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Booms and Busts in a Housing Market with Heterogeneous Agents*

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Abstract

We develop a dynamic partial equilibrium model of the housing market, where the dynamics of the house price is determined by the interaction between chartists and fundamentalists. The model endogenously generates episodes of boom and bust in the house price. The model can replicate the recent US house price dynamics, and points to endogenous and exogenous behavioral factors as the main determinants of such dynamics. From a policy standpoint, the model supports the view that an interest rate policy reacting to the house price could stabilize the house price dynamics.

1 Introduction

Since the late 1990’s a dramatic increase in housing prices has been observed in most of the countries around the world. For example, London real house prices tripled during the period 1996-2008, and in the United States the housing prices increased by 85 percent roughly during the same period.

It seems impossible to explain these phenomena merely from a rational point of view because fundamentals such as real rents or construction costs do not match up with this large price boom. Shiller (2005, 2008) was the first to

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emphasize the role played by speculative thinking, extrapolative expectations, optimism/pessimism deriving from market psychology in determining the dynamics of house prices, particularly in the recent spectacular price movements. He suggested that the same forces of human psychology driving financial markets could also have the potential to affect other markets, especially the housing market. Recurrent boom-bust house price cycles generate the need for an endogenous explanation for such phenomena, possibly incorporating bounded rationality into housing market modeling.

In this paper, we try to take on this challenge. We aim to build a stylized model of the housing market with no rational expectations able to produce endogenous prolonged movements in the house prices. In this model the house is an asset that can be collateralized and whose price can be driven both by fundamentals and by animal spirits. More generally, we want to stress and investigate the importance of the behavioral approach and bounded rationality. Note that ample empirical evidence exists to show that agents generally act in a bounded rational way (e.g., Kahneman and Tversky, 1973, Hommes, 2011).

To do so, we build on the model of Adam, Marcet and Kuang (2011) but we modify it in two ways. First, we introduce a different timing between demand and supply to account for the fact that it takes time to build new houses. So while households take their decision daily, the supply is based on a quarterly frequency. Hence the model generates two different dynamics for the house price at daily and at quarterly frequency, respectively. Second, we change the way agents form expectations. Instead of using Bayesian learning, we employ the Agent-Based framework of chartism and fundamentalism, where these two types of agents use different adaptive learning rules to forecast the future house price. Households are maximizing agents but they can be either chartists, believing the house price trend will continue, or fundamentalists, expecting mis-pricing will be corrected by the market. Moreover, they continuously evaluate these two different strategies according to past performance; this leads to endogenous shifts in the relative shares of the two groups (chartists vs. fundamentalists). These shifts have large effects on the house price dynamics. When chartists dominate the market, house price can sharply deviate from the underlying fundamental value but, if the animal spirits change, the market will be dominated by fundamentalists and the price will revert towards the fundamental value.

This type of framework has been used in research in financial markets. Using it to model the housing market seems a logical step given the chaotic state of real-estate markets in the last decade. We thus adapt to the housing market the setup in Lengnick and Wohltmann (2010) and Westerhoff (2008) and then insert it into our model structure, derived from Adam, Marcet and Kuang (2011). The mechanism of chartism and fundamentalism is one of the simplest methods that allow taking into account households’ beliefs and behavioral factors. As stressed in Piazzesi and Schneider (2009), the percentage of the households, believing it was a good time to buy a house because price would be raised further, increased

1To have a survey on the Agent-Based Computational models visit the Tesfatsion website, www.econ.iastate.edu/tesfatsi/ace.htm
towards the end of the boom.

We show that such a model is able to generate endogenous boom-and-bust cycles in the house price. The evolutionary selection of the two different forecasting rules by the agents causes waves in the relative shares of the two groups of agents who amplify and protract initial shocks. We use the partial equilibrium model of Adam, Marcet and Kuang (2011), because it allows us to find a closed form solution for the housing demand function and thus to identify and analyze the relevant feedback and amplification mechanisms in the model.

Moreover, the model is able to replicate the recent boom-and-bust cycle in the US house prices. We are able to discuss three determinants that the literature suggests as potential sources of the recent boom-and-bust cycle in the US house prices. First, the "Greenspan put" explanation that claims that the house price boom would have been caused by persistent low levels in the interest rate. Second, an explanation based on an overall loosening of credit standards that allowed more borrowing from the households, followed by a sudden freeze of credit at the onset of the crisis (e.g., Favilukis, Ludvigson and Van Nieuwerburgh, 2010, Mian and Sufi, 2009). Following Justiniano, Primiceri and Tambalotti (2013) we can call it a "credit liberalization" cycle narrative. The third, instead, refers to an explanation not based on fundamentals, but on exogenous forces modeled as a change in households' preference and housing demand. Justiniano, Primiceri and Tambalotti (2013) call it a "valuation" story; we could also name it a "behavioral" story because it is based on a change of behavior of agents unrelated to fundamentals. Our model identifies the shock to the preference rate for houses as the main driving force behind the recent behavior of house price in the US. Using the Michigan Survey of Consumers to calibrate such shock, the model captures quite well the persistence and hump shaped behavior of the boom and bust in the house price. On the contrary, narratives based on "fundamentals", as the interest rate behavior or the credit market liberalization, appear to be unimportant in explaining the house price movements.

Finally, we also show that an interest rate policy that reacts either to the deviations of the house price from steady state or to the rate of growth in the house price can substantially stabilize the house price.

Our paper is mainly related to Adam, Marcet and Kuang (2011) and to Lengnick and Wohltmann (2010). As said, from the former we take the model setup and from the latter the Agent-Based part of the model. Another related paper is Lengnick and Wohltmann (2010), who combine the chartist-fundamentalist model of financial markets and a standard New Keynesian macroeconomic model to generate endogenous business cycles and stock price bubble.

Adam, Marcet and Kuang (2011) develop a model able to replicate quantitatively the house price dynamics and the associated current account dynamics from 2001 to 2008 in the G7 economies, relaxing the rational expectations hypothesis and allowing households to be uncertain about how house prices are related to the economic fundamentals. To reach this goal, they use the concept of internal rationality, previously developed by Adam and Marcet (2010, 2011), where utility maximizer agents do not fully understand how price are formed,
so that their subjective probability distribution about prices may not exactly be equal to the true equilibrium distribution. Contrary to us, they find that the boom in the housing market in the U.S. economy would have been largely avoided if the interest rate had fallen by less at the beginning of the 2000’s.

Other works incorporates bounded rationality into the housing market.\(^3\)

Bolt, Demertzis, Diks and van der Leij (2011) develop a behavioral model of the housing market where agents have heterogenous expectations on the rate of return of holding a house. Similar to our model, agents are simple optimizers who rely on past performance to evaluate and revise their beliefs. They show that such a model generates bifurcations and multiple equilibria and they investigate to which extent these non-linearities could help explaining the boom-bust dynamics in the housing market. Bolt, Demertzis, Diks, Hommes and van der Leij (2014) estimates a similar model for various countries.

Burnside, Eichenbaum and Rebelo (2011) build an "epidemiological" model in which agents have heterogeneous expectations about long-run fundamentals, but they can infect each other by social interaction. Social dynamics can then generate waves of infectious optimism that vanishes as soon as people become more certain about fundamentals.

Tomura (2012) presents a business cycle model capturing the stylized features of housing market boom-bust cycles in developed countries. In particular, he focuses on the role of over-optimism and the role of monetary easing in generating strong booms in the housing market. Over-optimism of mortgage borrowers can cause boom-bust cycles, if mortgage borrowers are credit-constrained and savers who supply mortgage loans do not share the over-optimism of mortgage borrowers. In the presence of price stickiness, the model generates a low policy interest rate during a housing boom as an endogenous reaction through the Taylor rule to a low inflation rate.

Gelain, Lansing and Mendicino (2012) evaluate various policy actions that might be used to dampen the excess volatility in house prices in a DSGE model where the introduction of simple moving-average forecast rules for a subset of agents can significantly magnify the volatility and persistence of house prices and household debt, relative to an otherwise similar model with fully rational expectations. They find that macroprudential policies that modify the borrowing constraint are the most effective tool for dampening overall excess volatility in the model economy.

Dieci and Westerhoff (2013) investigate the impact of speculative behavior on house price dynamics. Their approach is inspired by recent work on Agent-Based financial market models. Speculative demand for housing is modeled through expectation formation mechanisms and behavioral rules of boundedly rational heterogeneous interacting agents. Real and speculative forces determine excess demand in each period and house price adjustments. The speculative behavior of heterogeneous market participants repeatedly destabilize the housing market and endogenous switches between bullish and bearish markets may occur, possibly leading to bifurcations and multiple equilibria. These dynamics imply lasting

\(^3\)See also Schiller (2007a,b) and Piazzesi and Schneider (2009).
and significant price swings around the fundamental steady state.

Iacoviello (2005) is the seminal contribution in the rational expectation DSGE literature. He develops a New-Keynesian business cycle model with two types of agents: borrowers and lenders. Borrowers receive nominal loans, but they are subject to a borrowing constraint where houses can be used as collateral. A recent refinement of such a model is proposed by Justiniano, Primiceri and Tambalotti (2013).

The paper is constructed as follows. Section 2 presents the first building block of our model based on Adam, Marcet and Kuang (2011). Section 3 explains the Agent-Based block of our model and the chartists and fundamentalists behavioral rules. Section 4 shows the results of simulations and comprises a thorough investigation of the model mechanics via sensitivity analysis. Section 5 investigates the ability of the model to replicate the recent house price dynamics taking into consideration the real interest rate dynamics, the credit tightness and a preference shock for housing demand. Section 5 analyzes the role of policy in dampening house price volatility. Section 6 concludes.

2 The Model

The structure of the dynamic partial equilibrium model is based on Adam, Marcet and Kuang (2011). This framework is very convenient because it allows us to find a closed form solution for housing demand.

We differ from Adam, Marcet and Kuang (2011) in two respects.

First, we adopt a different framework for expectation formation, assuming a chartist-fundamentalist mechanism with endogenous selection of forecasting strategies. Considering housing as an asset, we rely on a classical and simple framework in the Agent-Based analysis of the financial markets to describe the dynamics of house price and the process of expectations formation. Households belong to two different groups: chartists expect that the trend on the house price will continue in the next periods, while fundamentalists expect that the price will revert towards its perceived fundamental value. Moreover, the size of the two groups is not fixed but it changes across time according to the relative past performance of these two differing strategies. The model is thus able to generate endogenous waves of chartism and fundamentalism that could move the price away from its fundamental value.

Second, another important difference with respect to Adam, Marcet and Kuang (2011) is the timing of actions and decisions. Households solve their problem daily, which we suppose to be the smallest fraction of time for the real economy. House builders, instead, are assumed to operate on a quarterly basis, reflecting a time-to-build effect due to the necessary time that elapses for the construction of a house. They thus will base their production decision on the average of the house price in the past quarter.

From the last assumption it follows that demand and supply are not simultaneous. The house price thus does not emerge from the equality between
supply and demand, but its dynamics is driven by excess demand/supply. In this sense, this is a model of dis-equilibrium, the price reacts to the difference between demand and supply by increasing (decreasing) when demand is larger (lower) than supply.

2.1 The Household Problem

The economy is populated by a unit mass of households with identical preferences but potentially different and not rational beliefs, indicated by $E_t(\cdot)$, that we will specify later in Section 3.1 when we will introduce the distinction between chartists and fundamentalists. Households take daily decisions ($t$ stands for days) and their preferences are described by the following intertemporal quasi-linear utility function:

$$
\bar{E}_0 \sum_{t=0}^{\infty} \delta^t (c_t + j_t \log h_t),
$$

where $c_t > 0$ is the daily consumption of goods, $h_t$ is the daily consumption of housing services, $\delta \in (0, 1)$ is the discount factor, and $j_t$ is a preference shock for housing demand.

The household period-by-period budget constraint is:

$$
c_t + [h_t - (1 - \tilde{d})h_{t-1}]Q_t + R_t b_{t-1} + k_t = y_t + b_t + k_{t-1}p_t,
$$

where $Q_t$ is the house price at time $t$, $\tilde{d} \in [0, 1)$ is the daily depreciation rate of a house, $b_t$ is the household new loans, $R_t$ is the gross real interest rate on loans and $y_t$ is income, which is exogenous. The capital stock, $k_t$, is owned by the households who rent it to house builders for production. Capital fully depreciates in one period and its remuneration is $p_t$.

As in Kiyotaki and Moore (1997), households are allowed to borrow from banks subject to a borrowing constraint:

$$
b_t \leq \theta \frac{Q_t}{R_t} h_t.
$$

The parameter $\theta$ represents the share of assets that can be collateralized. It is fixed and cannot exceed the house value after the depreciation: hence $\theta \in (0, 1 - \tilde{d}]$. Kiyotaki and Moore (1997) interprets a value of $\theta$ lower than one as reflecting the cost the lenders suffer in case of default. A growing house price relaxes the collateral constraint, implying that the households will have greater access to credit.

Households maximize their utility function (1) subject to the sequence of...
budget and borrowing constraints (2-3):

$$\max_{c_t, h_t, b_t, k_t} \sum_{t=0}^{\infty} \delta^t \left\{ -\lambda_t \left( c_t + \left( h_t - (1 - \delta) h_{t-1} \right) Q_t + R_t b_{t-1} + k_t - y_t - b_t - k_{t-1} p_t \right) + \right\}$$

where $p_0, k_{-1}, b_{-1}$ are given initial conditions.

The first order conditions with respect to $c_t, h_t, b_t$ and $k_t$ are:

1. $$\frac{\partial c_t}{\partial h_t} : 1 - \lambda_t + \mu_t = 0 \quad (\mu_t \geq 0; \mu_t c_t = 0),$$
2. $$\frac{\partial c_t}{\partial b_t} : \frac{j_t}{h_t} - \lambda_t Q_t + (1 - \delta) \delta \tilde{E}_t \lambda_{t+1} Q_{t+1} + \gamma_t \theta Q_t = 0,$$
3. $$\frac{\partial h_t}{\partial b_t} : \lambda_t - R_t \delta \tilde{E}_t \lambda_{t+1} - \gamma_t R_t = 0 \quad (\gamma_t \geq 0; \gamma_t (\theta Q_t h_t - R_t b_t) = 0),$$
4. $$\frac{\partial k_t}{\partial b_t} : -\lambda_t + \kappa_t + \delta \tilde{E}_t \lambda_{t+1} p_{t+1} = 0 \quad (\kappa_t \geq 0; \kappa_t k_t = 0).$$

Assuming that the non-negativity of consumption holds ($\mu_t = 0$) and $R_t \delta < 1$, households will borrow as much as possible: hence the borrowing constraint is binding, so $b_t = \frac{\theta Q_t h_t}{R_t}$ and $\gamma_t > 0$. From equation (5) $\lambda_t = 1$; thus from (7):

$$\gamma_t = \frac{1}{\theta} - \delta > 0.$$  

Using these results, it is possible to derive the households’ demand for housing services from equation (6):

$$h_t^d = j_t \left[ \left(1 + \delta \theta - \frac{\theta}{R_t} \right) Q_t - \left(1 - \delta \right) \delta \tilde{E}_t Q_{t+1} \right]^{-1}. \quad (9)$$

The capital rented by the consumers to house builders should satisfy:

$$(1 - \delta p_{t+1}) k_t = 0, \quad (10)$$

so that either $p_t = \delta^{-1}$ or $k_t = 0$. Given the non-negativity constraint on capital, the quasi-linear utility function implies that at that price capital and consumption are not uniquely determined and agents are indifferent between increasing slightly the capital sold to firms at time $t$ in exchange for $\delta^{-1}$ more units of consumption at $t + 1$. The capital supply offered by consumers is thus perfectly elastic, so that $k_t$ is determined by firm’s demand at the market price of $p_t = \frac{1}{\delta}$.

Finally consumption can be obtained residually using the flow budget constraint:

$$c_t = y_t + b_t - \left( h_t - (1 - \delta) h_{t-1} \right) Q_t - b_{t-1} R_t - k_t - k_{t-1} \delta^{-1}. \quad (11)$$

---

6The utility function is linear in consumption as in Adam, Marcet and Kuang (2010). As them, we assume that the utility from consumption is bounded for high level of $c$. The first order conditions are thus necessary and sufficient for a maximum due to the linearity of the constraint and the concavity of the objective function in the households’ choice variable.
2.2 Housing Supply

As said above, we assume that house builders operate quarterly (q). The difference in the timing of the action among households and house builders reflects the time that elapses in creating new houses. The house builders borrow capital from the households in a competitive market and employ it as input in a simple decreasing return to scale production function:

\[ S_h^q = (\alpha \delta)^{-1} k_q^\alpha. \] (12)

\( k_q \) is the sum over a quarter of the daily capital received from household and \( \alpha \in (0, 1) \). The market for input is always in equilibrium and the price for capital is \( p_t = \delta^{-1} \forall t, q \).

The firm chooses \( k_q \) to maximize its profits, i.e., \( \max_{k_q \geq 0} E_q \{ S_h^q Q_{q+1} - \delta^{-1} k_q \} \), where \( Q_{q+1} \) is the quarterly house price in the next quarter. The first order condition is:

\[ k_q = \left( E_q Q_{q+1} \right)^{1/\alpha}. \] (13)

In maximizing profits, house builders need to form expectations about the next quarter house price. We assume house builders have static expectations, so that: \( E_q[Q_{q+1}] = Q_q \). The profit-maximizing input demand therefore becomes:

\[ k_q = (Q_q)^{1/\alpha}, \] (14)

and substituting it into the production function we obtain the quarterly supply of new houses:

\[ S_h^q = (\alpha \delta)^{-1} Q_q^{\alpha/\alpha}. \] (15)

The housing stock evolves according to:

\[ h_q = (1 - d) h_{q-1} + S_h^q. \] (16)

Note that this is an end-of-period definition of the housing stock. The stock of houses at the end of quarter \( q \), thus available for consumption in the next quarter \( q + 1 \), depends on the existing stock in the previous quarter, \( h_{q-1} \), net of depreciation, plus the production of new houses in the quarter. It follows that the stock of houses available for consumption in quarter \( q \) is equal to the stock at the beginning of quarter \( q \), that is, \( h_{q-1} \).

2.3 The Log-Linearized Model

In this part we log-linearize the model around its steady state, where the variables are constant. In our case this implies that the timing of actions does not

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7 The quarterly house price is defined as an average of the daily prices over the quarter.

8 Note that \( d \) is the quarterly depreciation rate, so that: \( 1 - d = (1 - \delta)^{64} \).
matter (e.g., if \( Q_t = Q \forall t \) then \( Q_q = Q \)) and we equalize demand and supply in a timeless fashion. The main steady state equations for our purposes are:

\[
h^d = \frac{Q}{1 + \delta \theta - \frac{\theta}{R} - \left(1 - \tilde{d}\right) \delta},\]

\[
S^h = \frac{1}{\alpha \delta} Q \tilde{t}^{\frac{1}{\alpha}},\]

\[
dh = S^h.
\]

Solving for \( Q \) we obtain the steady state value for the house price:

\[
Q = \left( \frac{d_j \alpha \delta}{1 + \theta \delta - \frac{\theta}{R} - \left(1 - \tilde{d}\right) \delta} \right)^{1-\alpha}.
\]

The log-linearized equations thus are:

\[
\hat{h}^d = \hat{j}_t + \frac{Q h^d}{j} \left[ \left(1 - \tilde{d}\right) \delta \hat{E}_t Q_{t+1} - \left(1 + \delta \theta - \frac{\theta}{R}\right) \hat{Q}_t - \frac{\theta}{R} \hat{R}_t \right],
\]

\[
\hat{Q}^h = \frac{\alpha}{1 - \alpha} \hat{Q}_q.
\]

The demand function in (20) depends positively from the preference for houses and from the expected future price, while negatively from the current price\(^9\) and from the interest rate. The housing supply is a positive function of the quarterly price.

Finally, log-linearizing (16) yields:

\[
\hat{h}_q = (1 - \tilde{d}) h_q \hat{h}_{q-1} + S^h \hat{S}_q^h.
\]

\section{An Agent-Based Approach to House Price}

In this Section we present the Agent-Based part of our model, where we adapt the Agent-Based framework in Lengnick and Wohltmann (2010) and Westerhoff (2008) to the housing market.

\subsection{Expectations}

Adam, Marcet and Kuang (2011) conclude that it is difficult to account for the U.S. house price dynamics assuming rational expectations. The empirical evidence on house price behavior, which alternates periods of persistently increasing and decreasing prices motivates the relaxation of the rational expectation hypothesis regarding beliefs on house prices. As Adam, Marcet and

\(^9\)Given our calibration \( 1 + \delta \theta - \frac{\theta}{R} > 0.\)
Kuang (2011), in order to concentrate on the effects of the Agent-Based part of the model on the housing market dynamics, we assume that households have correct beliefs (i.e., rational expectations) about all variables affecting their demand for housing services, except for the house price. Regarding the latter, they hold non rational beliefs.

More precisely, they can be either chartists $\hat{E}_t^c(\cdot)$ or fundamentalists $\hat{E}_t^f(\cdot)$. Chartists expect the price trend will continue, so their forecasting rule is given by:

$$\hat{E}_t^c[\hat{Q}_{t+1}] = \hat{Q}_t + l^c(\hat{Q}_t - \hat{Q}_{t-1}),$$

(23)

where $\hat{Q}_t$ is the percentage deviation of house price from its steady state value at $t$ and the parameter $l^c > 0$ represents the degree of "persistence" or trend-chasing in the house price expected by the chartists.

Fundamentalists, instead, believe that a fraction of the actual mis-pricing will be corrected in the future, so their forecasting rule is given by:

$$\hat{E}_t^f[\hat{Q}_{t+1}] = \hat{Q}_t + l^f(\hat{Q}_{t}^{fd} - \hat{Q}_t),$$

(24)

where the parameter $l^f > 0$ represents the fraction of the mis-pricing that fundamentalists expect to be corrected in the next period, and $\hat{Q}_{t}^{fd}$ is the perceived fundamental value, that we need to define.

Economic theory would suggest that the value of a house, as that of any asset, should be equal to the present discounted value of the expected returns from holding that asset. In our model, for fundamentalists this could be captured by equation (6):

$$Q_t = \left( \frac{j_t}{h_t^{fd}} + \gamma_t \theta Q_t \right) + (1 - \delta) \delta \hat{E}_t^f Q_{t+1},$$

(25)

that has the usual asset pricing interpretation: the value of the asset is given by the dividend today plus the expected capital gain/loss tomorrow. The benefit today of holding the house is equal to the marginal utility provided by the housing services plus the utility deriving from the relaxation of the borrowing constraint, that is, $\left( \frac{j_t}{h_t^{fd}} + \gamma_t \theta Q_t \right)$, while the capital gain tomorrow net of depreciation and discounting is $(1 - \delta) \delta \hat{E}_t^f Q_{t+1}$. One could then think of iterating forward equation (25) and find a value of the asset that depends on future expected "fundamentals", as one would do in a rational expectation framework. However, in our Agent-Based context it would not make sense to iterate this equation forward, simply because $\hat{E}_t^f Q_{t+1}$ does not obey rational expectations. So we can not use equation (25) to calculate $\hat{E}_t^f Q_{t+1}$ and then to substitute it iteratively forward in the same equation. In our Agent-Based framework, $\hat{E}_t^f Q_{t+1}$ is defined by the forecasting rule of the fundamentalists, equation (24). Instead, equation (25) pins down the demand given the particular forecasting rule of the agent.

So we need to find another route that it is coherent with the irrational beliefs of our agent based framework, where agents do not know the correct (and complex) determinants of house price dynamics. In addition, even expert economists
in the real world rarely agree on the actual mechanism linking fundamentals to
house prices. Hence, we assume that households can not identify the true funda-
mental price. In (24), fundamentalists thus use a perceived fundamental price.
Similarly to Lengnick and Wohltmann (2010), that link the perceived steady
state of the financial market to the aggregate economic activity, we link the
fundamentalists’ perceived fundamental price to the sectoral output, that is, to
the supply of housing services. The idea is that fundamentalists understand
that house supply depends on the expected price (see equation (21) in the pre-
vious Section). Hence, an increase in housing supply will then be interpreted
by fundamentalists as a signal of the house builders reaction to an expected
increase in the fundamental house price.\footnote{One can also argue that fundamentalists assume that house producers have superior information on the housing market, so they link }\( Q^{fd} \) to the observed \( S^h \).

Therefore, we assume that the fun-
damental price perceived by fundamentalists at the beginning of each quarter is
proportional to the amount of construction works that they observe. The latest
available observation to fundamentalists at the beginning of each quarter is the
new housing built during the previous quarter, \( S^h_{q-1} \). Hence:

\[
Q^{fd}_t = \text{const} \times S^h_{q-1} \quad q = \text{floor} \left( \frac{t-1}{64} \right)
\]  

(26)

The function \( \text{floor}(\cdot) \) simply rounds its argument to the nearest integers less
than or equal to the argument itself, and it is simply used to divide the daily
time scale into quarters, mapping the days \( t \) into the respective quarters \( q \). Note
that \( Q^{fd}_t \) is "fundamental" in the sense that both it depends on "fundamentals"
and it moves at low frequency in the model, because it is constant over the
quarter, being \( \hat{Q}^{fd}_t = \hat{Q}^f_t \). In log-deviations, (26) simply becomes

\[
\hat{Q}^{fd}_t = \hat{S}^h_q.
\]  

(27)

Inserting (23) and (24) into (20) yields the chartists’ demand function:

\[
\hat{h}^{d,c}_t = \hat{\gamma}_t + \frac{Q^{hd}}{\bar{j}} \left[ (1 - \hat{d}) \left( \hat{Q}_t + \bar{l} \left( \hat{Q}_t - \hat{Q}_{t-1} \right) \right) - \left( 1 + \delta \theta - \frac{\bar{\theta}}{\bar{R}} \right) \hat{Q}_t - \frac{\bar{\theta}}{\bar{R}} \hat{R}_t \right],
\]  

(28)

and the fundamentalists’ one:

\[
\hat{h}^{d,f}_t = \hat{\gamma}_t + \frac{Q^{hf}}{\bar{j}} \left[ (1 - \hat{d}) \left( \hat{Q}_t + \bar{l} \left( \hat{Q}^{fd}_t - \hat{Q}_t \right) \right) - \left( 1 + \delta \theta - \frac{\bar{\theta}}{\bar{R}} \right) \hat{Q}_t - \frac{\bar{\theta}}{\bar{R}} \hat{R}_t \right].
\]  

(29)

The relative shares of chartists and fundamentalists are endogenously de-
determined. Households learn about the past, and they change their beliefs ac-
cording to the past performances of the two forecasting rules. Therefore, each
group evaluates the attractiveness, \( A^i_t \), of each forecasting rule on the basis of
the following equation:

\[
A^i_t = \exp(\hat{Q}_t) - \exp(\hat{Q}_{t-1}) |\hat{h}^{d,i}_{t-2} + \eta A^i_{t-1}|, \quad i = c, f.
\]  

(30)
The attractiveness is thus partly related to the recent performance of the rule, measured by the term $\exp(\eta^{Q_t}) - \exp(\eta^{Q_{t-1}})\hat{h}_{t-2}^d$, and partly by its past attractiveness, where $\eta \in [0,1]$ is the memory parameter.

The fraction of agents that adopt a particular strategy ($W^i_t$) then is updated every day thanks to the Gibbs Probability, as in the framework of adaptive belief system proposed by Brock and Hommes (1997, 1998):

$$W^i_t = \frac{\exp(eA^i_{t-1})}{\sum_i \exp(eA^i_{t-1})} \quad i = c, f.$$  \hfill (31)

The more attractive is a strategy, the higher is the fraction of agents using it. The parameter $e$ is called the rationality parameter: other things equal, the higher is $e$, the larger will be the number of agents that switches towards the strategy with the highest attractiveness.

### 3.2 House Price Dynamics

The deviation of the house price from its steady state, $\hat{Q}_t$, evolves according to:

$$\hat{Q}_{t+1} = \hat{Q}_t + a(W^c_t \hat{h}_{t+1}^d + W^f_t \hat{h}_{t+1}^d - \hat{h}_{t-1}) + \varepsilon^Q_t.$$  \hfill (32)

(32) states that the change in the house price ($\hat{Q}_{t+1} - \hat{Q}_t$) reacts to the excess of demand over supply in the housing market. This is given by the difference between the sum of the demand deviations of chartists $\hat{h}_{t-1}$ and fundamentalists $\hat{h}_{t-1}$ from the relative steady state, weighted by their relative shares ($W^c_t$ and $W^f_t$ given by (31)), and the available supply of housing services, $\hat{h}_{t-1}$. The noise term $\varepsilon^Q_t$ is an i.i.d. normally distributed shock with standard deviation $\sigma^Q$. It captures the idea that the two strategies are not the only possible strategies that exist into the market.

The quantity actually exchanged in the market obeys to the short side of the market, so it is given by the minimum between the sum of the chartists and fundamentalists demand in the correspondent quarter and the relative existing stock:

$$G = \min \left\{ \sum_{t=64(q-1)+1}^{64q} \left( W^f_t \hat{h}_{t+1}^d + W^c_t \hat{h}_{t+1}^d \right) ; \hat{h}_{t-1} \right\}$$  \hfill (33)

The actions of households and house builders are not synchronized, because demand and supply run on a different time scale. We assume that a quarter is composed by 64 days. Hence, within one increment on house supply’s time index $q$, households perform 64 times their maximization problem generating their daily demand for houses. Therefore the model is implemented as follows: i) we run the daily demand for a quarter, given the shocks that hit the model; ii) then the quarterly price is equal to the mean of the daily price over that quarter.

\footnote{Recall that the housing stock is constant over the quarter, because it changes only at quarterly frequencies. So: $h_t = h_q$ where $q = \text{floor} \left( \frac{t+1}{64} \right)$.}
quarter; iii) we insert it into the supply equation to find the reaction of house builders and the new fundamental price; iv) we iterate.

A quarter is defined to contain days $64(q-1) + 1, ..., 64q$, for $q = 1, 2, ...$

\[ \hat{Q}_q = \frac{1}{64} \sum_{t=64(q-1)+1}^{64q} \hat{Q}_t. \]  

(34)

4 The Model Simulation

In this part of the paper we analyze the performance of the model. First, we use numerical simulations to investigate the ability of the model to generate fluctuations in the house price driven by endogenous waves of chartism and fundamentalism. Second, we inspect the transmission mechanism of the model by means of sensitivity analysis.

4.1 Calibration

The parameter calibration is reported in Table 1. As in Adam, Marcet and Kuang (2011), the annual discount factor $\delta$ is fixed at 0.96 and the annual depreciation rate at 3%, implying: $\ddot{d} = 0.0076$ and $\ddot{d} = 1.19 \cdot 10^{-4}$. $\alpha = 0.4$ implies decreasing returns in production and captures the fact that housing is a capital-intensive sector. Parameter $\theta$ in the borrowing constraint is calibrated as in Iacoviello (2005). $\eta, c, l^c$ and $l^f$ are set as in Lengnick and Wohltmann (2010).

The value of the parameter $\alpha$ in equation (32) is set to a lower value than in Lengnick and Wohltmann (2010). We argue that price elasticity to excess demand is much less in the housing market with respect to the financial market, because the house price is much more inertial and less volatile than asset prices in the financial market. Moreover, recall that the parameter $\alpha$ in equation (32) measures the elasticity of the daily house price to the daily excess demand in the housing market, so it is reasonable to assume that the daily change of the house price responds very little to daily excess demand. Finally, it is worth noting that a low value is consistent with the finding in Bolt, Demertzis, Diks, Hommes and van der Leij (2014) that points towards an almost random-walk behavior of the deviation of the house price from equilibrium.

We calibrate the variance of the shock to the evolution of the house price in equation (32), $\sigma_{Q}^{2}$, so that the variance of the simulated quarterly price is the same as the variance of real quarterly price, collected by Federal Housing Finance Agency (http://www.fhfa.gov/).

4.2 Waves of Chartism and Fundamentalism

Following Lengnick and Wohltmann (2010), we simulate a representative run for a period of 40 quarters to show how the model works. We have two different sources of shocks in the model: the noise term on the house price equation (32),
\( \varepsilon_t^Q \), and a shock to the preference for housing services in the utility function, \( j_t \). In this part of the paper, we analyze only the response of the system to repeated draw realizations of the noise term \( \varepsilon_t^Q \), while keeping \( j_t \) fixed at zero. The aim is to investigate how our Agent-Based framework interacts with the more standard partial dynamic model of households’ choice.

Figure 1 shows the dynamics of the relevant variables: the top left panel displays the quarterly house prices; the top right shows the evolution of housing stock. The two middle panels display: i) daily house price along with the perceived fundamental value; ii) waves of chartism (black) and fundamentalism (white), labelled *animal spirits*. Finally the bottom left panel shows the quantity actually exchanged on the housing market and the bottom right panel shows the housing stock, \( h_q \) (dashed line), and total demand, \( W^\ell_t h^d;c_t + W^f_t h^d;f_t \) (solid line). The model is able to generate endogenous waves of chartism and fundamentalism, that in turn cause fluctuations in both the house price and quantity exchanged. The continuous evaluation of past relative performance induces an endogenous competition between the two forecasting strategies that assures that none dominates forever. While fundamentalists dominate for most of the time, in some particular periods the vast majority of agents follows the chartists’ rule. When chartists prevail, the house price departs from its perceived fundamental value. As an example, quarters \( q = 3 - 4 \) and \( q = 32 - 36 \) exhibit a boom in the house price driven by chartists, while quarters \( q = 26 - 28 \) exhibit a bust. In phases dominated by fundamentalists, on the contrary, the house price tends to go back to its fundamental value, which is evident for \( q = 5 - 14 \) or \( q = 16 - 25 \).

Assume the house price starts trending upward, then the chartists’ rule may outperform the fundamentalists’ one strengthening and protracting the upward movement in the house price, and thus creating a boom. However, this sows the seeds for the subsequent bust. First, the supply of new houses increases with the price, and so does the available stock of housing. Therefore the excess demand tends to decrease, because the supply has a standard direct negative effect on the house price through equation (32). Second, the effect on demand of an increase in the house price depends on whether the negative substitution effect on demand (due to the increase in the current price) is offset by the positive wealth effect on demand (due to the increase in the expected future price). For chartists, the increase in the expected future price is due to the extrapolative expectations (equation (23)), while for fundamentalists this is due to the increase in the fundamental price caused the increase in the supply of new housing (equation (26)). Note the twofold role of an increase in supply: on the one hand, it forces a price decrease by increasing the stock of available houses, on the other hand it affects fundamentalists’ expectations by increasing their perceived fundamental value, and thus their demand. Hence, on the one hand, the forces counteracting the lengthening of the boom phase are standard: the substitution effect on demand and the contribution of the supply of new houses to excess demand. On the other hand, the Agent-Based mechanisms of expectations formation both of chartists, who are trend follower on a daily basis, and fundamentalists, through the perceived fundamental price, contributes to the prolonging of the boom phase. Note, however, that the fundamentalists’
expectations tend to stabilize the price at high frequencies, because they tend to anchor the price to the perceived fundamental one which is fixed over the quarter. Indeed, Figure 1 shows that when fundamentalists dominate, the price tends to move towards the fundamental value.

It is interesting to note that the two expectation formation mechanisms of our model tend to reinforce the trend in the house price, but at different frequencies: daily the chartists, while quarterly the fundamentalists.

Finally, the supply of new houses is closely influenced by the path of the quarterly house price (see the two top panels). The stock of existing houses, however, evolves very slowly because of the low depreciation rate. The exchanged quantity is the minimum between demand and the stock of existing housing stock. When there is excess supply, demand determines the quantity sold, and accordingly the time series is more volatile. On the contrary when supply drives the exchange quantity, the time series is represented by a broken line because this variable changes (very little) only at the end of each quarter.

4.3 Inspecting the Mechanism

We now perform a sensitivity analysis regarding the parameters of the model, simulating its dynamics for 1000 periods. With respect to our benchmark calibration in Table 1, we then change one parameter at a time in the log-linearized model, keeping however fixed the particular sequence of the realizations of the shock $\epsilon_t^Q$ that generates Figure 1. The purpose of this exercise is twofold. First, it is a robustness check on the mechanism of the model just described. Second, it provides a better understanding of the different effects at work in the model. Table 2 shows how some key statistics of the log-linearized model change with the parameters of the Agent-Based part of our framework.\footnote{We just consider either an increase or a decrease since the effects are symmetric.} In particular, these statistics are: the standard deviation of the daily house price, $\bar{Q}_t$, of the stock of houses, $\bar{h}_q$, of the excess demand, $(W_t^c \bar{h}_t^{d,c} + W_t^f \bar{h}_t^{d,f} - \bar{S}_t^h)$, and of the fundamental price, $\bar{Q}_t^{fd}$, and the average value of the shares of fundamentalists, $W_t^f$, and chartists, $W_t^c$. The first column shows the results employing the benchmark calibration in Table 1.

An increase in $l^c$ in equation (23) strengthens the trend following behavior of the chartist’s expectations of the house price. Not surprisingly, this causes an increase in the volatility of all the relevant variables. These effects, however, are very minor pointing to the fact that such a parameter does not play a key role in the model. The share of fundamentalists decreases but only slightly.

The effect of an increase in $l^f$ in equation (24) instead has quite large stabilizing effect on the model. The bigger $l^f$, the more the fundamentalists’ expectations react to the difference between the daily price and the fundamental price. As a consequence, the daily price is closer to the fundamental value and less volatile. So it is supply and hence the fundamental price. The fundamentalists’ strategy become more effective, and indeed the average share of fundamentalists is overwhelming: 81%. Note, however, that the volatility of the excess demand
increases. This is because the fundamentalists’ demand is more volatile since the expectation of the future price moves substantially to correct the deviation of the current price from the fundamental price. Therefore, in the case of high $I^f$ is the demand of fundamentalists that plays the stabilizing role on the price through excess demand.

An increase in the elasticity of the daily house price to the excess demand on the market, $a$, in equation (32) has a very intuitive stabilizing effect on all the variables: the price move on a daily basis to clear the excess demand on the market. Intuitively, the average share of fundamentalists rise to 67%, because the market is more stable.

The rationality parameter, $e$, in equation (31) determines the sensitivity of the shares of the two agents with respect to the relative attractiveness of the two forecasting rules. The higher is $e$, the greater the number of agents selecting the more attractive strategy. In the extreme case when $e = 0$, agents do not switch strategy, so the shares of the two agents are constant. In the other limiting case when $e = \infty$, all agents have always the same strategy, because they simply pick the forecasting rule with the best performance in the previous period. It is quite intuitive therefore that a decrease in $e$ mitigates all the volatilities, even if the quantitative effects are quite minor in our setup.

Finally, it is interesting to analyze also the effects of the return to scale parameter. A decrease in the return to scale parameter makes marginal costs steeper, and hence supply is less elastic with respect to the price. As a consequence, the volatility of supply, and thus of the fundamental price, diminishes. This increases the volatility of excess demand because supply does not move to counteract the movement in demand. Since the fundamental price is quite stable, on average the fundamentalists’ strategy outperforms the chartists’ one and fundamentalists are on average the majority in the market.

5 Matching House Price Data

In this Section we ask if the model is able to replicate the recent boom-and-bust house price dynamics in the US data. The aim is to identify the main driving forces of the dynamics of the house price according to our model.\footnote{\textsuperscript{13}}

We want to see if our model can match the behavior of the quarterly house price for the period going from Q1:2004 to Q1:2009. The data, Seasonally Adjusted Purchase-only Index, are taken from the Federal Housing Finance Agency. We assume that in the initial period, i.e., Q1:2004, the system is in steady state. We then compute the percentage deviation of the quarterly house price from its steady state value.

The debates among economists have focused on three main possible causes of the recent boom and bust in housing prices. The first narrative identifies the so-called "Greenspan put" as one possible causes of the crisis, that is a persistent low level of interest rates inducing excessive leveraging on the part of both

\footnote{\textsuperscript{13} Other contributions, based on non-rational expectation, are able to match the data quite well: see, for example, Adam, Kuang, Marcet (2011).}
the households, through debt accumulation (especially mortgage debt), and the financial intermediaries through excessive risk-taking. A second narrative points instead to a "liberalization" cycle as the main cause of the crisis, that is, an overall loosening of lending standards that allows more borrowing from the households for a given value of the collateral, followed by an abrupt increase of credit tightening at the onset of the financial crisis. A third narrative, instead, considers the possibility that exogenous and more direct factors drove up the housing price, in the sense of an exogenous increase in the demand due to a preference shift. Justiniano, Primiceri and Tambalotti (2013) call the latter the "valuation" story.\footnote{One may call it the "Bush-push", in the sense that the demand for housing was surely strongly promoted by the George W. Bush administration. "We can put light where there’s darkness, and hope where there’s despondency in this country. And part of it is working together as a nation to encourage folks to own their own home." President George W. Bush, Oct. 15, 2002. See for example: http://www.nytimes.com/2008/12/21/business/worldbusiness/21iht-admin.4.18853088.html?pagewanted=all&_r=0}

Our framework can accommodate these three possible explanations through, respectively: i) the exogenous interest rate; ii) a time-varying value of $\theta$ in equation (3), as a proxy for credit tightness; iii) the exogenous preference shock, $j_t$, in the utility function.\footnote{A preference shock for housing services as ours is also present in Iacoviello and Neri (2010), Liu, Wang, and Zha (2011) and Justiniano, Primiceri and Tambalotti (2013).} In order to evaluate the relative importance of these three possible driving factors in our model, we feed into it one exogenous path for each of these three variables.\footnote{In this Section, shocks to the evolution of the house price, $\epsilon^Q_t$, are muted in performing this impulse response type of exercise.}

Regarding the interest rate we use the percentage deviation in 30-Years Conventional Mortgage Rate from its value in the initial period Q1:2004. As displayed in Figure 2, this percentage deviation decreases steadily and substantially from 2004 to 2006, then it moves up and then down again, till it sharply increases from the Q2:2008. However, the change in this variable is rather small. We then fit this series into the demand functions of the two agents to see the resulting path of the house price. Results are shown in Figure 3: the reaction of the model (dashed line) is very small compared with real data (solid line). Moreover in the small box, where the simulated price series is shown more clearly, it is possible to note that the series is increasing and it is thus not able to capture the drop in house prices in the second part of the sample in the data. To test for the "liberalization" story that views the tightness of credit as the main source of the boom-and-bust behavior of the house price, we construct a path for the parameter $\theta$ in the borrowing constraint in the following way. First, we calibrate this parameter to be equal to Iacoviello (2005): $\theta = 0.55$. Second, we consider the net percentage of banks reporting tightening credit standards in the US according to The January 2012 Senior Loan Officer Opinion Survey on Bank Lending Practices.\footnote{http://www.federalreserve.gov/boarddocs/snloansurvey/201201/default.htm} This measure (see Figure 4) remains stable from 2004 to the third quarter of 2006, when access to credit...
starts tightening quite substantially till the second quarter of 2008. Finally, we define \( \theta_t \) as: \( \theta_t = 0.55 - 0.55 \times \text{tight credit} \), because the credit availability is an increasing function of \( \theta \). The results of feeding this time-varying value of \( \theta \) in our model are shown in Figure 5. Again, the simulated data do not match the real data both because the size of the changes in the house price is much smaller and because the shape of the path is different. It is clear that our model does not suggest this mechanism as the driving force of house price dynamics. Finally we consider the shock on house preferences \( j_t \). To build a time series for \( j_t \), we look at the quarterly table showing the Buying Condition for Houses in the Michigan Consumers Surveys. This measure is built from answers to the following question: Generally speaking, do you think now is a good time or a bad time to buy a house? We focus on the percentage of positive answers, and we normalized it to generate a series in a way to have figures in the subset \((-1, 1)\). Figure 6 visualizes the resulting path for \( j_t \). Values of the series higher than zero mean a positive preference shock, and vice versa. The shock is thus positive from 2004 to the first half of 2005, when it becomes negative and there remains till the end of our sample, even if reverts toward zero from the middle of the 2007. Figure 7 shows the response of the model to this path of the exogenous preference shock. In this case, our model economy is able to replicate the real price dynamics. In particular, the house price increase builds up very similarly to the data during the first two years and a maximum percentage deviation of house price is reached in the first half of 2006. After that the simulated time series exhibits a constant decline, while the data decrease slightly and then rise up again to a second maximum before starts decreasing. The simulated time series is not able to reproduce the mild twin-peaks in the data, and therefore the decrease in the simulated data happens 3 quarters before the one in the data. The rate of decrease after the peak, though, is quite similar. The final exercise consists in putting together all the three effects (see Figure 8). As evident also from the previous figures, basically all of the dynamics in house price is generated by the preference shock. Adding the interest rate and the credit tightness has basically no effects with respect to the case considering only the preference shock. Our analysis therefore suggests that by far the most important factor in the recent boom-bust dynamics of the house price in the US is a change in households’ preference and housing demand. As such our analysis emphasizes the importance of the behavioral approach and of the selection mechanism among different expectation rules as determinant factors of the boom and bust cycle in the housing market. On the contrary, narratives based on "fundamentals" as the interest rate behavior or the credit market liberalization appear to be unimportant in our framework.

It is interesting to note that our result is consistent with the findings of Justiniano, Primiceri and Tambalotti (2013), that employ a very different modelling strategy: more structural and less behavioral. Using a quantitative dynamic general equilibrium model with occasionally binding constraint and an asymmetric borrowing constraint, they find that the dynamics of house price in

18See also Iacoviello and Neri (2010) and Kiyotaki, Michaelides, and Nikolov (2010).
the US could be explained by a "valuation" effect, that is an exogenous shock to preference for housing. Similarly to our framework, a positive shock leads to an increase in the demand and then in the price of houses, that are used as collateral by the households, thereby expanding their ability to borrow, and ultimately generating a boom. On the contrary, like us, they find little role for the "liberalization cycle".

6 Leaning against the Wind Policies

In this Section we tackle the following question: "Could the boom in house price have been avoided with an appropriate interest rate policy?" This question fosters great discussion in the policy circles and central banks. Should monetary policy be concerned with financial stability and thus react to asset price, i.e., "leaning against the wind", or should it just focus on inflation (and possibly output) stabilization?

Here we are more concerned about house prices rather than financial assets. In this respect, the Adam, Kuang and Marcet (2011) model predicts that the recent house price dynamics would have been avoided and the current account deficit would have been considerably smaller, if the interest rate had fallen by less at the beginning of the 2000's.

Gelain, Lansing and Mendicino (2013) develop a DSGE model where simple moving-average forecast rules for a subset of agents significantly magnify the volatility and persistence of house prices and household debt. In their framework, a direct response of the central bank's interest rate rule to either house-price growth or credit growth would have the important drawback of substantially magnifying the volatility of inflation.19

We would like to ask the same type of question in our framework. To do so, we assume that the real interest rate (i.e., our policy variable) responds to the house price. We then solve for the optimal value of this response. Optimal is here defined as minimizing two different measures of the house price fluctuations: the distortion and the volatility of the house price.

The distortion measure is the average deviation of the house price from its steady state:

\[ \text{dis}(Q) = \frac{1}{T} \sum_{t=1}^{T} |Q_t|, \]

The volatility measure is the average change in the time series of the deviation of the house price from its steady state (which coincides with the average

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19 They show that macroprudential policies that directly affects the borrowing constraint are more effective tools in reducing the volatilities of house prices and household debt.
rate of growth of the house price):\(^{20}\)

\[
vol(Q) = \frac{1}{T-1} \sum_{t=1}^{T} |\dot{Q}_t - \dot{Q}_{t-1}|. \tag{36}
\]

Moreover, for this exercise, we adopt two policy rules. First, we assume that the real interest rate responds to the quarterly house price:

\[
\hat{R}_q = r^q \dot{Q}_q. \tag{37}
\]

Second, we modify the target making the interest rate to respond to the rate of growth in the house price:

\[
\hat{R}_q = r^q \left( \dot{Q}_q - \dot{Q}_{q-1} \right). \tag{38}
\]

Then we set the preference shock in house demands equal to zero. To find the optimal value of \(r^q\), we do a grid search on the set \(r^q \in [0,3]\). For each value of \(r^q\) we simulate 1000 runs of 100 quarters each, drawing different realizations of the shock to the house price \(\varepsilon^q_t\) and then we average across runs. The results are shown in Figures 9a and 9b. Figures 9a and 9b display the distortion and the volatility of the house price as a function of \(r^q\) for rule (37) and rule (38), respectively.

In the case of rule (37) the distortion and the volatility exhibit a similar behavior: they decrease substantially up to \(r^q = 1\) and then continue decreasing mildly as the policy reaction coefficient increases. Recall that in our model the real interest rate has a negative effect on demand (see equation (20)), so by increasing the real rate with the house price, the policy is able to stabilize the house price and the more so, the higher \(r^q\).

In the case of rule (38) instead the picture is quite different: reacting to the change in house price tends to increase both the distortion and the volatility of house price, at least for values of \(r^q < 1\). Interestingly, for values of \(r^q > 1\), Figure 9b exhibits a trade-off between the two measures of house price fluctuations. For stronger values of the reaction coefficient, the price distortion decreases, but at the expenses of a higher price volatility. The figure shows that in this case the policy could lead to increase, rather than decrease, the instability of the house price dynamics, amplifying our Agent-Based mechanism of evolutionary selection of expectation rules.

Admittedly, given the partial equilibrium nature of our model, our policy analysis and implications should be taken with care. First, we are forced to assume that the real, rather than the nominal, interest rate is the policy variable. Second, contrary to a general equilibrium model as in Gelain, Lensing and Mendicino (2013), our framework can not say anything about the possible deleterious effect of a policy rule on other policy relevant variables, as inflation, for

\(^{20}\)See Lengnick and Wohltmann (2010). For the same reasons as theirs, we do not use the variance of the simulated series. Our time series shows long deviations from the mean (which we interpret as boom and busts), so that when calculating the variance, one would not measure the volatility but rather the mean squared distortion.
example. Third, for the same reason, our framework can not take into account
the feedback effects of the fluctuations in the house price on changes in other
variables (as income for example), that are taken as exogenous in our partial
equilibrium structure.

Although we acknowledge the limits of the policy analysis in our context,
it seems that a policy suggestion emerges clearly from the experiments, in line
with Adam, Kuang and Marcet (2011): targeting the level of the house price,
the government could dampen the movements at the heart of booms and busts
in house prices. On the contrary, targeting the change in house price could have
destabilizing effects. However, to assess whether this is an optimal or sound
thing to do, a general equilibrium analysis is needed.

7 Conclusion

We developed a model to study the housing market starting from an Agent-
Based perspective. We showed that it is possible to generate an endogenous
creation of boom-and-bust dynamics in the house price by relaxing the rational
expectation hypothesis, and embedding into the model an Agent-Based mech-
anism of evolutionary selection of expectation rules based on backward-looking
behavior. The framework is based on the chartist-fundamentalist mechanism,
and, despite its simplicity, it is able to match the behavior of US house prices
quite well. The interaction between chartists and fundamentalists is sufficient
to create endogenous movements in the house price with a large influence on
the dynamics of the economic system.

The results point to the exogenous preference shock as the main driving
force behind the house price dynamics. On the contrary, the model suggests
that other competing hypothesis, as a prolonged period of low interest rates or
the liberalization in credit standards, have only minor effects on house price
dynamics.

Finally, the model provides a rationale for monetary policy to lean against
the wind in order to reduce the fluctuations in house prices.

Our framework can be expanded in several directions. The model is clearly
still rather simple in incorporating a really psychological foundation of expecta-
tions. Moreover, our framework could be embedded into a general equilibrium
model. This step would be particularly welcome to analyze the policy implica-
tions of our framework and the robustness of the results in the last Section.

References

(2005).


[19] Bolt, Wilko, Demertzis Maria, Diks Cees, Hommes Cars and Marco van der Leij, "Identifying Booms and Busts in House Prices under Heterogeneous Expectations". Mimeo, University of Amsterdam. (2014)


### Tables

<table>
<thead>
<tr>
<th>Calibration</th>
<th>α = 0.4</th>
<th>a = 0.0007</th>
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<td>δ = 0.96</td>
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Table 1: Calibration of the model

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<td>0.3330</td>
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Tab 2: Sensitivity Analysis
Figures

Figure 1: Representative run of the relevant variables
Figure 2: Percentage deviation of 30-Years Conventional Mortgage Rate

Figure 3: Model reaction to interest rate change
Figure 4: Net percentage of banks reporting tightening credit standard

Figure 5: Model reaction to credit tightening change
Figure 6: Preference shock

Figure 7: Model reaction to preference shock
Figure 8: Model reaction to the three effects
Figure 9a. House price distortion and volatility with the interest rate reacting at house price.

Figure 9b. House price distortion and volatility with the interest rate reacting at the rate of change in house price.