Housing Consumption and Bubble Size

Stefanie J. Huber⋆ Christina Rott‡ Giovanni Giusti†

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Abstract

This paper identifies a novel determinant of the magnitude of house price bubbles: the demand for housing consumption. We find in a controlled environment that the demand for housing consumption affects the fundamental value of real estate positively and dampens the house price bubble size in equilibrium. We present the first experimental design that allows to model the consumption side along with the investment side of housing. The endogenous nature of the dividend and the fundamental value of the real estate asset provide a credible framework to study house price bubbles.

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⋆ CeNDEF, Amsterdam School of Economics, University of Amsterdam and Tinbergen Institute, Amsterdam, The Netherlands. E-mail: s.j.huber@uva.nl.
‡ Department of Management and Organization, School of Business and Economics, Free University of Amsterdam, The Netherlands. E-mail: c.e.rott@vu.nl
† Escuela Superior de Ciencias Sociales y de la Empresa, Spain. E-mail: giovanni.giusti@upf.edu
1 Introduction

House price fluctuations have a substantial impact on economic performance. Empirical studies show that recessions associated with house price busts are not only twice as long but also twice as deep compared to normal recessions or recessions associated with equity price busts (Claessens et al. (2012), Claessens, Kose, and Terrones (2009), and IMF (2003)). Huber (2018) shows for a sample of 18 OECD countries that the average magnitude of housing bubbles that occurred between 1970-2014 varies a lot across countries. This raises the question what factors determine the magnitude of housing bubbles. In this paper, we investigate in a laboratory setting whether the consumption side of the housing asset is a driving factor for the magnitude of housing bubbles.

Studies have shown that times of intensive housing investment are often associated with bubbly episodes\(^1\). The related empirical cross-country literature investigating the determinants of house price fluctuations generally finds that credit availability and credit (mortgage) market conditions play an essential role for the magnitude of housing booms and busts\(^2\). These results have been confirmed in a controlled environment: Noussair and Tucker (2016) find that the breath of mortgage markets, the availability of cash in the economy, matters for the magnitude of experimental bubbles. Additional factors that matter for bubble formation and the bubble size have been identified. 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. Also the nature of the fundamental value (constant versus decreasing or increasing) has been shown to affect economies’ vulnerabilities to bubbles and the bubble size (Noussair et al. (2001)).

Housing is a special asset given its dual nature. The housing asset has a consumption side (it provides housing services) and an investment side. In many countries, housing makes up the largest component of wealth and constitutes the largest consumption expenditure share. All aforementioned studies assume that the bubbly asset is a pure investment good ignoring the fact that some assets, in particular housing, have an additional consumption side.

While the consumption of housing services constitutes the largest consumption expen-

\(^1\) 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.

\(^2\) Local and global credit aggregates, short- and long-term interest rates matter for the magnitude of house price fluctuations (Claessens et al. (2009), Agnelo and Schuknecht (2011), Igan and Loungani (2012)).
diture share for most economies, these consumption shares vary a lot across countries. 

Huber (2018) finds that countries characterized by lower housing consumption experienced bubbles of significantly larger magnitude during 1970-2014. However, conclusions on the causal effect cannot be easily drawn. A further challenge is the measurement of the real quantity of housing consumption (housing services). The consumer receives housing services independent of whether he owns or rents the real estate property he is living in. The larger the property and/or the better the quality, the more housing services are received. Cross-country data on the average size (square meters) and housing quality is however scarce.

We shed new light on the role of housing consumption as a potential determinant of the magnitude of house price bubbles in a laboratory experiment. The design of the experiment is closely related to the overlapping generation (OLG) model with housing in Huber (2018). Following the main model features, housing is explicitly modeled both as a consumption good and as an asset. Households live for two periods in the experimental setup. Young households decide how much housing services and how much of all other consumption goods to consume, how much to invest in the housing asset, and how much to save in riskless bonds. When old, households receive the return from their investment and savings. The dividend from investing in the asset house is given by the rental income the house generates (which is determined by the demand for housing services of the young generation). The fundamental value of a housing asset is determined by the discounted expected flow of future dividends that the asset generates. Hence, the demand for housing consumption determines the dividend and also the fundamental value of the housing asset endogenously.

We test the hypothesis that the demand for housing consumption is a driving factor for the magnitude of housing bubbles. Two treatments are implemented – one with a weak and one with a strong preference for housing services relative to other consumption goods. Weak (strong) preferences for housing services relative to other consumption goods lead to

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3 Bubbles are measured by independent house price booms (and boom-bust cycles). Housing consumption is measured by the CPI weight on housing services, including imputed rents.

4 See Piazzesi et al. (2007) for a more in-depth discussion. For example, the NIPA real housing quantities only reflect one input into the production of housing services and is often criticized to be grossly mis-measured. In a similar vein, Ozimek (2014) criticizes the measure of housing services provided by the Bureau of Labor Statistic (the CPI weight on housing services) for their measurement of imputed rents.

5 This method is advantageous given the data limitations and the resulting measurement problems for both key variables, housing consumption and the housing bubble. Furthermore, the controlled environment allows to establish a causal relationship.

6 In our context, consuming housing services when young can be best understood in terms of renting the housing asset from the old generation.
a low (high) demand for housing consumption. Consequently, the dividend of the housing asset and the fundamental value (FV) are expected to be smaller in the treatment with the low preference for housing services. This in turn has crucial implications on the maximum bubble size: In equilibrium, every asset needs to be affordable. It follows from the resource constraint of the economy that an economy with weak aggregate preferences for housing services will have more room for larger bubbles.

The results confirm that housing bubbles are substantially larger in the treatment with weak preferences for housing services. This result holds for a wide range of bubble measures, established experimental bubble indicators, and for the price-rent ratio. The weak and strong preferences for housing services are randomly induced across sessions. We therefore can conclude that preferences for housing services relative to other consumption goods causally and negatively affect the size of housing bubbles and they do so through the fundamental value.

Our study contributes to the existing literature on housing markets in two ways. First, this study highlights a novel factor that may determine the size of house price bubbles: the consumption side of housing assets. The role that housing consumption plays in generating experimental housing bubbles has not been explored in the past. Our paper aims to fill this gap. This "consumption channel" is universally valid as long as the asset under consideration is a consumption good at the same time. Examples of other assets that have an investment and a consumption side are for instance artwork, vintage cars, or jewelry. However, the consumption channel for bubble formation is arguably most relevant for the housing asset, given that the housing consumption expenditure constitutes the largest consumption expenditure share for most economies in the world.

Second, this paper – one of the first laboratory experiments on housing markets – contributes to the existing literature on experimental asset markets also methodologically. Our design provides a framework in which both a market for the traded asset (the house) and a market for the dividend of that traded asset (the price for housing services) exist. In the related literature, most experiments assume an exogenous dividend for the traded asset, e.g., Marimon and Sunder (1993), Noussair et al. (2001) or Ikromov and Yavas (2012). Furthermore, 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.

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. A notable exception is Weber et al. (2018), who conducted the to our knowledge first experimental study of assets with endogenous, price-dependent default probabilities. In contrast to our study, the asset has no consumption side and the dividend payment (the interest rate) is fixed and known. However the default probability of the issuer of the asset is endogenous, and hence the realized dividend (and FV) is endogenous as well.
In contrast, in our design, the dividend of the bubbly asset is determined endogenously by the choices of the market participants. The preferences for housing services and thus the demand for housing consumption determine the dividend of the housing asset, and hence the fundamental value of the housing asset endogenously. The endogeneity of the dividend in the housing market is a crucial and novel feature for the analysis of experimental (housing) bubbles on asset markets. Our solution for the design of an endogenous fundamental value provides a benchmark for experimental housing markets in the laboratory. In addition, we implement several novel design features for OLG market experiments such as the assignment of subjects to markets. We believe that the experimental design provides a good starting point for the study of policy interventions in an OLG environment.

The remainder of the paper is structured as follows: Section 2 provides an overview of the related experimental literature. Section 3 summarizes the OLG model. Section 4 describes the design and implementation of the lab experiment as well as the treatments and the hypotheses. Section 5 explains how we measure experimental bubbles and presents the experimental results including a discussion of potential alternative explanations of the bubble size and corresponding robustness checks. Section 7 concludes.

2 Related Literature on Experimental Bubbles

Our paper is related to the experimental literature on housing bubble formation and the underlying causes thereof. To our knowledge, there exist two papers on experimental housing bubbles. Ikromov and Yavas (2012) examine the impact of transaction costs, short selling restrictions, and the divisibility of assets on experimental housing markets. The authors find that transaction costs and the divisibility of assets reduce the magnitude of experimental housing bubbles. Bao and Hommes (2015) study the impact of the housing supply elasticity on house price bubble formation and find that an increase in the housing supply elasticity may stabilize speculative asset bubbles. In summary, the existing experimental housing bubble literature studies channels for house price formation that work either through the investment demand for housing or housing supply. The role housing

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10 In comparison to the existing literature, our assignment of subjects to markets 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. In addition, our incentive structure is novel for experimental OLG asset markets. As is common in the literature, subjects play several lifecycles in the experiment whereas, theoretically, subjects live for one lifecycle only. To address this issue in the experiment, only one lifecycle is chosen randomly and paid out. This design feature prevents subjects from hedging risk by playing different strategies in different lifecycles. 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.
consumption plays in generating housing bubbles has not been explored. Our paper fills this gap in the literature. To do this, we build upon the theoretical model of [Huber (2018)] and model the dual nature of the housing assets explicitly - considering the consumption and investment demand for housing separately.

The experimental design in this paper is related to a vast literature on bubble formation in experimental asset markets more generally. Most experimental studies assume an exogenous and finite dividend process, whereas our approach incorporates an endogenous and infinite dividend process. The seminal paper of the experimental asset market literature, [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 over time. SSW find that experimental asset prices deviate strongly from fundamental values. Several follow-up studies replicate and modify the experimental setting of SSW to study different drivers for bubble formation. 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)]. A common design feature is the tradable asset with a finite lifetime. The asset pays a common-knowledge dividend distribution every period, which is the only source of value.\footnote{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. In addition, they find 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. For a review of the literature see chapters 29 and 30 in [Plott and Smith (2008)].}

As mentioned earlier, our key contribution to the related literature is the endogenous nature of the dividend. We incorporate two simultaneous markets - one for the housing asset and one for the dividend. While the market for housing assets captures the investment demand for housing, the market for the dividend reflects the demand for housing consumption.\footnote{To simplify the already complex experimental design, the supply on both markets is fixed.} The dividend of a housing asset is the rental income the real estate generates. The
rental income (the dividend) is determined by the demand for housing consumption, hence
by the price for housing services.

We are not the first to bring an infinite horizon OLG model to the laboratory. The
seminal paper of an OLG laboratory experiment is Marimon and Sunder (1993) who ad-
dress questions of equilibrium selection and sunspots in the presence of multiple equilibria.
Following Marimon and Sunder (1993), Lim et al. (1994) implement 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 envi-
ronment 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 in-
stitution 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 de-
design. Second, we construct ‘generations’ in a different way by assigning subjects randomly
to one of two markets after each lifecycle instead of having them wait to be reassigned to
participate in the market. This different assignment strategy has two advantages. First,
it allows us to gather more observations. Second, we manage to stay closer to the theo-
retical model by randomly assigning subjects from a larger pool to new generations. This
reduces repeated play with the same subjects. Recall that in the model a pair of subjects
meets just once for a transaction. Additionally, the incentive structure is different. Our
subjects know that only one randomly chosen lifecycle will be paid out. This design feature
helps us to prevent subjects from hedging risk by playing different extremes in different
lifecycles. We think that this incentive structure is very important to align the experiment
with the theoretical model, where subjects live for one lifecycle only. To implement an in-
finitive time horizon in the laboratory, we follow Crockett and Duffy (2015) and implement
an indefinite horizon by assuming a constant probability of continuation each period.

13In Marimon and Sunder (1993)’s experimental design, 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.
3 The OLG Model

The model framework of Huber (2018) allows to study why countries with a lower preference for housing services experienced significantly larger housing bubbles during 1970-2014. We use the model framework to analyze the impact of the preference for housing services on the bubble size in the laboratory.

In this section, we first illustrate the underlying mechanisms driving the theoretical result in an intuitive way. Second, we briefly summarizes the – for our purpose – most relevant model ingredients of Huber (2018). We focus in particular on the household sector. In the experiment, subjects play the role of households.14 And third, we highlight the testable model predictions in this section.

3.1 Illustration of the Model Mechanism

Suppose that total consumption in an economy can be divided into two categories: Housing consumption, hence housing services $S$ and all other types of consumption $C$. Further, suppose that there are two identical countries. Country $High$ and country $Low$. These two countries differ in one aspect only – which is the aggregate preference for housing services relative to other consumption goods. Households in country $High$ have a stronger preference for housing services relative to other consumption goods. One can think of this as a country full of individuals that want to live in big and/or high-quality houses, but do not care if they can go out to restaurants or the theatre very often. Hence the relative demand for housing services is strong in country $High$. This leads to a high price of housing services relative to other consumption goods in country $High$, and hence a larger consumption expenditure share is spent on housing services. In contrast, in country $Low$, households do not care that much about housings services, as they prefer other types of consumption goods. The demand for housing services is low. And hence, the price for housing services relative to other consumption goods as well as the consumption expenditure share spent on housing services is lower in country $Low$.

This has important implications for the FV of real estate in both economies. Suppose that the FV of an asset is calculated by the expected discounted stream of dividends an asset generates. What is the dividend of a housing asset? It is the rental income that the asset generates, hence the price of housing services. Hence the FV is the expected discounted stream of the price for housing services. It follows that in country $High$ where the aggregate preference for housing services is stronger, the relative price for housing

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14The firms are simulated by the computer, and hence we skip the firm side in this presentation.
services is higher, the FV of the real estate will be higher as well – compared to country Low.

This in turn has crucial implications on the maximum bubble size: In equilibrium, every asset needs to be affordable. It follows from the resource constraint of the economy that country High, where the FV of real estate is large, will have no room for a large bubble. In country Low, where the FV is lower, there is room for larger bubbles. This prediction will be more formally discussed in section 3.3.

3.2 Model Setup

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

\[
u(C_{1,t}) + \xi^k v(S_t) + \gamma E_t \{ u(C_{2,t+1}) \}
\]

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

Young households supply their labor service inelastically for a real wage \( W \), and allocate their net wealth between consuming the bundle \( C_{1,t} \), housing services of size \( S_t \), save/invest in a 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 interest rate \( R_t \).

The dual motives of housing behavior is disentangled by modelling the consumption aspect (consuming housing services \( S_t \)) and investment aspect (investing in housing \( H_t \)) 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 the house price bubble size.

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15 As in [Iacoviello (2005)](Iacoviello2005), housing services and all other composite consumption are assumed to be separable. The log specification over housing services and composite consumption is based e.g. on [Davis and Ortalo-Magne (2011)](Davis2011), who find that the expenditure share on housing is constant (over time and across U.S. cities). Further, [Huber (2018)](Huber2018) finds for a sample of 18 OECD countries that cross-country differences in the expenditure share on housing services are constant over time.

16 As [Henderson and Ioannides (1983)](Henderson1983) 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".
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 invest in housing by buying housing stock $H_t$ from the old generation. The housing asset yields a dividend payment in the subsequent period – a rental income when old. Before the old household dies, he sells the remaining housing stock to the new young generation.

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

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

$$C_{1,t} + \frac{Z_t}{P_t} + \sum_{k=0}^{\infty} q_{t|t-k} H_{t|t-k} + p_{t}^r S_t \leq W_t + \delta q_{t|t}, \quad (3.2)$$

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. Prices written in lowercase letters define prices relative to the consumption bundle $C_t$, 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 $k = 0, 1, 2, ...$ $W_t$ denotes the wage of the young.

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

$$q_t \equiv q_t^F + q_t^B \quad (3.3)$$

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

$$q_t^F \equiv E_t \left\{ \sum_{k=0}^{\infty} \prod_{j=0}^{k-1} \frac{1}{R_{t+j}} (1 - \delta)^{k-1} p_{t+k}^r \right\} \quad (3.4)$$

The budget constraint when old is given by equation (3.5). 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 $\sum_{k=0}^{\infty} p_{t+k}^r H_{t|t-k}$, (2) the re-selling value of his housing stock

\footnote{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.} \footnote{At the end of the period the old household sells his remaining housing stock, i.e.}
payoff from his maturing bond holding, and (4) real profits generated by his intermediate firm, $D_{t+1}$. Formally, for each old household we have

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

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

### 3.3 Testable Predictions of the Model

**Prediction 1: The bubble size and the size of the fundamental**

Comparative statics of the steady state show that an increase in $\xi$ (capturing a rise in household’s preference for housing services relative to other consumption goods) leads to a higher rental price $p^r$. It follows that the fundamental value $FV$, the expected discounted stream of rental prices, increases. In a bubbly equilibrium it must hold that

$$B_t \in [0; W - FV_t] \quad \forall \quad t.$$  

[Huber (2018) refers to (3.6) as condition 1 for bubble existence. The larger the preference for housing services, the larger the fundamental value of the real estate stock today, the smaller the maximum theoretically possible aggregate bubble size today. In other words, countries that are characterized by a larger fundamental value of real estate (potentially because the demand for housing consumption is stronger), have less room for large bubbles, i.e. cannot experience large bubbles - in comparison to countries where the fundamental value of real estate is lower (i.e. the demand for housing consumption is weaker).]

**Prediction 2: Consumption Composition and Expenditure Shares**

An increase in $\xi$ induces a substitution from other consumption goods $C$ towards housing services $S$ when young. This leads to a decrease in the consumption expenditure share spend on other consumption goods when young (hence $C_1$ decreases) and an increase in the consumption expenditure share spend on housing services, hence the rental price $p^r$ increases.

**Prediction 3: The price-rent-ratio**

In policy debates, the price-rent-ratio (PRR) is often referred to as a good indicator for the detection of house price bubbles. The PRR decreases with $\xi$ increasing.

In section 5, we discuss the experimental result. Our results are in line and hence

$(1 - \delta) \sum_{k=0}^{\infty} q_{t+1} H_{t+k}$, to the young generation.

19 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 period and for one period only (i.e. when the founder is old), generating profits, $D_t$, for the owner when old.
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 make in a lifecycle. Second, we describe the assignment to markets and the overall structure of the experiment. Third, we present the hypothesis, treatments and the parameters choices and, finally, the procedure and the subject pool. For simplicity, we omit the time index $t$ in the notation of variables. The instructions are provided in the appendix.

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 make within each lifecycle.

Notes: The boxes in columns "Being Young" and "Being Old" summarize the decisions that subjects make.

Figure 1: Lifecycle and decisions when young and old

A lifecycle consists of two periods: In the first period of a lifecycle, subjects make decisions as a young household. In the second period of a lifecycle, subjects make decisions as an old household and receive payments that are based on their decisions when young
and old, as well as aggregate outcomes. The decision screens of a lifecycle can be found in
the appendix.

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 \( Z \). Each period is divided into two stages (both for young and old house-
holds). In the theoretical model, young households make decisions on the consumption
good \( C \), housing services \( S \), the housing asset \( H \) and the riskless bond \( Z \) simultaneously.
For reasons of feasibility and cognitive constraints (screen overload, remaining budget cal-
culation, dividend calculation), we allocate the consumption decisions to the first stage
and the investment decisions to the second stage.

In the first stage when young (young, stage 1), subject decide how many units of the
consumption good \( C \) and how many units of housing service \( S \) (the consumption side of the
housing asset) they want to purchase. They do so by clicking on a combination of \( C \) and
\( S \) in a graph on the decision screen, see screenshots in the Appendix. Next to the graph
in which they make their choices, a colored heat map is displayed. 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 preference for housing services, re-
lected by the parameter \( \xi \), affects the Happiness Points an individual gets from consuming
\( S \) as well as the price for one unit of \( S \), \( p^r \). Varying preferences for housing services are
exogenously induced through our treatment variation. The heat maps visualize nicely the
treatment variation, see screenshots in the Appendix.

The price for one unit of \( C \) is set to the numeraire (and equal to one). The (relative)
price for one unit of \( S \), \( p^r \), depends on all young’s purchases of \( C \) and \( S \) in the market.
In the general equilibrium model, the households are price takers. We do not implement
this feature in the lab experiment because we do not want to have an exogenous, constant
and common knowledge dividend as often assumed in experimental asset market designs.
A critical and novel feature of our experimental design is the endogenous nature of the
dividend of the housing asset (i.e., the price for housing services) that affects the FV of
the housing asset. The price \( p^r \) can only be calculated once all young in the market 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 market. Together with the own chosen combi-
nation of \( C \) and \( S \), the relative price for one unit of \( S \), \( p^r \), is calculated and displayed on
the screen. Subjects can try as many combinations as they wish (without time restriction).

\(^{20}\)In line with the model equation, Happiness Points (from \( C \) and \( S \)) = \( \log(C) + \xi \log(S) \).
Once they decide for a combination of \( C \) and \( S \), they press a "Submit" button, and their decision is submitted. We ask subjects to submit the maximum number of units of \( C \) and \( S \) they want to purchase. Once all young in the market have submitted their demands, the algorithm checks for availability of the demanded number of units, and the price for one unit of \( S \), \( p^r \), is displayed on the screen.\(^{21}\) Note that the price for one unit of \( S \), \( p^r \), and the number of Happiness points derived from the consumption of \( C \) and \( S \) depend on the preference for housing services \( \xi \), our treatment variation. We will explain the treatment variation in section 4.3.

In the second stage when young (young, stage 2), subjects purchase units of housing asset \( H \) in a double auction from the current old in the market. Before the young subjects get to the double auction, they learn how the dividend of the housing investment \( H \) will be determined, i.e. that it 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.\(^{22}\) The dividend resulting from each simulated combination of \( C \) and \( S \) is calculated and displayed on the screen. We implement a standard experimental double auction with the only exception that young subjects can only purchase and old subjects can only sell housing assets \( H \).

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 is over, the remaining budget remains automatically in the bank account (= is invested into a riskless bond \( Z \)) and earns a fixed interest payment of 5%.

In the first stage when old (old, stage 1), subjects learn about their investment return in asset \( H \), that is they receive a dividend payment for each housing asset \( H \) they bought when young.\(^{23}\) Subsequently, the old subjects enter a double auction in which they can sell housing assets \( H \) to the current young generation in the market. 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 \( H \)). There is no depreciation of the housing stock, thus the stock of housing assets \( H \) remains constant from generation to generation. Therefore,

\(^{21}\)In the case of excess demand, each young subject’s demanded units are reduced proportionally to the requested amounts until the supplied units of \( C \) and \( S \) on the market are matched.

\(^{22}\)As a help device, the same heat map as in the first stage when young is depicted because the future young will make the exactly same decision on purchasing \( C \) and \( S \) as the current young generation.

\(^{23}\)In each period, the dividend of the housing asset \( H \) is given by the price for housing services (the rental price \( p_r \)), which is determined by the demand for \( C \) and \( S \) of the current young generation in that period.
unsold units of the housing asset \( H \) are assigned randomly to the current \( young \) in the market at a punishment price. The punishment price is 50\% less (more) than the median trading price for the current \( old \) (\( young \)) in the market. This incentivizes subjects to trade the existing housing stock \( H \), such that the market clears.

In the second stage when \( old \) (old, stage 2), that is 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, the number of 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 \( Z \), and the total lifecycle happiness points.\(^{24}\)

Some realistic modifications compared to the theoretical model include relaxing the assumptions of rationality and of tenants being price takers as well as allowing participants to make decisions sequentially. This opens two possible channels through which the demand for housing services might affect the size of house price bubbles: through their impact on the (endogenous) fundamental value of the housing asset and/or their impact on the endowment or cash-to-asset ratio available when deciding on the investment in the housing asset. In the data analysis, we control for the cash-to-asset ratio in a robustness check and the results remain significant.

To facilitate decisions and ensure that decisions are as well-informed as possible, subjects can access a history screen from any decision or feedback screen (and go back to the decision or feedback screen). On the history screen, they find a summary of their decisions on \( C, S, H \), and the return from bond holding \( Z \) as well as the corresponding happiness points 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 Market Assignment and Experimental Structure

Each session is composed of 16 subjects. At the beginning of the experiment, 50\% of all subjects are randomly assigned to Cohort I and the remaining 50\% of subjects to Cohort II (eight in Cohort I and eight in Cohort II). All subjects are informed that they will remain in the assigned cohort for all periods of the experiment.

\(^{24}\)Remaining units of \( H \) and \( Z \) are transformed into Happiness Points with the following formula: Happiness Points (from \( H \) and \( Z \)) = log(return from selling the previously purchased \( H \) + divided per purchased \( H \) + 1.05*investment in bond \( Z \)).
At the beginning of period 1, four members of each cohort are randomly assigned to Market A and the other four members to Market B. Cohort I (II) starts as a young (old) generation in period 1 and subjects make decisions accordingly. Figure 2 presents an overview over each cohort’s lifecycles.

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

Figure 2: Chronological order of the experiment

From period 2 onwards, cohorts switch between generations in each period. That means that, in period 2, Cohort I (II) takes the role of the old (young) generation, the role of young (old) generation in period 3, etc. 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.

As an important design feature, subjects remain in the same market throughout a lifecycle and are randomly assigned to either market A or market B at the beginning of a lifecycle. That means that the formerly young subjects remain in the same market when turning old, while the formerly old subjects are randomly assigned to either market A or market B before a new lifecycle starts. The advantage of this assignment is that we reduce colluding behavior in small markets and repeated interaction of subject. Figure 3 summarizes the assignment to cohorts and markets.

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.

To implement an infinite time horizon in the lab, we follow Crockett and Duffy (2015) and implement an indefinite horizon by assuming a constant probability of continuation.
Figure 3: Assignment of subjects to Market A and B

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 Hypothesis, Treatments and Parameter Choices

We test the following hypothesis with our lab experiment:

\textit{Housing bubbles are of larger magnitude the weaker the preference for housing services (relative to other consumption goods).}

The comparative statics of the theoretical model predict that a stronger preference for housing services (relative to other consumption goods) leads to a higher relative price for housing services, \( p^r \), and to a larger consumption expenditure shares spent on housing services, thereby to a higher fundamental value \( FV \), to a smaller bubble size, and a lower

\[ \text{As Duffy (2016) points out, a continuation probability has the advantage that future payoffs are discounted at a rate } \delta \text{ (discount factor with infinite horizon) and the stationarity of an infinite horizon is induced.} \]
price-rent ratio. In order to test the before-mentioned hypothesis, we implement the following two treatments in a between-subject design (subjects are randomly assigned to either treatment):

- Treatment "Weak preference for housing services" ($\xi = 2$): Subjects have a weak preference for housing services (low $\xi$). Consequently, the utility from consuming housing services $S$ relative to the consumption good $C$ is low.

- Treatment "Strong preference for housing services" ($\xi = 6$): Subjects have a strong preference for housing services (high $\xi$). Consequently, the utility from consuming housing services $S$ relative to the consumption good $C$ is high.

In the model, this preference parameter $\xi$ determines the consumption expenditure spent on housing services as a fraction of the total consumption expenditure in equilibrium. We can calibrate this model parameter using the formula for the CPI weight of housing services and CPI data. The CPI weight is defined as spending on housing services divided by total spending on consumption, applying this definition to the model, uniquely pins down the parameter $\xi$ for each country:

$$\text{CPI weight}_{\text{HousingServices}} = \frac{\text{spending on housing services}}{\text{total spending on consumption}} = \frac{p^t S_t}{p^t S_t + C_{1,t}} = \frac{\xi}{1 + \xi}$$

With our parameter choices, we match the distance between the lower and larger implied $\xi$ for a sample of 18 OECD countries. Huber (2018) shows that there is a large variation in the consumption expenditure share spent on housing services across OECD countries, with shares around 15% falling into the lowest quartile and with shares around 30% falling into the highest quartile. The resulting parameter $\xi$ in countries with a higher expenditure share is roughly 300% larger than in countries with a lower expenditure share. We match this relative distance in our experiment. That is, in treatment "Strong preference for housing services" ($\xi = 6$), the relative preference parameter $\xi$ is 300% larger than in treatment "Weak preference for housing services" ($\xi = 2$). The remaining parameter choice and key equations are summarized in table 1.
### Parameter Calibration

<table>
<thead>
<tr>
<th><strong>Parameter</strong></th>
<th><strong>Calibration</strong></th>
<th><strong>Explanation</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S_supply</td>
<td>20 units of housing services</td>
<td>In each market (A and B), per period</td>
</tr>
<tr>
<td>H_supply</td>
<td>20 units of housing asset</td>
<td>In each market (A and B), per period</td>
</tr>
<tr>
<td>C_supply</td>
<td>20 units of consumption good</td>
<td>In each market (A and B), per period</td>
</tr>
<tr>
<td>Endowment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>General</td>
<td>250 EURUX</td>
<td>Beginning of each lifecycle (being young)</td>
</tr>
<tr>
<td>Initial</td>
<td>50 EURUX in Z</td>
<td>Cohort II subjects in period 1 (being old)</td>
</tr>
<tr>
<td>Prices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>numeraire and equal to one</td>
<td>Price for one unit of C</td>
</tr>
<tr>
<td>p'</td>
<td>( p' = \xi \frac{S_{\text{demand}}}{S_{\text{supply}}} )</td>
<td>Relative price for one unit of S</td>
</tr>
<tr>
<td>Q</td>
<td>determined in a double auction</td>
<td>Price for one unit of H</td>
</tr>
<tr>
<td>R</td>
<td>equals 5%</td>
<td>Interest rate on riskless bond holding Z</td>
</tr>
<tr>
<td>Dividend</td>
<td>equal to ( p' ) if ( S_{\text{demand}} = S_{\text{supply}} )</td>
<td>Rental income generated by asset H</td>
</tr>
<tr>
<td></td>
<td>equal to ( p' ) if ( S_{\text{demand}} &gt; S_{\text{supply}} )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>equal to ( p' \frac{S_{\text{demand}}}{S_{\text{supply}}} ) if ( S_{\text{demand}} &lt; S_{\text{supply}} )</td>
<td></td>
</tr>
<tr>
<td>Utility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP (from C and S)</td>
<td>( \log(C) + \xi \log(S) )</td>
<td></td>
</tr>
<tr>
<td>HP (from H and Z)</td>
<td>( \log(\text{return from selling } H) ) + dividend per H + 1.05*Z</td>
<td></td>
</tr>
<tr>
<td>Demanded units</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( X_i )</td>
<td>( \sum_{i=1}^{4} X_{\text{demand}} \leq X_{\text{supply}} )</td>
<td>No aggregate excess demand</td>
</tr>
<tr>
<td></td>
<td>( X_{\text{adj}} ) if ( \sum_{i=1}^{4} X_{\text{demand}} &gt; X_{\text{supply}} )</td>
<td>Aggregate excess demand</td>
</tr>
</tbody>
</table>

Notes: EURUX stands for experimental currency units. HP stands for Happiness Points. \( X_i \) denotes the actual individual demand of subject \( i \) of variable \( X \in \{C, S, H\} \), while \( X_{\text{supply}} \) denotes aggregate supply of \( X \). \( X_{\text{adj}} \) denotes the individual adjusted demand of subject \( i \) in case of aggregate excess demand and is given by \( X_{\text{adj}} = X_i \frac{X_{\text{supply}}}{\sum_{i=1}^{n} X_{\text{supply}}} \), hence individual demand gets proportionally adjusted.

**Table 1: Parameter choices**
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 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 services" ($\xi = 2$) and treatment "Strong preference for housing services" ($\xi = 6$) with two exceptions: First, the formula for the utility from $C$ and $S$ differs depending on the treatment: "Happiness Points (from $C$ and $S$) = $\log(C) + 2 \ast \log(S)$" for treatment "Weak preference for housing services" ($\xi = 2$); "Happiness Points (from $C$ and $S$) = $\log(C) + 6 \ast \log(S)$" for treatment "Strong preference for housing services" ($\xi = 6$). Second, the heat map and screenshots are adjusted accordingly. The beginning of the trial periods as well as the start of the incentivized periods are announced aloud by one of the experimenters.

The experimental sessions were conducted at the BEElab at Maastricht University in April, May and September 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%) [26]. The average age was 21 years. The conversion rate was 1 Happiness Point 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 Results

This section explains carefully how we measure experimental 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 $FV$. As common in the literature, the fundamental value is

\[ \text{Eckel and Füllbrunn} (2015) \text{ and } \text{Holt et al.} (2017) \text{ show that asset markets with a declining dividend and a higher share of male participants produce larger price bubbles. Though } \text{Holt et al.} (2017) \text{ show that there seem to be no gender differences on markets with constant dividend, we invited the same number of male and female students to each session.} \]
defined as the expected discounted stream of dividends the asset generates. For robustness purposes, we assume four alternative expectation formations: rational expectations, and three different types of adaptive expectations which are explained in section 5.1.1. For each alternative, we compute the corresponding bubble size, and show the difference and similarities of the raw data in the trading price, fundamental value and bubble formation across treatments, see section 5.2.1. Our results are robust to these variations.

Second, we employ and describe a wide range of indicators for measuring experimental bubbles, see section 5.1.2. These indicators are widely used in the experimental asset price literature, and we study their differences across the two treatments ("strong (ξ = 6)" versus "weak preference for housing services (ξ = 2)"). We also compare the price-rent-ratio (PRR) across the two treatments. In policy debates the PRR is often referred to as a good indicator for the detection of house price bubbles, the larger the PRR the more likely that a bubble exist. All employed indicators and the price-rent ratio reveal the same pictures; bubbles are significantly larger in the treatment "Weak preference for housing service" (ξ = 2) compared to the treatment "Strong preference for housing service" (ξ = 6), section 5.2.2.

Besides the descriptive statistics and comparative statics, 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 $B_t = Q_t - FV_t$, where $Q_t$ denotes the realized trading price in the experiment in period $t$, and $FV_t$ the fundamental value, i.e. the expected discounted stream of dividends. Next, we assume four different types of expectation formation, leading to four different measures for the fundamental value (and hence for the bubble size). We follow the expectation formation types widely used in the experimental asset price literature.

5.1.1 Expectation Formation and the 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:

\[
FV_{sophisticated}^{t=1} = \left(\frac{1 - x}{R}\right) p_t^r \\
FV_{sophisticated}^{t=2} = \left(\frac{1 - x}{R}\right)^2 \frac{p_t^r + p_{t+1}^r}{2} \\
\ldots
\]

\[
FV_{sophisticated}^{t} \equiv E_t \left\{ \sum_{j=1}^{\infty} \left(\frac{1 - x}{R}\right)^j \sum_{k=1}^{t} \frac{p_t^r}{t} \right\} \tag{5.1}
\]

For robustness purposes, we measure the expected fundamental value by alternative methods. The first alternative is called \textit{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:

\[
FV_{naive}^{t} = E_t \left\{ \sum_{k=1}^{\infty} \left(\frac{1 - x}{R}\right)^k p_t^r \right\} \\
= \frac{1}{R} (1 - x) p_t^r + \frac{1}{R^2} (1 - x)^2 p_{t+1}^r + \frac{1}{R^3} (1 - x)^3 p_{t+2}^r + \ldots \\
= p_t^r \left( \frac{1 - x}{R - (1 - x)} \right) \quad \forall \quad t \tag{5.2}
\]

The second alternative are \textit{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 the currently realized dividend. The myopic traders calculate and expect the following fundamental value:

\[
FV_{myopic}^{t} = E_t \left\{ \sum_{k=1}^{\infty} \left(\frac{x}{R}\right)^k p_t^r \right\} \tag{5.3}
\]
The third alternative assumes *omniscient traders*, who forecast the dividend process correctly:

\[
FV_{t=1}^{\text{omniscient}} = \left( \frac{1-x}{R} \right) p_{t}^1 + \left( \frac{1-x}{R} \right)^2 p_{t}^2 + \ldots + \left( \frac{1-x}{R} \right)^8 p_{t}^8 + E_t \left\{ \sum_{j=1}^{\infty} \left( \frac{1-x}{R} \right)^j p_{t}^9 \right\}
\]

\[
FV_{t=2}^{\text{omniscient}} = \left( \frac{1-x}{R} \right) p_{t}^2 + \left( \frac{1-x}{R} \right)^2 p_{t}^3 + \ldots + \left( \frac{1-x}{R} \right)^7 p_{t}^9 + E_t \left\{ \sum_{j=1}^{\infty} \left( \frac{1-x}{R} \right)^j p_{t}^9 \right\}
\]

\[
\ldots
\]

\[
FV_{t}^{\text{omniscient}} = \sum_{j=t}^{9} \left( \frac{1-x}{R} \right)^{j-t+1} p_{t}^j + E_t \left\{ \sum_{j=1}^{\infty} \left( \frac{1-x}{R} \right)^j p_{t}^9 \right\}
\]  

(5.4)

### 5.1.2 Experimental Bubble Indicators

In the experimental asset price literature, there are five well established indicators for measuring bubbles.

**Price Amplitude (PA)**

\[
PA_{\text{King}} = \frac{\max_t (Q_t - FV_t) - \min_t (Q_t - FV_t)}{FV_1}
\]

(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 the 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)**

\[
TD = \sum_t |Q_t - FV_t|
\]

(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 measure was first introduced by [Haruvy and Nousair](2006). The TD measures the difference between the trading price and the fundamental value, and is hence similar to the PA measures. However, the TD measure is more complete in the sense that it does not only measure the difference between the maximum and minimum deviation from fundamental value.
Average Bias (AB)

\[ AB = \frac{\sum_{t}(Q_t - FV_t)}{T} \]  

(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 the fundamental value.

Relative Absolute Deviation (RAD)

\[ RAD = \frac{1}{T} \sum_{t=1}^{T} \frac{|Q_t - FV_t|}{|FV|} \]  

(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 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 \( FV \).

Relative Deviation (RD)

\[ RD = \frac{1}{T} \sum_{t=1}^{T} \frac{(Q_t - FV_t)}{|FV|} \]  

(5.9)

was proposed by Stöckl et al. (2010). The Relative Deviation (RD) measure is very similar to RAD. While RAD averages the absolute difference between the mean price and the fundamental value, RD averages the difference between the mean price and the fundamental value. 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 The Fundamental Value and the Bubble

In the following, prices, fundamental values, and the bubble are expressed in experimental currency units. Figure (4) shows the average median trading price \( Q \) for the housing asset
(circles) and its fundamental value FV (diamonds). The fundamental value is computed as the average over all sessions assuming "sophisticated traders". All results presented in this section are robust to using the three alternative types of expectation formation explained in section 5.5.1. The point-dotted lines indicate the range of a reduced (increased) FV by 60%, respectively. The dotted lines indicate the maximally feasible average trading price $Q^{\text{max}}$. This latter measure will be discussed in a later section. The left column shows the averages for sessions with the treatment "Weak preference for housing service" ($\xi = 2$) and in the right column the averages for the treatment "Strong preference for housing service" ($\xi = 6$).

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" ($\xi = 6$). For the treatment "Weak preference for housing service" ($\xi = 2$), the average median trading price seems to slightly decrease over time. Figure (A2) in the Appendix shows that this slight decrease is driven by one outlier (session 12).

As expected, inducing a strong preference for housing services (relative to other consumption goods) leads to a significantly higher FV (18.60) compared to the treatment with a weak preference for housing services (6.18), ($z = -3.363, p = 0.0008, n = 16$, two-sided Mann-Whitney U test). As elaborated earlier in the paper, changes in the FVs are one
of the channels through which preferences for housing services affect the size of housing bubbles.

The point-dotted lines visualize that, for the treatment "Weak preference for housing service" ($\xi = 2$), the average median trading price is far outside of the range $[(1 - 60\%) \cdot FV, (1 + 60\%) \cdot FV]$. Here, the trading price is substantially larger than $1.60 \cdot FV$ while, for the treatment "Strong preference for housing service" ($\xi = 6$), 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" ($\xi = 2$) and 10.48 in the treatment "Strong preference for housing service" ($\xi = 6$). 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 FV value $\frac{B}{FV}$. On the left (right) panel 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" ($\xi = 2$) – the left panel ($z = 3.361, p = 0.0008$, two-sided Mann-Whitney U test). Note that the average bubble relative to the fundamental value is relatively constant over time for both treatments, except for one outlier (session 12).

The bubble size as well as the trading price $Q$ do not display any boom-bust cycles over time. Empirical work often measures 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 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 the two-period overlapping generation model that we use as a benchmark. The households live for two periods and 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 as possible to the model setup, the subjects are informed that only one lifecycle is chosen randomly and paid out. This avoids potential design problems, where results might be driven by

---

27 OLS regressions show the same patterns (using the periodic observations and clustering at the session level; $n = 144 = 16*9$). The results hold when including controls for period as well as gender and age composition.

28 We compare the two deterministic steady states of the OLG model, one with $\xi = 2$ and one with $\xi = 6$. In each deterministic steady state, the bubble and the price-to-rent ratio is constant, while larger in the steady state with $\xi = 2$. 

25
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. This is what we observe in our experiment, a relatively constant bubble size over time. We are thus confident that our incentive design has worked correctly.

Notes: The treatment $\xi = 2$ corresponds to "Weak preference for housing service", while $\xi = 6$ corresponds to the "Strong preference for housing service" treatment.

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

5.2.2 Experimental Bubble Indicators

The experimental asset price literature offers five well-established indicators for measuring bubbles. Table (2) 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 section 5.1.2.

The first column of table (2) shows the Price Amplitude (PA). According to this measure, the bubble in the treatment "Weak preference for housing service" ($\xi = 2$) is on average almost three times as large.

The second column of table (2) shows the Total Dispersion (TD) measured by the sum of all period absolute deviations of median trading prices from the FV. It is a measure of the magnitude of mispricing. According to this measure, the bubble is significantly larger in the treatment "Weak preference for housing service" ($\xi = 2$).

The third column of table (2) 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 "Weak preference for housing service" ($\xi = 2$).

The Relative Absolute Deviation (RAD) is shown in the forth column of table (2) and is easy to interpret. The value 3.49 for the treatment "Weak preference for housing service" ($\xi = 2$) means that on average prices per period differ 349% from the average FV in the market. This compares to 65% for the treatment "Strong preference for housing service" ($\xi = 6$) – a large difference.

The fifth column shows the Relative Deviation (RD) measure that is very similar to RAD. For the treatment "Weak preference for housing service" ($\xi = 2$) the two indicators RAD and RD are identical for each session. The market on average overvalues the housing asset by 349%. For the treatment "Strong preference for housing service" ($\xi = 6$), 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.

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

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

Table 2: Indicators for Experimental Bubbles
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 3 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 for any bubble measure.

Table 4 shows the OLS regression results, where the only explanatory variables is the treatment dummy taking value one if $\xi = 6$, and zero otherwise. The coefficient of the treatment dummy, the preference for housing services $\xi$, is negative, highly significant, and explains a large part of the variation in the mispricing indicators across treatments.

<table>
<thead>
<tr>
<th></th>
<th>RAD</th>
<th>RD</th>
<th>PA</th>
<th>TD</th>
<th>AB</th>
<th>B/FV</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta$ mean (median)</td>
<td>2.84***</td>
<td>2.91***</td>
<td>0.95***</td>
<td>106.09***</td>
<td>11.79***</td>
<td>2.96***</td>
</tr>
<tr>
<td>$Z$</td>
<td>2.731</td>
<td>3.361</td>
<td>3.361</td>
<td>2.626</td>
<td>2.626</td>
<td>3.361</td>
</tr>
</tbody>
</table>

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)$=\frac{1}{N}\sum_{t=1}^{N}|Q_{t} - FV_{t}|/|FV_{t}|$. RD (Relative Deviation)$=\frac{1}{N}\sum_{t=1}^{N}(Q_{t} - FV_{t})/|FV_{t}|$. PA (Price Amplitude)$=\max(Q_{t} - FV_{t})/FV_{t} - \min(Q_{t} - FV_{t})/FV_{t}$. TD (Total Dispersion)$=\sum_{t=1}^{N}|Q_{t} - FV_{t}|$. AB (Average Bias)$=\frac{1}{N}\sum_{t=1}^{N}(Q_{t} - FV_{t})$. 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 3: Mean Differences between Treatments

<table>
<thead>
<tr>
<th></th>
<th>RAD</th>
<th>RD</th>
<th>PA</th>
<th>TD</th>
<th>AB</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\xi$</td>
<td>-2.843***</td>
<td>-2.912***</td>
<td>-0.951*</td>
<td>-106.1**</td>
<td>-11.79**</td>
</tr>
<tr>
<td></td>
<td>(0.411)</td>
<td>(0.425)</td>
<td>(0.483)</td>
<td>(37.31)</td>
<td>(4.146)</td>
</tr>
<tr>
<td>Constant</td>
<td>3.493***</td>
<td>3.493***</td>
<td>1.440***</td>
<td>200.4***</td>
<td>22.26***</td>
</tr>
<tr>
<td></td>
<td>(0.382)</td>
<td>(0.382)</td>
<td>(0.469)</td>
<td>(21.27)</td>
<td>(2.363)</td>
</tr>
</tbody>
</table>

| $N$      | 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 |

Robust Std. Errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01. $\xi$ is equal to one if $\xi = 6$, and zero otherwise.

Table 4: Impact of $\xi$ on Bubble Size Indicators (OLS)
5.2.3 Price-Rent-Ratio (PRR)

In policy debates, the price-rent-ratio is often used as an indicator for whether housing markets are fairly valued, or in a bubble. Comparative statics of the deterministic OLG model show that a larger $\xi$ leads not only to a larger bubble, but also to a larger PRR.

As expected, we find that the PRR is significantly larger in the treatment "Weak preference for housing services ($\xi = 2$)" compared to the treatment "Strong preference for housing services ($\xi = 6$)". (z = 3.361 and p = 0.0008, two-sided Mann-Whitney U test)\(^{29}\)

In summary, all indicators considered paint the same pictures: Bubbles are significantly larger in a world with weak preferences for housing services ($\xi = 2$) than in a world with strong preferences for housing services ($\xi = 6$).

5.3 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.\(^{30}\) The same result holds for the well-established experimental bubble indicators (RAD, RD, PA, TD and AB). In this section, we discuss three alternative explanations for the obtained trading price $Q$ and the resulting bubble sizes and address them with corresponding robustness checks.

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 the "Weak preference for housing service" ($\xi = 2$) and 28.85 for the "Strong preference for housing service" ($\xi = 6$) treatment. A possible explanation could be that this trading price is obtained because of an upper endowment bound. Such an endowment mechanisms does not exist in the theoretical model in [Huber (2018)], but it does in the experiment. In the case of an upper endowment bound, participants in both treatments would (after purchasing the consumption good $C$ and housing services $S$) spend all remaining budget on housing assets $H$. The maximum bubble size is limited from below by the fundamental value of the housing assets $H$ and from above by the remaining budget. Since the endogenously realized price for housing service $p^*$, and thus the fundamental value, are both higher in the treatment "Strong preference for housing service" ($\xi = 6$). The difference in the bubble size across treatments could be simply a consequence of the

\(^{29}\)The PRR is on average 14.4 (5.0) in the treatment Weak (Strong) preference for housing services.

\(^{30}\)This result is robust to three alternative measurements for the fundamental value $FV_t$. 

upper endowment bound.

We compute the maximum possible trading price $Q_{max}$ as follows: After subtracting aggregate spending on $C$ ($=20$) and $S$ ($=p^r\cdot20$) from the endowment in the market ($=4\cdot250$), 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 $Q$. We therefore conclude that a substantial share of the housing bubble steams from the effect of the preference for housing services on the fundamental value.

Reaction to the Treatment Parameter $\xi$

Related to the previous concern, one 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 treatments ($z=0.000$ 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 "Strong preference for housing services ($\xi=6$)" compared to the treatment "Weak preference for housing services ($\xi=2$)" ($z=3.123$ 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 $S/C$ is also significantly larger with $\xi=6$ compared to the treatment "Weak preference for housing service" ($\xi=2$), ($z=-3.123$, $p=0.0018$, 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 do react to the treatment
The Cash-to-Asset Ratio

A third potential objection concerns the cash-to-asset ratio. A higher cash-to-asset ratio means that more money is available in the economy. That is equivalent to "better" access to the credit market. 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 for $H$ 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 $H$ is larger in treatment $\xi = 2$ by maximally $(6 - 2) \cdot 20 = 80$ experimental currency units. This corresponds to a potential price difference of 4 experimental currency units per unit of asset $H$ ($=80/20$ units of $H$).

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 $\xi$. 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 emerging endowment differences 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 "weak preference for housing services ($\xi = 2$)" by 2.7 experimental currency units ($= 0.674 \cdot 4$). 67.4% corresponds to the share of the endowment (after purchasing $C$ and $S$) that the participants invest in $H$ in the treatment "Strong preferences for housing services ($\xi = 6$)". Alternatively, we could have taken the share of the endowment invested in $H$ in treatment $\xi = 2$ (60.3%), but we decided for the more conservative robustness test. Tables (5) and (6) present the same tests for the bubble indicators as in

\footnote{The correlation coefficient is equal to -0.99.}
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 (5) and the OLS regression results in table (6), 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. The results confirm that housing bubbles are substantially larger in the treatment with weak preferences for housing services.

| Robustness check: Adjusted trading price for treatment \( \xi = 2 \) |
|-------------------|----------------|----------------|----------------|----------------|----------------|
| \( \Delta \) 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. \( PA^a \) (Price Amplitude) = \( \frac{\text{max}(Q^a_t - FV_t) - \text{min}(Q^a_t - FV_t)}{FV_t} \). \( TD^a \) (Total Dispersion) = \( \sum_{t=1}^{N} | Q^m,a_{t} - FV_t | \). \( AB^a \) (Average Bias) = \( \frac{1}{N} \sum_{t=1}^{N} (Q^m,a_{t} - FV_t) \). \( RAD^a \) (Relative Absolute Deviation) = \( \frac{1}{N} \sum_{t=1}^{N} \frac{|Q^a_t - FV_t|}{|FV_t|} \). \( RD^a \) (Relative Deviation) = \( \frac{1}{N} \sum_{t=1}^{N} \frac{(Q^a_t - FV_t)}{|FV_t|} \). \( B/FV \) = \( \frac{1}{N} \sum_{t=1}^{N} \frac{(Q^a_t - FV_t)}{FV_t} \). \( Q^a_t \) denotes the adjusted mean trading price and \( Q^m,a_{t} \) the adjusted median trading price. We adjust the realized trading price of treatment \( \xi = 2 \) by subtracting \( (4 \times 0.674) \).

Table 5: Mean Differences between Treatments (2)
6 Conclusion

Housing is a special asset given its dual nature: it entails a consumption side (providing housing services) and an investment side. There are other asset classes that are also simultaneously a consumption good and an investment good (examples could be artwork, oldtimers or jewelry). However, the consumption side of housing is particularly relevant given that the housing consumption expenditure constitutes the largest consumption expenditure share for most economies.

This paper tests the causal effects of housing consumption on the magnitude of housing bubbles in a controlled environment. The experimental design builds on the theoretical OLG model with housing developed by Huber (2018). We test the hypothesis that the demand for housing consumption is a driving factor for the magnitude of housing bubbles. Two treatments are implemented – one with a weak and one with a strong preference for housing services relative to other consumption goods. Weak (strong) preferences for housing services relative to other consumption goods lead to a low (high) demand for housing services.

We find that a lower share of consumption expenditure is spent on housing services in the treatment with a lower preference for housing services. Consistent with the cross-country stylized facts in Huber (2018) and the model prediction, our results confirm that housing bubbles are of substantially larger magnitude in the treatment with weak preferences for housing services. The bubble size (both absolute and relative) and the price-rent ratio are larger in the treatment with weaker preferences for housing services. Five well established experimental bubble indicators (RAD, RD, PA, TD and AB) draw the same

<table>
<thead>
<tr>
<th></th>
<th>RAD^a</th>
<th>RD^a</th>
<th>PA^a</th>
<th>TD^a</th>
<th>AB^a</th>
</tr>
</thead>
<tbody>
<tr>
<td>ξ</td>
<td>-2.513***</td>
<td>-2.624***</td>
<td>-0.942*</td>
<td>-81.82**</td>
<td>-9.091**</td>
</tr>
<tr>
<td></td>
<td>(0.406)</td>
<td>(0.425)</td>
<td>(0.483)</td>
<td>(37.31)</td>
<td>(4.146)</td>
</tr>
<tr>
<td>Constant</td>
<td>3.066***</td>
<td>3.066***</td>
<td>1.440***</td>
<td>176.1***</td>
<td>19.57***</td>
</tr>
<tr>
<td></td>
<td>(0.382)</td>
<td>(0.382)</td>
<td>(0.469)</td>
<td>(21.27)</td>
<td>(2.363)</td>
</tr>
</tbody>
</table>

Robust Std. Errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01. ξ is equal to one if ξ = 6, and zero otherwise.

Table 6: Impact of ξ on Adjusted Bubble Indicators (OLS)
We implement several novel design features that allow for endogenous fundamental values and a neat implementation of OLG models in the laboratory. First, and in contrast to the closely related literature, the dividend of the bubbly asset is determined endogenously. This means that a market for the traded asset and a market for the dividend of the traded asset exist, which is particularly important for assets that entail a consumption and an investment component. Second, our novel assignment to markets has the advantages of gathering more observations, simplifying the structure for the subjects and giving them the chance to get as much experience as possible. Finally, we select one played lifecycle randomly and pay the subjects for their decisions in that lifecycle rather than summing up a subject’s earnings over the entire experiment.

The novel study design provides an adequate starting point for follow-up studies. For instance, competing policy intervention on the housing market to manage bubbles can be analyzed in our OLG design. Follow-up work may also compare the relative merits of policy interventions that aim to foster the affordability of housing (for instance, rental subsidies, rental caps, or help-to-buy schemes) and their implications on economies’ vulnerability to housing bubbles and the bubble size.

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32 All results are robust to calculating the bubble size and the bubble indicators with four different fundamental values and after controlling for the cash-to-asset ratio.
33 As mentioned earlier, Weber et al. (2018) is also one of the first experiments that implements an endogenous dividend in the asset market.
34 For ethical reasons, it can be difficult to test the causal effect of policy interventions in the field. A laboratory setup provides therefore a credible alternative. Note that our two-period OLG design can be easily modified to an OLG environment with several periods per lifecycle if needed.
Appendix A: Individual Market Results

Parameter $\xi$ measures the preference for housing services $S$ (relative to other consumption goods $C$), $\xi = 2$ for treatment "Weak preference for housing services" and $\xi = 6$ for treatment "Strong preference for housing services".

Figure A1: Trading Price and Fundamental Value for Each Session (session averages)

Parameter $\xi$ measures the preference for housing services $S$ (relative to other consumption goods $C$), $\xi = 2$ for treatment "Weak preference for housing services" and $\xi = 6$ for treatment "Strong preference for housing services".

Figure A2: Trading Price and Fundamental Value (for each session and market)
<table>
<thead>
<tr>
<th>Session</th>
<th>PA</th>
<th>TD</th>
<th>AB</th>
<th>RAD</th>
<th>RD</th>
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<tbody>
<tr>
<td>S01 - Market A</td>
<td>0.52</td>
<td>138.11</td>
<td>15.35</td>
<td>2.52</td>
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<tr>
<td>S01 - Market B</td>
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<td>29.44</td>
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<td>S05 - Market B</td>
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<td>S07 - Market B</td>
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<td>S09 - Market A</td>
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<td>22.27</td>
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<td>31.23</td>
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**Treatment \( \xi = 2 \) Average** 1.56 187.81 20.87 3.29 3.29

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<thead>
<tr>
<th>Session</th>
<th>PA</th>
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<th>AB</th>
<th>RAD</th>
<th>RD</th>
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<td>-51.16</td>
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<td>0.48</td>
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<td>12.49</td>
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<td>0.69</td>
</tr>
</tbody>
</table>

**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) = \( \sum_{t=1}^{N} | Q_t^m - FV_t | \) (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) = \( \frac{1}{N} \sum_{t=1}^{N} |Q_t - FV_t | / |FV_1| \) (Stoeckel et al. 2010). RD (Relative Deviation) = \( \frac{1}{N} \sum_{t=1}^{N} (Q_t - FV_t) / |FV_1| \) (Stoeckel et al. 2010).

\( Q_t \) denotes the mean trading price and \( Q_t^m \) the median trading price.

Table A1: Indicators for experimental Bubbels (individual sessions and markets)
Appendix B: Instructions & Screenshots

Written Instructions

Welcome and General Instructions

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

Please read these instructions carefully; they will help you make appropriate decisions. You will receive 5 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: \[ 	ext{Happiness Points (from C and S)} = \log(C) + 2*\log(S). \]

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 Young's purchased units of C and S will be reduced proportionally to the requested amounts.

After all participants have submitted their consumption and housing 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; others’ offers are in black. If you want to buy more assets H - repeat this process.

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

If you have enough money in your bank account, you can buy an asset at one of the prices listed in the "Offers to sell" column which 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.

Assignment to group A and B

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

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

There will be two sequences of the just described experiment: One trial sequence with four periods, which does not enter the lottery for 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.
Screenshots

Screens when "Young"

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)
Handouts: Graphs and Table

Decisions in a lifecycle

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<th>Start repetition</th>
<th>Random assignment to Group A or B</th>
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<tr>
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<td>Stage 1</td>
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<tr>
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<td>Buy consumption good C</td>
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<td></td>
<td>Buy housing service S</td>
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<td>Stage 2</td>
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<td></td>
<td>Buy housing asset H</td>
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<td>Receive summary information on young</td>
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<tr>
<td>Dividend of H</td>
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<tr>
<td>Price of H</td>
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<tr>
<td>Interest rate of B</td>
<td></td>
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<tr>
<td>Remaining budget in bank account B</td>
<td></td>
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<tr>
<td>Total returns from H and B transformed in Happiness Points</td>
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</tbody>
</table>

Units of C and S transformed in Happiness Points

Receive summary information on young
Assignment and chronological order

- **8 participants in Group A:**
  - 4 Cohort I
  - 4 Cohort II

- **16 participants:**
  - Cohort I (8 participants)
  - Cohort II (8 participants)

- **8 participants in Group B:**
  - 4 Cohort I
  - 4 Cohort II

- **PERIOD 1:**
  - 4 Young
  - 4 Old

- **PERIOD 2:**
  - 4 Young
  - 4 Old

- **Etc.:**

- 8 Cohort II (Old in Period 1) randomly assigned Group A and B (Young in Period 2)

- 8 Cohort I (Young in Period 1) stay in same Group A and B (Old in Period 2)

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<table>
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<th>Period</th>
<th>1</th>
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