EUROPEAN CENTRAL BANK

EUROSYSTEM

Working Paper Series

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News and noise in the housing market

No 1933 / July 2016

Abstract

Housing prices are subject to boom and bust episodes with long-lasting deviation from fundamentals. By considering a present value housing price model under noisy information, I study the macroeconomic implications of movements in housing prices related (news) and not related (noise) to future fundamentals. I provide empirical evidence of the sizable macroeconomic effects of news and noise shocks. Following Forni et al. (2014, 2016), I identify news and noise shocks through a non-standard VAR technique which exploits future information. In the US, news shocks are the main driver of the housing market at low frequencies, but in the short-medium horizon noise shocks explain a large share of the variability in housing prices, residential investment and GDP. Historically, many housing cycles are driven by noise. The empirical findings are consistent with a model à la Iacoviello which features a rental market. In this model, the usual optimal policy exercise concerns an augmented Taylor rule and a pro-cyclical loan-to-value ratio. I propose pro-cyclical property taxes as the most effective policy tool to deal with fluctuations originating from the housing market.

JEL classification: E30, E40, E50

Keywords: Housing Market; Non-fundamental VAR; Noise; Macro-Prudential; Property Tax

Non-Technical Summary

Boom-bust episodes in the housing market have received increasing attention after the recent events in the US, Spain and Ireland. This paper analyses housing cycles through expectations about fundamentals, i.e. rents. In a first stage, I study empirically the macroeconomic effects of movements in housing prices related (news) and not related (noise) to future fundamentals. I employ the identification strategy developed in Forni et al. (2014, 2016) that uses future information in Vector Autoregressions (non-fundamental VAR). In the US (1960-2011), news shocks are the main driver of the housing market at low frequencies, but in the short-medium horizon noise shocks explain a large share of the variability in housing prices, residential investment and GDP. Historically, many housing cycles are driven by noise.

In a second stage, I show that the empirical findings are consistent with a Dynamic Stochastic General Equilibrium model à la Iacoviello which features a rental market. In addition to bonds, Savers and Borrowers can also trade housing services in exchange for rents. The extension allows for a proper comparison between the model and the VAR. The empirical results can be replicated by news and noise shocks to housing preference.

Finally, I study which is the best way to stabilize the economy in the model. I consider traditional policies in the literature like an augmented Taylor rule that can respond to housing prices and a pro-cyclical loan-to-value ratio that can respond to debt. On top of those, I propose property taxes that respond to housing prices as a new policy tool. My results suggest that the last policy is the most effective in terms of reducing fluctuations induced by news and noise shocks and improve welfare.

"[...] Long-term expectations [...] are arguably the more important determinants of housing demand. [...] Long-term expectations have been consistently more optimistic than short-term expectations across both time and location."

from *Case, Shiller and Thompson (2012) "What they have been thinking? Home Buyer Behavior in Hot and Cold Markets"*

1 Introduction

During the last decades, the housing market has been recognized as a powerful source of instability for many economies around the world. The most striking examples are the US, Spain and Ireland. By taking a pure accounting view on US data, housing contributes to GDP in two basic ways: through private residential investment, 5% of GDP, and consumption spending on housing services, 12-13% of GDP, for a total 17-18%. In 2013, the housing stock owned by households and non-profit organization was valued $21.6 trillion, whereas the capitalization of the stock market was $20.3 trillion. Furthermore, as documented in *"World Economic Outlook"*, Ch.2, IMF (2003), housing cycles have a strong impact on the macroeconomy.[1] The WEO reports that boom-burst episodes are less frequent in the housing market than in the stock market but the consequences for the economy are more severe and long-lasting in the former case.[2] In fact, housing is more closely linked to the real economy than other assets because of its unique features. First, housing is the main asset of households and changes in housing wealth have much stronger wealth effect than other assets, e.g. stocks.[3] Second, housing provides a flow of services, but because it is also a very illiquid asset it is employed as a collateral.[4] Third, the construction sector, that is mostly labor intensive, comprises an important part of the industrial sector in every economy.

[1]It analyzes equity and housing boom-bust episodes in the post-war period for 19-14 countries.
[2]Similar conclusions are reported by Agnello and Schuknecht (2009).
[3]Case et al. (2005), Case et al. (2011), Mian et al. (2012)
[4]Iacoviello (2005) and Iacoviello and Neri (2010).

Even if the relationship between the housing market and macroeconomics has been analyzed widely in the literature, frameworks in which the housing market is forward-looking are recent. In this paper, I argue that housing prices (HP) are forward-looking and they respond to news about fundamentals. Nonetheless, the future is uncertain and, therefore, forecasts and consequent decisions may be erroneous. As a result, this could lead to cycles in the housing market without any actual movement in (future) fundamentals. The paper provides empirical evidence of this phenomenon using the non-standard VAR technique developed in Forni et al. (2014, 2016). I apply a present value (PV) model under limited information to housing. The fundamental price is determined as the PV of the expected flow of services/dividends that housing provides, i.e. rents.[5] If the information about the future is noisy, boom-bust episodes can arise even without any movement in future rents, but with strong implications for the whole economy.

In fact, rents and HP share common long-term movements (Fig. 1), yet rents are much less volatile than HP which follow the typical booms-busts that characterizes asset prices.[6] Gallin (2008) shows that, in the United States, HP and rents are cointegrated: the price-rent ratio reverts to its long-run trend. Furthermore, HP tend to do most of the adjusting. Fig. 2 shows that HP and Rents in growth rates do not co-move, and their correlation is even slightly negative. The approach I take is able to reconcile the long-term co-movement and the short-term divergence of Rents and HP (Fig. 4). My empirical results suggest that news and noise shocks are a major source of fluctuations for HP, the real estate market and the whole US economy. News (anticipated and realized information about fundamentals) drives most of the medium and long-term movements but noise (anticipated but not materialized information about fundamentals) is more relevant for short-term fluctuations, even though very persistent. The historical decomposition suggests that noise was a main driver in many of the boom-bust events observed in the housing market since the '60s. Moreover, I show that my empirical findings are

[5]Whether a house is actually given for rent or it is inhabited by the owner, a market value for rents exists (either actual or imputed)

[6]The difference in the pattern displayed by the two variables plotted for HP and Rents is due to quality adjustment (in Shiller HP and Rents CPI Series)

consistent with a general equilibrium framework by using a model *à la Iacoviello*. I include a rental market[7] which introduces an explicit return to housing and consequently a fundamental value determined by rents. I study the optimality of standard policies like interest rate rule and loan-to-value ratio (LTV). In addition, I propose a pro-cyclical property tax as a new policy tool. If the major source of fluctuations lies in the housing market, the last policy is the most effective in stabilizing the economy.

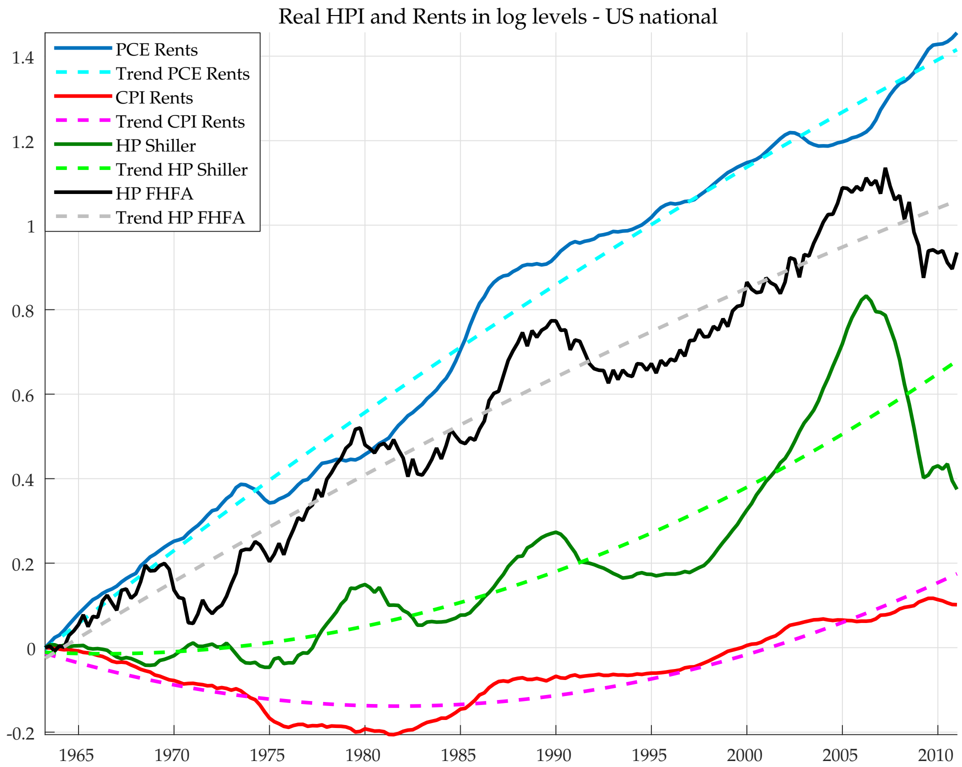

FIGURE 1: *Rent and HPI in real terms (deflated by IPD), US national data*

[7]In a similar fashion to Mora-Sanguinetti and Rubio (2014)

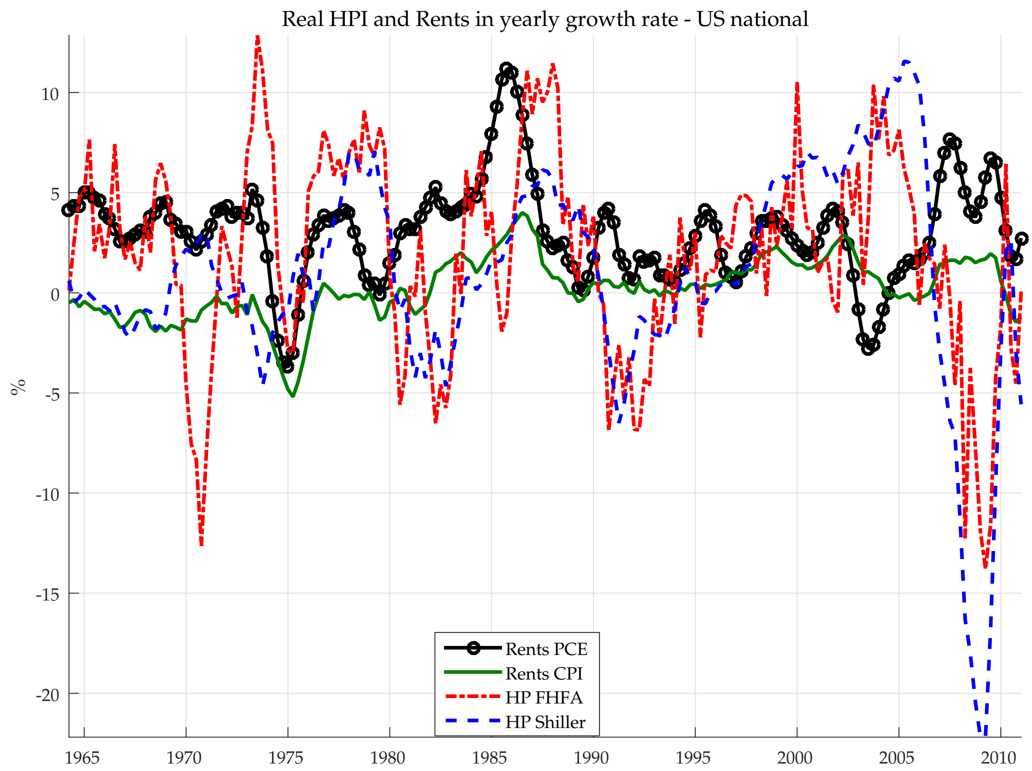

Figure 2: Real *Rent and HPI in growth rates, US national data*

Related Literature The paper brings together three different branches of the literature: (a) the news-driven business cycle literature, especially in an imperfect information framework (see Cochrane (1994), Beaudry and Portier (2006) Lorenzoni (2009), Angeletos and La'O (forth), Barsky and Sims (2012) and Blanchard et al. (2013)); (b) the papers relating with expectations in the housing market; (c) papers linking HP-rents and related analyses.

In the first branch of literature, the information structure includes three sources of fluctuations: a permanent *fundamental* shock, a transitory *fundamental* shock and a noise component which induces the limited information. Blanchard et al. (2013) find that noise is the main source for cyclical fluctuation, while Barsky and Sims (2012) reach the opposite conclusion. In this debate, Forni et al. (2014, 2016) consider a simplified information structure with a permanent anticipated shock which drives the *fundamental* process and a noisy component which only affects the signal observed by agents about the future. The advantage of this setup is two-fold. First, the theoretical interpretation of the underlying process is simpler. Second and most importantly, this structure allows the empirical exploration through non-standard VAR techniques which involve the dynamic rotation of reduced form residuals, i.e. future information. In Blanchard et al. (2013) and Barsky and Sims (2012), due to the transitory *fundamental* shock, agents never completely learn the past value of the fundamentals. Conversely, in Forni et al. (2014, 2016), agents can perfectly recover the past shocks which they could not distinguish contemporaneously. Within this framework, the future outside agents' information set can be used for identification. The methodology requires that we dispose of a variable which is *fundamental*, and as such affected just by news, and a signal which captures the expectations of agents about the future. Forni et al. (2014) study news and noise in the whole economy and find that news and noise explain more than one half of GDP, consumption and investment fluctuations and noise alone explain roughly one third of the variability, especially at high frequency.[8] Angeletos and La'O (forth) depart from the framework of symmetric information to include a disperse information setting in which higher order beliefs can play a major role in explaining business cycle fluctuations. On the other hand, they identify in a VAR a *belief shock* as the main driver of business cycle fluctuations that it is very similar to the signal shock in Forni et al. (2014).[9]

Recently, news and noise shocks have also been introduced into housing market. Regarding the empirical evidence, Lambertini et al. (2013b) introduce a proxy of expectations from surveys in a VAR and find that expectations about business conditions have a much stronger effect on the housing market and more important consequences for the whole economy than changes in expected housing prices. Yet, they use short-term expectations and do not distinguish between news and noise.[10]Also, Lambertini et al. (2013a) and Kanik and Xiao (2014) study news

[8]Forni et al. (2016) focus instead on the stock market and they come to similar conclusions to Forni et al. (2016): the bulk of short-term fluctuations in stock prices and non-residential investment is driven by noise, whereas news is more relevant for the medium and long-term dynamic.

[9]The theoretical interpretations are quite different, as Forni et al. (2014, 2016) do not take into consideration higher order beliefs

[10]The variable they use is the housing prices expectations 1-year ahead which may be not the best proxy to employ in this kind of analysis. In fact, Case et al. (2012) analyze the recent boom and subsequent collapse in the housing market of Metropolitan Statistical Areas (MSAs) in the US through surveys they collected for more than 20 years. Their available data contains both 1-year ahead expectations and 10-years ahead expectations of housing prices. They argue that long-term expectations are the most important ones in the case of housing. In fact, they analyze the housing cycle in the 2000s' and show that short-term expectations were actually under-reacting to information whereas the long-term expectations were on average much more optimistic. I will share this view and I will also employ a measure of long-term instead of short-term expectations in my *Indirect Approach*.

and noise shocks in DSGE models *à la* Iacoviello which features heterogeneity through a representative Saver and a representative Borrower who is collaterally constrained. The source of fluctuations comes from housing preferences in Kanik and Xiao (2014). Instead, Lambertini et al. (2013a) consider a wider source of fluctuations: they include anticipated shocks affecting TFP in the non-durable sector, TFP in the housing sector, monetary policy, inflation-targeting and cost push shocks. In these models, whenever agents expect HP to be higher in the future, they will immediately demand more housing and this will actually lead to an increase in HP. The boom can spread to the whole real economy both through the demand side and the supply side. As regards the demand side, the main mechanism is similar in Kanik and Xiao (2014) and Lambertini et al. (2013a): households will change their behavior due to the wealth effect and to a less tight collateral constraint. In fact, the value collateral owned by households will increase and will allow borrowers to have wider access to credit. In turn, wider access to credit will increase the pressure on demand not only for consumption goods, but even more for housing. As for the supply side, residential investment increases since agents demand more housing and are available to work more in order to accumulate it. This second channel is at work only in Lambertini et al. (2013a) as in Kanik and Xiao (2014) the housing stock is given. Unlike these works, I will explicitly model the link between HP and rents through a rental market following Ortega et al. (2009) and Mora-Sanguinetti and Rubio (2014).

Finally, the relationship between housing prices and rents has been studied widely. Among recent contributions, Campbell et al. (2009), Enders et al. (2013), Eichholtz et al. (2012) and Sun and Tsang (2013) stand out. Campbell et al. (2009) study the US housing market and find that expected rent growth is the main driver of the rent-price ratio from 1975 to 1997 together with the expected premia and by far the main factor from 1997 and 2007. Enders et al. (2013) studies 355 years on the housing market in Amsterdam and report two main findings. First, real housing prices and rents are cointegrated and share common fundamentals. Second, deviations from the fundamental housing prices can occur over long periods. Eichholtz et al. (2012) find that rents link the housing market to the real economy by analyzing the housing market of Amsterdam over the period 1550-1850. Sun and Tsang (2013) analyze MSAs in US from 1978 to 2011 and find that pricing error account for half of housing prices volatility.

In this paper, I will consider a framework in which the price of housing is forward-looking but, on the other hand, information about the future is noisy. Hence, bubbles or boom-bust episodes can easily arise as a result of this informational incompleteness. This theory of *noisy bubbles*, as defined by Forni et al. (2014, 2016), is a theory of rational bubbles under incomplete information.

Structure of the Paper The paper is organized as follows. Section 2 presents the econometric framework and the identification strategy. Section 3 reports the data, the empirical results and their historical interpretation. Section 4 exhibits the theoretical model and compares empirical and theoretical results. Section 5 displays the optimal policy exercise and Section 6 concludes.

2 A Present Value Model of Housing under Imperfect Information

In what follows, I will consider housing as an asset that provides a flow of housing services as stocks provide a flow of dividends. Housing services may be traded on the market and produce rental income or they may be directly enjoyed by the owner.[11] The PV model implies that HP is the sum of the expected discount flow of (present and) future rents.

Formally, the relationship between prices and rents is determined as follows:

$$p_t = \mathbb{E}_t \left[\beta_{(t,t+1)} \left(p_{t+1} + r_{t+1} \right) \right] \tag{1}$$

with $\beta_{(t,t+1)}$ the stochastic discount factor between time t and $t+1$.

[11]Notice that in both cases those housing services have a market value: an actual value in the former and an imputed value computed by public authorities for accounting/taxation purposes in the latter.

By iterating forward we obtain:

$$\begin{aligned} p_t &= \mathbb{E}_t\left[\sum_{i=1}^{\infty}\beta_{(t,t+i)}r_{t+i}\right] + \mathbb{E}_t\left[\underset{T\to\infty}{lim}\sum_{T=0}^{\infty}\beta_{(t,t+T)}\mathbb{E}_t\left[p_{t+T}\right]\right] \\ &= \mathbb{E}_t\left[\sum_{i=1}^{\infty}\beta_{(t,t+i)}r_{t+i}\right] \end{aligned} \tag{2}$$

where the second term drops out in the first line of (2) from standard transversality condition.

In my analysis, I embed imperfect information in the PV model as follows: agents receive noisy information about future fundamentals, in part correct and in part wrong. In other words, the process of rents is subject to anticipated shocks. Notice that, whereas the identification strategy employs a wide horizon (40 quarters, i.e. 10 years), I present the simplest possible structure for the rent process for the sake of clarity: the fundamental shock is anticipated only one period ahead:

$$r_t = r_{t-1} + f_{t-1} \tag{3}$$

Agents cannot directly observe the anticipated fundamental shock, but just a noisy signal of it, which is the sum of two orthogonal gaussian white noise components:

$$s_t = f_t + n_t \qquad f_t \perp n_t \tag{4}$$

$$\sigma_s^2 = \sigma_f^2 + \sigma_n^2 \tag{5}$$

where f_t is the *news shock*, an anticipated shock to rents which will be materialized (f stands for fundamental). The other component of the signal is the *noise shock* n_t, a shock to rents anticipated but not actually realized. It is key that the news shock f_t has a delayed impact on rents so that agents cannot disentangle the two components of the signal contemporaneously. They will only be able to draw information about the composition of the past signal s_{t-1} by observing the dynamics of rents r_t. In fact, $\Delta r_t = f_{t-1}$ meaning that the dynamics of rents is affected only by news but not by noise.

Nonetheless, the identification strategy that I apply in Section 2.1 does not impose so strict assumptions as the PV model in eq.(2) but it is way more general. In particular, the identification allows for both rational and irrational components. Other potential relevant features are time varying discount factors and risk premia.[12]

In the PV model, the signal is exactly the housing price today that reflects the expectations of future rents, a mixture of news and noise: $s_t = p_t$. I apply this idea in what I call the *Direct Approach*. This approach may neglect some potentially important issues that arise from the peculiarities of housing. For example, due to borrowing constraints and transaction costs the no arbitrage assumption might not be satisfied. Therefore, I depart from the assumption that HP constantly reflect expectations of future rents in what I define the *Indirect Approach* (in Appendix A). In this case, I capture expectations in the housing market through a survey on housing price expectations and new housing permits. The Direct Approach and the Indirect Approach yield very similar results. Other potentially relevant issues are the time to build in the residential investment and the segmentation between rental and built-to-buy market.[13] Notice that the identification strategy will rely on a ten-year horizon, over which these issues can be reasonably considered as uninfluential.

2.1 Identification Strategy

Blanchard et al. (2013) show that it is not possible to disentangle permanent news, transitory news, and noise components in a standard VAR framework. On the other hand, by simplifying the informational structure, Forni et al. (2014, 2016) argue that it is possible to disentangle news and noise by using a non-standard identification scheme. The reason why standard VARs fail is

[12] I (imperfectly) account for the former by including the FFR in the VAR, while I do not explicitly control for the latter.

[13] The time to build in the US is relatively short compared to other countries.

that the identification of structural shocks as a linear combination of present and past reduced form residual leads to a non-fundamentalness problem. Economic agents cannot contemporaneously distinguish news and noise and the same holds for the econometrician.[14] Forni et al. (2014, 2016) develop instead a three step procedure that employs future information, outside agents' information set. The first step involves the standard estimation of a VAR and the Choleski decomposition to identify the *fundamental surprise shock* and the *signal shock* (fundamental MA representation).[15] In the second step, they estimate the ratio of variances of news and noise and the third step employs dynamic rotations of reduced form residuals to identify news and noise (structural MA representation).

The *Forni, Lippi, Gambetti, and Sala* Methodology

I describe briefly the methodology of Forni et al. (2014, 2016) for the bivariate case.[16] First, I present a simple case, in which the fundamental news shock is anticipated one period ahead, to provide intuitively the mechanism behind the identification and then I describe a more general case. Notice that the actual identification employs (rents at) 40 quarters as the horizon to determine whether a shock to the signal is fundamental or noisy.

If we consider eq.(3) and (4) in a MA representation

$$\begin{pmatrix} \Delta r_t \\ s_t \end{pmatrix} = \begin{pmatrix} L & 0 \\ 1 & 1 \end{pmatrix} \begin{pmatrix} f_t \\ n_t \end{pmatrix} \tag{6}$$

it is trivial to see that the associated matrix has determinant 0 for $L = 0$ (comes from the lagged impact of the news shock). Therefore, the MA representation is non-fundamental and

[14] Enders et al. (2013) use nowcast errors about output growth to identify noise shocks to consumer sentiment. Dees and Zimic (2014) use nowcast error about output growth and forecast errors about trend output to identify news and noise. Each identification has its own pros and cons, but in the case of the housing market, the methodology I am using is the only possible one due the data required to implement Dees and Zimic (2014).

[15] Notice that fundamental in a time series framework means that the determinant of the matrix associated to the MA representation has no roots smaller than 1 in modulus. This is different from fundamentals in economic sense, e.g. the fundamentals of housing are rents.

[16] For a more detailed account, see Forni et al. (2014, 2016) and Lippi and Reichelin (1994). Mertens and Ravn (2010) show an application to fiscal policy.

non-invertible. In this case, noise and news shock cannot be expressed as a linear combination of present and past reduced form residuals. Thus, a VAR representation in the *structural shocks*, news and noise, does not exist. Intuitively, agents cannot distinguish the two shocks given their information set and the same holds for the econometrician. Adding other variables to the system cannot solve this issue. What the econometrician can recover is the following *fundamental representation*

$$\begin{pmatrix} \Delta r_t \\ s_t \end{pmatrix} = \begin{pmatrix} 1 & L\frac{\sigma_f^2}{\sigma_s^2} \\ 0 & 1 \end{pmatrix} \begin{pmatrix} u_t \\ s_t \end{pmatrix} = \begin{pmatrix} u_t + L\frac{\sigma_f^2}{\sigma_s^2} s_t \\ s_t \end{pmatrix} \tag{7}$$

where u_t can be defined as *unanticipated fundamental shock.* The signal extraction problem depends on the relative importance of the news and noise shocks in driving the signal: $\mathbb{E}_{t-1}(\Delta r_t) = \frac{\sigma_f^2}{\sigma_s^2} s_{t-1}$. In other words, u_t is the forecast error of the fundamental:

$$u_t = \Delta r_t - \mathbb{E}_{t-1}(\Delta r_t) = \ f_{t-1} - \frac{\sigma_f^2}{\sigma_s^2} s_{t-1} = \ \frac{\sigma_n^2}{\sigma_s^2} f_{t-1} - \frac{\sigma_f^2}{\sigma_s^2} n_{t-1} \tag{8}$$

We can express $\begin{pmatrix} u_t \\ s_t \end{pmatrix}$ as combinations of present and past structural shocks $\begin{pmatrix} f_t \\ n_t \end{pmatrix}$:

$$\begin{pmatrix} u_t \\ s_t \end{pmatrix} = \begin{pmatrix} L\frac{\sigma_n^2}{\sigma_s^2} & -L\frac{\sigma_f^2}{\sigma_s^2} \\ 1 & 1 \end{pmatrix} \begin{pmatrix} f_t \\ n_t \end{pmatrix} = \begin{pmatrix} \frac{\sigma_n^2}{\sigma_s^2} f_{t-1} - \frac{\sigma_f^2}{\sigma_s^2} n_{t-1} \\ f_t + n_t \end{pmatrix} \tag{9}$$

$\begin{pmatrix} u_t \\ s_t \end{pmatrix}$ can be identified through a standard VAR and, once the news to noise variance ratio is estimated, we can use this information to recover $\begin{pmatrix} f_t \\ n_t \end{pmatrix}$ as follows:

$$\begin{pmatrix} f_t \\ n_t \end{pmatrix} = \begin{pmatrix} L^{-1} & \frac{\sigma_f^2}{\sigma_s^2} \\ -L^{-1} & \frac{\sigma_n^2}{\sigma_s^2} \end{pmatrix} \begin{pmatrix} u_t \\ s_t \end{pmatrix} = \begin{pmatrix} L^{-1}u_t + & \frac{\sigma_f^2}{\sigma_s^2} s_t \\ -L^{-1}u_t + & \frac{\sigma_n^2}{\sigma_s^2} s_t \end{pmatrix} = \begin{pmatrix} u_{t+1} + & \frac{\sigma_f^2}{\sigma_s^2} s_t \\ -u_{t+1} + & \frac{\sigma_n^2}{\sigma_s^2} s_t \end{pmatrix} \tag{10}$$

Notice that by inverting L we are employing present and *future* values of the unanticipated fundamental and signal shocks, which, in other words, means we are using future reduced form residuals.[17]

The news shock can be expressed and thus recovered as the sum of the ex-ante expectation of the fundamental and the realized forecast-error of the fundamental:

$$f_t = u_{t+1} + \frac{\sigma_f^2}{\sigma_s^2} s_t \quad = \quad \Delta r_{t+1} - \frac{\sigma_f^2}{\sigma_s^2} s_t + \frac{\sigma_f^2}{\sigma_s^2} s_t = \Delta r_{t+1} \tag{11}$$

The noise shocks is instead the component of the signal that is not reflected in future changes of the fundamental:

$$n_t = -u_{t+1} + \frac{\sigma_n^2}{\sigma_s^2} s_t \quad = - \quad \Delta r_{t+1} + \frac{\sigma_f^2}{\sigma_s^2} s_t + \frac{\sigma_n^2}{\sigma_s^2} s_t = s_t - \Delta r_{t+1} \tag{12}$$

Consider a more comprehensive case, using a more general polynomial structure for the bivariate case (it is very easy to extend the scheme to the multivariate case). We define

$$\Delta r_t = c(L) f_t \tag{13}$$

and the Blaschke factor

$$b(L) = \prod_{j=1}^{n} \frac{L - k_j}{1 - \overline{k_j} L} \tag{14}$$

[17] This is quite intuitive: as $\begin{pmatrix} u_t \\ s_t \end{pmatrix}$ are combinations of present and past structural shocks $\begin{pmatrix} f_t \\ n_t \end{pmatrix}$, than $\begin{pmatrix} f_t \\ n_t \end{pmatrix}$ are combinations of present and future structural shocks $\begin{pmatrix} u_t \\ s_t \end{pmatrix}$.

with k_j $j = 1, 2, ..., n$ are the roots of c(L) smaller than one in modulus with $\bar{k}_j$ the respective complex conjugates. Following Lippi and Reichelin (1994), it is not possible to invert $b(L)$ in the past, but it is possible in the future: $b(L)^{-1} = b(L^{-1}) = b(F)$.

$$\begin{pmatrix} \Delta r_t \\ s_t \end{pmatrix} = \begin{pmatrix} a_{11}(L) & a_{12}(L) \\ a_{21}(L) & a_{22}(L) \end{pmatrix} \begin{pmatrix} u_t \\ s_t \end{pmatrix} = \begin{pmatrix} \frac{c(L)}{b(L)} & c(L)\frac{\sigma_f^2}{\sigma_s^2} \\ 0 & 1 \end{pmatrix} \begin{pmatrix} u_t \\ s_t \end{pmatrix} \tag{15}$$

$$\begin{pmatrix} u_t \\ s_t \end{pmatrix} = \begin{pmatrix} b(L)\frac{\sigma_n^2}{\sigma_s^2} & -b(L)\frac{\sigma_f^2}{\sigma_s^2} \\ 1 & 1 \end{pmatrix} \begin{pmatrix} f_t \\ s_t \end{pmatrix} \tag{16}$$

We can generalize the system by assuming that, even if the agents' expectations are not perfectly observable, the econometrician has access to a variable informative enough about the signal (z_t). The following steps exploit the relationship $\sigma_u = \frac{\sigma_f \sigma_n}{\sigma_s}$:

$$\begin{aligned}
\begin{pmatrix} \Delta r_t \\ z_t \end{pmatrix} &= \begin{pmatrix} a_{11}(L) & a_{12}(L) \\ a_{21}(L) & a_{22}(L) \end{pmatrix} \begin{pmatrix} \frac{u_t}{\sigma_u} \\ \frac{s_t}{\sigma_s} \end{pmatrix} = \begin{pmatrix} \frac{c(L)\sigma_u}{b(L)} & \frac{c(L)\sigma_f^2}{\sigma_s} \\ d(L)\sigma_u & f(L)\sigma_s \end{pmatrix} \begin{pmatrix} \frac{u_t}{\sigma_u} \\ \frac{s_t}{\sigma_s} \end{pmatrix} \\
&= \begin{pmatrix} \frac{c(L)\sigma_u}{b(L)} & \frac{c(L)\sigma_f^2}{\sigma_s} \\ d(L)\sigma_u & f(L)\sigma_s \end{pmatrix} \begin{pmatrix} b(L)\frac{\sigma_n}{\sigma_s} & -b(L)\frac{\sigma_f}{\sigma_s} \\ \frac{\sigma_f}{\sigma_s} & \frac{\sigma_n}{\sigma_s} \end{pmatrix} \begin{pmatrix} \frac{f_t}{\sigma_f} \\ \frac{n_t}{\sigma_n} \end{pmatrix} \\
&= \begin{pmatrix} c(L)\sigma_f & 0 \\ d(L)b(L)\frac{\sigma_f\sigma_n^2}{\sigma_s^2} + f(L)\sigma_f & -b(L)d(L)\frac{\sigma_f^2\sigma_n}{\sigma_s^2} + f(L)\sigma_n \end{pmatrix} \begin{pmatrix} \frac{f_t}{\sigma_f} \\ \frac{n_t}{\sigma_n} \end{pmatrix}
\end{aligned}$$

I formally explain the generalization of the identification to the multivariate case in Appendix C. In a more descriptive fashion, the identification in the multivariate case relies on the following assumptions: I) f_t is a news shock; II) the noise shock n_t does not affect rents at any lag; III) the signal shock is a sum of news and noise shocks; IV) additional shocks affects rents only with a lag and are observed. Moreover, notice that II) is imposed on impact and as a long run restriction (cumulatively over 40 quarters) but it is employed for testing the goodness of the identification assumptions at any other horizon. In other words, we can check ex-post that the noise shock does not have any significant impact on rents at any horizon (Fig. 4). For what concerns the plausibility of IV), rents are a slow moving variable since contracts are usually annual.[18] Furthermore, Forni et al. (2016) test the identification through Monte Carlo simulations for a variety of data generating processes. They show that: (a) the identification recovers the true IRFs without other active shocks; (b) if other shocks not observed by agents hit the fundamental but their variance is small relative to the news shock, the estimation still recovers the true IRFs; (c) if other shocks not observed by agents hit the fundamental and their variance is bigger than the variance of the news shock , the estimated IRFs are biased. Nonetheless, in this case the noise shock affects the fundamental and thus the diagnostic check, implied by II), will reject the validity of the identifying assumptions. The same diagnostic would reject the restriction II) in case temporary fundamental shocks are a relevant driver of the fundamental. In fact, they would be (wrongly) captured by the noise shock but have a significant impact on rents. Finally, the identification does not impose any restriction on the response of the signal (HP) at any horizon, both for the news and noise shock.

More precisely, the identification strategy comprises of the following steps (in the bivariate case):

Step 1: Estimate a standard VAR for $\begin{pmatrix} \Delta r_t \\ z_t \end{pmatrix}$ and obtain the corresponding MA representation

Step 2: $a_{12}(0) = \frac{c(0)\sigma_u}{b(0)} = 0 \Rightarrow c(0) = 0$. This restriction implies that the signal does not affect the fundamental measure contemporaneously. Unanticipated fundamental and signal shocks are identified at this point for the bivariate case.

Step 3: Given the estimate $\hat{a}_{12}(L) = \frac{\widehat{c(L)\sigma_f^2}}{\sigma_s}$ take the roots of $\hat{a}_{12}(L)$ smaller than one in modulus in order to estimate $b(L)$ as shown in (14)

Step 4: $\hat{a}_{11}(1)$ is estimated as $\frac{\widehat{c(1)\sigma_u}}{b(1)}$. Notice that since $b(1) = 1$ and $\sigma_u = \frac{\sigma_f \sigma_n}{\sigma_s}$, the following condition holds for the ratio of variances of news and noise shocks: $\frac{a_{12}(1)}{a_{11}(1)} = \frac{\sigma_f}{\sigma_n}$ estimated

[18]See Duarte and Dias (2015).

as $\frac{\hat{a}_{12}(1)}{\hat{a}_{11}(1)} = \frac{\widehat{\sigma_f}}{\sigma_n}$. [19]

Step 5: Since $\frac{\sigma_f^2}{\sigma_s^2} + \frac{\sigma_n^2}{\sigma_s^2} = 1$, $\widehat{\sigma_f} = sin(arctan(\frac{\widehat{\sigma_f}}{\sigma_n}))$ and $\widehat{\sigma_n} = cos(arctan(\frac{\widehat{\sigma_f}}{\sigma_n}))$ can be directly computed. At this point the variance of the news and noise shock is identified.

Step 6: Finally, using $\begin{pmatrix} f_t \\ n_t \end{pmatrix} = \begin{pmatrix} b(F)\frac{\sigma_n}{\sigma_s} & \frac{\sigma_f^2}{\sigma_s^2} \\ -b(F) & \frac{\sigma_n^2}{\sigma_s^2} \end{pmatrix} \begin{pmatrix} u_t \\ s_t \end{pmatrix}$ one can recover the structural shocks.

3 Empirics

3.1 Data Description

I employ US quarterly national data from 1960 Q1 - 2011 Q1. I include the following variables in a VAR: (log) GDP (Real Gross Domestic Product - GDPC1), (log) residential investment (Real Private Residential Fixed Investment - PRFIC1), FFR (Effective Federal Funds Rate - FEDFUNDS),[20] (log) Stock Prices (S&P 500) and (log) PCE (personal consumption expenditures) Rents .[21]

In the baseline specification, I employ the (log) Census Bureau *Median Sales Price for New Houses Sold* (MSPNHSUS) and (log) *Average sales price of houses sold* (ASPUS) both available at FRED. [22]

[19] In practice, the ratio $\frac{\widehat{\sigma_f}}{\sigma_n}$ is computed as the ratio of the cumulated long-run responses $\frac{CIRF(\Delta r_t to\, s_t)}{CIRF(\Delta r_t to\, u_t)}$. Notice that the theoretical restriction of a null effect of the noise shock on the fundamental should hold at every horizon. In practice, this is imposed on impact and in the long-run (40 quarters), but it is used for testing at the other horizons (noise has no significant effect on the fundamental at each horizon).

[20] downloaded from FRED

[21] Stock Prices (S&P 500) and PCE Rents (US SVS,HSLD CNSMPT.EXPNDS(FOR SVS),HSG.& UTLYS., HSG., RNT. SADJ) are downloaded from Datastream. Similar results hold for CPI Rents.

[22] The same results hold by using the HPI downloadable from R. J. Shiller's website from the book "Irrational Exuberance" (2nd edition) which aggregates different sources for different periods. I take the nominal series and I deflate it with the IPD for the non-farm business sector, obtaining a series labeled as SHPI henceforth. SHPI aggregates different sources until the *Case&Shiller HPI* becomes available (1987). *Case&Shiller HPI* is a repeated sale index that controls for the quality of housing units traded. Thus, it is somehow a noisier series even if it has the advantage of being a better indicator from 1987 onward. The results with this alternative HP series are presented in Appendix A.

3.2 VAR - Direct and Indirect Approach

As a natural implication of asset pricing, I consider HP as the signal of expectations of future rents (*Direct Approach*). In other words, HP are assumed to incorporate new information about rents which becomes available to agents. In an alternative identification scheme that I call the *Indirect Approach*, I relax this assumption and I do not impose the PV relationship explicitly (results in Appendix A). In this case, the signal is a principal component from "New Housing Starts" and the answer to the question in the Michigan Survey "It is a good time to buy housing? - Is housing a good investment?". As an additional robustness check, I also report in Appendix A results obtained using the *Home Constructors Stock Price Index* as signal (on a restricted sample). This means that the News-Noise shocks are captured by the segment of the stock market more closely related with the housing market.

In the *Direct Approach*, the variables included in the VAR are **[Rents, Census HPI, GDP, Residential Investment, FFR, S&P 500]**. It might be argued that asset prices such as HP should contemporaneously react to the other variables and therefore results are reported also with the following ordering **[Rents, GDP, Residential Investment, FFR, Census HPI, S&P 500]**.

The VAR is estimated in (log-)levels by OLS without explicitly modeling the possible cointegration relations among the variables. Sims et al. (1990) have shown that this procedure yield consistent estimates, whereas VECM may introduce biases in case the assumed cointegration relationship is not the actual one. The optimal number of lags is two as consistently suggested through AIC, BIC, and HQC criteria.[23]

3.2.1 Testing identified shocks

I test the orthogonality of the identified shocks to agents' information sets by following Forni and Gambetti (2011). The test consists of regressing the identified shocks on lagged values of principal components (PCs) from a large macroeconomic dataset and checking that none of the PC is significant. As reported in Table 1A and Table 2A (Appendix), all the values reported are

[23] Similar results hold with also with three lags, with a loss in statistical significance

indeed bigger than 0.1 and therefore the identified shocks are exogenous with respect to the current information set.

3.2.2 Impulse Responses and Variance Decomposition

Figure 3 report the IRFs to the fundamental unanticipated shock and to the signal shocks. The forecast error shock generates a permanent effect on Rents, HP, GDP and SP. There is no significant effect on the FFR and Residential Investment as the latter time series is very particular. In fact, Residential Investment is not characterized by a trend as cyclical fluctuations dominate every other component of the time series. This is why I never observe a permanent change in this variable. The signal shock predicts future growth in Rents, GDP and stock prices because it incorporates news. Generally, the signal is more relevant in the short-run, whereas the fundamental unanticipated shock is dominant at the medium-long term.

Figure 4 shows the IRFs to news and noise shocks. First, the noise shock does not have any significant effect on the fundamental variable. This is a positive test for the identification strategy and it is related to the assumption that the fundamental allows to infer the past values of news and noise. Conversely, the news shock has a lagged but persistent effect on Rents. The lagged response of rents after the news shock is another good indication of the identification. The news shock is constrained to have a delayed effect on rents (0 on impact). The fact that Rents do not jump immediately after the shock means that the identification is supported by the data. Finally, consider the potential bias that may arise from transitory fundamental shocks. These kind of shocks are neglected in this identification strategy but, if relevant, they would still be captured by the noise shock. The reason lies in the fact that also transitory fundamental shocks have zero long run effect on rents, but, differently from the noise shock itself, they should affect rents at intermediate horizons. Given that noise shocks have no relevant effect on rents at any horizon, we can conclude that identified noise shock does not contain also transitory fundamental shocks.

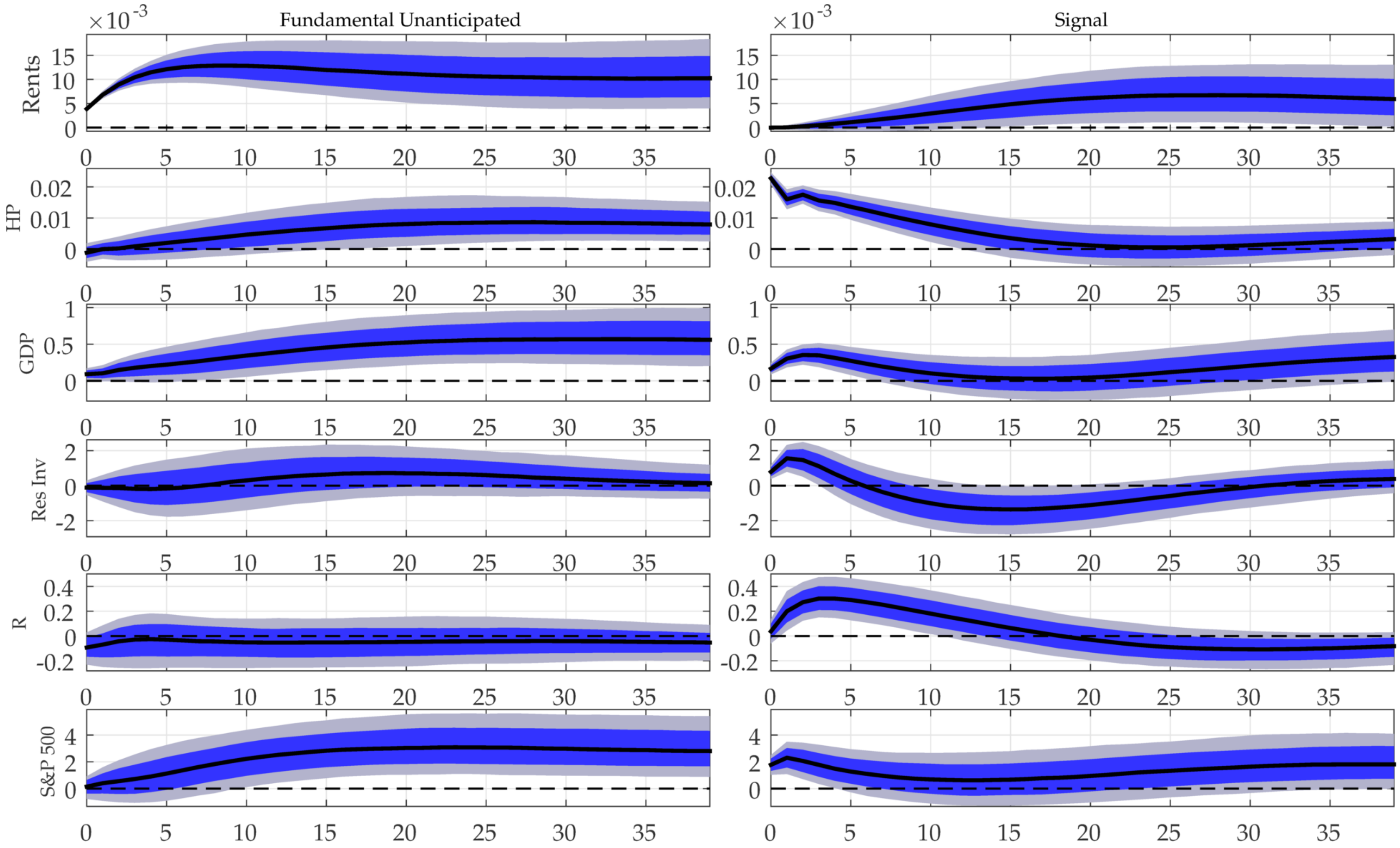

FIGURE 3: *IRFs to fundamental unanticipated and signal shocks. The solid black line is the median, the dark and light blue shaded areas represents 68% and 90% confidence bands respectively (2000 bootstrap replications). The shocks are identified through the following ordering: [Rents, HP, GDP, Res Investment, R, S&P 500]*

Regarding the economic intuition, let us consider an agent that receives information on a future increase in rents. There is now an incentive to buy a house as renting will be more expensive tomorrow relative to today. Therefore, this will induce a downward pressure on Rents (the point estimated IRF is even negative). Then, the news shock is materialized and Rents grow. As a result, the increase in Rents occurs slowly after the shock and the IRFs seem to be even negative around the impact period. Another feature that should be noticed is that the news shock to the Rents has the same permanent effect on GDP and SP, meaning that the fundamentals in the housing market are in line with (or determined by) the macroeconomy.

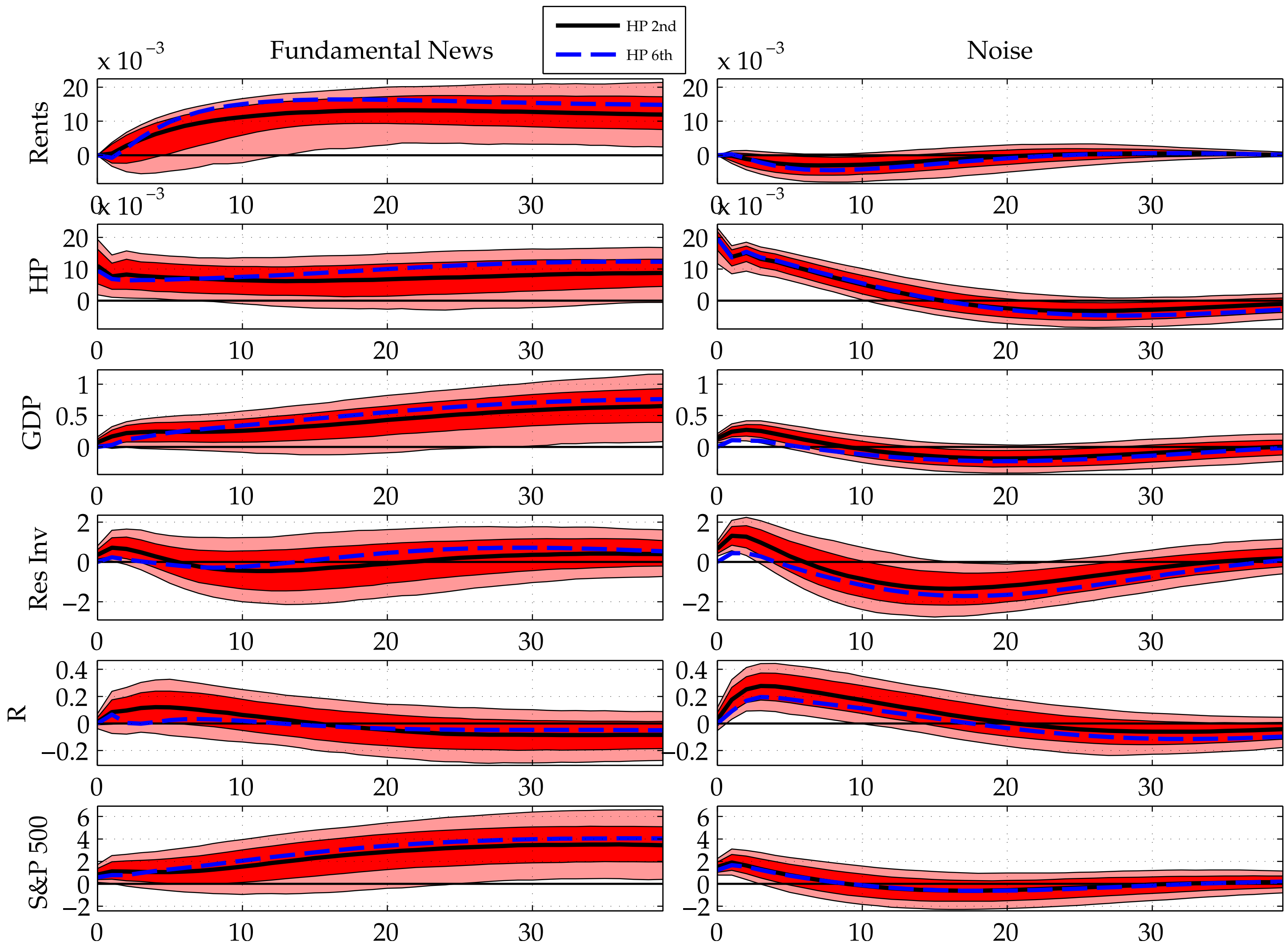

FIGURE 4: *IRFs to news and noise shocks. The solid black line, the red and light red shaded areas represent the median, 68% and 90% confidence bands respectively (2000 bootstrap replications) with the following ordering: [Rents, HP, GDP, Res Investment, R, S&P 500]. The dotted blue line corresponds to the median IRFs with the following ordering: [Rents, GDP, Res Investment, R, HP, S&P 500]*

The news shock also generates a permanent effect on HP, as implied by the PV relationship. On the other hand, the noise shock is stronger on impact. The noise shock appears to be more important in the first 7 quarters, as reported by the variance decomposition in Figure 4. On the other hand, after 15 quarters the effect of noise dies out and the effect of news becomes dominant. Notice that HP are even below their initial level for a few quarters after a noise shock. The responses of HP and Rents are consistent with the long-run co-movement but short-term divergence observed in the data (Fig. 1-2). Similar dynamics are shared by GDP, Residential Investment and Stock Prices. The overshooting can be interpreted as the bust which follows the boom in the first quarters after the noise shocks: when the fundamental does not increase as expected, the economy has to adjust. Particularly striking is the case of Residential Investment: after the news shock there is a moderate increase, whereas the reaction is even stronger in the first quarters after the noise shock. In the former case, Residential Investment goes back to the initial level, whereas in the latter there is a strong and prolonged bust. In fact, the noise shock has the lion's share of the FEV for Residential Investment.

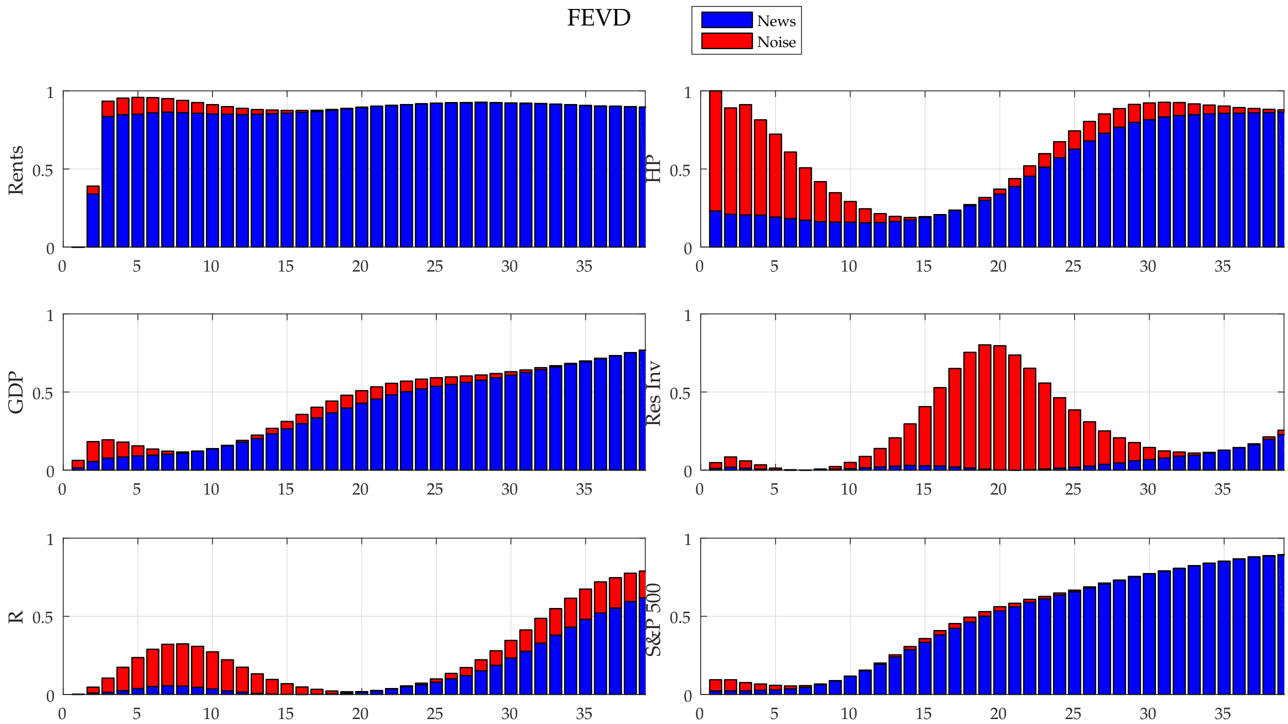

FIGURE 5: *Variance Decomposition - share of the variance explained by News and Noise at each quarter (not cumulative)*

3.2.3 Historical Decomposition

In historical terms, noise is a major component in most of the cycles in the sample. This is true for both the housing market (Fig. 6) and output fluctuations in the US economy (Fig. 7): the episodes in the '70s, mid '80s and the Big Recession are characterized by a strong noisy component. I report the historical decomposition both with Census HPI and Shiller's series (SHPI) (Fig. 8). In the latter case, the results are striking. Notice that the component labeled as "Other" should not be interpreted as fundamental component but only has the residual not explained by the noise shock.

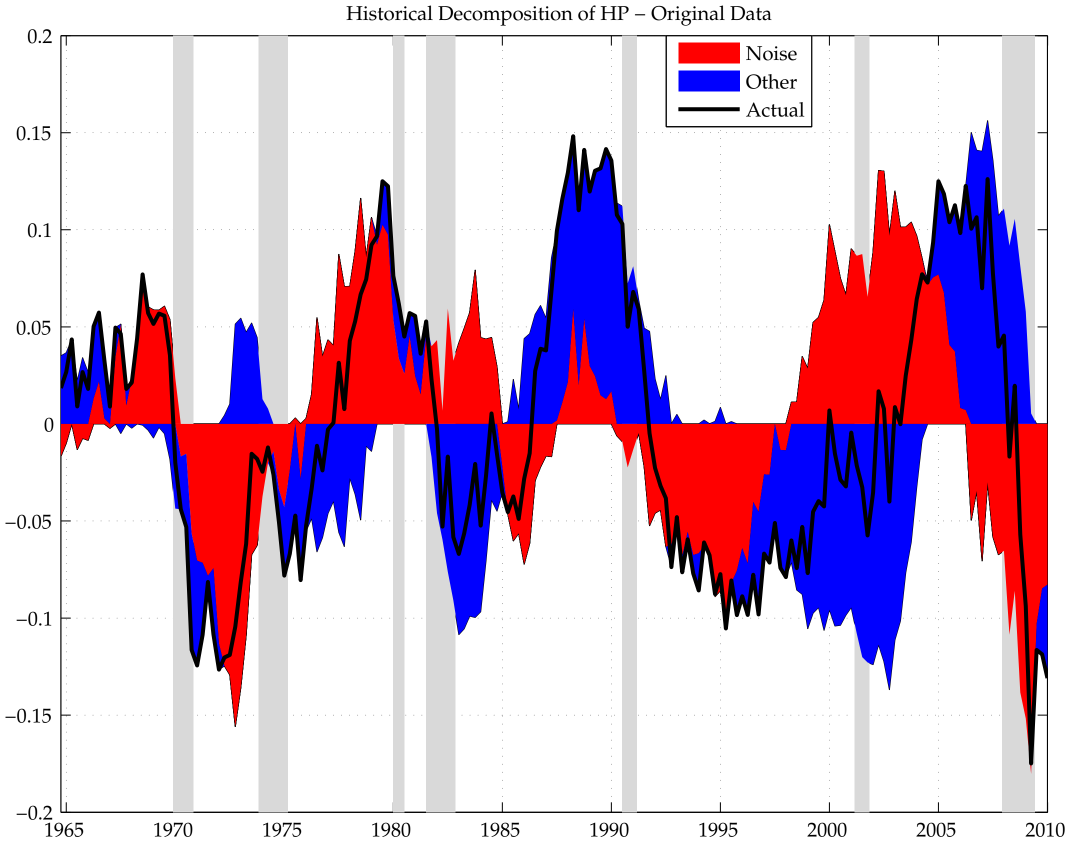

Figure 6: *Historical decomposition of Census HPI in deviation from the trend (solid black line) into the noisy component (red) and residual component (blue)*

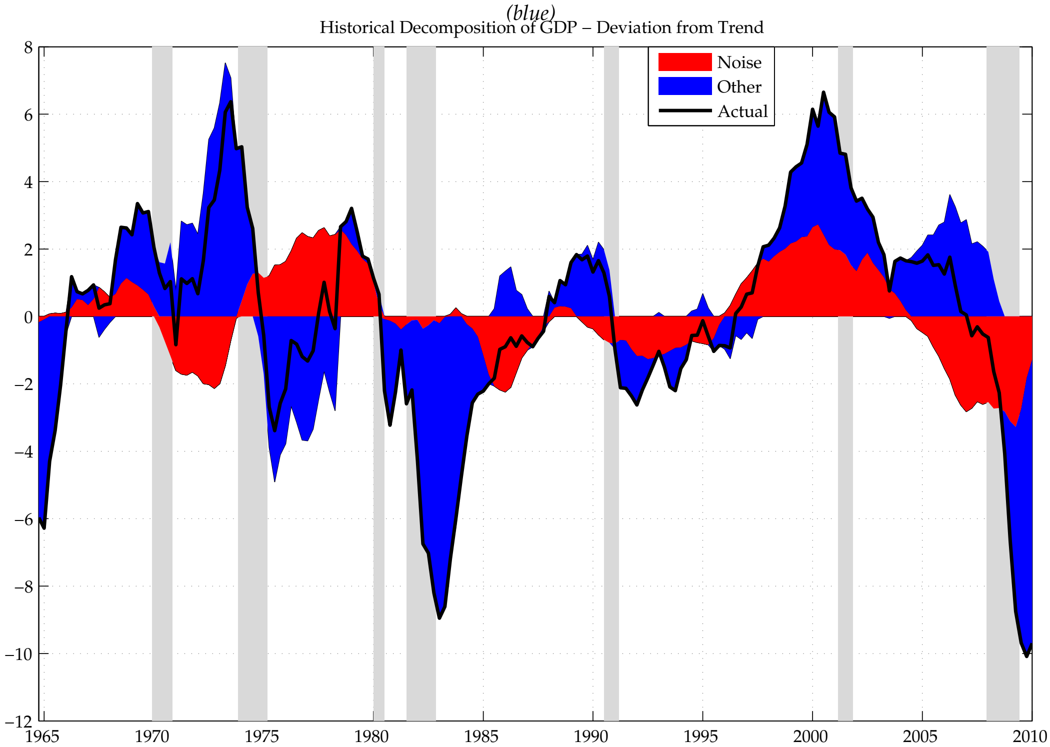

Figure 7: *Historical decomposition of real-log GDP in deviation from the trend (solid black line) into the noisy component (red) and residual component (blue)*

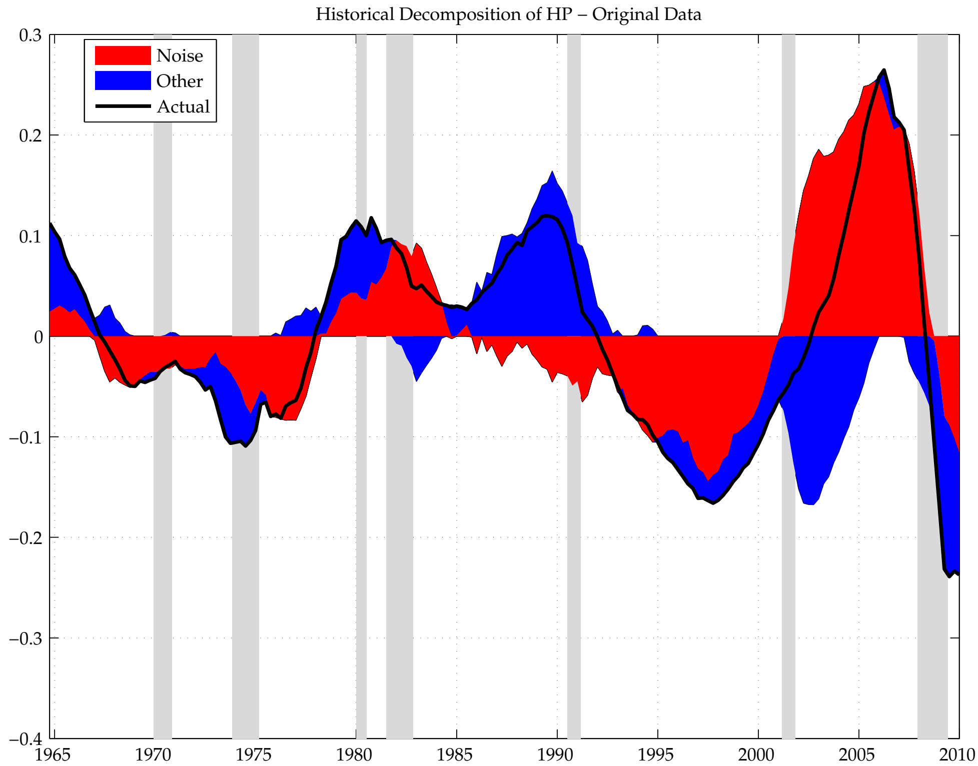

Figure 8: *Historical decomposition of the SHPI in deviation from trend (solid black) into the noisy component (red) and residual component (blue)*

3.2.4 Identified Shocks and Historical Episodes

In order to improve the readability of the plot, I report the yearly moving average of the identified shocks. The graph shows that the most sizable shocks identified match some important historical events.

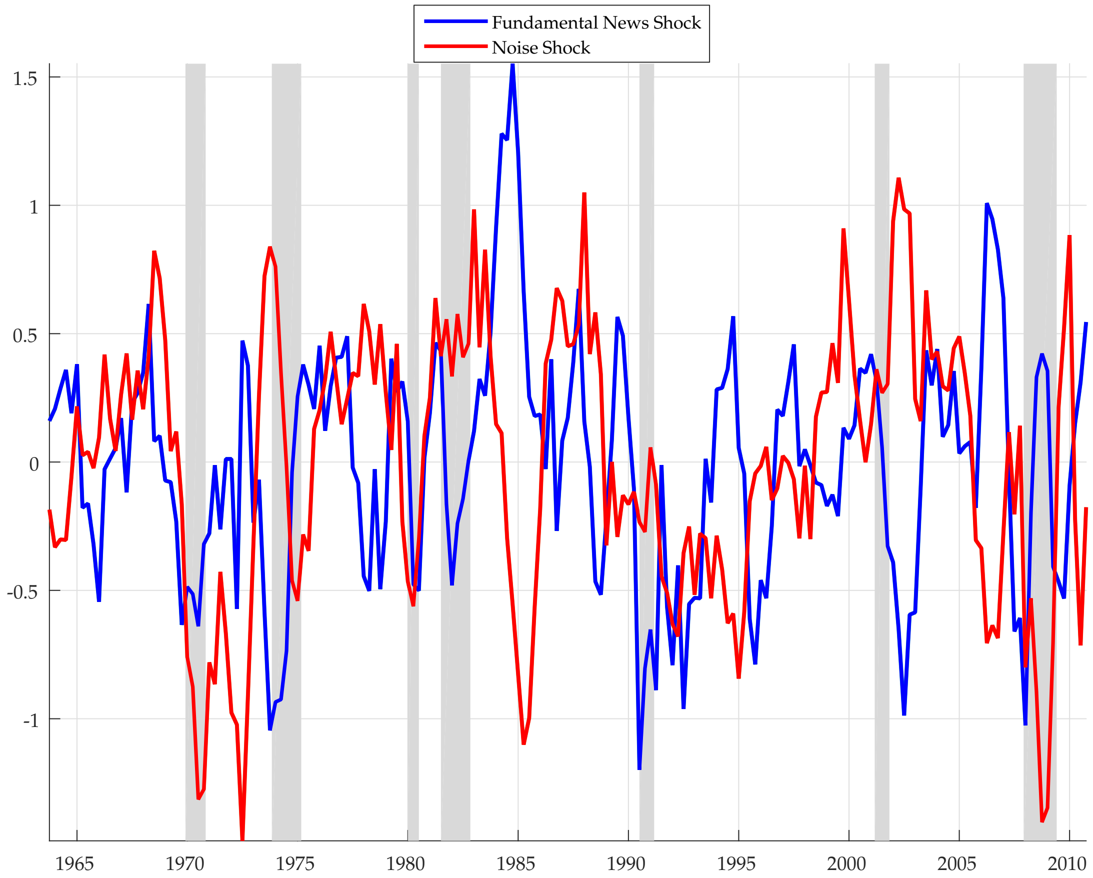

FIGURE 9: *Identified Shocks and NBER Recessions - yearly MA*

Basically, all the NBER recessions are matched by negative news shocks, with the exception of the Big Recession that is accompanied by the second biggest noise shock. Another period is characterized by a relevant sequence of noise shocks going from the recession of 1969-70 to the first oil shock in 1973. Finally, in the mid '80s we observe a sequence of sizable news and noise shocks. These shocks are arguably related to some important changes occurring in the US in that period: financial liberalization, a relaxation of the regulation of mortgages-related interest rates (1980-86), and a new legislation much more favorable to home ownership (1980-86).[24]

In this empirical section we have seen that both news and noise shocks matter in the US housing market. The former explains the bulk of variation in HP, GDP, and Residential Investment at

[24] https://www.fdic.gov/bank/historical/history/137_165.pdf In particular, the *Economic Recovery Tax Act* of 1981 introduced the *"Accelerated Cost Recovery System"* that changed the regulation concerning the depreciation of property. The *"Modified Accelerated Cost Recovery System"* (MACRS) replaced ACRS for property placed into service after 1986. Finally, the *Tax Reform Act* of 1986 improved the tax deductability of home mortgages.

low frequencies, whereas the latter is the dominant component at high (and medium) frequencies. Moreover, noise shocks produce the boom-bust cycles observed in the housing market and with strong recessionary effects for American economy. In fact, many fluctuations in HP that we have historically observed are characterized by an important noisy component. Furthermore, the identified news and noise shocks are consistent with historical events concerning economics or politics.

4 Theoretical Model

In this section, I show that the rents-based asset pricing of housing arises naturally in a model à la Iacoviello. Specifically, I consider the empirically validated model of Iacoviello and Neri (2010) and I add a rental market in which Savers and Borrowers exchange housing services. The model incorporates imperfect information: agents receive signal shocks about future housing preferences that are partially realized (news) and partially not realized (noise). Instead of introducing news-noise shocks *ad-hoc*, I rely on the empirical results of Section 3 for my simulations. While the empirical analysis in Section 3 can accommodate both rational and irrational components, the model in Section 4 relies exclusively on rational expectations under limited information. Therefore, we may consider the model as a test of the rational expectation hypothesis under limited information. On the one hand, given the available noisy information on future fundamentals, the model can implicitly test whether rational expectation can replicate the empirical patterns. On the other hand, the model cannot assess whether agents perceive the available information in a rational way (i.e. how the signal is shaped).

4.1 A DSGE Model with a Rental Market

The economy is populated by two types of households, Savers and Borrowers, who are characterized by different discount factors. Savers consume, work, accumulate capital and housing; they own the representative firm and the labor unions. Borrowers consume, work, accumulate housing and debt. The novelty comes from the rental market for housing, in a fashion very similar to Mora-Sanguinetti and Rubio (2014): the Saver can rent out a share of the housing he owns to the Borrower. I introduce imperfect information in the form of a signal about the future housing preferences.

4.1.1 Saver

The problem of the Saver is to maximize utility which depends on consumption (subject to habits), housing services (weighted by h_t) and labor supply in the consumption sector and in the housing sector. The Saver owns capital in both sector, part of the housing stock, and lends to the Borrower through a one period bond denominated in nominal terms. He also owns the firm and labor unions from which obtains dividends. As usual, capital is rented to the firm in exchange for a return but, additionally, the Saver can also rent out part of the housing stock He owns to the Borrower in exchange for rents.

$$\begin{aligned}
\max \quad & \mathbb{E}_0 \sum_{t=0}^{+\infty} \beta_s^t \left(log\ \left(C_t^s - \epsilon_s C_{t-1}^s\right) + h_t log\left(H_t^o\right) - \frac{1}{1+\eta}\left(\left(n_t^{sc}\right)^{1+\xi_s} + \left(n_t^{sh}\right)^{1+\xi_s}\right)^{\frac{1+\eta}{1+\xi_s}}\right. \\
s.t. \quad & C_t^s + k_t^c + k_t^h + k_t^b + p_t^l l_t + q_t^h\left(H_{s,t}^o - (1-\delta)\, H_{s,t-1}^o + H_t^r - (1-\delta)\, H_{t-1}^r\right) - B_t + \Phi_t = \\
& k_{t-1}^c\left(1 + r_t^c - \delta_c\right) + k_{t-1}^h\left(1 + r_t^h - \delta_h\right) + p_t^b k_t^b + \left(p_t^l + r_t^l\right) l_{t-1} \\
& + \frac{w_t^c n_t^{sc}}{X_t^{wc}} + \frac{w_t^h n_t^{sh}}{X_t^{wh}} - \frac{R_{t-1}B_{t-1}}{\pi_t^c} + q_t^r H_t^r + \Gamma_t + a(u_t^c) + a(u_t^h)
\end{aligned}$$

where C^s is consumption, $k^i\ i = c,\ h$ is capital in the consumption and housing, k^b are intermediate inputs in the housing sector. $r^i\ i = c,\ h,\ l$ are the rental rates of capital in the consumption, housing sector and land. $p_b,\ p_l$ stands for the price of intermediate inputs and of land, $H_s^O,\ H^r$ are the owner occupied and rented housing stock respectively priced at q^h but rented for q^r, l is land, B is the debt and R the nominal interest rate, $w^i n^i\ i = c,\ h$ is the labor income in the two sectors, divided by X_t^{wi} the markup in the labor market coming from labor unions, Φ is the investment adjustment cost and $a(u^i)\ i = c,\ h$ is a function of capacity utilization of capital, Γ represents profits from the representative firm and labor unions, π is inflation in the consumption sector.

$$FOC_{H^o_{s,t}} : \lambda^s_t q^h_t = \frac{h_t}{H^o_t} + \beta_s \left(1 - \delta_h\right) \mathbb{E}_t \left[\lambda^s_{t+1} q^h_{t+1}\right] \tag{17}$$

$$FOC_{H^r_{s,t}} : q^h_t = q^r_t + \beta_s \mathbb{E}_t \left[\left(1 - \delta_h\right) q^h_{t+1} \frac{\lambda^s_{t+1}}{\lambda^s_t}\right] \tag{18}$$

Eq. (17) is the standard optimality condition that equates the marginal cost of owning a unit of housing today to the marginal utility coming from an unit of housing. By combining (17) and (18) we obtain

$$q^r_t = \frac{h_t}{H^o_t}$$

which is the indifference condition between enjoying housing services or renting-out. By iterating forward eq. (17-18)

$$q^h_t = \mathbb{E}_t \left[\sum_{i=0}^{+\infty} \beta^s_{t,t+i} q^r_{t+i}\right] = \mathbb{E}_t \left[\sum_{i=0}^{+\infty} \beta^s_{t,t+i} h_t\right] \tag{19}$$

This is why expectations in housing preferences are equivalent to expectations of fundamentals with the advantage of carrying a structural interpretation, in this case a demand side one.

4.1.2 Borrower

The problem of the Borrower is to maximize utility which depends on consumption (subject to habits), housing services (weighted by h_t) and labor supply in the consumption sector and in the housing sector. The Saver only owns part of the housing stock which, due to limited liability, is the collateral that allows him to borrow from the Saver. The Loan-to-Value ratio (LTV) denominated m represents the inverse of the down-payment.

$$\max \ \mathbb{E}_0 \sum_{t=0}^{+\infty} \beta_b^t (log \ \left(C_t^b - \epsilon_b C_{t-1}^b \right) + h_t log \left(\widetilde{H_t^b} \right) \frac{1}{1+\eta} \left(\left(n_t^{bc} \right)^{1+\xi_b} + \left(n_t^{bh} \right)^{1+\xi_b} \right)^{\frac{1+\eta}{1+\xi_b}}$$

$$s.t. \qquad C_t^b + q_t^h (H_t^b - (1-\delta) H_{t-1}^b) + q_t^r H_t^r + \frac{R_{t-1} B_{t-1}}{\pi_t^c} = \frac{w_t^{bc} n_t^{bc}}{X_t^{wc}} + \frac{w_t^{bh} n_t^{bh}}{X_t^{wh}} + B_t$$

$$B_t \leq \mathbb{E}_t \left[\frac{m \, q_{t+1}^h H_t^b \pi_{t+1}}{R_t} \right]$$

where all the variables appearing in the optimization problem are the same as in the Saver's problem but with a different subscript. The only new variable is

$$\widetilde{H_t^b} = \left[\kappa \left(H_t^b \right) + (1-\kappa) \left(Z_t \right)^{\xi_h - 1} \right]^{\frac{1}{\xi_h - 1}} \tag{20}$$

meaning that the Borrower derives utility from a flow of housing services coming from the stock he owns and from the stock he rents from the Saver, aggregated through the CES.

$$FOC_{H_t^r} : \lambda_t^b q_t^r = \frac{h_t}{\widetilde{H_t^b}} \left[\kappa \left(H_t^b \right)^{\xi_h - 1} + (1-\kappa) \left(H_t^r \right)^{\xi_h - 1} \right]^{\frac{2-\xi_h}{\xi_h - 1}} (1-\kappa) \left(H_t^r \right)^{\xi_h - 2} \tag{21}$$

$$\begin{aligned} FOC_{H_{b,t}} : \ \lambda_t^b q_t^h = & \ \frac{h_t}{\widetilde{H_t^b}} \left[\kappa \left(H_t^b \right)^{\xi_h - 1} + (1-\kappa) \left(Z_t \right)^{\xi_h - 1} \right]^{\frac{2-\xi_h}{\xi_h - 1}} \kappa \left(H_t^b \right)^{\xi_h - 2} \\ & + \mathbb{E}_t \left[\frac{m \, q_{t+1}^h \pi_{t+1} \mu_t}{R_t} \right] + \beta_b \left(1 - \delta_h \right) \mathbb{E}_t \left[\lambda_t^b q_{t+1}^h \right] \end{aligned} \tag{22}$$

Eq. (21) is the intertemporal condition that equates the utility drawn from an addition rented housing unit to its cost. Eq. (22) concerns instead the owning decision. Differently from the Saver, the Borrower also takes into the collateral constraint that is always binding with the calibration employed here. We can rearrange (21) as

$$\frac{\lambda_t^b q_t^r}{(1-\kappa)(H_t^r)^{\xi_h - 2}} = \frac{h_t}{\widetilde{H_t^b}} \left[\kappa \left(H_t^b\right)^{\xi_h - 1} + (1-\kappa)(H_t^r)^{\xi_h - 1}\right]^{\frac{2-\xi_h}{\xi_h - 1}}$$

and by substituting in (22)

$$FOC_{H_{b,t}}: \ \lambda_t^b q_t^h = \frac{q_t^r}{C_t^b (1-\kappa)(H_t^r)^{\xi_h - 2}} \left(H_t^b\right)^{\xi_h - 2} + \mathbb{E}_t \left[q_{t+1}^h \left(\lambda_{t+1}^b \beta_b (1-\delta_h) + \frac{m\, \pi_{t+1} \mu_t}{R_t}\right)\right]$$

We can see that the Saver is the marginal investor as he is not subject to credit constraint as the Borrower.

4.1.3 Production and Nominal Frictions

The representative final good firm operates in the consumption sector under monopolistic competition (X_t is the markup) and in a perfectly competitive housing sector:

$$max\, \frac{Y_t}{X_t} + q_t IH_t - w_t^{sc} n_t^{sc} - w_t^{bc} n_t^{bc} - w_t^{sh} n_t^{bh} - w_t^{sh} n_t^{sh} - r_t^c u_t^c k_{t-1}^c - r_t^h u_t^h k_{t-1}^h - r_t^l l_{t-1} + p_t^b k_t^b$$

under the following technologies

$$Y_t = \left[z_t^c \left(n_t^{sc}\right)^{\alpha} \left(n_t^{bc}\right)^{1-\alpha}\right]^{1-\mu_c} \left(u_t^c k_{t-1}^c\right)^{\mu_c}$$

$$IH_t = \left[z_t^h \left(n_t^{sh}\right)^{\alpha} \left(n_t^{bh}\right)^{1-\alpha}\right]^{1-\mu_h-\mu_l-\mu_b} \left(u_t^h k_{t-1}^h\right)^{\mu_h} \left(k_t^b\right)^{\mu_b} l_{t-1}^{\mu_l}$$

The non-durable consumption sector is standard, due to monopolistic competition and price stickiness à la Calvo we obtain the usual New-Keynesian Phillips Curve:

$$ln\, \pi_t - \iota_\pi ln\, \pi_{t-1} = \beta_s \mathbb{E}\left[ln\, \pi_{t+1} - \iota_\pi ln \pi_t\right] - \epsilon_\pi ln\left(\frac{X_t}{X_{ss}}\right)$$

which is also characterized by price indexation (ι_π).

The housing sector employs labor and capital but also land and intermediate structures. Land is assumed to be fixed, therefore the expansion of the housing stock is marginally costly. Intermediate structure generates hump-shaped fluctuations in the housing market.

Due to the market power of labor unions, we observe a wedge between the wage paid by the firms and the wage disposable to the workers. Also wages are subject to price indexation:

$$ln\,\omega_t - \iota_{wc} ln\pi_{t-1} = \beta\mathbb{E}\left[ln\,\omega_{t+1} - \iota_w ln\pi_t\right] - \epsilon_w ln\frac{X_t^w}{X_{ss}^w}$$

where $\omega_t = \frac{w_t \pi_t}{w_{t-1}}$ is the wage inflation for each agents/sector (same golds for the other 3 segment of the labor market).

Iacoviello and Neri (2010) have showed that such combination of nominal frictions is able to yield a certain smoothness in the IRFs and to tackle some puzzles that otherwise arise in two sector models, e.g. a negative response of residential investment after an expansionary monetary policy shock. Moreover, Iacoviello and Neri (2010) estimate the model and the parametrization used here follows their findings.

4.1.4 Market Clearing

The market clearing conditions are given by eq.(23)-(24)-(25) which respectively concern the housing sector, consumption sector and land. Land is an input employed in the production of housing but they available land is assume to be fixed and normalized to 1. Such assumption implies that increasing the housing stock is relatively costly and so IRFs in housing are relatively smooth. Equilibrium in the housing market entail that the new houses produces are equal to the houses demanded. In the consumption sector, production is split across consumption, capital employed consumption sector itself, capital employed in the housing sector and intermediate structures used in the production of housing.

$$IH_t = H_t^o - (1-\delta)\,H_{t-1}^o + H_t^r - (1-\delta)\,H_{t-1}^r + H_t^b - (1-\delta)\,H_{t-1}^b \tag{23}$$

$$Y_t^c - \Phi_{k_t^c} - \Phi_{k_t^h} = C_t + IK_t^c + IK_t^h + k_t^b \tag{24}$$

$$l_t = 1 \tag{25}$$

4.1.5 Monetary Policy and Shocks

Monetary policy follows a standard Taylor Rule: the monetary authority increases the nominal interest rate when gross inflation is higher than 1 (the steady state) and when GDP is increasing with respect to the previous period. There is no target of the output gap because in two sector models such concept is not well defined.

$$R_t = \left(\frac{1}{\beta_s}\right)^{(\phi_R)} \pi_t^{(\phi_\pi)(1-\phi_R)} \left(\frac{GDP_t}{GDP_{t-1}}\right)^{(\phi_y)(1-\phi_R)} \tag{26}$$

Finally, the exogenous sources of variation present in the model are: housing preference shocks, monetary policy shocks, cost-push shocks, TFP shocks in consumption sector, TFP shocks in housing sector, investment specific technology shocks. I will mainly focus on the housing preferences shock because such a shock will be able to reproduce the empirical results in the model.

4.1.6 Parameters

All the parameters are chosen following the empirically validated model for the US in Iacoviello and Neri (2010) (Appendix B). There are two additional parameters related to the preferences of the Borrower for owning-renting housing: κ, defined over $[0, 1]$, represents the preference for owning. ξ_h stands for the elasticity of substitution between housing services from houses owned and houses rented. The parameter κ is set to 0.6 to match SS ratios with US data: the homeownership rate of households with income below the median (50%)[25] and the price-rent ratio (6%). The parameter ξ_h is 2 to achieve linear aggregation.

[25] http://www.census.gov/housing/hvs/files/currenthvspress.pdf

4.2 Comparison Empirical and Theoretical Results

I introduce news and noise shocks to match the process I observe in the empirical patterns: a 11-period anticipated shock to the housing preference of the Saver and of the Borrower. Housing preference shocks are the only shocks in the model that can generate IRFs similar to those from the VAR. I compare the empirical IRFs to the theoretical IRFs from the model and to the IRFs recovered by applying the identification strategy employed in Section 2 to simulated data from the model.[26] Both the magnitudes and the shapes of the IRFs are quite consistent between the theory and the empirics.

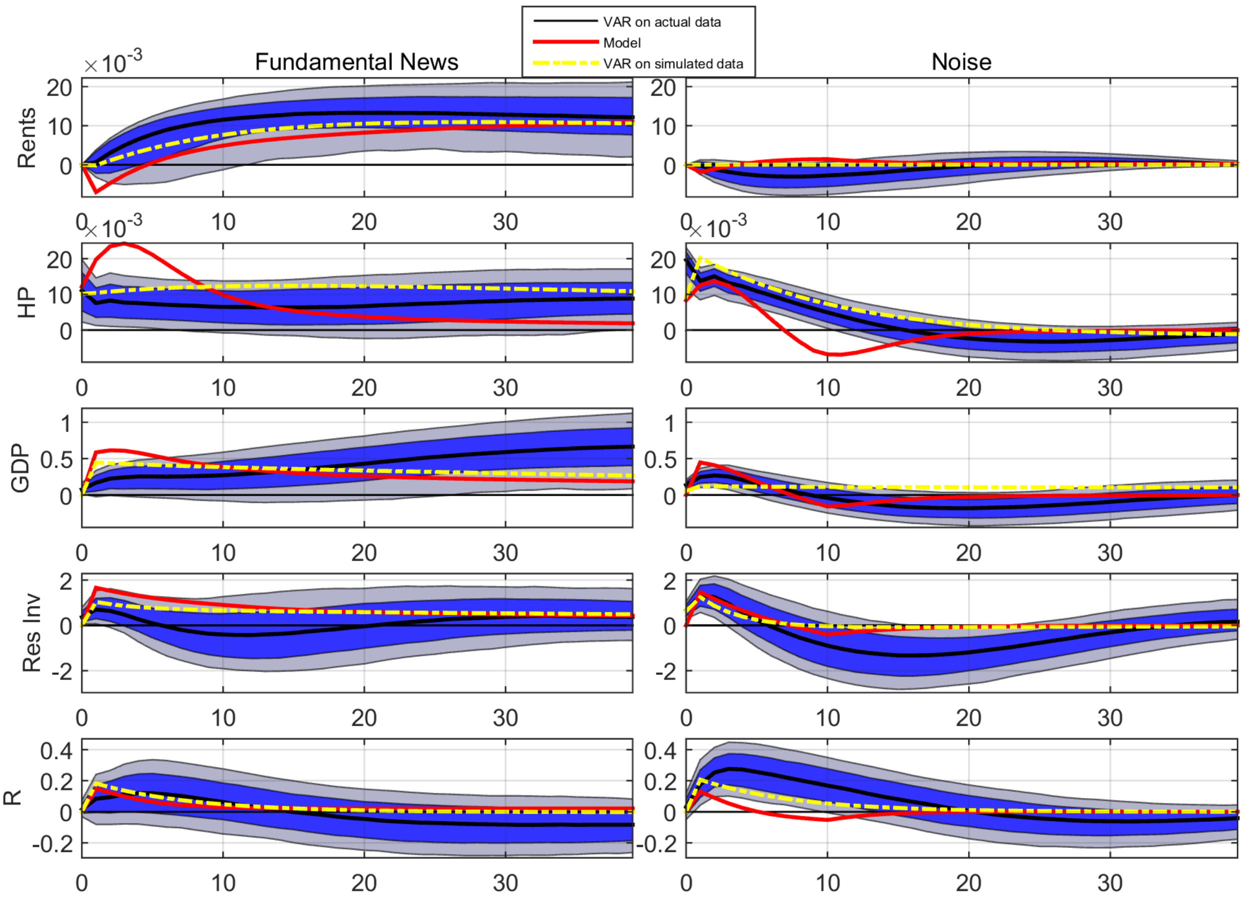

FIGURE 10: *Comparison of empirical IRFs and corresponding confidence intervals (solid black and blue shaded areas) with IRFs simulated from the model (red) and the IRFs obtained by applying the identification strategy to simulated data from the model (yellow)*

[26]Notice that this comparison is an approximation as I am not using a unit root process as we observe in the data, but only a very persistence process (0.99). I also constrain the number of lags in the VAR that uses simulated data to the lags I used in the empirical part.

This consistency implies that, conditioning on the structure of the signal shock (drawn from the empirical results), we do not reject the hypothesis of rationality under imperfect information. In the model, agents receive at time t new information on the higher value of h_t after 11-periods. In the case of news, the information is actually materialized, whereas, in the case of noise, the information is gradually reversed and $h_{t+11} = h_t$. Nonetheless, in both cases $\mathbb{E}_t [h_{t+11}] > h_t$ leads to an immediate update of the PV relationship (eq.17-18) that boosts HP on impact.[27] As a result, the Saver, who is the most patient agent, transfers resources in a twofold manner. First, he shifts the consumption path towards the future because he holds a comparative advantage in this substitution over the Borrower. This holds both for consumption goods and housing services. Second, capital flows from the consumption sector to the housing sector in order to boost residential investment. The Borrower boosts immediately consumption and debt as the value of the collateral increases due to the raise in HP. Labor supply also increases because there is a (expected) higher weight on housing in the utility function of both agents. Overall, the economy experiences a boom as showed in Fig. 10 by the plot of GDP. Then, in the case of news, the economy reaches a new equilibrium with an higher preference for housing (Fig. 10 - left column). On the other hand, in the case of noise, agents expectations prove false: the boom is reversed and HP, GDP and residential investment fall even below the initial level (Fig. 10 - right column).[28]

4.3 Optimal Policies

Due to the symmetry of the model, the only role for policy lies in stabilization. A standard issue in this literature is that welfare gains are very small. Nonetheless, my model displays significant consumption equivalent welfare gains, close to 1% of the Borrower steady state consumption.

[27] As already mentioned in Section 3.2.2, rents fall in the first periods after the shock because the Borrower wants to substitute the rented housing stock with homeownership because he expects rents to be higher in the future. As a result, demand in the rental market falls.

[28] Notice that agents do not discount the correctness the new information they receive about h_{t+11}. This is often the case in the literature on news and noise shocks in DSGE models. Furthermore, my simulations are equivalent to the discounting case because the variance of the news shock and of the noise shock is the same (so discounting has no actual effects).

The policies I consider can reduce the volatility of many variables quite significantly (Table 2B - Appendix B). In this case, I calibrate the variance of news and noise shocks to housing preferences such that the variance of the process matches what is estimated in the Iacoviello and Neri (2010). Notice that in the estimation of their model the shocks to housing preferences are the most important.

I do not assume an *ad hoc* objective function, instead, the goal of optimal policy is the maximization of aggregate welfare. Aggregate welfare is defined as

$$W_t = (1-\beta_s)\, W_t^S + (1-\beta_b)\, W_t^B$$

I evaluate three policies: an Augmented Taylor Rule that can target housing prices, a pro-cyclical LTV ratio that can respond to debt, and finally a pro-cyclical property tax. The first two policies are standard in this literature, whereas the property tax (PT) is the novelty I am introducing.

The Augmented Taylor-Rule is given by:

$$r_t = (r_{t-1})^{\rho_r} (r_{ss})^{1-\rho_r} (\pi_t)^{(1-\rho_r)\phi_\pi} \left(\frac{GDP_t}{GDP_{t-1}}\right)^{(1-\rho_r)\phi_Y} \left(\frac{q_t^h}{q_{t-1}^h}\right)^{(1-\rho_r)\phi_Q} \tag{27}$$

The LTV Rule is determined by:

$$LTV_t = (LTV_{t-1})^{\rho_m} (LTV_{ss})^{(1-\rho_m)} \left(\frac{B_t}{B_{t-1}}\right)^{(1-\rho_m)m_B} \tag{28}$$

where the LTV is the collateralizable share of the housing stock (or the inverse of the down-payment).

The PT Rule can be described as:

$$Tax_t = (Tax_{ss})^{(1-\rho_T)} (Tax_{t-1})^{\rho_T} \left(\frac{q_t^h}{q_{t-1}^h}\right)^{(1-\rho_T)t_q} \tag{29}$$

The PT reacts pro-cyclically to movements in housing prices. When housing prices go up, the tax rate will increase and viceversa. This is equivalent to taxing the housing market during booms and subsidizing it during busts (the gross tax rate is 1 in SS so that net taxes are 0 in SS). This policy is particularly appealing because local housing markets are often characterized by different dynamics and property taxes are set at the local level in most countries.[29]

Each period agents choose the housing stock they want to own and Tax_t affects this decision through the term $q_t H_t^i Tax_t$ for both the Saver and the Borrower. Therefore, the optimality conditions are altered as well (tax revenues are redistributed to agents such that their budget constraint is globally not affected).

Table 1 displays the results of welfare maximization and corresponding consumption equivalent (CE) welfare gains[30] when the only source of uncertainty comes from the news-noise shocks to housing preferences.

Table 2 presents the same results as in Table 1 but in case all the shocks are active.[31] The optimal coefficients follow the same pattern as in Table 2 but they are generally weaker in magnitude. The picture is less clear when we consider CE welfare gains. Nonetheless, the conclusion is still that the highest welfare gains are reached when all policies are considered together, and the only counter-cyclical response in that case comes from TAX.

Policy	Optimal Parameters								CE Welfare Gains		
	Interest Rate				LTV		TAX		Saver	Borrower	Total
	ρ_R	ϕ_π	ϕ_Y	ϕ_Q	ρ_m	m_B	ρ_T	t_q			
R	**0**	**2.1**	**0.32**	**0.97**	-	-	-	-	-0.001	0.133	0.106
LTV	0.6	1.4	0.51	-	**0**	**-20**	-	-	0.006	0.148	0.112
R+LTV	**0.97**	**2.68**	**9.93**	**1.43**	**0**	**-20**	-	-	0.006	0.148	0.112
TAX	0.6	1.4	0.51	-	-	-	**0**	**3.83**	-0.017	0.186	0.146
TAX+R+LTV	**0.98**	**2**	**0**	**-**	-	**0**	**0**	**3.78**	-0.0280	0.198	0.153

TABLE 1: *Optimal Parameters and Consumption Equivalent Welfare Gains - only news-noise shocks to housing preference active*

[29] Crowe et al. (2013) show that, in the US, property taxes affect HP and HP volatility, through an instrumental variable approach.

[30] Consumption equivalent welfare gains represents the units of consumption, as a percentage of consumption in steady state, that agents are available to give away in order to have the optimal policies implemented. Considering the standards in the literature, CE welfare gains are quite sizable.

[31] Notice that variance and persistence of the shocks is the same as in the estimation of Iacoviello and Neri (2010).

Policy	Optimal Parameters								CE Welfare Gains		
	Interest Rate				LTV		TAX		Saver	Borrower	Total
	ρ_R	ϕ_π	ϕ_Y	ϕ_Q	ρ_m	m_B	ρ_T	t_q			
R	**0**	**1.1**	**0.23**	**0.15**	-	-	-	-	0.163	0.604	0.515
LTV	0.6	1.4	0.51	-	**0**	**-20**	-	-	0.164	0.845	0.71
R+LTV	**0**	**1.1**	**0.25**	**0**	**0**	**-20**	-	-	0.164	0.845	0.71
TAX	0.6	1.4	0.51	-	-	-	**0**	**3.53**	-0.101	0.655	0.504
TAX+R+LTV	**0**	**1.1**	**0.16**	**-**	-	**0**	**0**	**2**	0.026	1.03	0.83

Table 2: *Optimal Parameters and Consumption Equivalent Welfare Gains - all shocks active*

The simplest perspective to take in order to analyze the results consists of considering how general or specific a policy is. PT directly influence the cost of housing transactions, but do not enter directly into any other equation. If the source of fluctuations is the housing preference shock, R and the LTV Ratio will indirectly affect the housing decision, but they will also influence other variables in the economy in a direct fashion. On the other hand, the PT affects housing decisions directly and other variables only indirectly. For this reason, the latter policy is more efficient at stabilizing this source of instability. The advantage of such direct intervention is clear, there is no need to distort other decision to affect the housing market. This can be seen by considering the modified equation from the model. The FOC_{H^o} in eq.(18) is modified by pro-cyclical property tax as follows:

$$
\begin{aligned}
q_t^h\left(1+Tax_t\right) &= q_t^r+\beta_s\mathbb{E}_t\left[\left(1-\delta_h\right)q_{t+1}^h\left(1+Tax_{t+1}\right)\frac{\lambda_{t+1}^s}{\lambda_t^s}\right]\\
q_t^h\left(1+t_q\Delta_{q_t}\right) &= q_t^r+\beta_s\mathbb{E}_t\left[\left(1-\delta_h\right)q_{t+1}^h\left(1+t_q\Delta_{q_{t+1}}\right)\frac{\lambda_{t+1}^s}{\lambda_t^s}\right]\\
q_t^h &= \mathbb{E}_t\left[\sum_{i=0}^{+\infty}\beta^i\frac{\left(1-\delta_h\right)}{1+t_q\Delta_{q_t}}\frac{\lambda_{t+i}^s}{\lambda_t^s}q_{t+i}^r\right]
\end{aligned}
$$

The term $t_q\Delta_{q_t}$ corrects the stochastic discount factor (SDF) that enters the pricing of housing in a counter-cyclical way. When q^h is increasing, $q_t^h > q_{t-1}^h \Rightarrow \Delta_{q_t} < 1$ and the SDF will decrease. Intuitively, agents know that taxation will move in the same direction of HP inflation, therefore they will adjust the expected gains. In other words, agents internalize the way the pro-cyclical property tax operates and from this internalization comes most of stabilizing effect of such a policy.

5 Conclusions

In this paper, I apply a present value model to housing prices, considering rents as the market value of the flow of dividends that housing provides to the owner. I consider an incomplete information framework, where agents receive noisy signals about future fundamentals and, as a result, housing prices can also move due to incorrect beliefs about the future. In the empirical section, I have applied the non-standard structural VAR procedure developed by Forni et al. (2014, 2016), which employs future reduced form residuals to recover shocks related (news) and not related (noise) to future fundamentals. The identification exploits 40 quarters future data (on the fundamental) to determine whether shocks to the signal are fundamental or noisy. The paper shows that, in the US, news and noise can explain large fraction of the variability of housing prices and residential investment, with relevant consequences for the whole economy. In particular, noise shocks explain a good share of fluctuations at high frequencies, whereas the news shocks have more important implications for the long run. I have studied whether my empirical results are consistent with a general equilibrium setup. In particular, I have considered a model à la Iacoviello which includes a rental market. The comparison between the results from the VAR and from the DSGE model shows that the IRFs are characterized by very similar shapes. Whereas the VAR identification can accommodate both rational and irrational components, the model relies exclusively on rational expectations. The consistency between the VAR and DSGE results can be interpreted, conditioning on the structure of the information process, as a failure to reject the hypothesis of rational expectations under limited information. Optimal policies have been studied in this framework and the results suggest that pro-cyclical property taxes, internalized by agents, are the most efficient way of stabilizing the housing market.

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A Empirical Appendix

A.1 Direct Approach - Census HPI

Shocks	Lags	Principal Components					
		1	2	3	4	5	6
Learning	2	0.691027	0.722341	0.399187	0.121248	0.1663	0.235052
	4	0.388685	0.410481	0.153404	0.160175	0.187133	0.285955
Signal	2	0.305346	0.66352	0.815606	0.728616	0.847985	0.810634
	4	0.213099	0.358816	0.471606	0.55996	0.791841	0.813295
News	2	0.10541	0.135557	0.117866	0.227223	0.276208	0.339871
	4	0.107715	0.119619	0.136464	0.205062	0.307707	0.390124
Noise	2	0.966438	0.725752	0.820026	0.906561	0.947466	0.90443
	4	0.807781	0.820922	0.958303	0.989601	0.984482	0.966127

TABLE 1A: *Fundamentalness test of the identified shocks with HP ordered second. The values reported are the p-values of an F-test from the regression of the identified shocks on the 2 and 4 lags of the first 6 principal components from a dataset containing 128 macro-variables.*

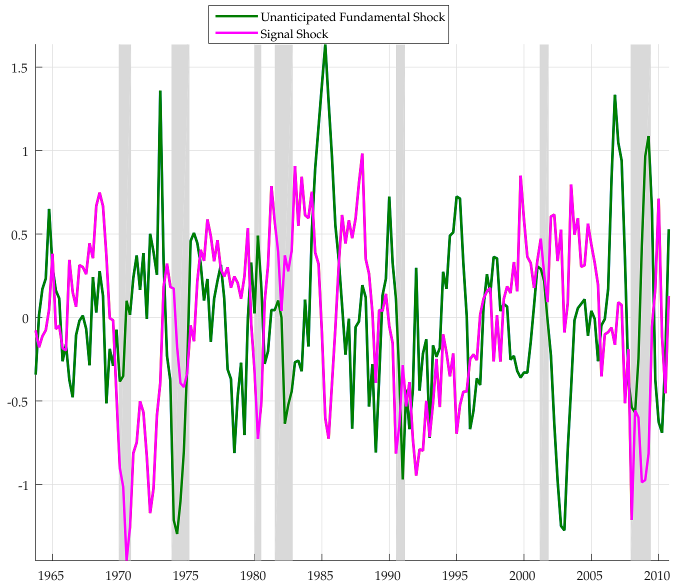

FIGURE 1A: *Identified Shocks and NBER Recessions - yearly MA*

A.2 Shiller - Direct Approach

The VAR includes **[Rents, Case-Shiller HPI, GDP, Residential Investment, Mortgages, FFR, Stock Price]**

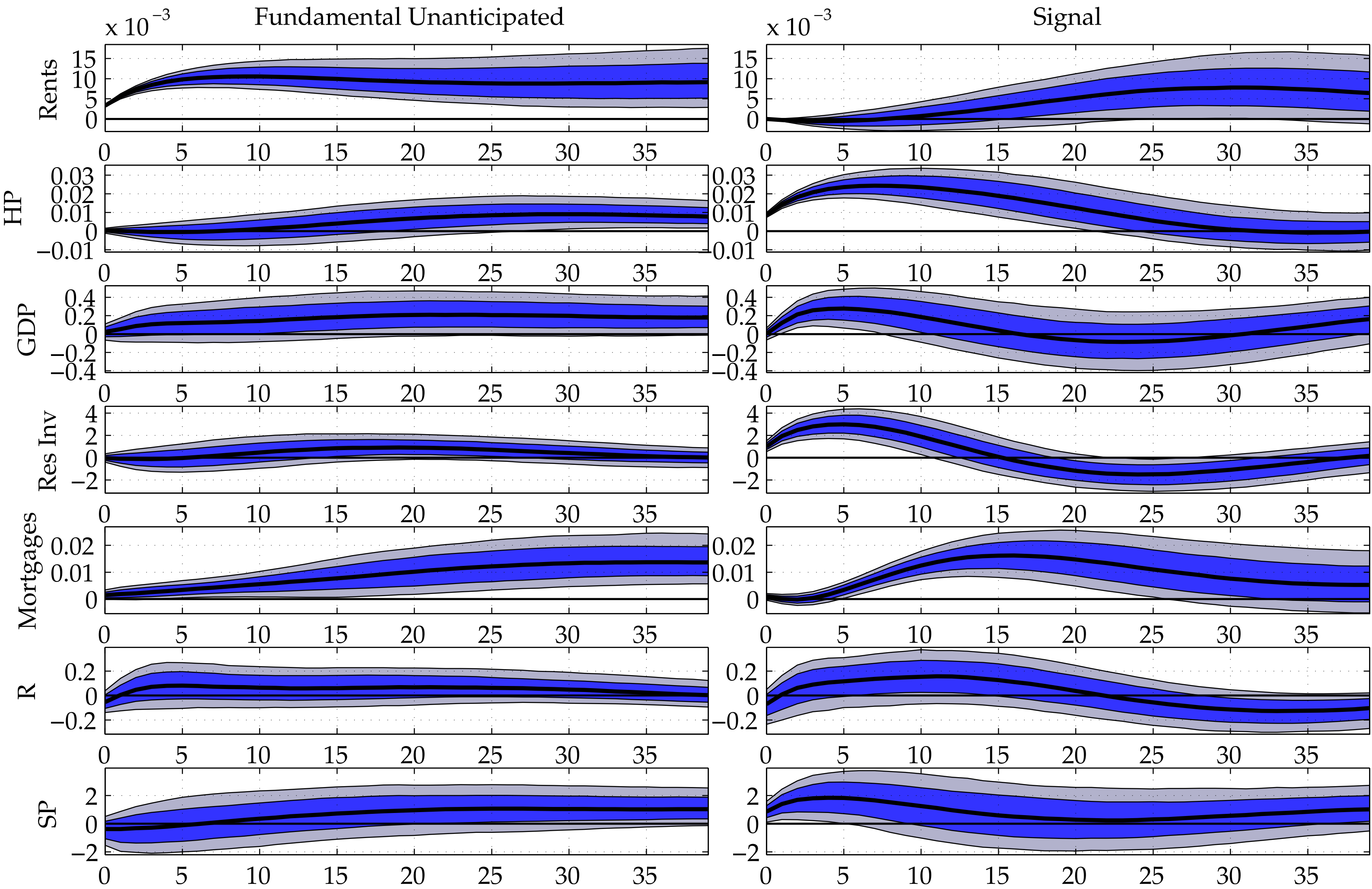

Figure 2A: *IRFs to fundamental unanticipated and signal shocks. The solid black line is the median, the dark and light blue shaded areas represents 68% and 90% confindence bands respectevely (2000 bootstrap replications). The shocks are identified through the following ordering: [Rents, HP, GDP, Res Investment, R, S&P 500]*

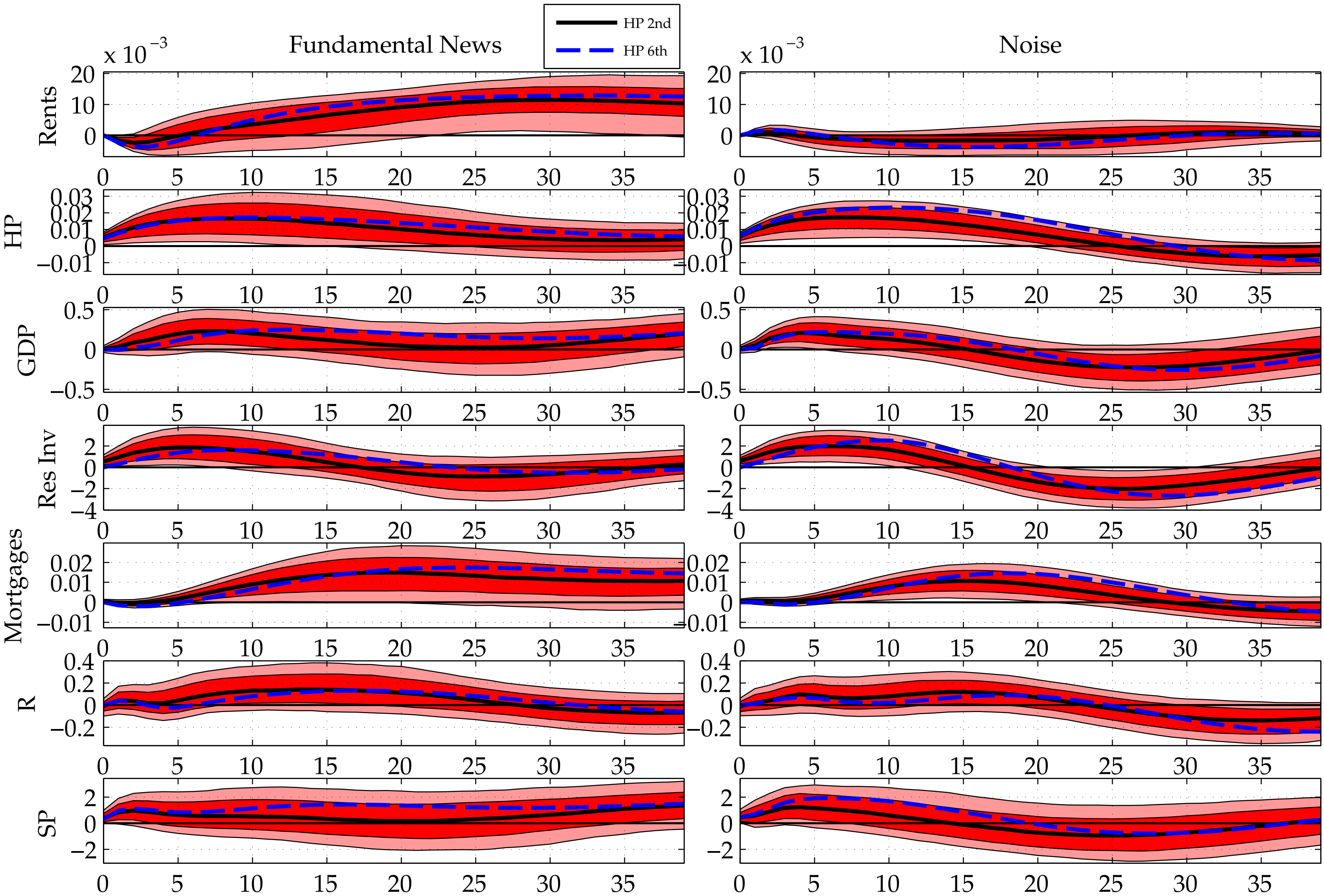

FIGURE 3A: *IRFs to news and noise shocks. The solid black line, the red and light red shaded areas represent the median, 68% and 90% confidence bands respectevely (2000 bootstrap replications) with the following ordering: [Rents, HP, GDP, Res Investment, R, S&P 500]. The dotted blue line corresponds to the median IRFs with the following ordering: [Rents, GDP, Res Investment, R, HP, S&P 500]*

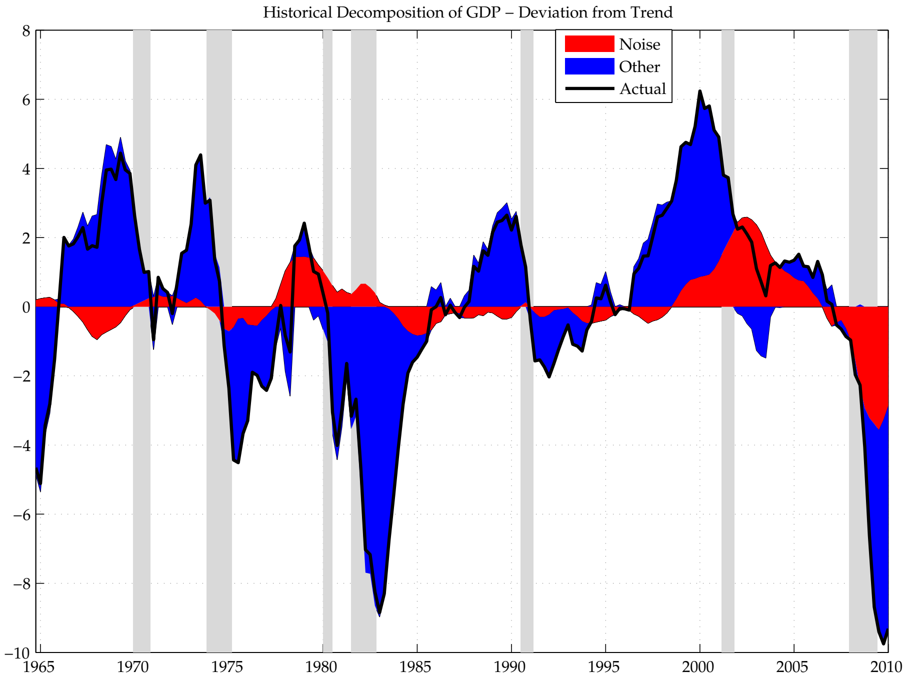

Figure 4A: *Historical decomposition of GDP deviation from trend (solid black) into the noisy component (red) and residual component (blue)*

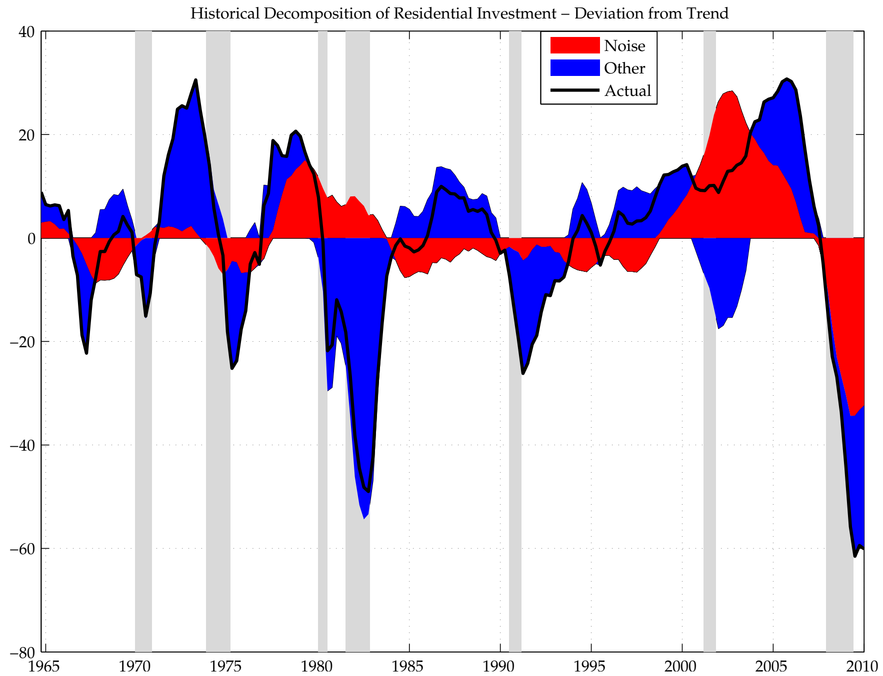

Figure 5A: *Historical decomposition of the residential investment (detrended) into the noisy component (red) and residual component (blue)*

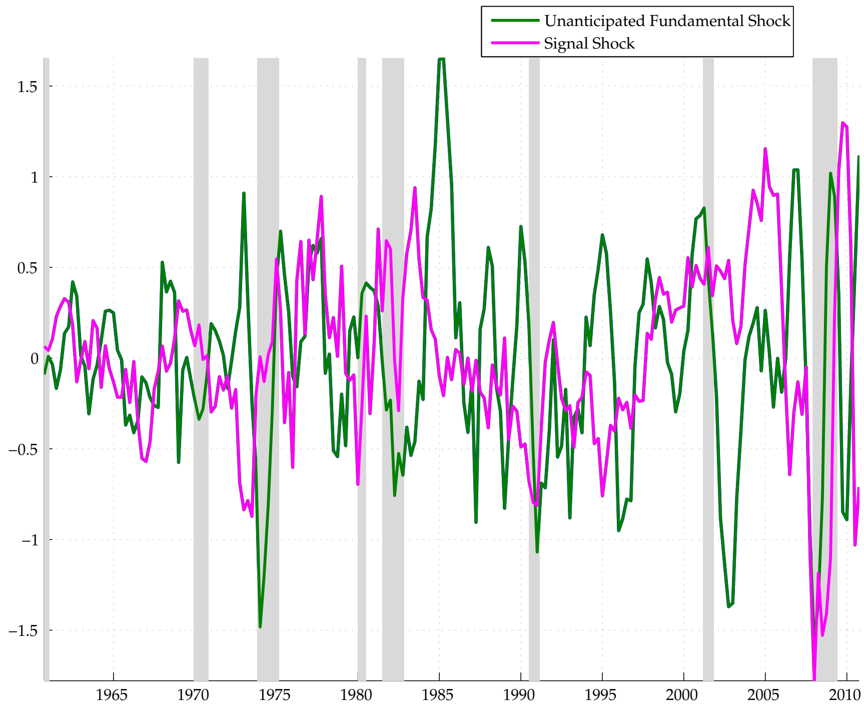

Figure 6A: *Identified Shocks and NBER Recessions - yearly MA*

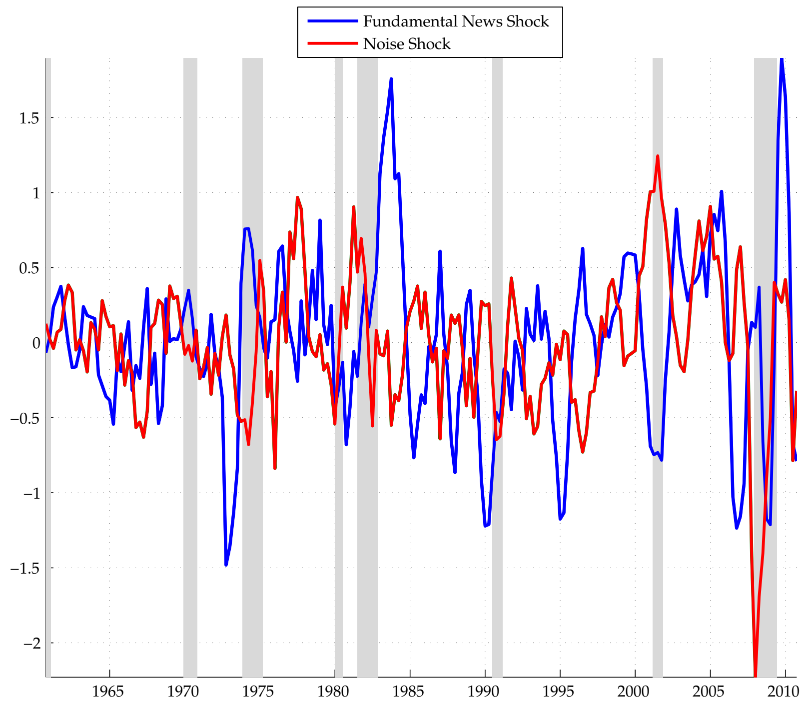

Figure 7A: *Identified Shocks and NBER Recessions - yearly MA*

A.3 Indirect Approach

This alternative approach disentangles news and noise by employing, as proxies for expectations of future rents, a principal component which combines the information in two variables: "New Housing Permits" and "Good time to buy a house" from the Michigan Survey of Consumers. In this way, I am trying to capture long-term expectations both in the demand and the supply side of the housing market. I aim at tackling the possible issue concerning the stickiness of HP. Nevertheless, with this second approach results are very similar to the once obtained with the main approach. The variables included in the VAR are: **[Rents, Signal, GDP, FFR, Residential Investment, HPI]**.

Shocks	Lags	Principal Components					
		1	2	3	4	5	6
Learning	2	0.998296	0.885869	0.892563	0.348918	0.398302	0.488204
	4	0.991189	0.977453	0.971829	0.62546	0.251734	0.407071
Signal	2	0.297075	0.249063	0.358016	0.165789	0.288894	0.344969
	4	0.473736	0.344224	0.495365	0.225295	0.321297	0.454878
News	2	0.546284	0.254595	0.252539	0.292286	0.440151	0.448377
	4	0.712607	0.199353	0.1902	0.356447	0.430265	0.54143
Noise	2	0.346741	0.157853	0.12769	0.145991	0.188053	0.218343
	4	0.300678	0.274593	0.346633	0.277472	0.299725	0.183071

Table 2A: *Fundamentalness test of the identified shocks. The values reported are the p-values of an F-test from the regression of the identified shocks on the 2 and 4 lags of the first 6 principal components from a dataset containing 125 macro-variables.*

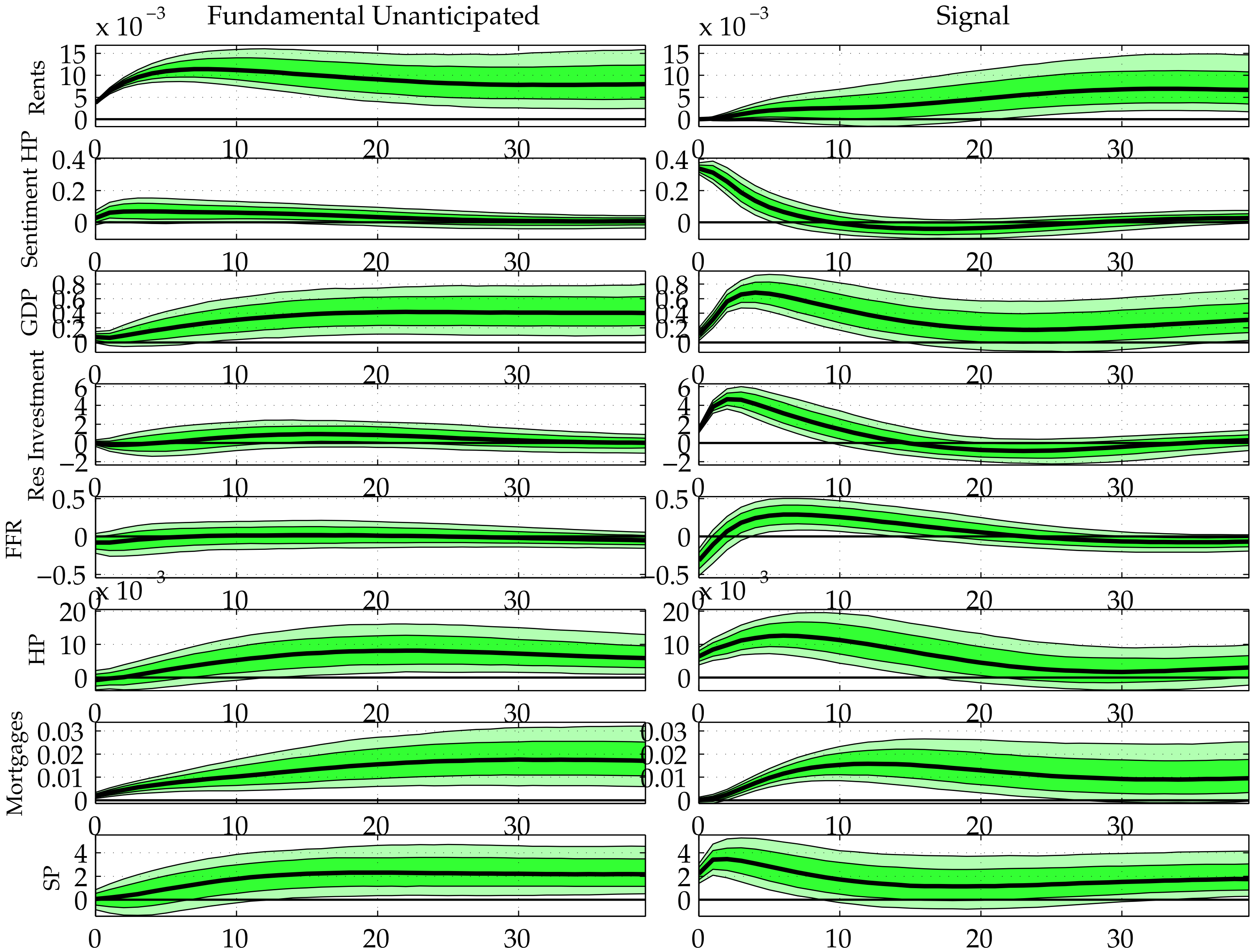

Figure 8A: *IRFs to fundamental unanticipated and signal shocks. In black the shocks are identified through the following ordering: [Rents, Signal, GDP, Res Investment, R, HP, SP]*

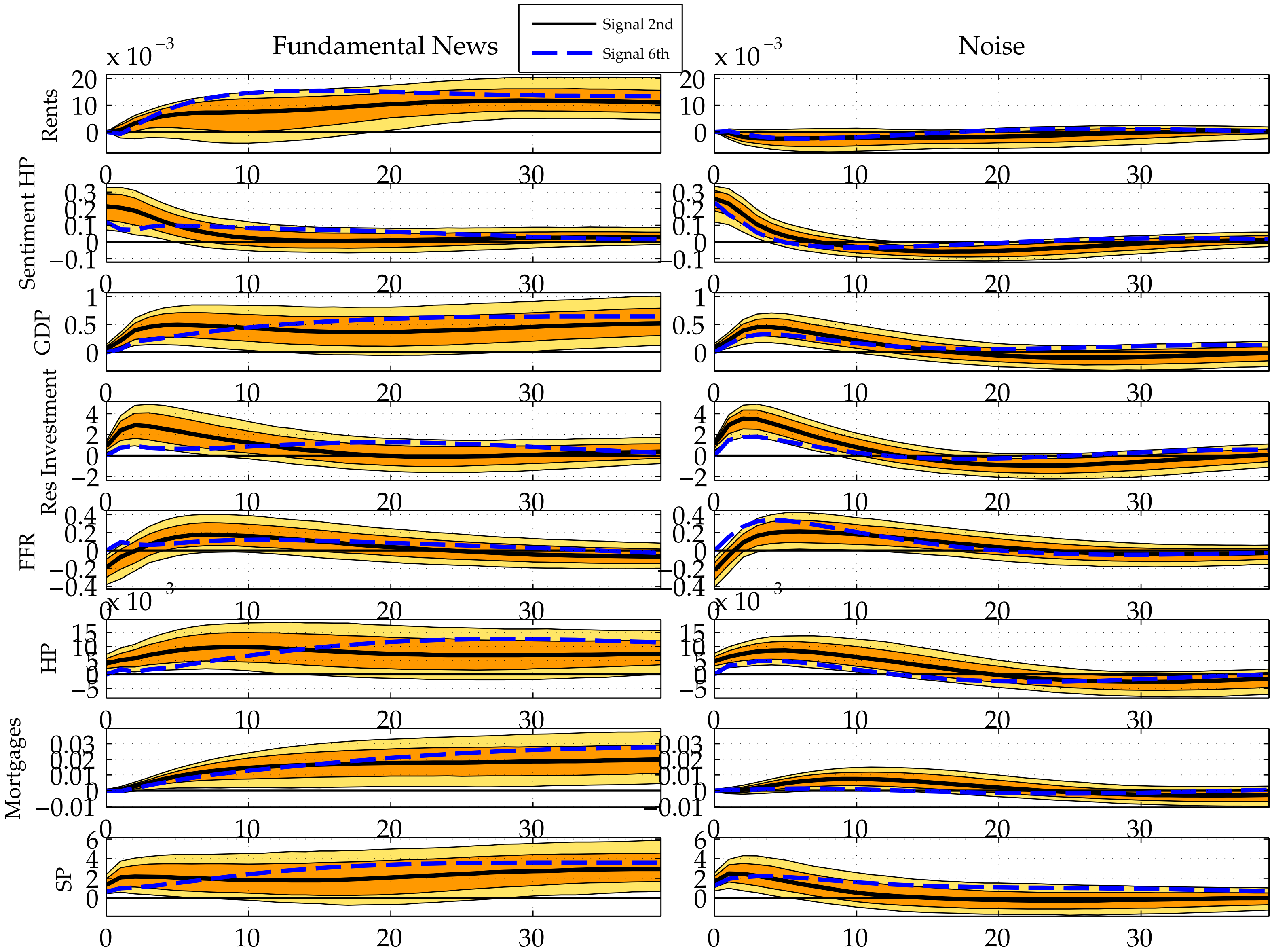

FIGURE 9A: *IRFs to news and noise shocks. In black the shocks are identified through the following ordering: [Rents, Signal, GDP, Res Investment, R, HP, Mortgages, SP]. In orange the corresponding bootstrapped confidence bands are reported. In blue the shocks are identified through the following ordering: [Rents, GDP, Res Investment, R, HP, Signal]*

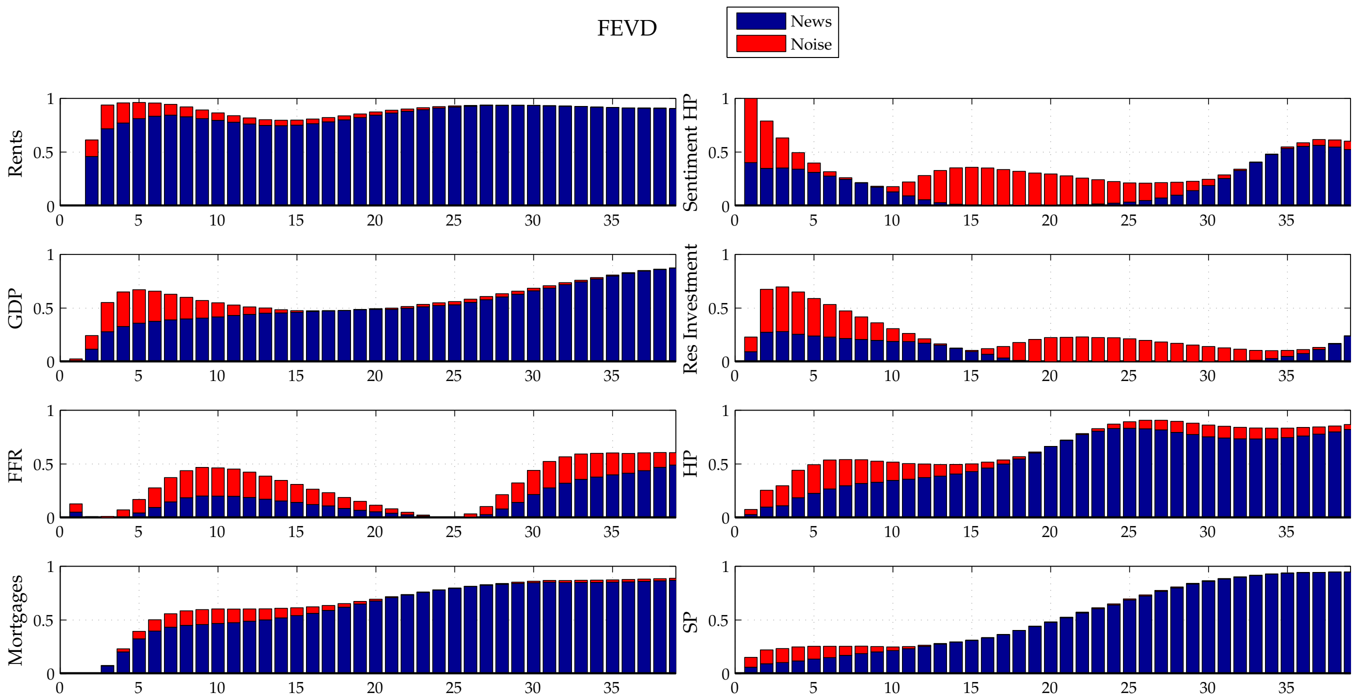

FIGURE 10A: *Variance Decomposition: share of the variance explained by News and Noise jointly, and by News and Noise individually*

A.4 Indirect with Shiller HPI

Similar results hold by employing the Shiller HPI:

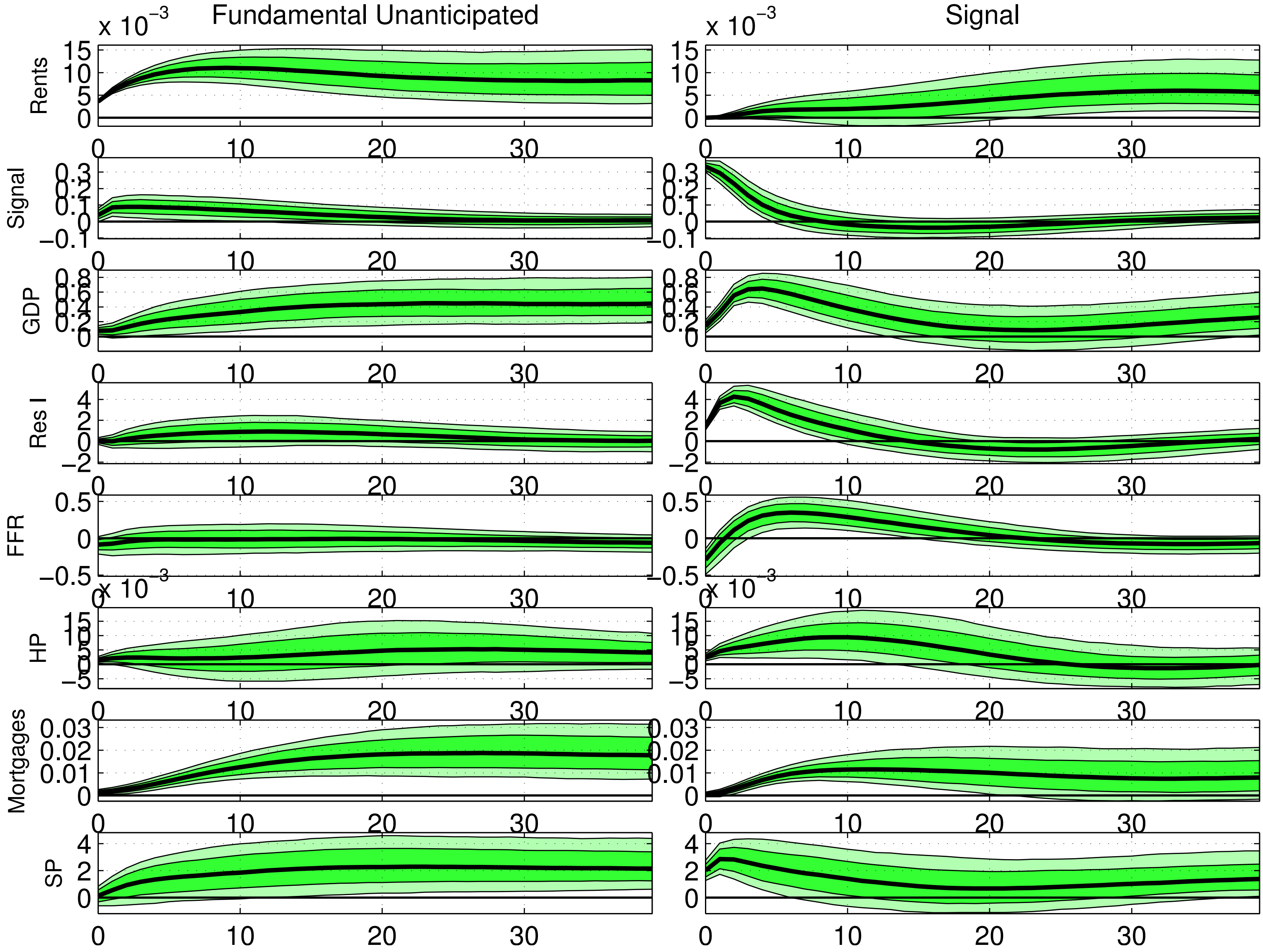

FIGURE 11A: *IRFs to news and noise shocks. In black the shocks are identified through the following ordering: [Rents, Signal, GDP, Res Investment, R, HP]*

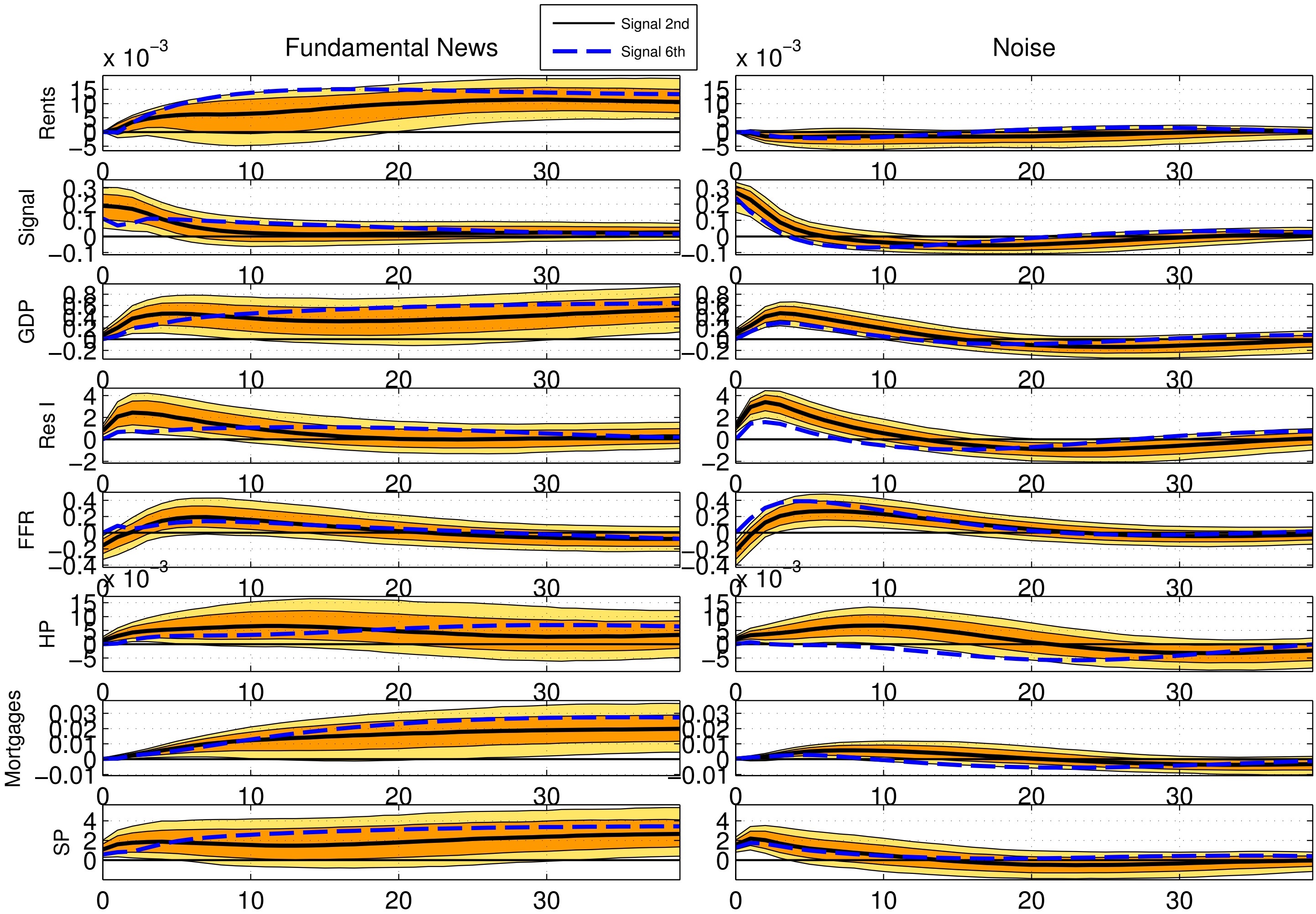

FIGURE 12A: *IRFs to news and noise shocks. In black the shocks are identified through the following ordering: [Rents, Signal, GDP, Res Investment, R, HP]. In orange the corresponding bootstrapped confidence bands are reported. In blue the shocks are identified through the following ordering: [Rents, GDP, Res Investment, R, HP, Signal]*

A.5 Home Builders Stock Price Index

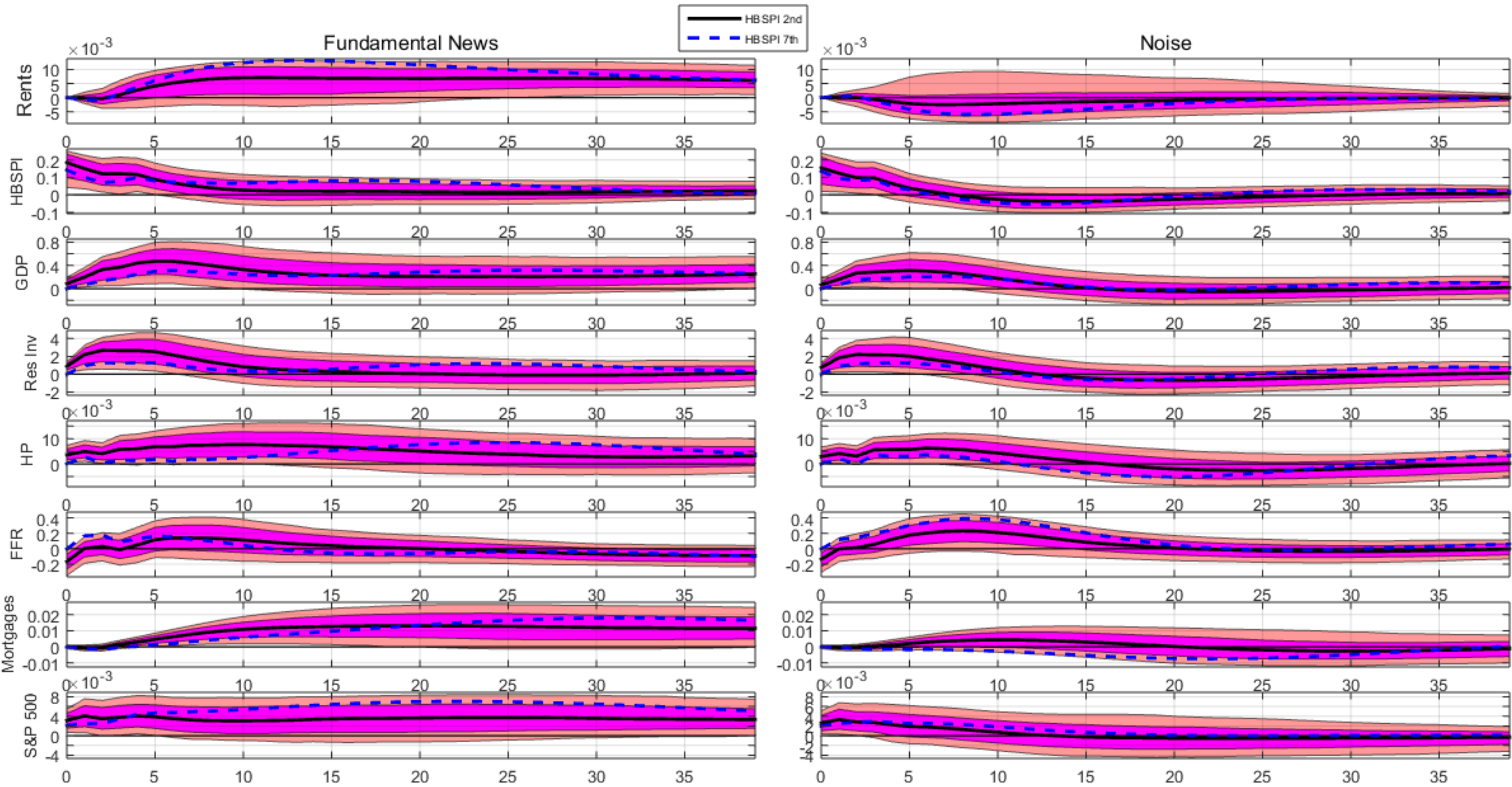

FIGURE 13A: *IRFs to news and noise shocks. In black the shocks are identified through the following ordering: [Rents, HBSPI, GDP, Res Investment, R, HP, Mortgages, S&P 500]. In magenta shaded areas the corresponding bootstrapped confidence bands are reported. In blue the shocks are identified through the following ordering: [Rents, GDP, Res Investment, R, HP, Mortgages, HBSPI, S&P 500]*

B Model Appendix

B.1 The equilibrium of the model

Saver

$$FOC_{B_t} : \beta_s \, \mathbb{E}_t \left[\frac{R_t \lambda^s_{t+1}}{\pi^c_{t+1}} \right] = \lambda^s_t \tag{30}$$

$$FOC_{k^c_{t-1}} : \lambda^s_t \left(1 + d\Phi_{k^c_t}\right) = \beta_s \mathbb{E}_t \left[r^c_{t+1} u^c_{t+1} - a(u^c_{t+1}) + 1 - \delta_k - \Phi_{k^c_{t+1}} \right] \tag{31}$$

$$FOC_{k^h_{t-1}} : \lambda^s_t \left(1 + d\Phi_{k^h_t}\right) = \beta_s \mathbb{E}_t \left[r^h_{t+1} u^h_{t+1} - a(u^h_{t+1}) + 1 - \delta_k - \Phi_{k^h_{t+1}} \right] \tag{32}$$

$$FOC_{u^c_t} : r^c_t = a_{u^c_t} \tag{33}$$

$$FOC_{u^h_t} : r^h_t = a_{u^h_t} \tag{34}$$

$$FOC_{H^o_t} : q^h_t \lambda^s_t = \frac{h_t}{H^o_t} + \beta_s \left(1 - \delta_h\right) \mathbb{E}_t \left[q_{t+1} \lambda^s_{t+1} \right] \tag{35}$$

$$FOC_{n^{sc}_t} : \left[(n^{sc}_t)^{1+\xi_s} + \left(n^{sh}_t\right)^{1+\xi_s} \right]^{\left(\frac{1+\eta}{1+\xi_s} - 1\right)} (n^{sc}_t)^{\xi_d} = \frac{\lambda^s_t w^{sc}_t}{X^{wc}_t} \tag{36}$$

$$FOC_{n^{sh}_t} : \left[(n^{sc}_t)^{1+\xi_s} + \left(n^{sh}_t\right)^{1+\xi_s} \right]^{\left(\frac{1+\eta}{1+\xi_s} - 1\right)} \left(n^{sh}_t\right)^{\xi_d} = \frac{\lambda^s_t w^{sh}_t}{X^{wh}_t} \tag{37}$$

$$FOC_{H^r_{s,t}} : \lambda^s_t q^h_t = q^r_t A_r + \beta_s \mathbb{E}_t \left[\left(1 - \delta_h\right) q^h_{t+1} \lambda^s_{t+1} \right] \tag{38}$$

$$FOC_{k^b_t} : p^b_t = 1 \tag{39}$$

$$FOC_{l_t} : \frac{p_t^l}{C_t^s} = \beta_s \mathbb{E}_t \left[\left(p_t^l + r_t^l \right) \frac{1}{C_{t+1}^s} \right] \tag{40}$$

$$\begin{aligned} C_t^s &= -\left[k_t^c + k_t^h + k_t^b + p_t^l l_t + q_t^h (H_{s,t}^o - (1-\delta) H_{s,t-1}^o + H_t^r - (1-\delta) H_{t-1}^r) - B_t + \Phi_t \right] \\ &+ k_{t-1}^c (1 + r_t^c - \delta_c) + k_{t-1}^h (1 + r_t^h - \delta_h) + p_t^b k_t^b + \left(p_t^l + r_t^l \right) l_{t-1} \\ &+ \frac{w_t^{sc} n_t^{sc}}{X_t^{wc}} + \frac{w_t^{sh} n_t^{sh}}{X_t^{wh}} - \frac{R_{t-1} B_{t-1}}{\pi_t^c} + q_t^r H_t^r + \Gamma_t + a(u_t^c) + a(u_t^h) \end{aligned}$$

Borrower

$$FOC_{B_t} : \mu_t = \lambda_t^b - \beta_b \mathbb{E}_t \left[\frac{R_t}{\pi_{t+1}^c} \lambda_{t+1}^b \right] \tag{41}$$

where μ_t is the multiplier on the collateral constraint

$$\mu_t \left(B_t - \mathbb{E}_t \left[\frac{m \, q_{t+1} H_t^b \pi_{t+1}^c}{R_t} \right] \right) = 0 \tag{42}$$

$$\begin{aligned} FOC_{H_{b,t}} : \lambda_t^b q_t^h &= \frac{h_t}{\widetilde{H_t^b}} \left[k \left(H_t^b \right)^{\xi_h - 1} + (1-k) \left(Z_t \right)^{\xi_h - 1} \right]^{\frac{2-\xi_h}{\xi_h - 1}} \left(H_t^b \right)^{\xi_h - 2} \\ &+ \frac{m \, q_{t+1}^h \pi_{t+1}^c \mu_t}{R_t} + \beta_b (1-\delta_h) \mathbb{E}_t \left[\lambda_{t+1}^b q_{t+1}^h \right] \end{aligned} \tag{43}$$

$$FOC_{Z_t} : \lambda_t^b q_t^r = \frac{h_t}{\widetilde{H_t^b}} \left[k \left(H_t^b \right)^{\xi_h - 1} + (1-k) \left(H_t^r \right)^{\xi_h - 1} \right]^{\frac{2-\xi_h}{\xi_h - 1}} \left(H_t^r \right)^{\xi_h - 2} \tag{44}$$

$$FOC_{n_t^{bc}} : \left[\left(n_t^{bc} \right)^{1+\xi_s} + \left(n_t^{bh} \right)^{1+\xi_s} \right]^{\left(\frac{1+\eta}{1+\xi_s} - 1 \right)} \left(n_t^{bc} \right)^{\xi_d} = \frac{\lambda_t^b w_t^{bc}}{X_t^{wc}} \tag{45}$$

$$FOC_{n_t^{bh}} : \left[\left(n_t^{bc} \right)^{1+\xi_s} + \left(n_t^{bh} \right)^{1+\xi_s} \right]^{\left(\frac{1+\eta}{1+\xi_s} - 1 \right)} \left(n_t^{bh} \right)^{\xi_d} = \frac{\lambda_t^b w_t^{bh}}{X_t^{wh}} \tag{46}$$

$$C_t^b = w_t^{bc} n_t^{bc} + w_t^{bh} n_t^{bh} - q_t^h \left(H_t^b - (1-\delta) H_{t-1}^b\right) - q_t^r H_t^r - \frac{R_{t-1} B_{t-1}}{\pi_t^c} + B_t \tag{47}$$

Firm

$$FOC_{n_t^{sc}} : (1-\mu_c)\, \alpha \frac{Y_t}{X_t n_t^{sc}} = w_t^{sc}$$

$$FOC_{n_t^{sh}} : (1-\mu_h-\mu_l)\, \alpha \frac{q_t IH_t}{n_t^{bc}} = w_t^{sh}$$

$$FOC_{n_t^{bc}} : (1-\mu_c)\,(1-\alpha) \frac{Y_t}{X_t n_t^{bc}} = w_t^{bc}$$

$$FOC_{n_t^{bh}} : (1-\mu_h-\mu_l)\,(1-\alpha) \frac{q_t IH_t}{n_t^{bh}} = w_t^{bh}$$

$$FOC_{k_{t-1}^c} : \mu_c \frac{Y_t}{X_t k_{t-1}^c} = r_t^c z_t^c$$

$$FOC_{k_{t-1}^h} : \mu_h \frac{q_t IH_t}{k_{t-1}^h} = r_t^h z_t^h$$

$$FOC_{l_t} : \mu_l q_t IH_t = r_t^l$$

$$l_t = 1$$

$$FOC_{k_t^b} : \mu_b \frac{Y_t}{k_t^b} = p_t^b$$

Nominal Frictions

Price Stickiness:

$$ln\,\pi_t - \iota_\pi ln\,\pi_{t-1} = \beta_s \mathbb{E}\left[ln\,\pi_{t+1} - \iota_\pi ln\pi_t\right] - \epsilon_\pi ln\left(\frac{X_t}{X_{ss}}\right)$$

Wage stickiness:

$$ln\,\omega_t^{sc} - \iota_{wc} ln\pi_{t-1} = \beta_s \mathbb{E}\left[ln\,\omega_{t+1}^{sc} - \iota_{wc} ln\pi_t\right] - \epsilon_w^{sc} ln\frac{X_t^{wc}}{X_{ss}^{wc}}$$

$$ln\,\omega_t^{bc} - \iota_{wc} ln\pi_{t-1} = \beta_b \mathbb{E}\left[ln\,\omega_{t+1}^{bc} - \iota_{wc} ln\pi_t\right] - \epsilon_w^{bc} ln\frac{X_t^{wc}}{X_{ss}^{wc}}$$

$$ln\,\omega_t^{sh} - \iota_{wc} ln\pi_{t-1} = \beta_s \mathbb{E}\left[ln\,\omega_{t+1}^{sh} - \iota_{wc} ln\pi_t\right] - \epsilon_w^{sh} ln\frac{X_t^{wh}}{X_{ss}^{wh}}$$

$$ln\,\omega_t^{bh} - \iota_{wh} ln\pi_{t-1} = \beta_b \mathbb{E}\left[ln\,\omega_{t+1}^{bh} - \iota_{wh} ln\pi_t\right] - \epsilon_w^{bh} ln\frac{X_t^{wh}}{X_{ss}^{wh}}$$

B.2 Parametrization

Parameter	Value	Interpretation	Parameter	Value	Interpretation
β_s	0.9925	discount factor saver	ξ_s	0.66	saver's disutilty across sectors
β_b	0.97	discount factor borrower	ξ_b	0.97	borrower's disutility across sector
h_{ss}	0.12	utility from housing in SS	η_s	0.52	saver's labor supply elasticity
μ_c	0.35	capital share durables	η_b	0.51	borrowers's labor supply elasticity
μ_h	0.1	capital share housing	ϕ_{kc}	14.25	capital adjustment cost consumption sector
μ_l	0.1	land share	ϕ_{kh}	10.9	capital adjustment cost housing sector
μ_b	0.1	intermediate goods share	α	0.79	labor share
δ_h	0.01	depreciation housing	ρ_r	0.59	monetary policy intertia
δ_{kc}	0.025	depreciation capital in durable sector	ϕ_π	1.44	response to inflation in Taylor Rule
δ_{kh}	0.03	depreciation capital in housing sector	ϕ_y	0.52	response to ouput in Taylor Rule
X, X_{wc} X_{wh}	0.98	price and wage markups	θ_π	0.83	price stickiness
m	0.85	loan to value ratio	ι_{wc}	0.4	wage indexation in consumption sector
ϵ_s	0.32	habits in consumption - saver	ι_π	0.69	price indexation
ϵ_b	0.32	habits in consumption - borrower	θ_{wc}	0.79	wage stickiness in consumption sector
ζ	0.69	capacity utilization	θ_{wh}	0.91	wage stickiness in housing sector

TABLE 1B: *Parametrization of the model*

B.3 IRFs

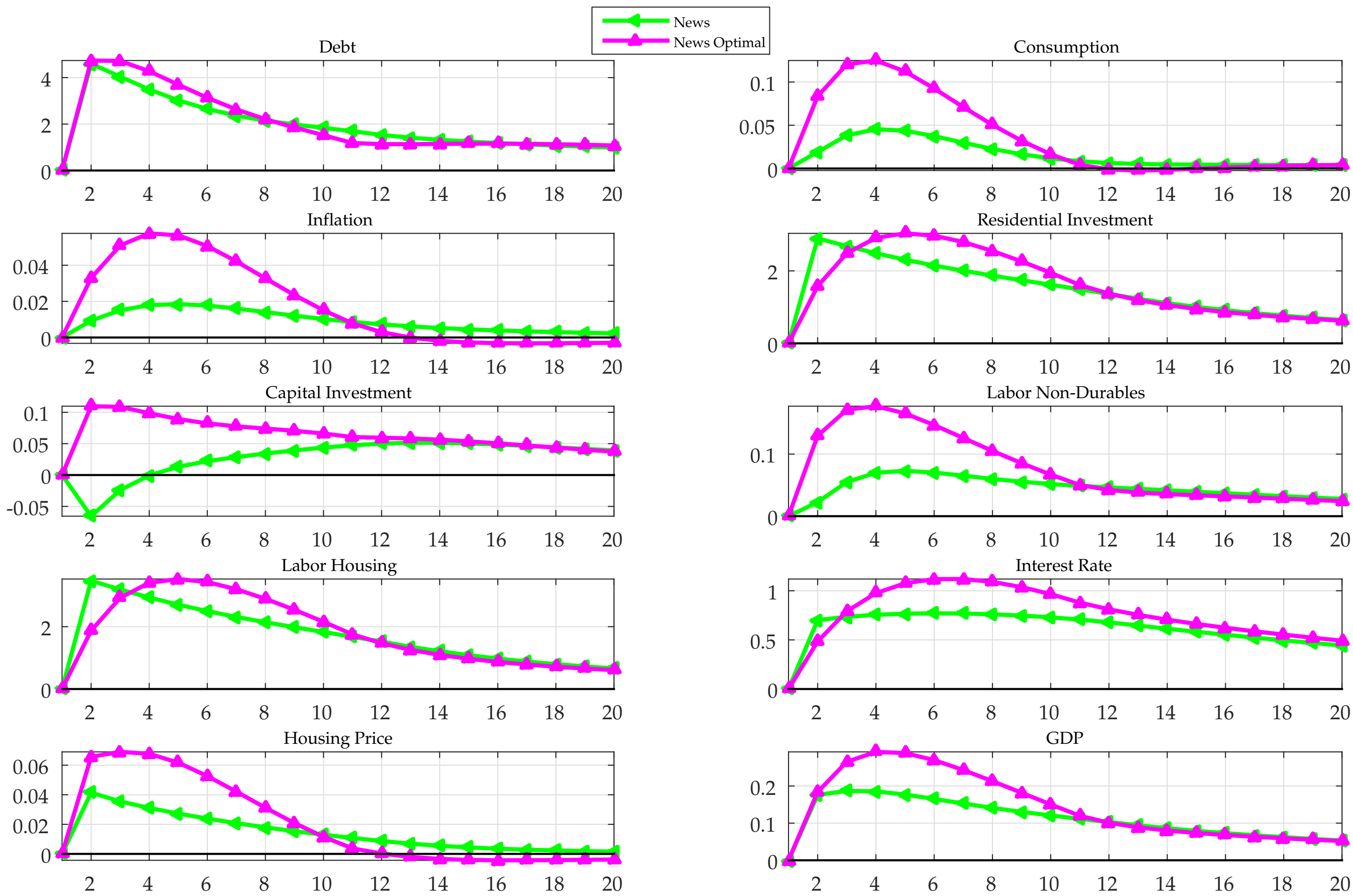

FIGURE 1B: *IRFs with baseline and best policy*

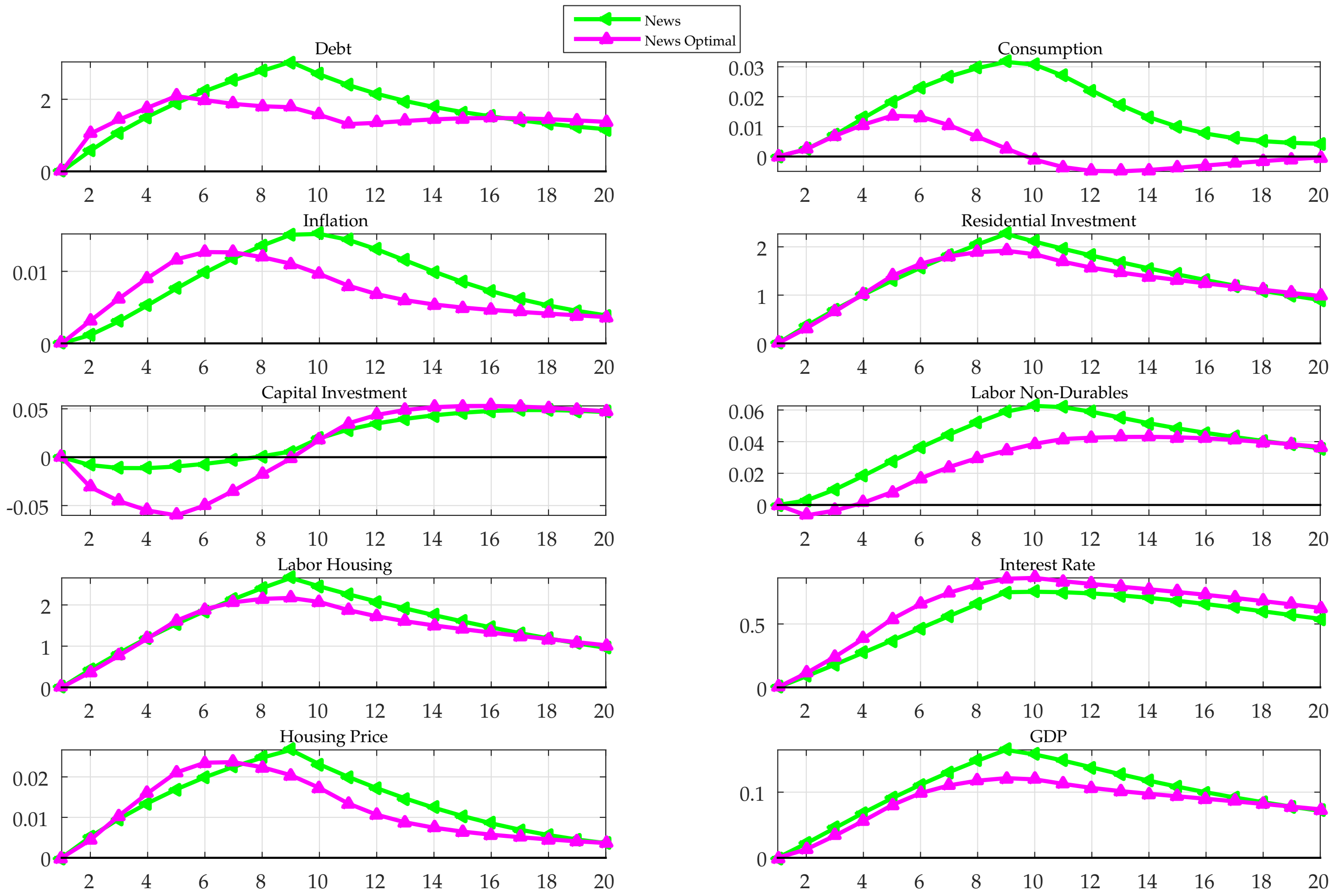

Figure 2B: *IRFs with baseline and optimize Tax*

B.4 Volatility

Variable	Policy	
$Debt$	42.84	30.23
GDP	1.21	4
c_s	3.95	1.84
c_b	17.14	4.23
H_S	-0.13	-0.95
H_B	9.80	5.73
q	0.40	0.68
IH_t	1.61	1.21
n_{cs}	18.75	4.82
n_{hs}	15.07	4.68
n_{cb}	9.96	12.31
n_{hb}	10.70	13.15
U_s	2.14	2.5
U_b	10.69	8.4
π	-252	-0.79

TABLE 2B: *Reduction in volatility with respect to the baseline case (estimated Taylor Rule with constant LTV and Tax)*

C FGLS Identification - Multivariate Case

The generalization of the FGLS identification from the bivariate to the multivariate case is quite straightforward. In fact, other variables only affect the first stage in the identification, i.e. the estimation of the reduced form VAR and recursive ordering step. Let us consider a block of additional endogenous variables y_t in the MA representation of the VAR, driven by ε_t^y. All the elements in the MA matrix are assumed to be rational functions.

$$\begin{pmatrix} \Delta r_t \\ s_t \\ y_t \end{pmatrix} = \begin{pmatrix} a_{11}(L) & a_{12}(L) & r(L) \\ a_{21}(L) & a_{22}(L) & t(L) \\ z(L) & u(L) & V(L) \end{pmatrix} \begin{pmatrix} u_t \\ s_t \\ \varepsilon_t^y \end{pmatrix} \tag{1c}$$

$a_{12}(L) = 0$ implies a zero impact effect of the signal on rents. While in the bivariate case this assumption was sufficient to identify $\begin{pmatrix} u_t \\ s_t \end{pmatrix}$, in the multivariate case we need to impose further restrictions: $r(L) = 0$ $t(L) = 0$ and $V(L) = 0$ lower triangular. This ordering implies that rents do not react on impact to any shock in ε_t^y. I believe that this assumption is reasonable as rents are a slow moving variable, with rental contracts usually lasting at least one year. On the other hand, also the signal (HP) is assumed not to react on impact to other shocks ε_t^y in the ordering displayed above. Such an assumptions is more controversial because asset price or agents expectations may react on impact to all available information. For this reason, in the empirical analysis I test the robustness of my results to such an assumption, by ordering the signal also second-to-last (before stock prices).

After imposing the Cholesky orthogonalization, the structural MA representation can be recovered post-multiplying the matrix in (1c) by:

$$\begin{pmatrix} b(L)\frac{\sigma_n^2}{\sigma_s^2} & -b(L)\frac{\sigma_f^2}{\sigma_s^2} & 0 \\ 1 & 1 & 0 \\ 0 & 0 & I \end{pmatrix} \tag{2c}$$

which is the same matrix employed in the bivariate case, appended with an identity matrix. Clearly, this second step has no impact on the identification.

Acknowledgements
I would like to thank my supervisor Evi Pappa and Alejandro Vicondoa for constant suggestions and support. Thanks also to Fabio Canova, Michalis Rousakis, Yuriy Gorodnichenko, Pierre-Olivier Gourinchas, Maarten Dossche, Vivien Lewis and all the participants at seminars at the European University Institute and at the European Central Bank. Special thanks to Luca Sala for sharing his codes. This work was partly carried out during my stay at the ECB and has been presented in the DED Seminar Series.

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ISSN 1725-2806 (online)
ISBN 978-92-899-2181-7
DOI 10.2866/383026
EU catalogue No QB-AR-16-050-EN-N