \qquad (5.1)
\end{aligned}$$

For robustness purposes, we measure the expected fundamental value by alternative methods. Our results are robust to these variations.

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

$$\begin{aligned}
q^F_{t,naive} &\equiv E_t \left\{ \sum_{k=1}^{\infty} \left(\frac{1-x}{R}\right)^k p^r_{t=1} \right\} \\
&= \frac{1}{R}(1-x)p^r_{t=1} + \frac{1}{R^2}(1-x)^2 p^r_{t=1} + \frac{1}{R^3}(1-x)^3 p^r_{t=1} + ... \\
&= p^r_{t=1} \left(\frac{1-x}{R-(1-x)}\right) \quad \forall \quad t \qquad (5.2)
\end{aligned}$$

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

$$q^F_{t,myopic} \equiv E_t \left\{ \sum_{k=1}^{\infty} \left(\frac{x}{R}\right)^k p^r_t \right\} \qquad (5.3)$$

The third alternative assumes *omniscient traders*, they forecast the dividend process correctly:

$$
\begin{aligned}
q^F_{t=1,omniscient} &= \left(\frac{1-x}{R}\right) p^r_1 + \left(\frac{1-x}{R}\right)^2 p^r_2 + ... + \left(\frac{1-x}{R}\right)^8 p^r_9 \\
&+ E_t\left\{\sum_{j=1}^{\infty}\left(\frac{1-x}{R}\right)^j p^r_9\right\} \\
q^F_{t=2,omniscient} &= \left(\frac{1-x}{R}\right) p^r_2 + \left(\frac{1-x}{R}\right)^2 p^r_3 + ... + \left(\frac{1-x}{R}\right)^7 p^r_9 \\
&+ E_t\left\{\sum_{j=1}^{\infty}\left(\frac{1-x}{R}\right)^j p^r_9\right\} \\
&\dots \\
q^F_{t,omniscient} &\equiv \sum_{j=t}^{9}\left(\frac{1-x}{R}\right)^{j-t+1} p^r_j + E_t\left\{\sum_{j=1}^{\infty}\left(\frac{1-x}{R}\right)^j p^r_9\right\}
\end{aligned}
\tag{5.4}
$$

5.1.1 Bubble Indicators

In the experimental asset price literature, there are five well established indicators for measuring bubbles. Table (1) shows these indicators for all sessions and compares the averages for both treatments.

Price Amplitude (PA)

$$PA_{King} = \frac{max_t(Q_t - q^F_t) - min_t(Q_t - q^F_t)}{q^F_1} \tag{5.5}$$

is defined as the difference between the peak and the trough of the period house price relative to the fundamental value, normalized by the initial fundamental value in period 1. A high Price Amplitude suggests large price swings relative to fundamental value, and is evidence that prices have departed from fundamental values. This measure was first proposed by King *et al.* (1991).

Total Dispersion (TD)

$$TD = \sum_t |Q_t - q^F_t| \tag{5.6}$$

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 deviation measure is similar to the amplitude measures and measures the difference between the trading price and the fundamental value. However, this deviation measure is more complete in the sense that it does not only measure the difference between the maximum and minimum deviation from fundamental value. Total Dispersion (TD) was first introduced by Haruvy and Noussair (2006).

Average Bias (AB)

$$AB = \frac{\sum_t (Q_t - q_t^F)}{T} \tag{5.7}$$

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

Relative Absolute Deviation (RAD)

$$RAD = \frac{1}{T} \sum_{t=1}^{T} \frac{|Q_t - q_t^F|}{|\bar{q}^F|} \tag{5.8}$$

was proposed by Stöckl *et al.* (2010) and measures the average level of mispricing. It is similar to the TD measure, but has two important advantages: The measure is independent of (1) the number of periods, and (2) the absolute level of the fundamental value. The *Relative Absolute Deviation (RAD)* is shown in the fourth column of table (1) and is calculated by averaging the absolute differences between the mean price and the fundamental across all periods and is normalized by the absolute value of the fundamental value of the market $\bar{q}^F$. T denotes the total number of periods in the asset market.

Relative Deviation (RD)

$$RD = \frac{1}{T} \sum_{t=1}^{T} \frac{(Q_t - q_t^F)}{|\bar{q}^F|} \tag{5.9}$$

was proposed by Stöckl *et al.* (2010). The fifth column in table (1) shows the *Relative Deviation (RD)* measure that is very similar to RAD. While RAD averages the absolute difference between the mean price and the fundamental value, RD averages just the difference between the mean price and the fundamental value. Hence, positive and negative deviations from FV offset each other. When RAD and RD deliver the same number, the mean trading price has never been below the fundamental value, e.g. there has never been a negative bubble.

5.2 Descriptive Statistics and Statistical Inference

5.2.1 Bubble Relative to Fundamental Value

Figure (4) shows the average median trading price for the housing asset (green line) and its fundamental value FV (blue line). The fundamental value is computed as the average over all sessions assuming sophisticated traders. The black doted lines indicate the range of a reduced (increased) FV by 60%, respectively. The red dotted lines indicate the maximally feasible average trading price. This measure will be discussed in a later section. The left column shows the sessions with the treatment *Weak preference for housing service* and in the right column the treatment *Strong preference for housing service*.

As it can be seen in figure (4), the housing asset is on average overvalued in both treatments: The average median trading price Q is similar for both treatments and equals 28.58 for $\xi = 2$ and 28.85 for $\xi = 6$ ($z = 0.000, p = 1.0000, n = 16$, two-sided Mann-Whitney U test). The average median trading price is relatively constant over time for the treatment Strong preference for housing service. For the treatment Weak preference for housing service, the average median trading price seems to slightly decrease over time. Figure (7) in the Appendix shows that this slight decrease is driven by one outlier (session 12).

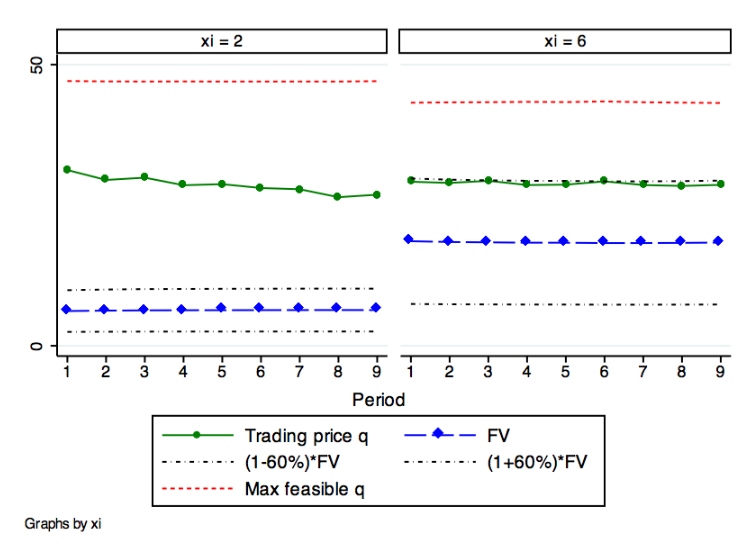


Figure 4: Average Median Trading Price and FV (by Treatment)

The FV is substantially larger in the treatment with a strong preference for housing services (18.60) compared to in the treatment with a weak preference for housing services (6.18). The black dotted lines visualize that, for the treatment Weak preference for housing service, the average median trading price is fare outside of the range $((1-60\%)\cdot FV, (1+60\%)\cdot FV)$. The trading price is substantially larger than $1.60 \cdot FV$ while, for the treatment Strong preference for housing service, the trading price lies in between the bounds $((1-60\%)\cdot FV, (1+60\%)\cdot FV)$.

The absolute bubble size is defined as the difference between the median trading price and the corresponding fundamental value. The absolute bubble size is on average 22.26 in the treatment Weak preference for housing service with $\xi = 2$ and 10.48 in the treatment Strong preference for housing service with $\xi = 6$. The distributions are statistically significantly different ($z = 2.626, p = 0.0087, n = 16$, two-sided Mann-Whitney U test).

Figure (5) shows the average bubble relative to the fundamental value $\frac{q_t^B}{q_t^F}$. On the left (right) side of the figure, the relative bubble sizes for the weak (strong) preference for housing services $\xi = 2$ ($\xi = 6$) are displayed for each session. On average, the relative bubble size is 3.53 (0.57) in the treatment with a weak (strong) preference for housing service. It is evident that the relative bubble size is significantly larger in the treatment Weak preference for housing service, i.e. for $\xi = 2$ - the left graph ($z = 3.361, p = 0.0008$, two-sided Mann-Whitney U test). Note that the average bubble relative to the fundamental value is relatively constant over time for both treatments.

5.2.2 Experimental Bubble Indicators

The experimental asset price literature offers five well-established indicators for measuring bubbles. Table (1) shows these indicators for all sessions and compares the averages for both treatments. For a detailed explanation and calculation of the five bubble measures, we refer to the previous subsection.

The first column of table (1) shows the *Price Amplitude (PA)*. According to this measure, the bubble in the treatment with a weak preference for housing services is on average three times as large.

The second column of table (1) shows the *Total Dispersion (TD)* measured by the sum of all period absolute deviations of median trading prices from the FV. It

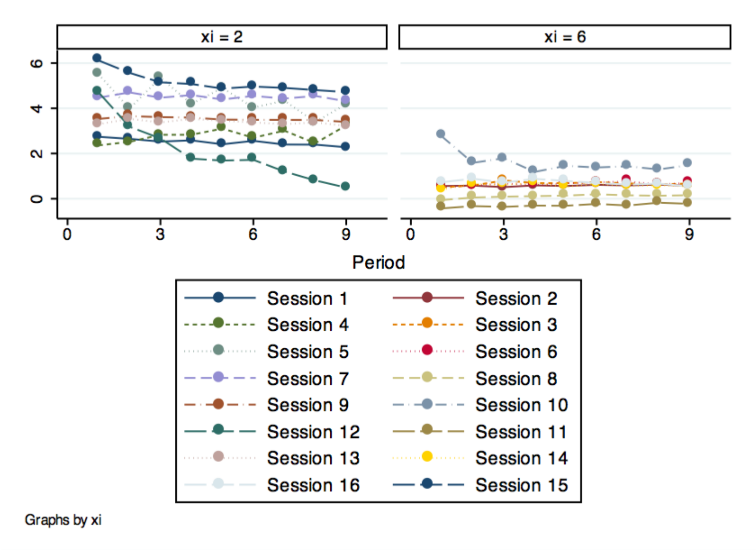


Figure 5: Bubble Relative to FV (by Treatment and Session)

is a measure of the magnitude of mispricing. According to this measure, the bubble is significantly larger in the treatment with a weak preference for housings services.

The third column of table (1) shows the measure *Average Bias (AB)*, it averages the sum of all median price deviations from the FV. This measure is substantially larger for the treatment with a weak preference for housings services.

The *Relative Absolute Deviation (RAD)* is shown in the forth column of table (1) and is easy to interpret. The value 3.49 for the treatment with a weak preference for housing services means that on average prices per period differ 349% from the average FV in the market. This compares to 65% for the treatment with a strong preference for housing services - a large difference.

The fifth column shows the *Relative Deviation (RD)* measure that is very similar to RAD. For the treatment weak preferences for housing services the two indicators RAD and RD are identical for each session. The market on average overvalues the housing asset by 349%. For the treatment with a strong preferences for housing services, RAD and RD differ in the session 11. On average, the housing asset has been undervalued in this session. Considering all session, according to RD, on average the housing asset is overvalued by 58%, while according to RAD the housing asset is overvalued by 65% on average.

In summary, all indicators considered paint the same pictures. Bubbles are substantially larger in a world with weak preferences for housing services, i.e. in the treatment with $\xi = 2$.

To test the differences between the two treatments (strong preference versus weak preference for housing services) we conduct Mann-Whitney-U-Tests and OLS regression analysis for each experimental bubble indicator. For the Mann-Whitney-U-Test, we consider conservatively one session as an independent observation. Table (2) shows that aggregate markets with a weak preference for housing services are characterized by strong mispricing compared to markets where the aggregate preference for housing services is strong. The difference in the bubble size across the two treatments is statistically significant. The Z-value is highly significant for all mispricing indicators.

Table (3) shows the OLS regression results. The coefficient of the treatment parameter, the preference for housing services ξ is negative, highly significant, and explains a large part of the variation in the mispricing indicators across treatments. An increase in the preference for housing services by one standard deviation (across

Session	PA	TD	AB	RAD	RD
S1 Average	0.48	140.34	15.59	2.49	2.49
S4 Average	1.82	159.42	17.71	2.55	2.55
S5 Average	2.41	252.50	28.06	4.41	4.41
S7 Average	0.59	258.90	28.77	4.48	4.48
S9 Average	0.42	200.99	22.33	3.49	3.49
S12 Average	4.21	114.72	12.75	2.10	2.10
S13 Average	0.64	194.90	21.66	3.36	3.36
S16 Average	0.96	281.23	31.25	5.07	5.07
Treatment $\xi = 2$ Average	**1.44**	**200.38**	**22.26**	**3.49**	**3.49**
S2 Average	0.31	99.99	11.11	0.60	0.60
S3 Average	0.38	113.89	12.65	0.68	0.68
S6 Average	0.37	103.05	11.45	0.64	0.64
S8 Average	0.27	18.16	2.02	0.14	0.11
S10 Average	1.29	252.76	28.08	1.58	1.58
S11 Average	0.47	-48.62	-5.40	0.27	-0.26
S14 Average	0.36	92.29	10.25	0.59	0.59
S15 Average	0.46	122.79	13.64	0.71	0.71
Treatment $\xi = 6$ Average	**0.49**	**94.29**	**10.48**	**0.65**	**0.58**

PA (Price Amplitude)= $max(Q_t - FV_t)/FV_1 - min(Q_t - FV_t)/FV_1$ (Porter, Smith 1995). TD (Total Dispersion)= $\sum_{t=1}^{N} \mid Q_t^m - FV_t \mid$ (Haruvy, Noussair 2006). AB (Average Bias)= $\frac{1}{N}\sum_{t=1}^{N}(Q_t^m - FV_t)$ (Haruvy, Noussair 2006). RAD (Relative Absolute Deviation)= $\frac{1}{N}\sum_{t=1}^{N} \mid Q_t - FV_t \mid \; / \mid \bar{FV} \mid$ (Stoeckel et al. 2010). RD (Relative Deviation)= $\frac{1}{N}\sum_{t=1}^{N}(Q_t - FV_t) \; / \mid \bar{FV} \mid$ (Stoeckel et al. 2010). Q_t denotes the mean trading price and Q_t^m the median trading price.

Table 1: Indicators for Experimental Bubbles

treatments), is associated with a decrease of the RAD ratio by 1.44, which is about 82.58% of the variation in RAD.

	RAD	RD	PA	TD	AB	B/FV
Δ mean (median)	2.84***	2.91***	0.95***	106.09***	11.79***	2.96***
Z	3.361	3.361	2.731	2.626	2.626	3.361

Notes: The values represent the difference in means (medians) of the two treatments and Z-values from a Mann-Whitney-U-Test (Z). * Significant at the 10 percent level. ** Significant at the 5 percent level, *** Significant at the 1 percent level. RAD (Relative Absolute Deviation)= $\frac{1}{N}\sum_{t=1}^{N} \mid Q_t - FV_t \mid \ / \mid \bar{FV} \mid$. RD (Relative Deviation)= $\frac{1}{N}\sum_{t=1}^{N} (Q_t - FV_t) \ / \mid \bar{FV} \mid$. PA (Price Amplitude)= $max(Q_t - FV_t)/FV_1 - min(Q_t - FV_t)/FV_1$. TD (Total Dispersion)= $\sum_{t=1}^{N} \mid Q_t^m - FV_t \mid$. AB (Average Bias)= $\frac{1}{N}\sum_{t=1}^{N} (Q_t^m - FV_t)$. B/FV= $\frac{1}{N}\sum_{t=1}^{N}(Q_t - FV_t)/FV_t$. Q_t denotes the mean trading price and Q_t^m the median trading price.

Table 2: Means across Treatments: Differences in Distribution (Mann-Whitney-U-Test (1))

	RAD (1)	RD (2)	PA (3)	TD (4)	AB (5)
ξ	-0.711***	-0.728***	-0.238*	-26.52**	-2.947**
	(-6.92)	(-6.85)	(-1.97)	(-2.84)	(-2.84)
Constant	4.915***	4.950***	1.915**	253.4***	28.16***
	(8.50)	(8.52)	(2.72)	(7.16)	(7.16)
N	16	16	16	16	16
R^2	0.774	0.770	0.217	0.366	0.366
adj. R^2	0.757	0.754	0.161	0.321	0.321

t statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01. Std. Errors adjusted for 16 clusters in Session. Adding additional controls (age, ratio of female subjects, and reported risk aversion) does not alter the size of the coefficient of interest ξ.

Table 3: Impact of ξ on Bubble Size Indicators (OLS)

6 Robustness Checks

We have shown in the previous section that the housing bubble in absolute terms (and relative to the FV) is significantly larger in the treatment with weaker preferences for housing services.[19] The same result holds for the experimental bubble indicators (RAD, RD, PA, TD and AB).

In this section we discuss four potential concerns the reader might have, and address them with corresponding robustness checks. In particular, we test alternative explanations for the obtained trading price Q and the resulting bubble sizes.

Upper Endowment Bound

As it can be seen in figure (4), the average median trading price Q is similar in both treatments, 28.58 for $\xi = 2$ and 28.85 for $\xi = 6$. A valid concern is that this trading price is obtained because of an upper endowment bound. It could be that in both treatments participants spend all remaining budget (after purchasing the consumption good C and housing services S) on housing assets H. In this case, the market price would be obtained by the endowment upper-bound in the economy. The difference in the bubble size across treatments would then simply be obtained by construction, i.e. because the endogenously realized fundamental value in both treatments is different. The red doted line in figure (4) shows the maximum possible trading price Q^{max} for both treatments. This upper bound, Q^{max}, is significantly higher than the actual trading price Q for both treatments.

We compute maximum possible trading price Q^{max} as follows: After subtracting aggregate spending on C $(= 20)$ and S $(= p^r \cdot 20)$ from the endowment in the market $(= 4 \cdot 250)$, the participants could spend maximally 47.02 and 43.32 experimental currency units per unit of housing asset H, in treatment $\xi = 2$ and $\xi = 6$, respectively. The difference between the upper bound Q^{max} and the realized market price for H amounts to 18 and 14 experimental currency units in the case of treatment $\xi = 2$ and $\xi = 6$, respectively. This corresponds to a difference between the upper bound Q^{max} and the realized trading price Q of at least 30%. This gap is to large for being considered a constraint for the realized trading price Q.

Reaction to the Treatment Parameter ξ

Related to the previous concern, the reader might wonder whether participants react to the treatment parameter or whether the similar trading prices Q result from pure randomness. Indeed, the trading prices Q are not significantly different across treat-

[19] This result is robust to three alternative measurements for the fundamental value q_t^F.

ments (z = 0.000 and p = 1.0000, two-sided Mann-Whitney U test). However, the purchase decisions for the consumption good C, and thus the ratio of housing services over consumption S/C differ significantly. As the model predicts, participants purchase significantly fewer units of C in the treatment with a strong preference for housing services (z = 3.123 and p = 0.0018, two-sided Mann-Whitney U test). On average, the purchased amount of C is 19.90 with $\xi = 2$ and 19.13 with $\xi = 6$, a small yet statistically significant difference. The difference in the ratio housing services over consumption S/C across treatments is significant (z = -3.123, p = 0.0018, two-sided Mann-Whitney U test). 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 subjects, and determines in turn the dividend of housing asset H (the steady state model prediction is $p^r = 2$ in 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 relative price for housing services $p^r_{\xi=2} = 1.99$ and $p^r_{\xi=6} = 5.74$. 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 react to the treatment parameter ξ.

The stable Bubble Size

A third potential concern the reader might have, is the stable bubble size B over time for both treatments, refer to figure (5). The bubble size as well as the trading price Q do not display any boom-bust cycles over time. Empirical work is often measuring bubbles in asset prices by boom-bust cycles. If a price increase is larger than a certain threshold during an upturn, this episode is considered as an asset price boom and is used as an indicator for a bubbly episode. Many experimental asset markets display boom-bust cycles as well. However, these experiments are based on infinite horizon models - in contrast to our two-period overlapping generation model. The households live for two periods only, they only buy and sell the asset H once in their lifetime. In the experiment, subjects play several lifecycles but are incentivized to treat the lifecycles as independent lifecycles. To stay as closely to the model, the subjects are informed that only one lifecycle is chosen randomly and is paid out. This avoids potential design problems, where results might be driven by e.g. risk hedging (in one lifecycle the subject tries one extreme, in the next the opposite extreme). If subjects are correctly incentivized (they live for one lifecycle only), then one should 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 every lifecycle.[20]

The Cash to Asset Ratio

A fourth potential objection concerns the cash-asset ratio. Haruvy and Noussair (2006), Caginalp *et al.* (2001) and Caginalp *et al.* (1998) report that high initial cash-to-asset ratios drive bubble formation. Kirchler *et al.* (2012) show that bubbles emerge when a decreasing fundamental value is coupled with an increasing cash-to-asset ratio. In contrast, when fundamentals follow a constant time trajectory, Kirchler *et al.* (2012) find that the levels of cash holdings of traders do not affect asset prices. However, Noussair and Tucker (2016) replicate the findings of Kirchler *et al.* (2012) and include a new treatment, in which cash holdings are at high levels early in the life of the asset. In this treatment, Noussair and Tucker (2016) observe overpricing and asset bubbles, indicating that greater cash levels are indeed associated with higher prices, even when fundamental values are constant over time. As indicated earlier, the youngs' remaining budget after purchasing C and S, and before entering the double auction of H is different in both treatments. With $\xi = 2$, the endogenously determined steady state price for one unit of S is 2, and it is 6 with $\xi = 6$. Since all parameters and the experimental setup are otherwise identical, the remaining budget when entering the double auction of H differs by $(6-2) \cdot 20 = 80$ experimental currency units in the two treatments. This corresponds to a potential price difference of 4 experimental currency units per unit of asset H.

Ideally, we would like to control for the cash-to-asset ratio in the regression analysis. However, the cash-to-asset ratio is highly correlated with the treatment variable ξ.[21] Therefore, we cannot perform joint regressions. We propose the following adjustment to address the concern that the different bubble sizes might be driven by endogenously resulting different endowments across treatments. We adjust the trading price in treatment $\xi = 2$ for the difference in the cash-to-asset ratio. We do so by reducing the realized trading price Q in the treatment with weak preferences for housing services ($\xi = 2$) by $0.674 \cdot$ (4 experimental currency units). 67.4% corresponds to the share of the endowment (after purchasing C and S) that the participants invest in H in the treatment with strong preferences for housing

[20] If we would extend the two-period overlapping generation model to an overlapping generation model where agents live for many periods, the extended model would allow for boom-bust cycles in the price Q of the asset house H over the lifetime of a specific household.

[21] The correlation coefficient is equal to -0.99.

services ($\xi = 6$). Alternatively, we could have taken the share of the endowment invested in H under treatment $\xi = 2$ (60.3%), but we decided for the more conservative robustness test.

Tables (4) and (5) present the same tests for the bubble indicators as in the previous section, but calculated with the adjusted trading price Q^a for the treatment $\xi = 2$. As it can be seen from the non-parametric test results in table (4) and the OLS regression results in table (5), some tests become marginally less significant (for the measures PA, TD, and AB), however the main bubble indicators RAD and RD remain significantly different across treatments at the 1% level.

Summarizing our results, we find laboratory evidence for the model mechanism and for the empirical regularity that countries characterized with stronger preferences for housing services (relative to other consumption goods) are less prone to experience large house price bubbles. We find high mispricing in treatments with a weak preference for housing services, while over-evaluation is significantly smaller when the preference for housing services is strong.

	Robustness check: Adjusted trading price for treatment $\xi = 2$					
	RAD^a	RD^a	PA^a	TD^a	AB^a	(B^a/FV)
Δ mean (median)	2.51***	2.62***	0.94**	104.74**	11.64**	2.53***
Z	3.361	3.361	2.415	2.521	2.521	3.361

Notes: The values represent the difference in means (medians) of the two treatments and Z-values from a Mann-Whitney-U-Test (Z). * Significant at the 10 percent level. ** Significant at the 5 percent level, *** Significant at the 1 percent level. P^A (Price Amplitude)= $max(Q_t^a - FV_t)/FV_1 - min(Q_t^a - FV_t)/FV_1$. TD^a (Total Dispersion)= $\sum_{t=1}^{N} \mid Q_t^{m,a} - FV_t \mid$. AB^a (Average Bias)= $\frac{1}{N}\sum_{t=1}^{N}(Q_t^{m,a} - FV_t)$. RAD^a (Relative Absolute Deviation)= $\frac{1}{N}\sum_{t=1}^{N} \mid Q_t^a - FV_t \mid \ / \mid \bar{FV} \mid$. RD^a (Relative Deviation)= $\frac{1}{N}\sum_{t=1}^{N}(Q_t^a - FV_t) \ / \mid \bar{FV} \mid$. B/FV= $\frac{1}{N}\sum_{t=1}^{N}(Q_t^a - FV_t)/FV_t$. Q_t^a denotes the adjusted mean trading price and $Q_t^{m,a}$ the adjusted median trading price. We adjust the realized trading price of treatment $\xi = 2$ by subtracting $(4 * 0.674)$.

Table 4: Differences in Distributions (Mann-Whitney-U-Test (2))

	RAD^a	RD^a	PA^a	TD^a	AB^a
	(1)	(2)	(3)	(4)	(5)
ξ	-0.628***	-0.656***	-0.235*	-26.18**	-2.909**
	(-6.19)	(-6.18)	(-1.95)	(-2.81)	(-2.81)
Constant	4.323***	4.378***	1.910**	228.5***	25.39***
	(7.50)	(7.55)	(2.71)	(6.46)	(6.46)
N	16	16	16	16	16
R^2	0.733	0.732	0.214	0.360	0.360
adj. R^2	0.714	0.713	0.157	0.314	0.314

t statistics in parentheses. * p<0.1, ** p<0.05, *** p<0.01. Std. Errors adjusted for 16 clusters in Session. Adding additional controls (age, ratio of female subjects, and reported risk aversion) does not alter the significance level or size of the coefficient of interest ξ.

Table 5: Impact of ξ on Adjusted Bubble Indicators (OLS)

7 Conclusion

The experiment in this paper tests the theoretical prediction in Huber (2017) that economies with lower preferences for housing services relative to other consumption goods tend to experience larger house price bubbles. The hypothesis is tested in an overlapping generation lab experiment where two preference levels for housing services are assigned in a between-session design.

Huber (2017) shows empirically that economies with a lower share of consumption spent on housing services experienced larger housing bubbles during 1970-2014. However, conclusions on the causal effect cannot be easily drawn due to data availability issues, potential measurement errors regarding housing bubbles and preferences for housing services, and the problem of reversed causality. In the absence of econometric clarity on causality, this experiment seeks to provide an alternative basis to test the causal effects.

Consistent with empirical data and the model's predictions we find that a lower share of consumption is spent on housing services in the treatment with a lower preference for housing services. We find that the bubble size (both absolute and relative) and the price-rent ratio are larger in the treatment with lower preferences for housing services. This result is robust to calculating the absolute and relative bubble size with four different fundamental values.[22] Five well established experimental bubble indicators (RAD, RD, PA, TD and AB) draw the same conclusions.

[22] The absolute bubble size is measured by the difference of the realized trading price from its fundamental value. The relative bubble size is measured by the ratio of realized trading price over fundamental value. We use as a robustness check three additional alternative measurements for the fundamental value.

This paper adds to the evidence of the importance of preferences for housing services relative to other consumption goods as a driver of economies' vulnerability to house price bubbles. The results suggest that policy makers might want to keep track of indicators of preferences for housing services (e.g. expenditure shares on housing services). Being aware of the environment in which policy makers have to make decisions concerning the housing market seems to be crucial. Depending on the environment, more or less far-reaching policy interventions might be necessary to reduce the likelihood of housing bubble occurrence and size as well as the negative consequences they bring with them.

This paper also contributes a carefully developed experimental design for OLG models. This provides a basis for several potential extensions. Including for example the analysis of competing approaches to policy intervention on the housing market to manage bubbles. Follow up work could also study the relative merits of potential policy interventions aiming to foster the affordability of housing services e.g. rental subsidies, rental caps or help-to-buy schemes. It would be interesting to study the potentially different implications of these tools on economies' vulnerability to bubbles.

The proposed experiment provides a good starting point for follow-up studies because it provides novel OLG design features. Our experimental design provides a framework where a market for the traded asset and a market for the dividend of the traded asset exists. In the related literature, most experiments assume an exogenous dividend for the traded asset. In contrast, in our design the dividend of the bubbly asset is determined endogenously by the choices of the market participants. Furthermore, our novel assignment to markets has the advantages of gathering more observations, simplifying the structure for the participants and giving them the chance to get as much experience as possible. Finally, our incentive structure is novel and important in a world with overlapping generations. From the played life-cycles we select one randomly and pay the participants for their decisions in that lifecycle rather than summing up each participant's earnings over the entire experiment. As discussed previously, we find very stable patterns over the different lifecycles of a subject, which indicates that our incentive structure is closely in line with the model.

8 Appendix A: Individual Market Results

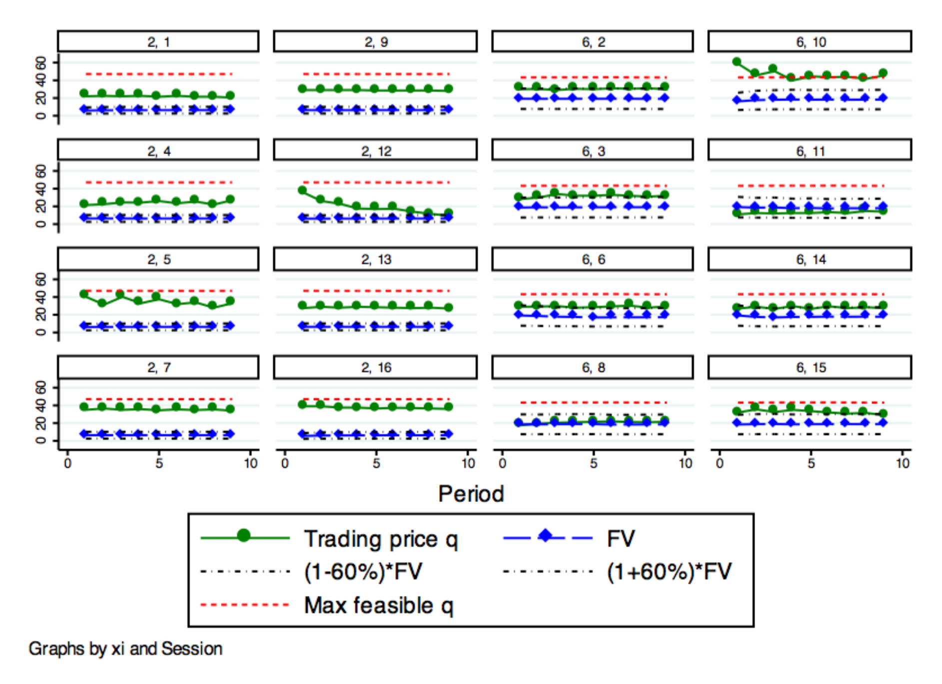


Figure 6: Trading Price and Fundamental Value for Each Session (Group Averages)

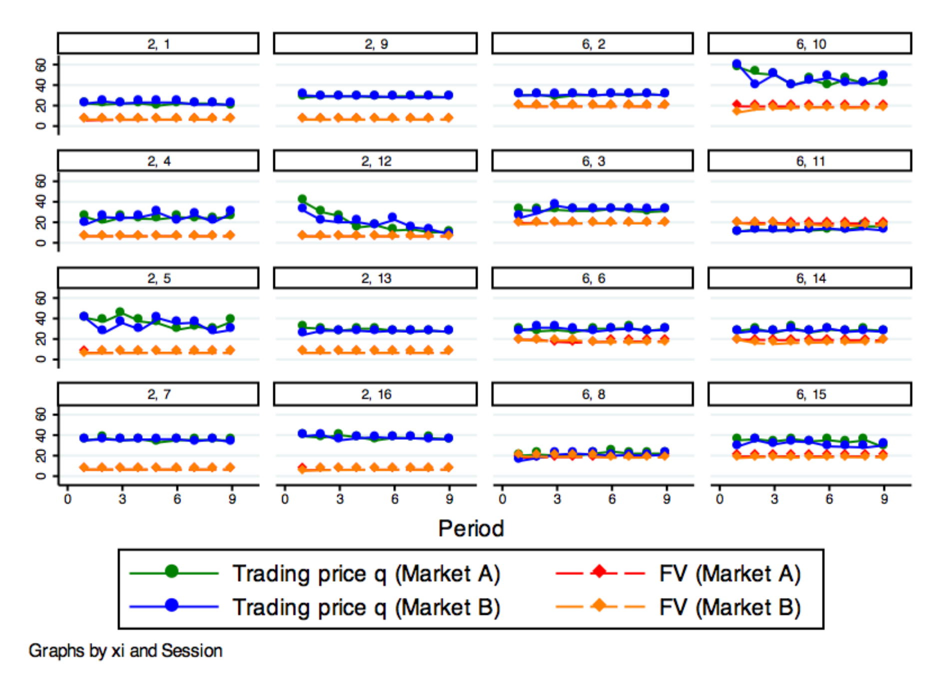


Figure 7: Trading Price and Fundamental Value (for each Session and Group)

Session	PA	TD	AB	RAD	RD
S1- Group A	0.52	138.11	15.35	2.52	2.52
S2 - Group B	0.47	142.58	15.84	2.48	2.48
S4 - Group A	0.78	156.90	17.43	2.72	2.72
S4 - Group B	1.74	161.94	17.99	2.84	2.84
S5 - Group A	2.47	264.94	29.44	4.53	4.53
S5 - Group B	2.34	240.06	26.67	4.30	4.30
S7 - Group A	0.53	258.90	28.77	4.45	4.45
S7 - Group B	0.64	258.90	28.77	4.51	4.51
S9 - Group A	0.43	200.40	22.27	3.43	3.43
S9 - Group B	0.41	201.58	22.40	3.54	3.54
S12 - Group A	4.88	117.18	13.02	2.14	2.14
S12 - Group B	3.54	112.25	12.47	2.06	2.06
S13 - Group A	1.01	202.4	22.49	3.43	3.43
S13 - Group B	0.29	187.4	20.82	3.30	3.30
S16 - Group A	1.27	281.39	31.27	5.06	5.06
S16 - Group B	0.65	281.07	31.23	5.06	5.06
Treatment $\xi = 2$ Average	**1.56**	**187.81**	**20.87**	**3.29**	**3.29**
S2 - Group A	0.17	98.78	10.98	0.58	0.58
S2 - Group B	0.05	101.20	11.24	0.59	0.59
S3 - Group A	0.16	111.06	12.34	0.65	0.65
S3 - Group B	0.59	116.72	12.97	0.69	0.69
S6 - Group A	0.45	102.51	11.39	0.66	0.66
S6 - Group B	0.29	103.58	11.51	0.62	0.62
S8 - Group A	0.19	25.10	2.79	0.16	0.16
S8 - Group B	0.35	11.22	1.25	0.12	0.06
S10 - Group A	1.01	244.74	27.19	1.46	1.46
S10 - Group B	1.56	260.78	28.98	1.70	1.70
S11 - Group A	0.42	-51.16	-5.68	0.24	-0.24
S11 - Group B	0.52	-46.07	-5.12	0.30	-0.28
S14 - Group A	0.33	85.07	9.45	0.47	0.47
S14 - Group B	0.38	99.51	11.06	0.70	0.70
S15 - Group A	0.44	133.2	14.8	0.73	0.73
S15 - Group B	0.48	112.38	12.49	0.69	0.69
Treatment $\xi = 6$ Average	**0.48**	**89.87**	**9.99**	**0.65**	**0.55**

PA (Price Amplitude)= $max(Q_t - FV_t)/FV_1 - min(Q_t - FV_t)/FV_1$ (Porter, Smith 1995). TD (Total Dispersion)= $\sum_{t=1}^{N} \mid Q_t^m - FV_t \mid$ (Haruvy, Noussair 2006). AB (Average Bias)= $\frac{1}{N}\sum_{t=1}^{N}(Q_t^m - FV_t)$ (Haruvy, Noussair 2006). RAD (Relative Absolute Deviation)= $\frac{1}{N}\sum_{t=1}^{N} \mid Q_t - FV_t \mid \;/\mid \bar{FV} \mid$ (Stoeckel et al. 2010). RD (Relative Deviation)= $\frac{1}{N}\sum_{t=1}^{N}(Q_t - FV_t)\;/\mid \bar{FV} \mid$ (Stoeckel et al. 2010).
Q_t denotes the mean trading price and Q_t^m the median trading price.

Table 6: Indicators for experimental Bubbels (individual sessions and groups)

9 Appendix B: Robustness Check

9.1 T-Test (as robustness check instead of Whitney-U-Test)

WORKS - TO BE INCLUDED

9.2 Without outliers

To test whether results are driven by outliers, we redo the analysis while excluding the markets with the highest RAD in each treatment from the analysis.

WORKS - TO BE INCLUDED

10 Appendix C: Instructions & Screenshots

10.1 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 Euro for participating in this experiment and another 5 Euro 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 EURO at the exchange rate of 1 Happiness Point = 3 Euro.

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 on your total returns from housing assets H and the 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 that will be deposited in your bank account. You can use this money for buying 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 service 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 it 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 fix and equal to 1 EURUX. Each of the different **combinations of C and S** defines a **price for housing service 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 member's 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 for 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 will 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 service 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 YoungâĂŹs purchased units of C and S will be reduced proportionally to the requested amounts.

After all participants have submitted their consumption and housing service decisions, the price for S will be computed. 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 with 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 future "Youngs" purchase of C and S, i.e. 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 by the future "Young" and its implication 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 you. Your available bank account balance (after having purchased C and S) will be displayed on 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 for buying 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 writing a number in the text area "Enter offer to buy" press 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 a 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; othersâĂŹ 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 contain 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 in 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 that equals 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, i.e. the budget that you did not spend on consumption good C, housing service S, and housing asset H will stay on 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 on 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 write 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 others, 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 in 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 for. You loose 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 find on the decision screens when "Young" a button labeled "History." If you click on the button, you get to the respective screen and can get back anytime to the decision screen. You will find a summary over your decisions on C, S, H, and B as well as the corresponding Happiness Points you received in all previous periods of this experiment. Furthermore, you 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.

<u>Assignment to group A and B</u>

In total, 16 participants participate in this experiment including yourself. All 16 participants will be assigned randomly to Cohort I and Cohort II at the beginning of the experiment, i.e. 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. 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 make decisions accordingly. To start, each member of Cohort II will be endowed with 5 units of housing assets H and 50 EURUX on the 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. 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. 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, lifecycle 2 consists of periods 3 and 4, etc. Cohort II's lifecycle 1 consists of periods 2 and 3, 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 âĂIJYoungâĂİ 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.

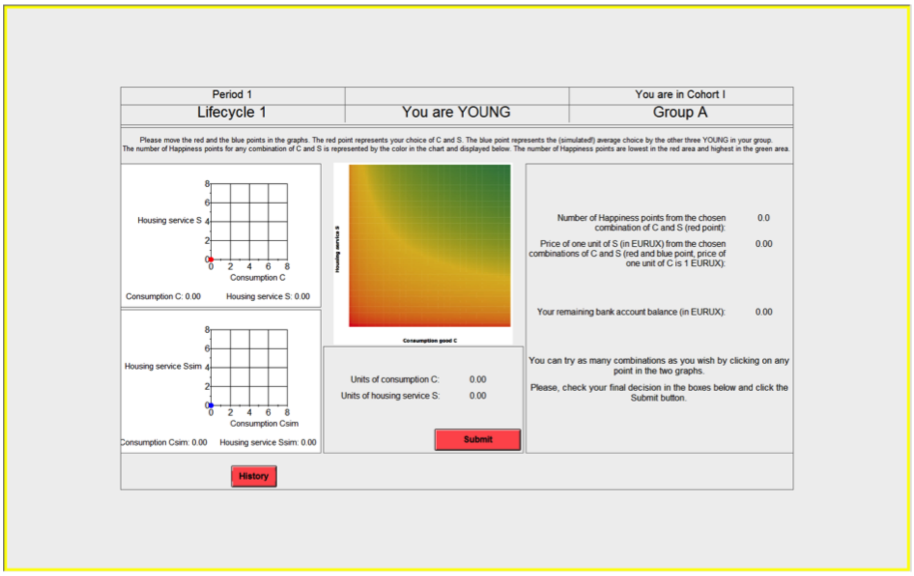
There will be two sequences of the just described experiment: One trial sequence with four periods, which does not enter the lottery for the payment. It is there to help you get familiar with the experiment. Then there will be a sequence out of which one lifecycle will be chosen randomly at the end of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

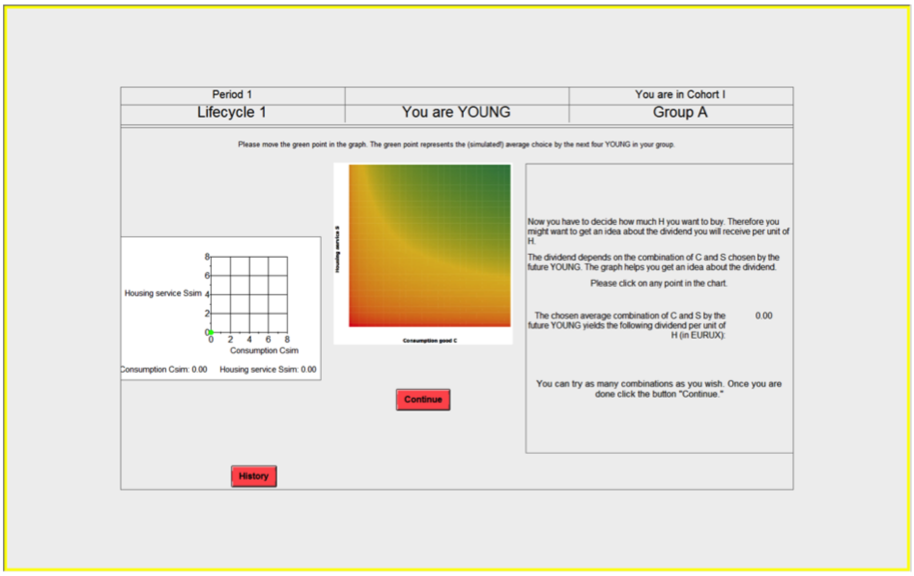
10.2 Screenshots

<u>Screens when "Young"</u>

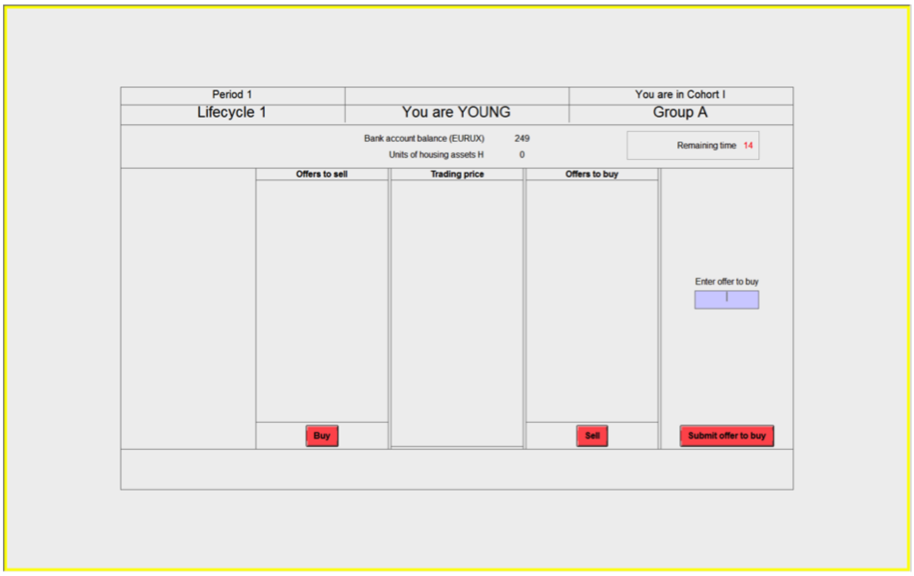
Stage 1 (consumption C and housing service S)



Stage 2 (Simulation of dividend)

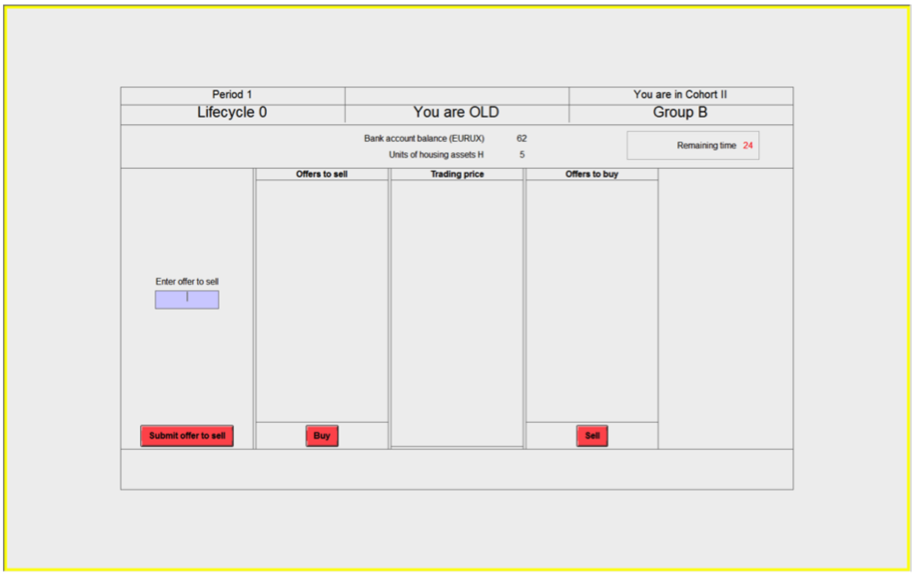


Stage 2 (Housing asset H)



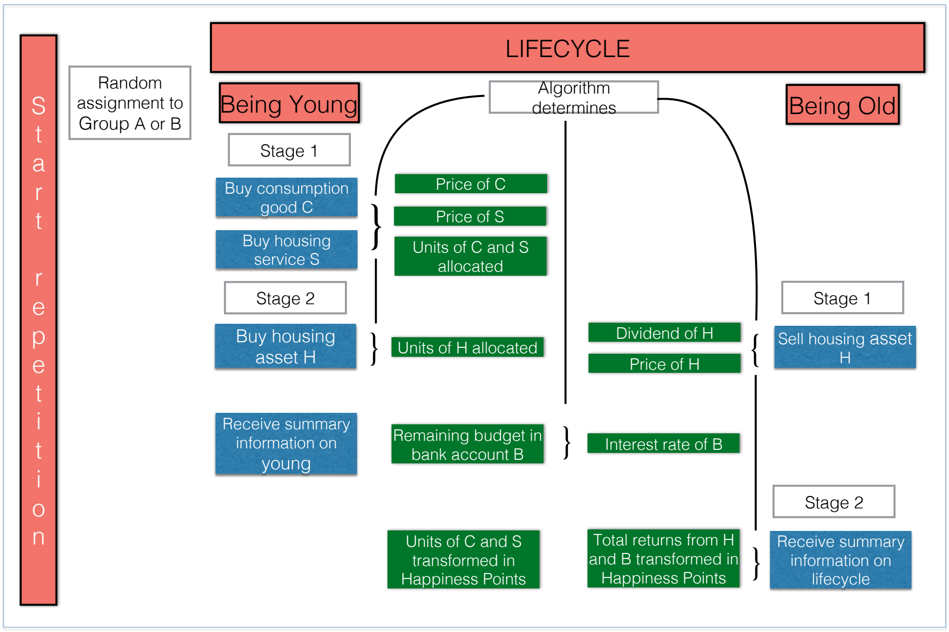
Decision screens when "Old"

Stage 1 (Housing asset H)

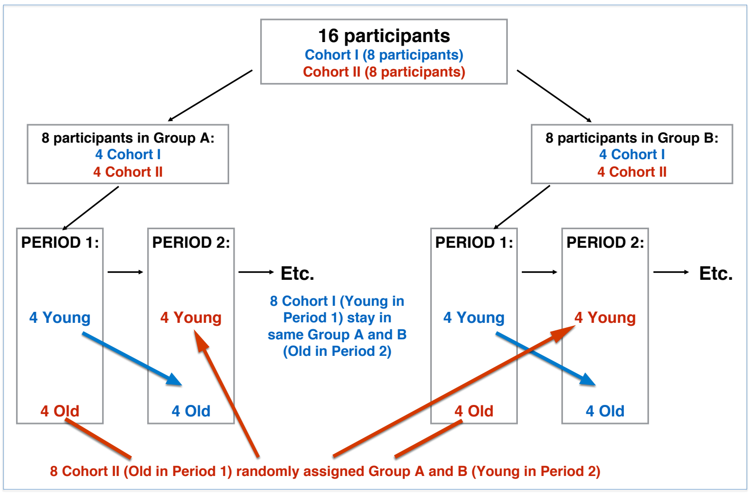


10.3 Handouts: Graphs and Table

Decisions in a lifecycle



Assignment and chronological order



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

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