Aggregate shocks and the volatility of house prices*

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Abstract

Both housing prices and housing transactions are much more volatile than GDP. In addition, housing transactions fluctuate much more than housing prices and they are positively correlated. This paper documents these features and asks whether they can arise in a suitably calibrated model of the economy that is subject to aggregate shocks to interest rates, to individual earnings and to demographics fluctuations. In other words our aim is quantitative asking whether we can have a theory of housing prices capable of generating the observed size of fluctuations. Our model successfully replicates the main properties of the earnings, and financial and housing wealth distributions and poses houses as large items that are costly to buy and sell, that come in fixed sizes and that give utility to the owner and is embodied in an overlapping generations structure. Our findings is that certain combination of shocks (to earnings and dividends and to financial intermediation can generate flucuations in housing prices that are higher by a factor of 3, which seems too small relative to actual housing price movements relative to fundamentals. Housing prices movements are HIGHER, SMALLER than stock price moments.

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1 Introduction

There is a tradition of work in modern macroeconomics using models with a large number of households subject to idiosyncratic earnings shocks where savings are used to smooth consumption across time (see Aiyagari (1994) Krusell and Smith (1997) to cite a few). This work has studied the determinants of wealth inequality as the outcome of uninsurable income shocks where households have access to a perfectly liquid asset that is used to smooth consumption across time. In the model economies of this type households are continually adjusting their asset level. In this paper we extend this work to environments where there are various assets, financial assets that are perfectly divisible and can be costless adjusted and other assets that come in predetermined but quite large sizes, that can be traded only at a considerable cost, that can be partially purchased on credit, and that give the owner some advantages (due perhaps to the tax system or to moral hazard reasons). We take these assets to be houses.

The specific aim of our work is to build blocks for the study of asset price changes. In this regard, an important specificity of our work that departs from standard macroeconomic models is that the stock of assets is not capital which is essentially lagged output. Instead, we take the opposite extreme and model the stock of assets as Lucas trees that are in limited supply and where the model determines their prices instead of their quantities. As we will see, this structure is equally well posed as the standard growth model to map to a modern aggregate economy.

There are several paper in the literature related to us. Gruber and Martin (2003) study an economy with illiquid durable consumption goods. They show that the decision rules display areas of inaction, and that financial wealth displays more dispersion than wealth held in the form of consumer durables. They also compare economies with identical parameterizations varying transaction costs (finding that higher transaction costs yield more savings) and the relative size of down payments (the bigger the down payment the higher savings). Martin (2005) is quite an interesting paper that explores in the context of a representative household model what are the implications of changes in characteristics over time (like those matching some of the demographics of the last half century) for asset prices, in particular housing prices, and interest rates. Ortalo-Magne and Rady (2003) is a slightly different paper that made interesting claims about the possibility of chain effects in the changes of the price of houses of different sizes due to the multiplying effects of capital gains –small changes in the price of small houses induce large increases in the equity of their highly leveraged owners that may want to switch to larger houses pushing their prices even further. In a way our work aims in part to find out the quantitative possibility of this channel if any. Nakajima (2004) studies the response of of housing prices to an increase in the volatility of individual earnings and finds that the level of housing prices moves quite a bit in response to what is a pure second moment change without any change in the level of economic activity. This is the only paper that we know that poses endoegenous prices and its key finding is that under certain circumstances housing prices can increase beyond those of liquid assets, albeit not by much. Davis and Heathcote (2005) is interested in the business cycle properties of housing construction, but they worry about housing quantities not prices. Diaz and Puch (1998) documents how the properties of model economies relate to the down payment requirements. Chambers, Garriga and Schlagenhauf (2005) connects the increase in housing ownership to reductions in the down payment. Finally, Diaz and Luengo-Prado (2004) studies the determinants of housing tenure choice. There are other papers that also work on housing prices, but there notion of houses lacks some of the features that we think are more crucial to capture their essence, namely that they are big relative to its purchasers finances, that they are very costly to buy and sell, and that they provide an advantage to the owner that prevents the appearance of a rental market as a good substitute of ownership. A fourth feature, is, we think, new, that we both have different sizes and that houses cannot be built from scratch, in fact ours is more a model of hosing lots rather than a model of structures.

In particular, our work is closely related to Gruber and Martin (2003 and to Diaz and Luengo-Prado (2004) and we have slightly different calibration properties. For example we manage to get a larger group of people with no housing; but our wealth Gini Index while being closer to that in the data than the former paper is further than the one in the latter paper; we generate too much indebtedness and this two paper too little. So what is our value added? First, we are building the blocks of a structure capable of addressing price changes by having a finite number of housing (or perhaps better of lots) sizes and what is more important, units since we have an economy of the Lucas trees variety. Second, we are interested in the dynamics of the purchases and upgrades of houses and in this regard we provide information of effective down payments of first and repeated home buyers. Third, our structure is designed to be expanded in the direction of aggregate uncertainty and we give some information of how to do this, which is a challenge both theoretically and computationally.

2 Discussion

We pose a model where we give houses the utmost opportunity to have prices move around. As Davis and Heathcote (2005) have pointed out, housing prices move due to changes in the price of land rather than structures, consequently we model houses as land. Also we abstract from population growth making the supply of houses as rigid as possible.

3 Data Fluctuactions

We concentrate on two important properties of housing prices and housing sales. Housing prices are very volatile. In fact they are more volatile than GDP. Moreover, units sold comove with housing prices but they have an even larger volatility. Figures 1 and 2 shows the properties of HP-filtered GDP and housing prices for the U.S and Canada. It is clear that prices move a lot more than GDP.

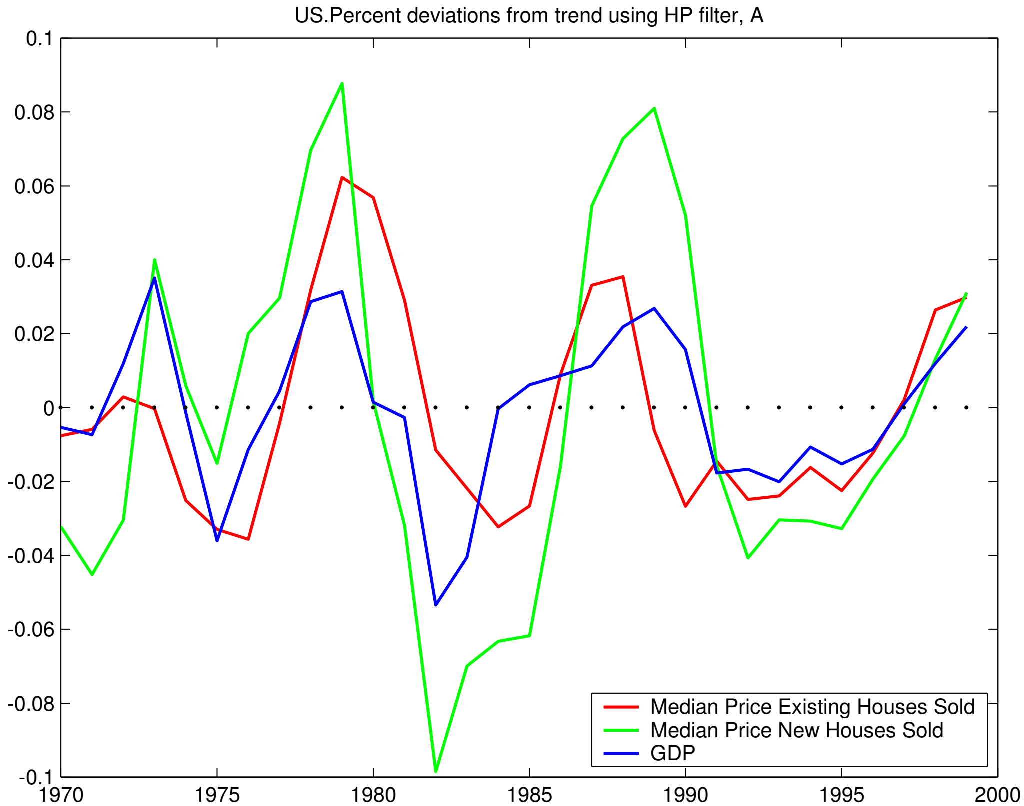

Figure 1: Housing prices and GDP, US

Figures 3, 4, 5 and 6 displays the residuals of units sold and the housing price indices (for the U.S. we display both the median price for existing houses and for new houses). It is clear that units sold move much more than housing prices which in turn move more than GDP.

In terms of the correlations with U.S. GDP, it is .56 for the median price of existing houses and .78 for the median new house. The correlation of units sold with GDP is .66.

	σ_i/σ_{GDP}	$\rho_{i,GDP}$
Median Price Existing Houses Sold	1.287	0.559
Median Price New Houses Sold	2.274	0.780
Units Sold	6.767	0.656

Table 1: Business cycles properties of houses prices and sales

Annual data 1970-99. σ_i/σ_{GDP} : standard deviation of HP deviations relative to GDP. $\rho_{i,GDP}$: correlation coeficient of HP deviations with HP deviations of GDP.

In 1999 the median price of new dwellings sold was $160.000. The mean size of new

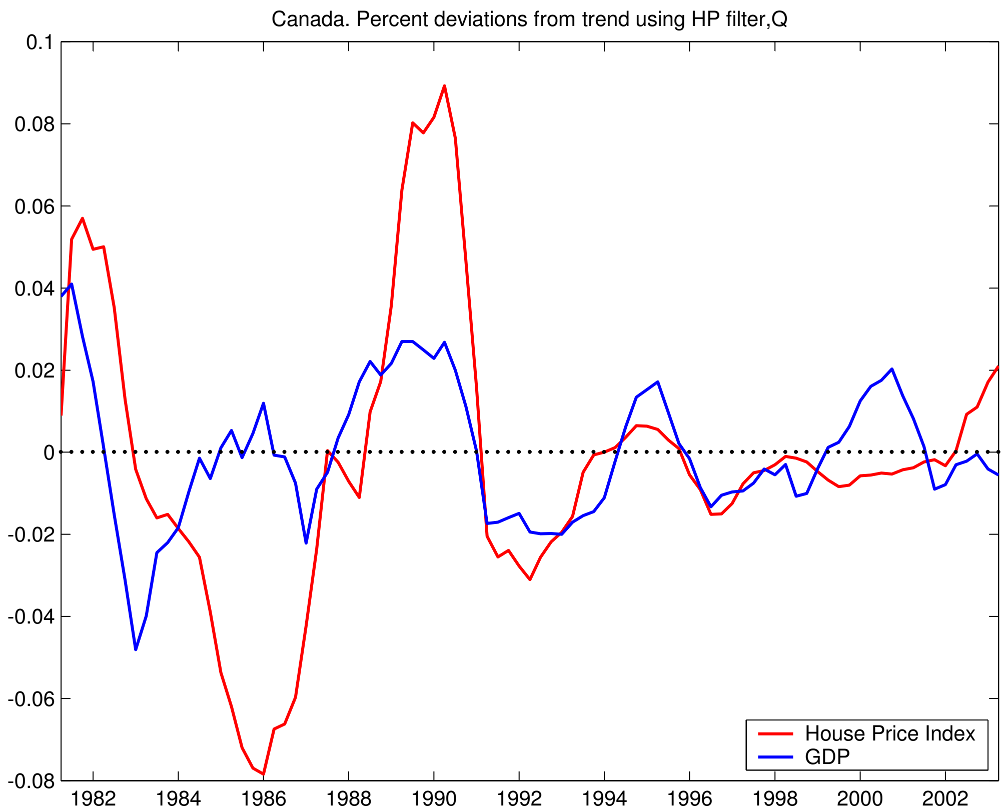

Figure 2: Housing prices and GDP, Canada

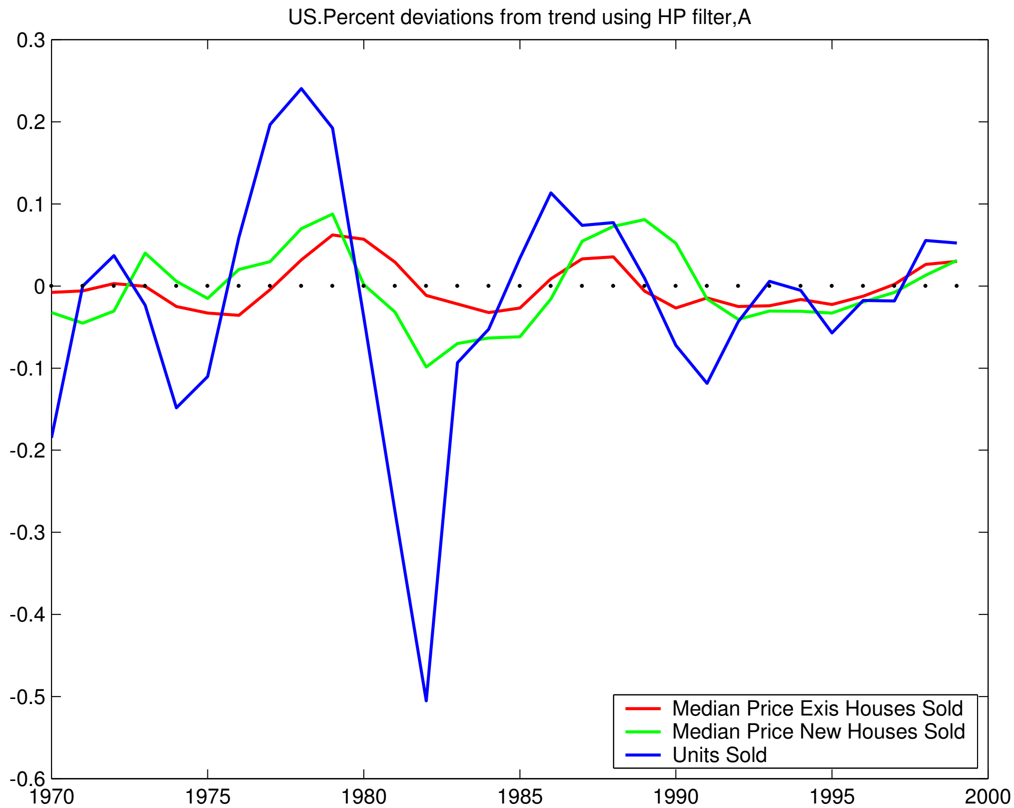

Figure 3: Units Sold and Housing Prices, US

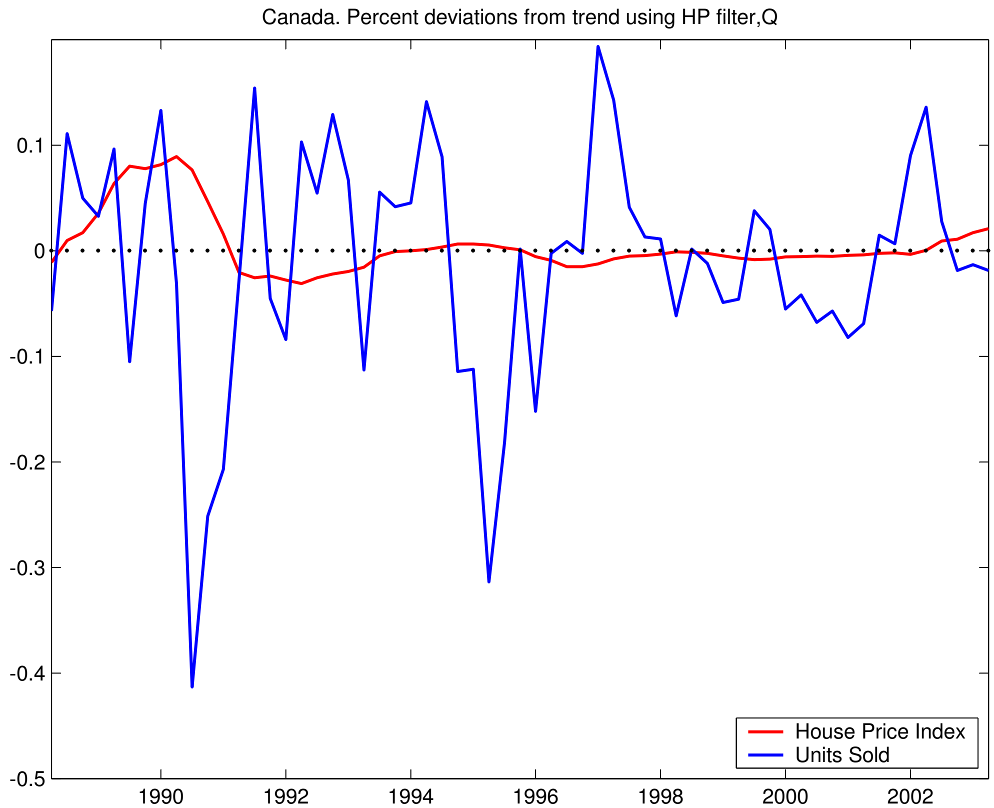

Figure 4: Units Sold and Housing Prices, Canada

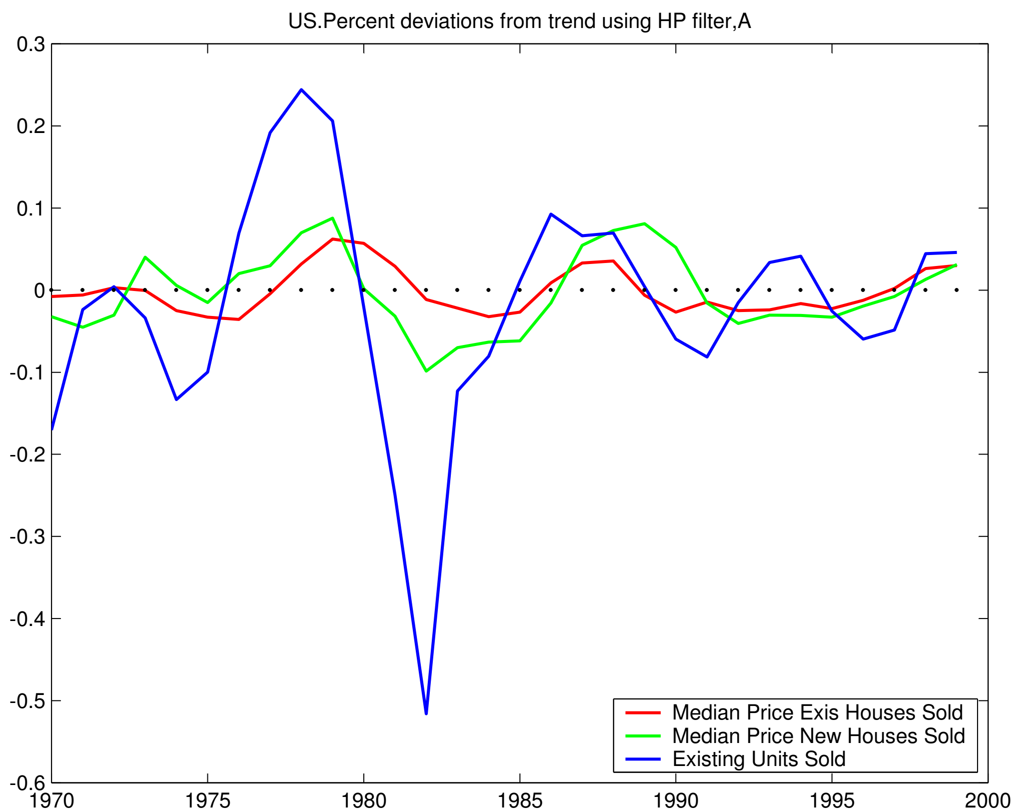

Figure 5: Units Sold and Housing Prices (existing houses), US

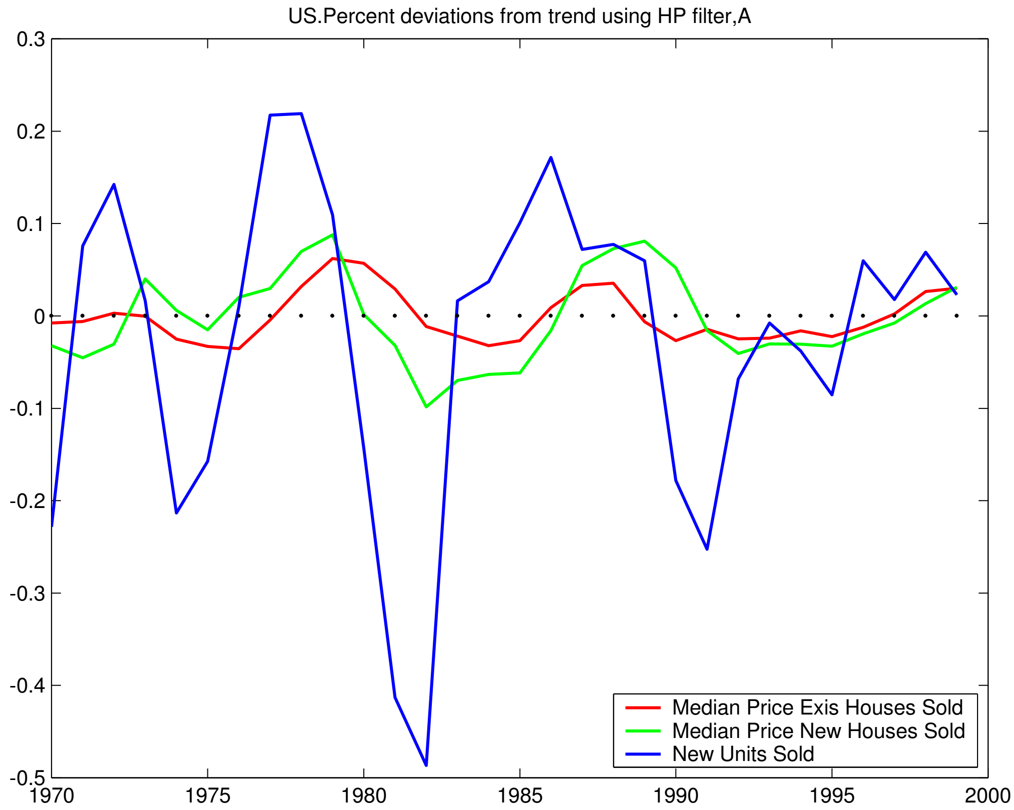

Figure 6: Units Sold and Housing Prices (new houses), US

houses sold between \$100.000 -\$149.999 was 1776 square feet and the mean size of new houses sold between \$150.000 -\$199.999 was 2110 square feet.[1]

4 A stationary version of the model economy

We give here just a brief description of the stationary version of the model. The interested reader is referred to Rios-Rull and Sanchez-Marcos (2006) for details. We move to the version with aggregate uncertainty that requires a heavier apparatus in Section 5.

We can think of the model economy as being of the Bewley (1984), Huggett (1993), Aiyagari (1994) variety, with a continuum of agents and incomplete markets where there are three assets. A liquid asset or Lucas tree that pays constant dividend r with total size normalized to 1. In addition, there are two other type of assets that we denominate dwellings (small ones or flat and larger ones or flats) that are indivisible and that affect the utility function directly only to the owner (and hence there is no scope for owning more than one). There are less dwellings than households. Trades of the liquid asset do not require resources and can be done in any size while trades, of the dwellings use real resources.

Agents preferences and shocks Households are born and die exponentially with probability π. Preferences are given by $u_d(c)$ where d indicates the type of dwelling a household may be associated with. Agents can own either a house, or a flat, or nothing, $d \in \{0, f, h\}$. Houses are better than flats which is better than nothing $u_h(c) > u_f(c) > u_0(c)$. Individuals are heterogeneous in their earnings ability that is uncertain. Households belong to an earnings group, $e \in E = \{e^1, \cdots, e^{N_e}\}$, which evolves according to a Markov process, $e \sim \Gamma_{ee'}$. Conditional on the earnings group household draw their period earnings from distribution $F(\epsilon, e) = \left[\frac{\epsilon - \underline{\epsilon}}{\bar{\epsilon} - \underline{\epsilon}}\right]^{\chi}$

Markets Agents can transfer resources across time with the liquid asset that is not subject to transaction costs. Its price is p_ℓ. Agents can buy and say dwellings in spot markets at prices $\{p_\ell, p_f, p_h\}$ respectively. Dwellings are traded with costs that we pose on the buyer and that we write as $\phi(d, d') = p_{d'}(1+\delta)$ if $d = 0$ and $\phi(d, d') = p_{d'}(1+\delta) - p_d$ otherwise.

There is also an annuity market that allows agents to take into account the contingency of their early death. This feature increases slightly the effective rate of return and prevents assets from disappearing, the assets of the dead are shared by the survivors.

There are borrowing constraints and dwellings can be used as collateral. Individuals can borrow a fraction $1 - \alpha$ of the value of the dwelling that they own. There is no

[1] Source: "Characteristics of New Housing", Current Construction Reports, 1999. US Department of Housing and Development and US Department of Commerce, Table 23.

bankruptcy allowed in this economy, and negative liquid assets can be thought of as held by intermediaries that operate on a per unit borrowed cost $\bar{r}$. If the liquid assets are negative, the value tomorrow of yp_ℓ units of liquid asset today is $y[p_\ell(1+\bar{r})+r]$. If liquid assets are positive, the value tomorrow of yp_ℓ units of liquid asset today is $y[p_\ell + r]$. We write for compactness the rate of return as $R(p_\ell, r, \bar{r}, \ell)$

Household's Problem To write the problem of household in a convenient way given that it is non concave we use two different functions. Function $V_{e,d}(y)$ denotes the value function of an household that belongs to an earnings class e, has dwelling d and financial savings y before the realization of the earnings shock ϵ and after realization of the earning class shock e. Function $W_{e,d}(a)$ is the value function of a household in earnings class e, has dwelling d and cash in hand a. Consequently their relation is

$$V_{e,d}(y) = \sum_{e'} \Gamma_{e,e'} \int_{\underline{\epsilon}}^{\bar{\epsilon}} W_{e',d}[y\, R(p_\ell, r, \bar{r}, \ell) + \epsilon]\; F(d\epsilon, e') \tag{1}$$

Furthermore, denote by $W^{d'}_{e,d}(a)$ the maximal utility of an household that belongs to earnings class e, starts the period with dwelling d, has dwelling tomorrow d' and has cash in hand a. We write the problem of an household conditional to not changing dwelling as

$$W^{d}_{e,d}(a) = \max_y u_d(c) + \pi\, \beta\, V_{e,d}(y) \qquad \text{subject to:} \qquad c + p_\ell y = a, \tag{2}$$

while that of an household that trades dwellings is

$$W^{d'}_{e,d}(a) = \max_y u_{d'}(c) + \pi\beta\, V_{e,d'}(y) \qquad \text{subject to:} \qquad c + p_\ell y - \phi(d, d') = a. \tag{3}$$

Putting it all together

$$W_{e,d}(a) = \max_{d',y}\; u_{d'}(c) + \pi\beta\, V_{e,d'}(y) \qquad \text{subject to:} \qquad c + p_\ell y - \phi(d, d') = a. \tag{4}$$

Stationary equilibrium The economy in steady state is characterized by a distribution of households over dwellings, assets, and earnings shocks, x defined over an appropriate family of subsets of these variables (which we take to be the product of the Borel sets of an interval $A = [0, \widehat{a}]$, where $\widehat{a}$ is a nonbinding upper bound and all possible values for dwellings and the idiosyncratic shock). A stationary equilibrium is a specific distribution of households x^* together with a set of asset prices $\{p^*_\ell, p^*_f, p^*_h\}$ such that when the distribution of households is given by $x*$ and the households face constant prices forever given by $\{p^*_\ell, p^*_f, p^*_h\}$ then their choices *(i)* induce a distribution of households next period that is again x^*, and *(ii)* prices clear assets markets, that is

$$\int_{E,D,A} y\; dx = 1, \qquad \int_{E,f,A} dx = \mu_f, \qquad \int_{E,h,A} dx = \mu_h. \tag{5}$$

5 The model economy with aggregate shocks

We explore a variety of aggregate shocks. We denote the aggregate state of the economy by $z \in Z = \{z^1, \cdots, z^{n_z}\}$ and it follows a Markov chain with transition $\Gamma_{z,z'}$. In particular there can be shocks to dividends r_z, shocks to the parameters of the distribution from where earnings are drawn $\{\underline{\epsilon}_{z,e}, \bar{\epsilon}_{z,e}\}$, and shocks to the loans' mark-up $\bar{r}_z$

In this economy, the aggregate state vector is $\{z, x\}$. An equilibrium with fully rational agents is a set of value functions $V_{z,e,d}(x, y)$ and $W^{d'}_{z,e,d}(x, a)$, decision rules, $d'_{z,d,e}(x, a)$, $y_{z,d,e}(x, a)$, prices vector $p_z(x)$ and law of motion of distribution of agents in the economy $x' = G_z(x)$ such that i) agents solve their problem

$$W_{z,e,d}(x, a) = \max_{d',y} u_{d'}(c) + \pi\beta\, V_{z,e,d'}[G_z(x), y] \tag{6}$$

$$\text{s.t.:} \quad c + p_{\ell,z}(x)y - \phi(d, d') = a. \tag{7}$$

where

$$V_{z,e,d'}(x, y) = \sum_{z',e'} \Gamma_{z,z'}\ \Gamma_{e'|z',z,e} \int_{\underline{\epsilon}}^{\bar{\epsilon}} W_{z',e',d'}[y\, R(p_{\ell,z'}[G_z(x), r_{z'}, \bar{r}_{z'}, y]) + \epsilon]\ F_z(d\epsilon, e') \tag{8}$$

ii) markets clear and iii) agents actions generate the law of motion $G_z(x)$.

In order to characterize the equilibrium both the agents and the researchers have to know the function that sets the equilibrium prices $p_z(x)$ and also the law of motion of the distribution, $x' = G_z(x)$, a daunting task. We get around this problem by following the approach developed by Krusell and Smith (1997) and Krusell and Smith (1998) where agents do not use the whole distribution as a state vector but only some moments of it including at least sufficient statistics for current prices. This is a form of bounded rationality but has proved to work very well in a variety of environments: Colussi (2006), and Storesletten, Telmer and Yaron (2007) who find that the best approximation of the distribution of agents is provided by the aggregate capital in the economy together with the conditional expected equity premium and find that including the equity premium as a predictor, increases the forecast accuracy more than including other 18 moments of the distribution of agents simultaneously. We follow a similar approach and use the minimal set of moments necessary to both compute and forecast prices, that is, the prices themselves.

To avoid notational clutter we use the same symbols for value functions, decision rules and pricing functions than before even if its arguments are now different. In this boundedly rational environment, agents solve

$$W_{z,e,d}(p, a) = \max_{d',y} \{u_{d'}[a - p_\ell y - \phi(d, d')] + \pi\ \beta\ V_{z,e,d'}(p, y)\} \tag{9}$$

with

$$V_{z,e,d'}(p, y) = \sum_{z',e'} \Gamma_{z,z'}\ \Gamma_{e'|z',z,e} \int_{\underline{\epsilon}}^{\bar{\epsilon}} W_{z',e',d'}[y\, R(\Psi_{\ell,z,z'}(p), r_{z'}, \bar{r}_{z'}, y]) + \epsilon]\ F_z(d\epsilon, e') \tag{10}$$

An equilibrim for this economy with limited rationality is a set of value functions, decision rules $d'_{z,e,d}(p,a)$, $y_{z,e,d}(p,a)$, forecasting function $\Psi z, z'(x)$ and a true pricing function $p = \zeta(z, x)$, and law of motion of the distribution $G_z(x)$ such that

(i) The decision rules solve the household problem given forecasting function Ψ.

(ii) Pricing function ζ clears the market.

(iii) Forecasting function Ψ is a good one, i.e. is the best (log)linear predictor of prices given the aggregate shock and current prices and, moreover, lagged prices and aggregate statistics of the distribution (correlation of financial and housing wealth for instance) do not help to forecast prices.

Note that the last condition seems fuzzy. In practice it requires two things that there is no other (log)affine forecasting function that does better and that there is no other (obvious) moment of the distribution or of lagged distributions that when used to forecast prices changes in any observable way the decision rules of the agents.

We pose an affine forecasting pricing function, $p^E = \Psi_{z,z'}(p)$ be such a forecasting function. The constants are indexed by the shocks today and tomorrow, while the slopes are the same for all shocks. This is a total of 12 constants and 9 coefficients.

Note that function ζ does not really have to be computed. Along the simulations we solve each period for the market clearing prices.

6 Mapping the Model to the data

To specify the model we have to choose some parameters and functional forms. We have mapped a stationary version of the model to the data in Rios-Rull and Sanchez-Marcos (2006) and we will only give here a cursory description. We provide a detailed description of the aggregate uncertainty features. of what we have done.

6.1 The Stationary Economy

We describe the speficication by groupd of features posing in parenthesis the number of parameters that have to be pinned down.

Parameters that can be set independently Some details of the specification of the model are independent of the equilibrium and can be set beforehand: population turnover, 1.5% per year, implying 67 years of average adult life in the absence of population growth (which sets $\pi = 0.985$); we also set ex ante some features of the financial system such as a 1.% mortgage premium, this is borrowing rate minus lending rate, a 20.% down payment and a 10.% cost of buying a dwelling, as a stand in for real estate commissions, taxes, and the time and hassle for the households involved in the purchase of the dwelling.

Preferences (3) Preferences are time separable with discount rate β. We consider the following utility function

$$u_d(c) = \frac{c^{1-\sigma}}{1-\sigma}\,\gamma^d \tag{11}$$

This is a standard CRRA per period utility function with risk aversion parameter σ and two (because of normalization) utility shifters γ^d. The risk aversion coefficient is a very hard to pin down parameter and consequently we set it to 2.

Earnings Shocks (11) We choose an earnings process with three earnings classes and within each earnings class there is an interval of earnings with a continuous density. The cdf function is $F(\epsilon, e) = \left[\frac{\epsilon - \underline{\epsilon}}{\bar{\epsilon} - \underline{\epsilon}}\right]^{\chi}$. This gives 5 parameters for the intervals of earnings (one is normalization), 4 possible parameters of the transition matrix $\Gamma_{e,e'}$ since we assume zero the probabilities of going from the top group to the bottom group and vice-versa and the additional parameter χ that adds flexibility to vary the mean to median ratio within each earnings class. To achieve a life cycle earnings profile where households increase their earnings on average over time, we assume that all households are born as poor. In models without housing there is a lot of work to estimate these parameters, and in this paper we use a process quite similar to that in the latter paper.

Asset parameters (3) While we normalize the size of the Lucas tree to 1, the size of its dividend d has to be specified. Also the number of flats μ^f and the number of houses μ^h relative to the population has to be set.

6.2 Description of Targets/Moments to match

We have to specify at least 14 targets that statistics of our model economy should satisfy with a suitable choice of the model parameters.

- Aggregate macroeconomic which include targets of income shares, total wealth and housing holdings, ownership rates and definition of flats and of houses.

    1. We target a labor share out of income of 0.84. Note that the absence of depreciation in our model makes the labor share larger.
    2. Financial asset wealth relative to income: 2.18.
    3. Owner occupied housing wealth times relative to income: 2.61.
    4. Fraction of households that own a house: 0.35.
    5. Fraction of people with flat: 0.30
    6. House prices relative to flat prices $\frac{p_h}{p_f}$: 2.0.

- Financial targets associated to the purchases of houses.

7. Down payment the first time a household buys a dwelling: 16.3%.
8. Down payment of repeated buyers 26.5%.
9. Ratio of mortgage debt to income of 34%.
10. Fraction of people with debt in the model (those who have negative financial assets is 44.4%.
11. Average ratio of financial debt to housing value is 49.1%. This number has been increasing in the last few years and our target is appropriate for the early nineties.

- Targets associated to the cross sectional distribution of earnings and of wealth (note that the number of targets of the last two groups is quite large).

12. Average earnings of those aged 31-60 relative to those of the group aged 20-30: 1.4.
13. General Properties of the Lorenz Curve of earnings from the 1998 SCF.
14. General Properties of the Lorenz Curve of assets from the 1998 SCF.

6.3 Steady States in the Model Economies

The model does in general quite well in matching our targets despite having 17 parameters for 12 specific targets plus the general properties of the Lorenz curves. Moreover, of those 17 parameters there are 4 that play little role (3 that define the bounds of the earning classes and the parameter χ that governs the curvature of the density of earnings within each earning class.

6.3.1 The Baseline Model Economy

Table 2 reports the performance of the Baseline Model Economy relative to the targets. We see that these targets are achieved quite accurately, except for the average ratio of debt to housing which is too high, partly associated to the slightly higher wealth concentration in the model than in the data as shown in Table 3. The only other statistic that is not very closed to the target is the ratio of earnings between the middle age and the young which is exaggerated in the model due to the process for earnings that we chose (where all agents enter in the low earnings class).

Notice also that the turnover in houses is smaller in the model economy than in the data. While 2.5% of households purchase a dwelling in the model economy, twice as many do so in the data. This is to be expected as the only reason to change housing status in the model is a change in financial conditions that make dwellings more or less affordable and there are no changes of dwellings of the same type. In the data, people change locations and family membership which accounts for most of the purchases that do not involve a

	Economy	
	Model	Target
1. Labor Share	84%	84%
2. Financial asset wealth relative to income	2.18	2.18
3. Owner occupied housing wealth relative to income	2.61	2.61
4. Households that own a house	35%	35%
5. Households what own a flat	30%	30%
6. House prices relative to flat prices $\frac{p_h}{p_f}$	2.0	2.0.
7. Downpayment first-time buyers	18.4%	16.3%
8. Downpayment repeat buyers	27.9%	26.5%
9. Ratio of mortgage debt to income	26.7%	34.0%
10. Fraction of People with Debt	44.6%	44.4%
11. Ratio Debt to Housing Value	67.9%	49.2%
12. Earnings of ages 31-60 relative to ages 20-30	1.8	1.4

Other Statistics

	Model	Data
Households that buy a flat each year	2.35%	
Households that buy a house	0.14%	
Households that buy a dwelling	2.49%	5.0%

Table 2: Main Statistics in the Data and in the Baseline Model Economy

		Quintiles					
		1st	**2nd**	**3rd**	**4th**	**5th**	**Gini**
Total	Model	0.24	1.30	2.27	9.92	86.27	0.819
Assets	U.S.	-0.29	1.35	5.14	12.38	81.42	0.796
Financial	Model	-22.34	-17.43	-1.39	2.33	138.83	1.568
Assets	U.S.	-7.27	-0.25	1.14	6.92	99.45	0.953
Housing	Model	0.00	5.69	20.92	31.56	41.84	0.457
Wealth	U.S.	0.00	1.40	12.31	22.08	64.21	0.656

Table 3: Wealth Distribution in Model and Data (1998 SCF)

substantial change in the value or quality of the dwelling and that we have completely abstracted from.

Why which means that a little under 4.% of dwellings change owners every year. Of those about 60% come from regular demographic turnover.

Table 3 shows the wealth distribution of financial and of housing assets in the model and in the data while Table 4 shows the distribution of earnings. We see that while the model replicates quite well the distribution of total assets, it does not do such a great job in terms of its components. Financial wealth is a lot more skewed in the model while housing wealth is less skewed in the model. This is due to the fact that the model has only two types of dwellings which is insufficient to replicate the variety of housing holdings in the data. The earnings distribution in the model is the best that can be achieved once one notices that there is no retirement in the model.

	Quintiles					
	1st	**2nd**	**3rd**	**4th**	**5th**	**Gini**
Model	3.5	5.0	7.8	11.1	72.7	0.654
U.S.	-.2	4.0	13.0	22.9	60.2	0.611

Table 4: Earnings Distribution in Model and Data (1998 SCF)

7 Pricing Behavior with Aggregate Shocks

We face our model economies with a variety of aggregate shocks that generate business cycles in order to see the implied behavior of housing prices. We consider aggregate shocks to earnings, aggregate shocks to dividends, aggregate shocks to the mortgage premium (as a proxy for a productivity shock to the lending technology), aggregate shocks to the size of the downpayment (as a proxy for monetary policy or other financial shocks) and aggregate shocks to all these variables combined. Our purpose here is less to study business cycles than to see their impact in housing prices. The difference between recessions and expansions are quite large: earnings increase from -5% of the steady state to plus 5%; dividends increase from -5% of the steady state to plus 5%; and the mortgage mark up goes from 2% to zero. All these changes are positive and when combined generate about a 10% of an increase in output. We model the average duration of expansions and recessions to last 20 periods to exaggerate the surprise implied by a switch from recessions to expansions. This model is extremely expensive to solve, hence to report the properties of the model economies we just pose a realization where there has been a recession for a while and then there is switch to an expansion that lasts for 10 periods before there is a switch back to a recession. We start with the Baseline Model Economy.

7.1 Shocks to earnings

Figure 7 displays the equilibrium time path in the Baseline Model Economy when there are aggregate shocks to earnings, all earnings going up in unison from 5.% below their steady state value to 5% above. The economy is in a recession for the first 15 periods then moves into an expansion that lasts 10 periods and then again goes to a recession. The graph normalizes the prices in the last period of the recession to one.[2] Some important features of the economy after a long time in recession is that every period 4.12% of the population buy dwellings (a much larger number than the 2.49% that buy in the steady state), 3.14% of the population sell dwellings and the rest of the dwellings come to the market because of death. Of those dwellings that households sell, the vast majority, 97.39% are flats and the rest houses. In the first period of an expansion there are important changes, purchases fall to 3.22%, and it continues falling for the duration of the expansion. Only with the arrival of a new recession sales start to pick up.

The price of a flat in a recession is 2.47 times average household income while that of a house is 5.09 times and those that sell have a cash in hand (value of earnings plus after interest financial asset) of -92% of the value of the dwelling, this is, their net wealth is 8% of value of the flat which will barely pay the following period's interest if hit by a bad earnings shock while those that buy the flat have a cash in hand of 25%. The reason for the low wealth holdings of the flat sellers is that they have had bad earnings shocks that have made them dig deeper in debt, which they can do in this model.

When an expansion comes there is a sudden capital gain in all assets. This is just the result of the increase precautionary savings in an environment without capital accumulation Mendoza, Quadrini and Rios-Rull (2007) displays a similar property). The liquid asset (the stock market) has a capital gain of 12.13%, the increase in the price of a flat is 11.99%, while that of a house is 14.23%. This mechanism induces a big capital gain for the homeowners since there assets went up far more than their liabilities. Note that the average flat seller in a recession (an agent with .64 in earnings and -8.68 in debt) will move from owing 91.9% of the value of the flat to owing 89.3% of the value of the flat. Moreover, the switch to an expansion in earnings by increasing the value of the liquid asset, reduces the interest rate. While a casual look at the graph seems to pinpoint that the interest rates remain constant except for the periods when the economy switches from expansion to recession (where they have a large increase) or from recession to expanse (where there is a large drop), we should point out that what matters for the agents is the whole return and this is lower in expansions since there is a 10% possibility of a large reduction, while in recessions the opposite holds.

Note that the initial increase in the price of houses is just an implication of the fall in the interest rate as it is of the same magnitude as that of the price of the liquid asset, *i.e.* the stock market. The additional increase in the price of houses occurs for different

[2]Note that there are some oscillations due to sampling error. The model economy is simulated with 250,000 households (so in any given period there are on average 3750 sales due to demographic turnover (1.5%)), yet even with this sample size there is variation in the number of people dying each period which accounts for the oscillations even after the economy having experienced a large recession.

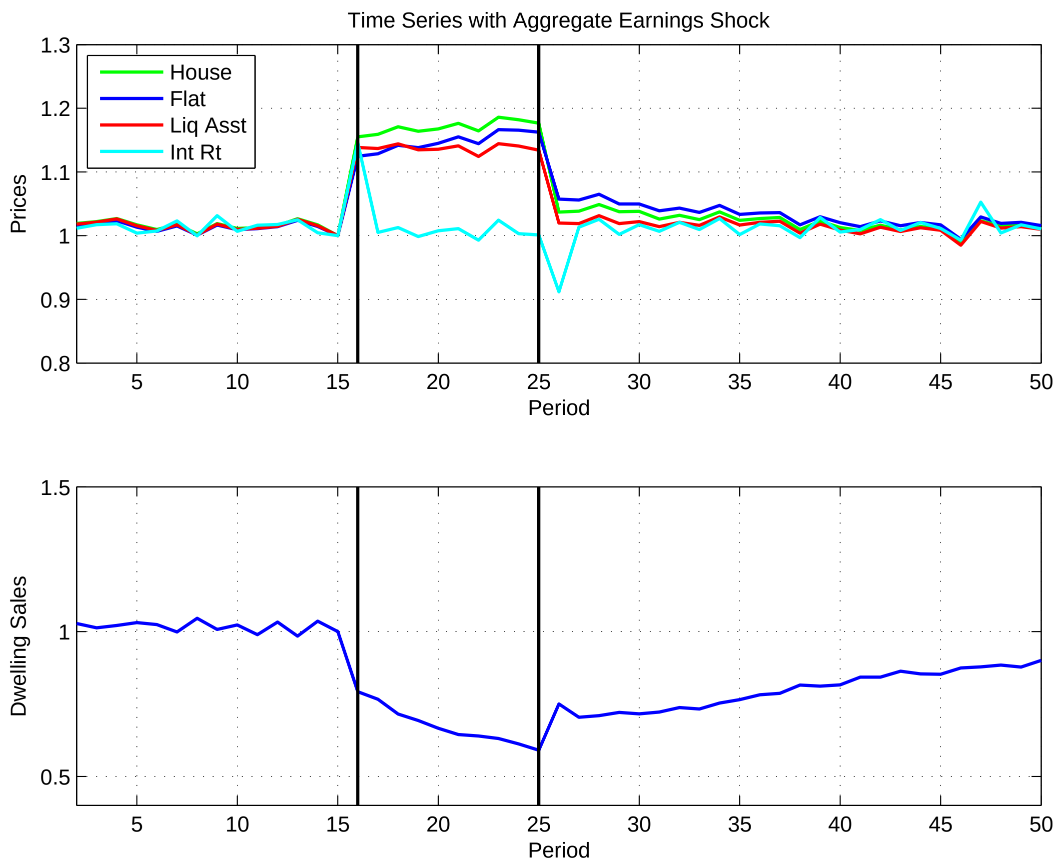

Figure 7: Asset Prices and Dwelling's Sales: Baseline Economy with Earnings Shocks

reasons. This can be seen by taken a look at the number of sales of dwellings. The reason is that there is a large group of households that is saving to buy a house, to build up enough to make the down payment. The houses for sale come partly from demographic turnover But the sudden switch to good times increase the value of the assets and hence prompts a (partial) redistribution of resources from those with labor income to capital income. The upshot of this is that the set of households who are likely to buy the house have suddenly been priced out of the market. Consequently, purchases are delayed, turnover goes down. An additional

Upon the end of the expansion, prices drop drastically, with the liquid asset again doing all its drop in one period. Dwellings take a big initial drop and then drop more over recovering their initial level. Sales experience first a small surge dramatic surge and then they keep on growing for a while more. It takes about 15 more periods before they recover their pre-expanssion level.

7.2 Shocks to the mortgage mark-up

We now look at an economy subject to the mortgage mark-up shop. The equilibrium path of this economy under the particular realization that we look at is shown in Figure 8.

7.3 All shocks

Figure 9 displays the equilibrium time path of a multiplicative utility economy with aggregate shocks. The economy is in a recession for the first 15 periods then moves into an expansion that lasts 10 periods and then again goes to a recession.

The effects on prices are clear. Upon The price of dwellings increases by more than 20% immediately, with houses increasing slightly more than flats. Prices then continue going up but extremely slowly reaching a total increase of 28% for houses and 27% for flats. The increase in the price of the liquid asset is of similar magnitude but the increase only occurs upon arrival of the expansion without any further movements. The increase is of 20%.

Note that the initial increase in the price of houses is just an implication of the fall in the interest rate as it is of the same magnitude as that of the price of the liquid asset, *i.e.* the stock market. The additional increase in the price of houses occurs for different reasons. This can be seen by taken a look at the number of sales of dwellings: the appearance of an expansion dramatically reduces sales (the increase previous to it is just due to the fact that the economy needs to settle down first) . The reason is that there is a large group of households that is saving to buy a house, to build up enough to make the down payment. The houses for sale come partly from demographic turnover and partly from people who have fallen in hard times. But the sudden switch to good times increase the value of the assets and hence prompts a (partial) redistribution of resources from those with labor income to capital income. The upshot of this is that the set of

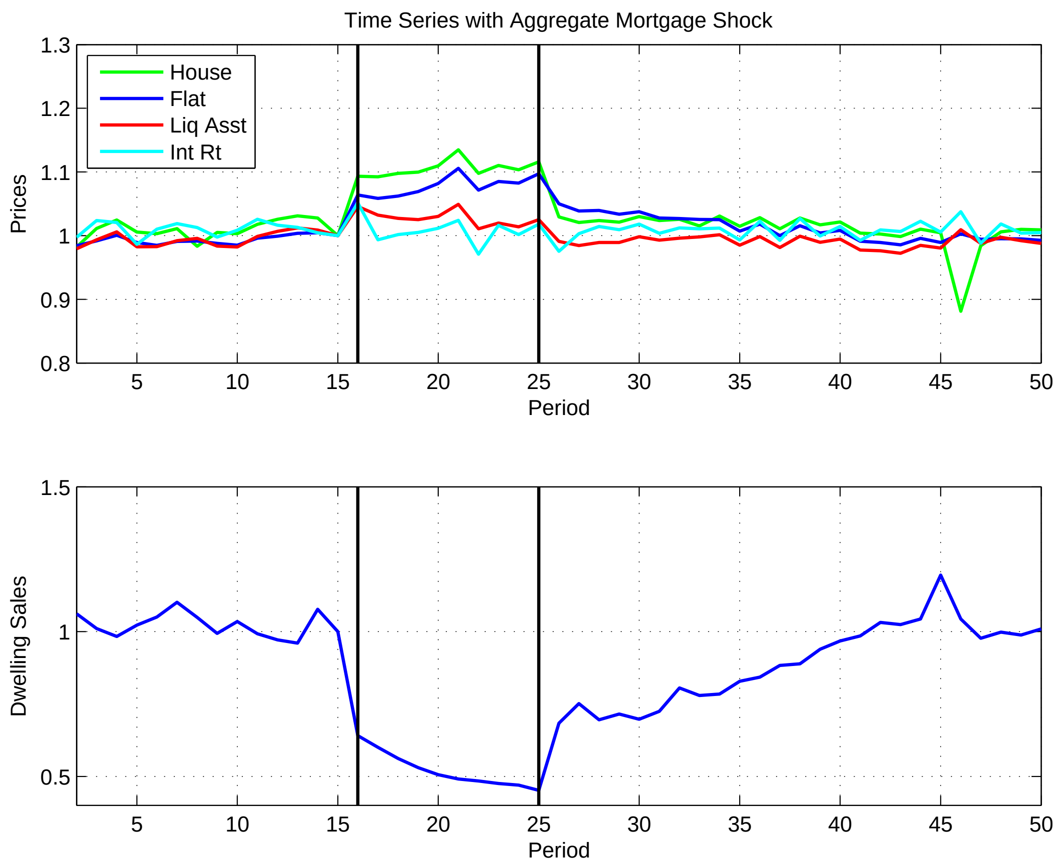

Figure 8: Fluctuations of Dwelling's Prices and Sales with all shocks

households who are likely to buy the house have suddenly been priced out of the market. Consequently, purchases are delayed, turnover goes down. An additional.

Upon the end of the expansion, prices drop drastically, with the liquid asset again doing all its drop in one period and dwellings moving a lit bit down relatively slow for a few more years. Sales experience first a dramatic surge and then they keep on growing for a while more. It takes about 15 more periods before they recover their pre-expansion level.

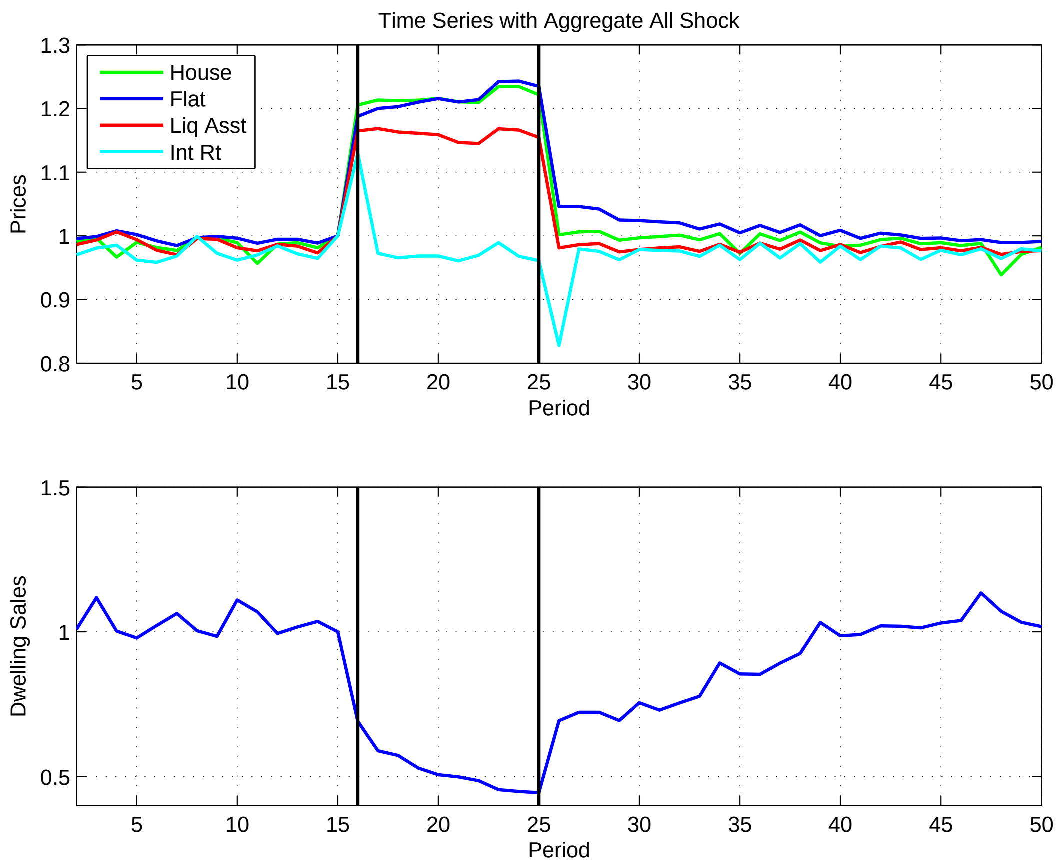

Figure 9: Fluctuations of Dwelling's Prices and Sales with all shocks

8 Conclusions

To be done.

Appendix

A Computational Procedures

We solve the problem of the agent by posing a discrete choice of asset position with 700 points on the liquid asset. We use piecewise linear interpolation of the value function with respect to the prices of the assets to arrive to the solution (there are four points in the grids of dwellings and 5 for the liquid asset).

We use exceptionally high powered hardware (a 26 processor cluster) and mpi fortran. Still it takes around 4 hours to find the equilibrium value function for given forecasting functions. In addition, it takes us around 4 more hours to simulate 100 periods of an economy populated with 250,000 agents, the number required to get around 8,000 purchases of dwellings. We ran 900 period samples to run regressions that assess the forecasting function. We search for coefficients of these functions that constitute a fixed point.

B Price Forecasting Functions

Agents forecast prices that are contingent on the aggregate exogenous state in the following period. Those forecasts depend on the current aggregate exogenous state and linearly on the current price of the same asset only. The slope of the linear dependence on the current price does not depend on the exogenous stated. Formally, we write the forecasting function Ψ as

$$p^{j\prime} = \Psi_{z,z'}(p) = \alpha_0^j + \alpha_1^j \, 1_{\{z=1,z'=2\}} + \alpha_2^j \, 1_{\{z=1,z'=2\}} + \alpha_3^j \, 1_{\{z=1,z'=2\}} + \alpha_4^j \, p^j \tag{12}$$

Table 5 displays the estimated values of coefficients of the forecasting functions and the associated R^2 statistics, which are actually very high.

For the sake of comparison we compare the performance of the equilibrium forecasting function with two alternatives, one that ignores any dependence of future prices on current prices and another that allows the forecasts to depend linearly on the current prices of all assets and not only on the the same asset. Table 6 reports the findings. We can see that the differences are very small. There are only small gains of using the current price for flats. There are almost no gains for using all prices. Consequently, we use own current price to forecast future prices.

Table 5: OLS Estimates for Price Forecasting Functions

	α_0	α_1	α_2	α_3	α_4	R^2
Dependent variable						
p^ℓ	5.230	1.398	-0.439	0.955	0.312	**0.989**
p^h	9.447	4.067	-1.926	2.225	0.499	**0.989**
p^f	2.856	1.758	-1.097	0.639	0.688	**0.990**

Table 6: R^2 with various sets of regressors

Regressors	p^ℓ	p^h	p^f
Forecast depends only on z and z'	0.987	0.987	0.976
What we use	0.989	0.989	0.990
What we use + All Lagged Prices	0.989	0.990	0.990