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Behavioural Finance at Home: Testing Deviations of House Prices from their Fundamental Values

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I introduce a new test of whether house prices are always equal to their fundamental values, which are defined to account for the unique frictions in housing asset markets, based on the speed of their reaction to monetary shocks. This test is justified with two conceptual frameworks and existing empirical work on monetary transmission. The results of applying this test to US data using local projections reject the hypothesis, but are instead consistent with behavioural expectations in housing markets. I also use a sign decomposition based on the conceptual frameworks to identify that consumption demand is the most important driver of US house price cycles, although asset demand is also relatively important. Therefore housing cycles usually arise from partially behavioural reactions to changes in housing demand.

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1 Introduction

Housing is the largest asset on most households' balance sheets, as well as one of the largest items of consumption, in many developed countries (Piazzesi and Schneider, 2016; Musso et al., 2011). However the cyclical movements in house prices[1] have also been shown to be intricately linked to financial cycles (Borio, 2014) and their downturns are associated with some of the most serious recessions (Jorda et al., 2015b). It is therefore very important to understand the drivers of house price fluctuations as they have huge economic and social implications.

One key consideration is whether changes in house prices are the result of changes in rational expectations of fundamentals, because otherwise this implies the potential for housing bubbles that could cause serious macroeconomic shocks when they burst (Glaeser and Nathanson, 2015). There are very different approaches to the issue of housing bubbles in the existing literature. The vast majority of theoretical macroeconomic models that incorporate housing surveyed by Piazzesi and Schneider (2016) do so in settings in which agents have full information rational expectations[2] and there are few frictions in housing markets. As a result house prices in the models surveyed are equal to the full information rational expectations of the present value of the stream of future rents. This is referred to as the fundamental value of a housing asset[3]. Therefore changes in house prices in these models are always due to changes in the fundamental value of housing. In reality there are frictions in housing markets, such as search costs, and it is possible to extend this approach to construct an adjusted fundamental value that also incorporates these features, as shown by Dusha and Janiak (2018). There is also a large behavioural housing literature, surveyed in Salzman and Zwinkels (2017), that suggests that house prices may deviate from fundamental values, even after adjusting for transaction costs and frictions.

[1]Throughout this paper house prices, housing values, housing rents and other related variables are all considered in real terms unless stated otherwise.

[2]Full information rational expectations are defined as agents expectations being equal to the true conditional expectations of a future variable, conditioning on complete knowledge of the economy: see the survey in Coibion et al. (2018) for a detailed discussion.

[3]This definition can be taken from Santos and Woodford (1997) under the condition that there are no 'rational bubbles' or from Glaeser and Nathanson (2015) who use it in a housing context.

These deviations may result from behavioural features such as non-rational expectations, so changes in house prices need not result from changes in the fundamental value of housing.

Providing empirical evidence on whether house prices are equal to their fundamental value is very hard. Testing the proposition directly is limited by the impossibility of estimating the fundamental value of housing without making extreme approximations, such as those in Mayer and Sinai (2007). Testing the proposition indirectly is more plausible but has its own problems. If asset prices are equal to their standardly defined fundamental value then the asset market is efficient, so tests of efficiency can be used as tests for consistency with asset prices being given by their fundamental value (Fama, 1970). Even so, testing market efficiency in aggregate house prices remains difficult. Aggregate house price series are not available at high frequencies, so it is hard to rule out the possibility that time series and event study predictability of house prices and excess housing returns reflect changes in risk premia rather than deviations from efficiency. Additionally after adjusting for transaction costs and rigidities in housing markets the adjusted fundamental value relation no longer necessarily implies market efficiency. These rigidities include the time spent searching for a house, property transaction taxes and the institutional feature of US housing markets that prices are often committed to before exchange takes place. Therefore a lack of efficiency in housing markets does not necessarily show an inconsistency with house prices being equal to their adjusted fundamental value.

The test I introduce in this paper is based on the reaction of house prices to monetary shocks at time horizons shortly after the shock, but long enough to allow for contractual rigidities. Monetary shocks are relatively unique as a variable in that the adjusted fundamental value of housing should have an unambiguously signed reaction to monetary shocks as soon as the contractual rigidities in housing markets no longer bind. I illustrate why this is likely to be the case using two conceptual frameworks that build on the fundamental value of housing: one that also considers the roles of consumption demand and housing supply and one that also considers the role of search frictions, as well as relevant empirical work on the transmission of monetary shocks. This is a test of consistency with house prices equalling their adjusted fundamental value, as it is possible that house prices could still react to monetary shocks as soon as contractual rigidities no longer bind but still not be given by their fundamental value. However if house prices do not react at the specified horizon then this rejects house prices being always equal to their fundamental value, but is consistent with several alternate behavioural explanations of house prices.

I implement this test using narrative shocks in a local projections specification. This lets me obtain potentially consistent estimates of the timing of the effects of the shocks, which could be significantly distorted in an auto-regressive model if the model is mis-specified. The narrative shocks I use are based on the natural experiment approach in Romer and Romer (2004), however I build on this approach by additionally controlling for information related to housing and financial markets to ensure that the estimates are as accurate as possible. The results show that house prices barely react to monetary shocks at a horizon of one to two months, the length of contractual rigidities, but have clearly statistically and economically significant reactions at horizons greater than a year. This provides strong evidence against house prices always being equal to the fundamental value of housing, even adjusting for the rigidities in housing markets. These results could be explained by imperfect information, for instance agents in housing markets not observing macroeconomic shocks perfectly, or behavioural features such as non-rational expectations, for instance agents in housing markets not understanding the functioning of housing markets perfectly. I suggest that both of these features are likely to be important.

As a secondary piece of work I use an approach inspired by the conceptual frameworks to provide estimates of the relative importance of the consumption demand, asset demand and supply channels in driving US house price cycles. I use band-pass filters to capture the cycle in US housing variables and then use sign analysis based on the linear and rank correlations between the cycles in different series to assess the relative importance of different channels. I find that consumption demand is the most important channel. Asset demand also appears to be relatively important, particularly in some time periods, whereas the supply channel appears to be by far the least important of the three.

Overall, I conclude that aggregate house prices do not appear to be always equal to their fundamental value. Limited information on shocks, non-rational expectations and behavioural features may all be important features of housing markets. This suggests that macroeconomic models that are based on full information rational expectations may be seriously mis-specified. It also suggests that changes in consumption and asset demand, which are the most important proximal drivers of house price cycles, may not have their origins in changes in fundamentals, so investors and policymakers should view them with caution.

This paper is primarily related to two main strands of the existing literature. The first of these is the empirical literature on whether housing markets can be explained as the full information rational expectation net present value of a stream of rents and hence whether housing markets are efficient. Many papers surveyed in Ghysels et al. (2013) show strong predictability in house prices and excess returns to housing, so the predictability does not just stem from movements in rents or discount rates. This predictability has been known since at least Case and Shiller (1989) and has been confirmed with more modern econometric methods for variables including past returns (Schindler, 2013), valuation ratios (Campbell et al., 2009) and housing wealth to income ratios (Balcilar et al., 2019). This predictability has also been confirmed with respect to specific policy changes in event study approaches, such as that in Jung and Lee (2017). The predictability also gives rise to clear cycles in house prices, the stylised facts of which are summarised with a US focus in Sinai (2015), in the context of financial cycles in Drehmann et al. (2012) and in the context of bubbles in Glaeser and Nathanson (2015). It is hard to rule out completely time-varying risk premia as an explanation of these results, but the strength and patterns of the predictability lead the authors of most of these studies to conclude that housing markets are inefficient, so deviate from their fundamental values. In a survey of the literature Glaeser and Nathanson (2015) suggest that deviations of house prices from their fundamental values could theoretically be explained by search and institutional frictions in housing markets, but the size of deviations leads them to conclude that additional factors like non-rationality are also likely to be needed to explain the deviations. However there do not appear to have been attempts in this literature to empirically test whether housing markets deviate from their fundamental values after taking into account search costs and contractual rigidities.

I primarily contribute to this literature by introducing an empirical method to study whether house prices are consistent with always being equal to their adjusted fundamental value, instead of just their fundamental value, which is also robust to changes in time-varying risk premia. Specifically I study whether there is a reaction of house prices to monetary shocks as soon as contractual rigidities no longer bind, as these shocks should have clearly signed effects on adjusted fundamental values at this horizon. This approach is in the spirit of event studies but focuses on whether there is a reaction of house prices as soon as prices can respond to the event, rather than focusing on whether there are lagged reactions which may result from changes in risk premia or search costs. This is a test for consistency with adjusted fundamental values, so positive results can theoretically prove that house prices are not always equal to their adjusted fundamental value, but negative results cannot prove that they are always equal to their adjusted fundamental value. I implement this test using narrative monetary shocks in a local projections approach to provide clear empirical evidence on the timing of the reaction of house prices to monetary shocks. The results show virtually no reaction of house prices to monetary shocks at the horizons when contractual rigidities stop binding, despite statistically and economically significant reactions with sensible signs at much longer horizons. This strongly suggests that house prices are not equal to their adjusted fundamental value, so housing market inefficiencies are not simply the result of search frictions and contractual rigidities.

I make an additional contribution by providing new stylised facts on house price cycles. Specifically I provide empirical estimates of the relative importance of the consumption demand, asset demand and supply channels in driving US house price cycles, on the basis of a sign decomposition suggested by the conceptual frameworks. I find that the consumption demand channel is the most important and the supply channel is by far the least important.

The second strand of work that this paper is related to is the empirical monetary shocks literature. This literature aims to estimate the effects of monetary policy shocks on a number of different macroeconomic variables, of which house prices are usually just one. Individual papers take different approaches to this. Older papers, such as Fratantoni and Schuh (2003), tended to use recursive restrictions to identify monetary shocks in auto-regressive models. Concerns over the identification of shocks using this method then led to a series of papers which either augmented or replaced these zero restrictions with sign restrictions (Del Negro and Otrok, 2007; Jarociński and Smets, 2008; Musso et al., 2011). Most recent papers have used narrative shocks, which can be used in either autoregressive models (Miranda-Agrippino, 2016), local projections (Jorda et al., 2015a) or both (Coibion et al., 2017). The broad conclusion of these empirical papers is that expansionary monetary shocks increase house prices, although these increases often only occur with a lag and the extent and significance of the increases are fairly variable between papers[4]. These results are also broadly consistent with empirical partial equilibrium estimates based on regulatory changes, such as Bhutta and Ringo (2017), and surveys, such as Fuster and Zafar (2015). This is because these approaches suggest that changes in interest rates cause little reaction in house prices at short horizons but may ultimately increase house prices as the quantity of purchases and willingness to pay for housing rises.

I contribute to this literature in two ways. Firstly I contribute by explicitly studying the response of house prices to a monetary shock at the horizon which corresponds to contractual rigidities no longer binding, as well as producing an impulse response function (IRF) in the style of the existing literature. Secondly I also consider the addition of controls that are chosen to be specifically relevant to housing in the generation of my narrative monetary shocks and the estimation of the shocks effects on house prices. The IRFs produced including these controls are fairly similar to those produced without the controls and those from the existing literature. Therefore these results also allow one to have greater confidence in the estimated effects of monetary shocks on house prices from the existing literature, even when this literature focuses on estimating the effects of monetary shocks on a

[4]Results from the literature are also compared to the equivalent empirical results produced in this paper in Section 4.

wide range of variables.

The rest of this paper is laid out as follows: Section 2 sets out how I use monetary shocks to test whether house prices are consistent with always being equal to the adjusted fundamental value of housing, Section 3 presents the results of this test and the effects of monetary shocks on aggregate house prices in the US, Section 4 presents the new stylised facts on the relative importance of different proximal drivers of US housing cycles and Section 5 offers some concluding remarks.

2 Testing whether house prices are consistent with fundamentals using monetary shocks

The fundamental value of a house in the absence of rational bubbles is defined as the full information rational expectation of the net present value of the stream of rents that are either received from renting the property or saved by living in it (Glaeser and Nathanson, 2015). Assuming or using assumptions that imply that house prices are equal to their fundamental value is extremely common across the housing literature: it is used in virtually all of the macroeconomic models of house prices surveyed by Piazzesi and Schneider (2016) and is the basis of many of the papers of housing cycles considered in Glaeser and Nathanson (2015). House prices being equal to their fundamental value can be mathematically expressed as:

$$HP_t \;=\; E_t\,(\sum_{k=0}^{\infty}\frac{HR_{t+k}}{DR_{t+k}}) \tag{1}$$

where HP = real house prices, HR = real housing rents, DR = real discount rate and t denotes the time period.

The logic that is sometimes used for this valuation is that if the price of housing is below (above) its fundamental value then agents would demand more (less) housing, increasing (decreasing) house prices and restoring the condition. However there are rigidities in housing markets, such as search frictions and contractual rigidities, that may mean that this logic is not applicable. Papers such as Dusha and Janiak (2018) show how the fundamental value can be adjusted to also incorporate transaction costs, such as the cost of time spent searching for the right house. In this case house prices are equal to the net present value of the housing rents to sellers plus sellers transaction costs and are also equal to the net present value of the housing rents to buyers minus buyers transaction costs. One then also needs to adjust for the fact that in the US house prices are set when both parties sign a legal contract, which is usually between two and eight weeks before the closure of the deal[5]. It is not then generally possible to renegotiate the price unless property specific issues are found and penalties, such as the loss of earnest money payments, are often imposed if a party withdraws from the transaction. Therefore the expectations used in the adjusted fundamental value should be lagged to reflect this. Therefore house prices being equal to their adjusted fundamental value can be mathematically expressed as follows:

$$E_{t-1}\,(\sum_{k=0}^{\infty}\frac{HR^{s}_{t+k}}{DR^{s}_{t+k}}+TC^{s}_{t}) = HP_t \; = E_{t-1}\,(\sum_{k=0}^{\infty}\frac{HR^{b}_{t+k}}{DR^{b}_{t+k}}-TC^{b}_{t}) \tag{2}$$

where HP = real house prices, HR = real housing rents, DR = real discount rate, TC = real transaction costs, ^{b} denotes for buyers, ^{s} denotes for sellers and t denotes the time period.

The logic in this case is similar to above but indicates that more agents will search for (try to sell) housing if the price is below (above) their fundamental valuation after adjusting for transaction costs at the horizon that accounts for agents having to make legal offers prior to exchange.

The test I use for whether house prices are consistent with being equal to their adjusted fundamental value is based on their reaction to monetary shocks. Monetary shocks are relatively unique in that if house prices are equal to their adjusted fundamental value they should have a clearly signed response to monetary shocks as soon as contractual rigidities stop binding. Monetary shocks are by definition unexpected (Ramey, 2016), so their effects cause changes in the expected values of sellers and buyers in Equation 2 once the contractual rigidity no longer binds and new expectations can be used. By considering their likely effect through each of the

[5]See the origination insight reports from Ellie May for survey data supporting this.

channels in Equation 2, one can demonstrate that the effects through all channels are likely to imply that expansionary (contractionary) monetary shocks imply increases (decreases) in house prices if they are equal to the adjusted value of housing once new expectations can be used. The following paragraphs consider each channel at a time under the null hypothesis that house prices are equal to their adjusted fundamental value.

The effects of an expansionary monetary policy shock through discount rates are relatively clear. The shock will reduce base rates directly. It is also likely to reduce risk premia, illiquidity premia and other premia that drive the difference between the housing discount rate and base rates. Theoretically this is likely to be true as improved economic and financial conditions could reduce housing risk and risk aversion while increasing housing liquidity, while empirically this is likely to be true as Gertler and Karadi (2015) show that expansionary monetary policy shocks reduce the housing finance premium. Therefore the shock is very likely to reduce discount rates and so increase house prices through this channel.

The effects through housing rents and transaction costs are less simple, and so are explained with reference to two simple conceptual frameworks that build on the adjusted fundamental value of housing and are included in the Appendix. The first also includes consumption demand and housing supply to explain the rents channel and the second also includes search frictions to explain the transaction cost channel. The first framework explains the linked markets for housing consumption and housing ownership in terms of a consumption demand curve in the housing consumption market, a supply curve in the housing ownership market and an asset demand curve in both markets. This framework helps to demonstrate why the effect of an expansionary monetary shock on house prices through the consumption channel is very likely to be positive, even though housing rents themselves may not rise. Theoretically consumption demand is very likely to rise as a result of improved economic conditions and empirically other forms of consumption rise (Coibion et al., 2017). This should place upwards pressure on rents in the housing consumption market and the value of housing in the housing ownership market. However the increase in asset demand resulting from reduced discount rates will place positive pressure on house prices in the housing ownership market but negative pressure on housing rents in the housing consumption market. Therefore the overall effect on housing rents is ambiguous, although the effect on house prices should be unambiguously positive.

The second framework in the Appendix helps to demonstrate how even though part of the adjustment to an expansionary monetary shock could occur through search costs, part of it should unambiguously occur through house price rises. Equation 2 suggests that the only way house prices could fall is if transaction costs for sellers fall and/or transaction costs for buyers rise sufficiently to outweigh the increases in the discounted stream of rents through the channels discussed above. However this cannot happen as a result of changed search costs because it would be inconsistent with bargaining. It would imply that there are more buyers relative to sellers, which would increases the bargaining position of sellers, as their outside option has improved, while agents' valuation of owning a house would increase due to the shock. Therefore, bargaining should ensure that house prices increase, even if the shock causes a change in market tightness that affects search costs.

More unusual transmission mechanisms of monetary shocks to house prices are also likely to either amplify the effects above or not have a significant signed effect. For instance the analysis in Ngai and Tenreyro (2014) suggests that there will be thick market effects if the expansionary shock increases the quantity of housing traded, as seems likely after an expansionary monetary shock. One can also be confident that monetary shocks won't rapidly cause significant changes in any other aspects of housing that investors have direct preferences over, such as housing's environmental, social and governance (ESG) impacts.

Therefore one can be confident that monetary shocks should have unambiguously signed effects on house prices once contractual rigidities no longer bind if they are equal to the adjusted fundamental value of housing. This is not true for most other shocks, as the reaction of base rates will act in the opposite direction from most other channels in aggregate demand shocks and the reaction of housing supply will operate in in the opposite direction from most others channels in aggregate supply shocks. Therefore we cannot say that there should be a clearly signed response of house prices to most shocks: in theory it will be ambiguous and even in practice if we suspect a sign it may well be sufficiently small that we cannot detect it.

The null hypothesis of the test of whether house prices are consistent with always being equal to there adjusted fundamental value is therefore that expansionary (contractionary) monetary shocks increase (decrease) house prices at a horizon of one to two months. This is only a test of consistency with house prices being equal to their adjusted fundamental value, as alternate explanations of house prices may also imply that they respond to monetary shocks rapidly. Therefore the test can, at least in theory, reject the hypothesis that house prices are equal to their adjusted fundamental value, but it cannot prove it. However several prominent alternate explanations of house prices could imply that house prices respond much more slowly to monetary shocks. For instance agents may not have accurate information on shocks in real time, violating the full information assumption, so would not be able to react to shocks as rapidly. Agents may also have non-rational expectations as they may not use all available variables when forecasting, due to the amount of effort involved, or may not adjust forecasts to complex new information, due to not understanding it. Therefore they may not react until easily accessible and understandable information on shocks becomes available. Indeed, even if there are only some agents that have non-rational expectations then those agents that do have rational expectations may exacerbate deviations from fundamental values (Brunnermeier and Oehmke, 2013), as no agent is wealthy enough to materially affect aggregate US house prices alone. Therefore evidence against the hypothesis would fit with these alternate explanations of house prices.

To identify monetary shocks I build on the narrative approach of Romer and Romer (2004)[6]. These shocks were originally constructed by regressing the intended change in the effective federal funds rate around Federal Open Market Committee meetings on the Federal Reserve's internal forecasts of its macroeconomic targets.

[6] I don't use high frequency shock measures based on futures markets for two reasons. Firstly, Miranda-Agrippino (2016) as well as Romer and Romer (2000) suggest that Federal Reserve forecasts are better than private sector forecasts. Secondly, I want to include the largest natural experiment in the modern era of US monetary policy: the period of non-borrowed reserve targeting, and data on high frequency measures is only available for more recent periods.

However Ramey (2016) suggests that one could also control for the broader state of financial markets, which transmit monetary policy and so are also taken into account by the Federal Reserve. This is likely to be especially important in the case of an asset price like house prices, so I also include the Chicago Fed financial conditions index, the effective federal funds rate, the 5 year term spread and the 30 year mortgage rate as additional financial controls in the baseline case. However I also repeat the estimation without these additional controls to assess the changes they may cause. The baseline generating regression is therefore:

$$\Delta i_t^{int} = \phi^1 + \phi^2 i_t^{int} + \sum_i \phi_i^3 \; \Delta E_{FR}(\pi_{t+i}) + \sum_i \phi_i^4 \; E_{FR}(\pi_{t+i}) + \sum_i \phi_i^5 \Delta E_{FR}(gr_{t+i}) \\ + \sum_i \phi_i^6 \; E_{FR}(gr_{t+i}) + \sum_i \phi_i^7 \; E_{FR}(un_{t+i}) + \sum_j \phi_j^8 \; fin_t^j + \epsilon_t \quad (3)$$

where i_t^{int} = the intended federal funds rate, $E_{FR}(x)$ = the federal reserve's expectations of variable x, π = inflation, gr = GDP growth, un = unemployment and fin = financial control variables, t denotes the time period, i denotes the quarter of the forecast and ranges from -1 to 2, j ranges from 1 to 4.

To estimate the effect of monetary shocks on real house prices, I use these narrative monetary shocks in the local projection method of Jorda (2005). This approach is robust to the exact data generating process of real house prices and directly estimates their response to the narrative shocks at each forecast horizon. This is crucial when the timing of effects is of particular interest, as it allows me to be confident that the timing results from the genuine correlations between real house prices and monetary policy shocks at different lags and not simply from a mis-specified model. Ramey (2016) also suggests that the small sample estimates with narrative monetary shocks could be improved by including additional lagged controls, so I also include short (one year) and long (four year) real house price changes, real housing rents changes and housing starts. I also repeat the estimation without these additional controls to assess the changes they may cause. The baseline local projections regressions are therefore:

$$\Delta_h lnHP_{t+h} = \beta^h s_t + + \sum_k \gamma^k \ HV_{t-1}^k + \varepsilon_t \quad (4)$$

where $lnHP$ = log real house prices, s = the narrative monetary shocks, HV = housing control variables, t denotes the time period, h denotes the horizon and k ranges from 1 to 6.

I bootstrap across both stages of the process to account for the generated regressors in the standard errors. Specifically, I use a block normal bootstrap with block length of a year to allow for the additional variance produced by any remaining auto-correlation in the errors. This bootstrap approach is computationally efficient, as it only requires bootstrapping moments of the distribution instead of its extreme values, so I use 1000 repetitions at each forecast horizon.

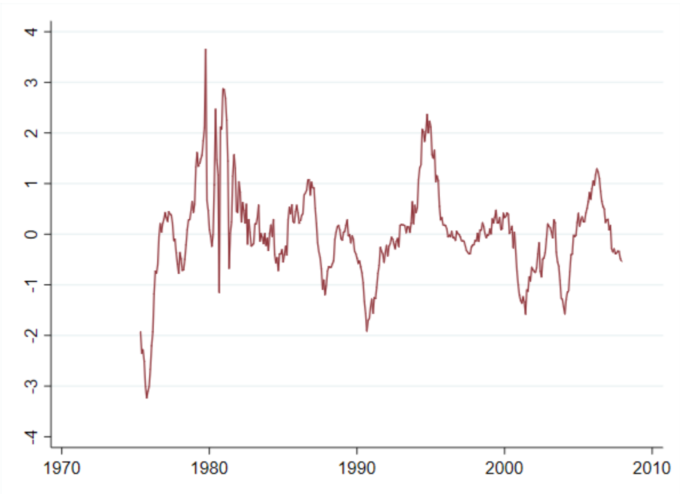
I can then formally test whether there is a statistically and economically significant reaction of real house prices to monetary shocks at a horizon of one to two months. I can also calculate estimated impulse response functions of real house prices to monetary shocks. These let me compare my results to those from the existing literature and check that the overall sign of the response of real house prices is consistent with the narrative shocks not simply capturing endogenous movements in base rates and that the shocks are not so rapidly reversed that an identified expansionary shock is effectively a contractionary shock.

3 Conducting the test with narrative monetary shock data

I now move on to conducting the test of whether US real house prices are consistent with always being equal to their adjusted fundamental value by estimating the response of aggregate US house prices to narrative monetary shocks at different horizons.

As discussed in Section 1, I produce the narrative shocks by using the approach of Romer and Romer (2004) but also including additional financial control variables. I therefore estimate Equation 3 and take the residuals as the narrative monetary shock series. This approach yields shocks which have very low levels of auto-correlation and are highly variable, so to present them graphically I take a one year moving sum. The resulting series is plotted in Figure 1. There are several periods in which the existing literature identifies clear narratives for exogenous loosening or tightening based on a combination of political and operational reasons. The first and largest of these is the period of non-borrowed reserve targeting from 1979-1982. However political pressure for loose policy in the late 1970s and the early 2000s as well as the desire to gain credibility in the 1990s are also commonly suggested[7]. All of these are visible in the shock series.

Figure 1: Moving sum of monetary shocks



Notes: Plot of the one year centered moving sum of the narrative monetary shocks generated from Equation 3. The vertical axis is in percentage points and the horizontal axis is in years.

To estimate the effect of monetary shocks on real house prices, I use the narrative monetary shocks in the local projection method of Jorda (2005) with additional lagged housing controls, as discussed in Section 1. I therefore estimate Equation 4 at each horizon considered to produce an IRF of real house prices to a monetary shock. The data used is the monthly repeat transactions house price index produced by Freddie Mac deflated with CPI index. In the Appendix I also repeat the main

[7]See Romer and Romer (2004) and the sources cited therein for details

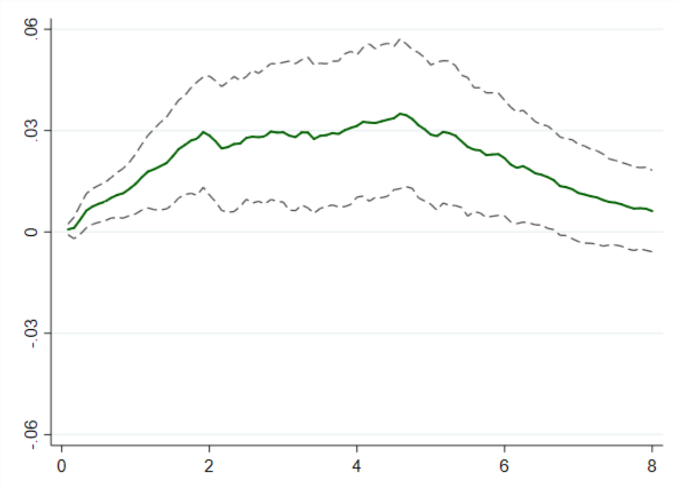
analysis in this paper using Case-Shiller data and the results are very similar.

Figure 2 shows the IRF of real house prices to a one percentage point decline in the narrative shock measure, which is a large expansionary shock but less than the largest absolute value observed in the shock series. The IRF is plotted to a horizon of eight years and a 95% confidence interval is shown along wit the central estimates. It is clear that the effects of the shocks near impact is virtually zero. This is not just because the effects of the narrative monetary shocks are always small, which could be the case if the monetary shocks measure partly capture endogenous influences or if monetary shocks are rapidly reversed and overcompensated for. The cumulative effect slowly rises from approximately zero to economically and statistically significant responses that are maintained over horizons of several years before declining to ultimately have effects close to zero again. The maximum effects occur at horizons of approximately two to five years, where a one percentage point expansionary shock causes an approximately three percentage point increase in real house prices, which is generally statistically significant at the 95% level. Therefore the monetary shocks do have significant effects, they just do not appear to occur near impact.

Table 1 plots the effects of a one percentage point decline in the narrative monetary shock measure at a horizon of one and two months to more formally examine the results at the horizons indicated by the test. The effect of the shocks at these horizons is virtually zero, both economically and statistically, quantitatively confirming what can be seen visually in Figure 2. The change corresponds to only about a tenth of a percentage point in real house prices after a large (one percentage point) monetary shock and is not statistically significant at any reasonable level. There is, therefore, effectively no response near impact. The scale of the actual changes caused by the shocks in the data reinforces the messages above. The estimates suggest that even the approximately 3 percentage point increase in the narrative shocks at the height of the period of non-borrowed reserve targeting, easily the largest shock in the series, caused virtually no change in real house prices near impact, but caused a fall in real house prices of approximately 8% after two to three years.

The result that monetary policy shocks have no effect on house prices near impact is also consistent with visual inspections of IRFs of real house prices to monetary

Figure 2: Impulse response function of real house prices to a monetary shock



Note: Plot of the estimated cumulative log change in real house prices in response to a one percentage point decrease in the narrative federal funds shock measure with bootstrapped 95% confidence intervals. The vertical axis is is units, so 0.05 corresponds to a 5% increase, and the horizontal axis is in years since the shock.

shocks near impact in existing empirical work. The vast majority of work appears to find essentially no effects near impact, but significant effects of with a lag measured in years. This is true for older papers, such as Fratantoni and Schuh (2003), Del Negro and Otrok (2007), Jarociński and Smets (2008) and Musso et al. (2011), that use timing and sign restrictions in auto-regressive models. It is also true of newer papers, such as Jorda et al. (2015a), Ungerer (2015), Coibion et al. (2017) and Alessi and Kerssenfischer (2019) that mainly use narrative shocks. These papers find that a one percentage point expansionary monetary shock has a maximum positive impact on house prices of between one and ten percent. Therefore the existing empirical literature implicitly provides strong support for the results of my test.

It is also necessary to consider the effects that the control variables have on my results, as some of these controls are an addition to those commonly used in the literature to estimate the empirical effects of monetary shocks. Figure 3 shows the IRFs produced using no additional controls in the shock generation estimation (upper panel) or the local projection estimation (lower panel). The results are

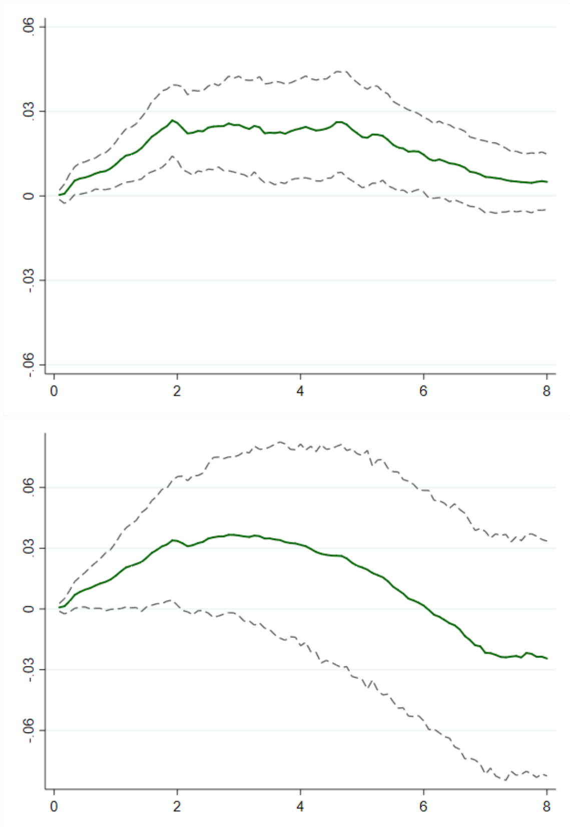
Table 1: Response of real house prices to monetary shocks near impact

Cumulative real house price growth	h = 1	h=2
Monetary shocks	-.001	-.001
	(-.002 to .001)	(-.004 to .002)
House price growth (1 year)	.118*	.235*
	(.069 to .167)	(.135 to .334)
House price growth (4 years)	-.011	-.025
	(-.033 to .010)	(-.068 to .019)
Housing rents growth (1 year)	.014	.015
	(-.105 to .133)	(-.232 to .262)
Housing rents growth (4 years)	-.005	-.008
	(-.048 to .037)	(-.094 to .079)
Log housing sales (1 year)	-.000	-.001
	(-.001 to .000)	(-.002 to .001)
Log housing sales (4 years)	.000	.000
	(-.000 to .000)	(-.001 to .001)
Constant	.015	0.024
	(-.089 to .120)	(-.187 to .236)
Adjusted R^2	0.382	0.413

Notes: The left column shows estimates of the effects of a one percentage point increase in the narrative federal funds shock measure at a one month horizon and the right column shows estimates at a two month horizon. Bootstrapped 95% confidence intervals are shown and * = significant at the 5% level.

broadly similar to those in the baseline case, especially for the upper panel. All three IRFs have virtually no effects near impact, then slowly rise to have economically and statistically significant effects of approximately three percent at horizons of several years before declining again. The only clearly noticeable differences between the IRFs are whether real house prices are just above or just below their initial level at horizons over six years and even these differences are not large. Therefore the controls do not appear to be responsible for changing the results of the estimation dramatically.

Figure 3: Impulse response function of real house prices to a monetary shock with fewer controls



Note: Plots of the estimated cumulative log change in real house prices in response to a one percentage point decrease in the narrative federal funds shock measure with bootstrapped 95% confidence intervals. The vertical axis is is units, so 0.05 corresponds to a 5% increase, and the horizontal axis is in years since the shock. The upper panel uses no additional controls in the shock generation estimation and the lower panel uses no additional controls in the local projection estimation.

This increases the confidence one can have in the results presented here, as the results in Figure 3 function as robustness checks. However it also may increase the confidence one could have in the results from the literature that estimate the effects of narrative monetary shocks on a wide variety of variables without including variable specific controls because, at least in the case of housing, these additional controls do not appear to be necessary.

Taken together, these results provide strong evidence against the hypothesis that house prices are always consistent with being equal to their fundamental value, even after this fundamental value is adjusted for search frictions and contractual rigidities. The results are, however, consistent with agents not observing monetary shocks well in real time or agents' expectation not reacting rationally to available information on monetary shocks. I would suggest that both of these factors are likely to play a role in explaining the results. Identifying monetary shocks in real time is clearly hard, as even experts struggle to identify monetary shocks (Ramey, 2016). Also many agents in housing markets are clearly not experts and so survey evidence, such as that in Case et al. (2012), suggests that some homebuyers do not have rational expectations. Monetary shocks do not seem relatively harder to measure or understand than many other shocks. Indeed, identifying monetary shocks benefits from the Federal Reserve having very clearly specified aims, presenting its policy tools in quantitative form and publishing information which Ericsson (2016) shows can be used to essentially infer its information. The equivalent is not necessarily true for other shocks, such as productivity shocks or financial shocks. This suggests that agents may struggle to observe or use expectations that respond rationally to many macroeconomic shocks. Therefore models of housing markets based on full information rational expectations, which are common in macroeconomics, may be seriously mis-specified so their implications could be very misleading.

4 New stylised facts on the drivers of housing cycles

The two conceptual framework in the Appendix are primarily introduced to explain why monetary shocks are very likely to have an unambiguously signed effect on house prices once contractual rigidities no longer bind. However the first framework also implies a sign decomposition[8] that can be used to analyse the relative importance of proximal drivers of house price movements. These proximal drivers are some of the channels through which the ultimate shocks that drive housing cycles are transmitted. This first conceptual framework explains the linked markets for housing consumption and housing ownership with a consumption demand curve that directly affects the housing consumption market, a supply curve that directly affects the housing ownership market and an asset demand curve that directly affects both markets. This implies the following effects of shifts in the curves, where all effects are normalised to increase real house prices: shifts in housing supply, such as those generated by housing regulation or building cost changes will reduce the quantity of housing and increase real rents. Shifts in consumption demand, such as those generated by higher incomes or consumer confidence, will increase the quantity of housing and real rents. Shifts in housing asset demand, such as those generated by increased real house price expectations or easier housing credit will increase the quantity of housing and reduce real rents. This implies the correlation structure for movements driven by each type of shift in Table 2.

It is important to note that these frameworks aim to capture some of the main mechanisms in housing markets and I do not claim to capture all mechanisms in housing markets. This is why I limit the models to sign analysis that seems unlikely to be invalidated by including other variables. One aspect of this simplification is that I use one variable for each series, rather than including separate variables for each expected future value of the series. Therefore it is appropriate to apply the sign restrictions to components of the variables that have enough persistence[9]

[8]This sign decomposition is also very likely to remain valid if the search frictions in the second framework are included too, as discussed in the Appendix.

[9]This is one of the reasons why it was necessary to confirm in the previous section that the

that there will not be lagged effects that more than offset the effects of an initial change in a variable. As a result of this, and the interest in housing cycles due to their macroeconomic consequences, I focus on the cyclical components of housing variables. Burns and Mitchell (1946) historically suggested that business cycles occur at lengths of 1.5 to 8 years, however Drehmann et al. (2012) suggests that more recent housing cycles can have longer lengths, so in the baseline case I extract cyclical components with cycles of between 3 years and 40 years. However, I extract cyclical components with longer maximum cycle lengths and shorter minimum cycle lengths in the Appendix and there are no meaningful changes in my main results.

The correct filter to extract cycles from data depends upon the exact data being analysed. Parametric approaches such as unobserved components models require a model with very specific assumptions over the form of the components to be kept or removed. Therefore the cycle obtained can reflect the assumed model as much as the data in question. Non-parametric approaches, such as band-pass filters, overcome this main problem. These filters aim to isolate the components of a variable driven by cycles at a specified range of frequencies and so fit with the definition of housing cycles used here. It is necessary to difference any data used to remove unit roots before applying these techniques (Murray, 2003) and use a finite sample approximation to the ideal filter (Baxter and King, 1999). Band-pass filters include the desired frequencies from all components of the series: signal components and noise components. Therefore it is important to check that there really are strong auto-correlations in the data before being using a band-pass filter. Therefore, in practice, one has to understand the order of integration and persistence of the data before deciding exactly how, and whether it is appropriate at all, to use them. To aid this decision in the case of real house prices, Table 3 displays the results of applying integration tests to real house prices in levels and growth rates and the auto-regressive parameters from the augmented Dickey-Fuller test.

Despite the low power of unit root tests, the results support the assumption used

narrative monetary shocks do have sensibly signed effects on house prices at reasonable horizons, as otherwise they might be so rapidly more than reversed that what was identified as an expansionary shock would effectively be a contractionary shock.

Table 2: Cyclical correlations implied by the first conceptual housing market framework

	HP	HQ	HR
HP	1		
HQ	-	1	
HR	+	-	1

	HP	HQ	HR
HP	1		
HQ	+	1	
HR	+	+	1

	HP	HQ	HR
HP	1		
HQ	+	1	
HR	-	-	1

Notes: Cyclical correlations based on shifts in the three curves in the first conceptual housing market framework. The top correlation matrix denotes a shift in housing supply, the middle correlation matrix denotes a shift in housing consumption demand and the bottom correlation matrix denotes a shift in housing asset demand. HP = real house prices, HR = real housing rents and HQ = the quantity of housing.

in previous work, such as Drehmann et al. (2012), that real house prices contain a unit root in levels but not in growth rates. Therefore there is no non-stationary

Table 3: Integration and persistence properties of monthly real house prices

	Level	Growth rate
Augmented Dickey-Fuller test	-	*
Phillips-Perron test	-	*
Elliot et al. test	*	*
Dickey-Fuller persistence parameter	1.00	0.88

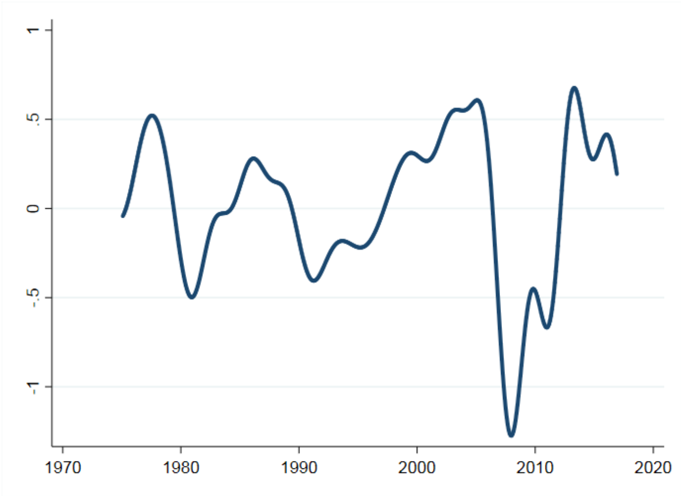
Notes: Results of applying integration tests to real house prices in levels and growth rates. The null hypothesis of the tests is integration of order of at least one and * = significant at the 5% level.

issue when applying a band-pass filter to real house price growth. The real house price growth series is highly persistent in growth rates, so I use the Christiano and Fitzgerald (2003) filter. This filter is fairly accurate for persistent processes, as it is derived from a random walk, and has the advantage of allowing filtered values to be constructed for all time periods in the sample. The high persistence of the series and visual inspection of the raw data suggest that the filter will primarily capture cyclical signal, rather than certain frequencies from noise.

Figure 4 shows the extracted cyclical component of monthly real house price growth data. A very clear cyclical component emerges, which is similar to that produced in Drehmann et al. (2012). It is associated with US recessions: it has small troughs alongside the 1980s Volcker recessions and the early 1990s recession and a significant trough alongside the great depression. In all these cases it also peaks towards the end of the preceding booms. The only exception to this is that there is little decline around the dot-com recession.

I now produce equivalent cycles for rents and the quantity of housing supplied. Since real house prices are in growth rates I would ideally also take the growth rates of real rents and the housing stock. For real rents I use the growth rate of the

Figure 4: Cyclical element of real house price growth

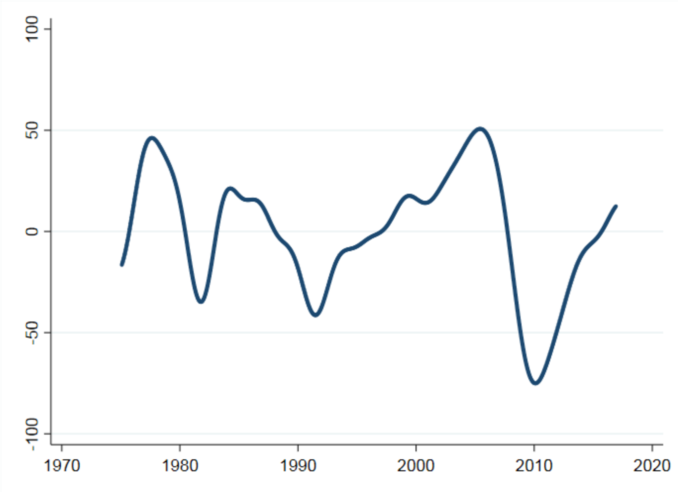


Notes: Plot of the component of monthly real house price growth rates with frequencies that give cycles of between 3 and 40 years in length, extracted with the Christiano-Fitzgerald filter. The vertical axis is in percentage points and the horizontal axis is in years.

CPI rent of primary residence series. Since there is no complete time series data on the US housing stock available, I use housing starts from the Census Bureau as a proxy. These series also conform to typical guides for stationarity. I apply the same Christiano-Fitzgerald filter to these series as applied to real house price growth to housing starts and real rental price growth. These cyclical components of these two variables are plotted in Figures 5 and 6 respectively. They both appear reasonable: the cyclical component of housing starts appear to be fairly similar to the real house price cycle and so is also related to the US business cycle, as measured by NBER recessions. There does not appear to be as clear a cycle in rents as the other two variables, but some downturns are visible.

I now have data series which correspond to the cyclical changes in the three main variables from the conceptual framework. Therefore their empirical associations can be used to judge the relative importance of housing consumption demand, housing asset demand or housing supply, based on which of the predicted associations in Table 2 are closest to the empirical associations. This may seem similar in principle

Figure 5: Cyclical element of housing starts

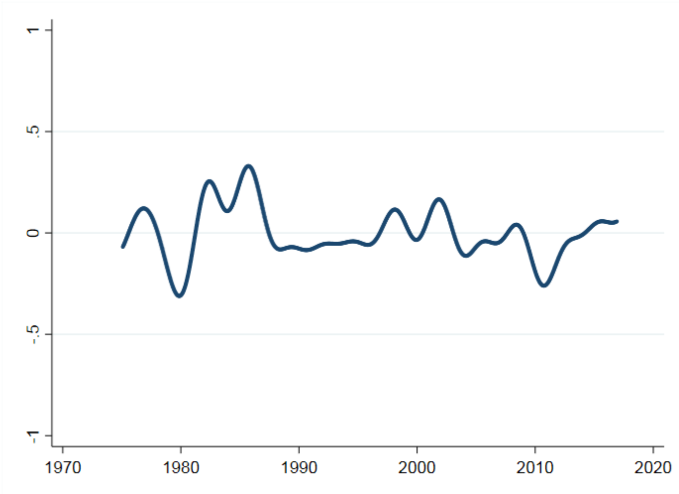


Notes: Plot of the component of monthly log housing starts (scaled up by 100 in construction) with frequencies that give cycles of between 3 and 40 years in length, extracted with the Christiano-Fitzgerald filter. The vertical axis is in units and the horizontal axis is in years.

to a sign restricted VAR or FAVAR, however there are important differences. Firstly, in my setting I do not assume that the changes I am capturing are independent and exhaustive, as I am clear in my conceptual framework that I am identifying transmission mechanisms, not structural shocks. For instance, a credit supply shock is extremely likely to influence both the asset and consumption demand for housing over time. Secondly, I don't use a very specific statistical model to try to remove all past correlations and trends, but instead aim to keep particular cyclical components of interest, so have far more flexibility and robustness. On the other hand this flexibility implies that I cannot conduct the formal decompositions associated with sign restricted VARs or FAVARs and can only compare relative importance. Thirdly, sign restricted VARs impose their restrictions, so give no evidence as to the validity of the restrictions themselves, whereas I do not impose my restrictions when calculating correlation structures, so could obtain a result which simply supports the rejection of the conceptual framework.

To study the empirical associations between the three variables I calculate stan-

Figure 6: Cyclical element of real housing rental price growth



Notes: Plot of the component of monthly real housing rental price growth rates with frequencies that give cycles of between 3 and 40 years in length, extracted with the Christiano-Fitzgerald filter. The vertical axis is in percentage points and the horizontal axis is in years.

dard linear correlations and Spearman rank correlations, in case there are important non-linear associations. In both cases I produce confidence intervals using a block normal bootstrap with block length of a year, which is asymptotically valid as both statistics are asymptotically normal. The linear correlation matrix and 95% confidence intervals are displayed in Table 4. The results show a very strong positive and significant correlation between the house price series and the housing starts series. Even at the lower end of the confidence interval this correlation is still economically significant and at the top end it is close to perfect positive correlation. The correlations between the housing rents series and the other two series are also positive, but they are weaker and only significant in one of the two cases.

Table 5 shows the Spearman rank correlation matrix. The rank correlations are extremely similar to the linear correlations: there is a very strong positive and significant correlation between the house price series and the housing starts series and the correlations between the housing rents series and the other two series are also positive, but they are weaker and less significant. Therefore there do not appear

Table 4: Housing market cyclical linear correlations

	HP	HN	HR
HP	1		
HN	0.62*	1	
	(0.40 to 0.83)		
HR	0.27*	0.27	1
	(0.06 to 0.49)	(-0.03 to 0.56)	

Notes: Linear correlations between the cyclical components of real house price growth, real rental price growth and housing starts. Bootstrapped 95% confidence intervals are also shown and * = significant at the 5% level. HP = real house prices, HR = real housing rents and HN = the quantity of new houses started.

to be important non-linear associations between the variables and the results of the rank correlations simply support the results of the linear correlations.

The strong and significant positive correlations between the house prices and housing starts variables shows that housing supply shifts are clearly the least important of the three cyclical transmission mechanisms. This does not imply that there are no supply effects, but only that they are strongly outweighed by consumption and asset demand shifts as a driver of housing market cycles. The positive correlations between the housing rents variable and each of the other two variables suggests that consumption demand is the most important driver of housing cycles. However, the correlations between housing rents and the other two variables are weaker than those between house prices and housing starts and only two of the four correlations are statistically significant. Therefore, asset demand changes may also have been important and in particular unusual periods could even have been the most important driver. For instance it is interesting that the only period in which

Table 5: Housing market cyclical rank correlations

	HP	HN	HR
HP	1		
HN	0.64*	1	
	(0.41 to 0.87)		
HR	0.31*	0.27	1
	(0.04 to 0.57)	(-0.03 to 0.57)	

Notes: Linear correlations between the cyclical components of real house price growth, real rental price growth and housing starts. Bootstrapped 95% confidence intervals are also shown and * = significant at the 5% level. HP = real house prices, HR = real housing rents and HN = the quantity of new houses started.

cyclical real house price growth and housing starts appear to grow significantly accompanied by a decrease in cyclical real rental price growth is during the early 2000s housing boom, suggesting that shifts in asset demand may have outweighed shifts in housing consumption in this period. However over most of the sample shifts in consumption demand were the most important, shifts in asset demand were also relatively important and shifts in housing supply were the least important proximal drivers of US housing cycles.

5 Conclusion

It is important to understand if house price fluctuations are driven by changes in fundamentals, because if they are not then this implies the potential for housing bubbles that could have serious macroeconomic consequences. However assessing whether changes in house prices are driven by changes in the fundamental value of housing is extremely difficult, especially once the definition of fundamental value is adjusted to account for the search frictions and contractual rigidities in housing markets.

In this paper I introduce a new test of whether real house prices are consistent with always being equal to the adjusted fundamental value of housing. This test is based on the idea that monetary shocks should cause clearly signed reactions in the adjusted fundamental value of housing as soon as contractual rigidities no longer bind: an idea that I support with two conceptual frameworks and references to existing empirical work on the transmission mechanisms of monetary policy. Therefore I test whether real house prices have a significant reaction to monetary shocks at the horizon when contractual rigidities no longer bind, which is within two months.

I implement this test using narrative monetary shocks, which are constructed with the Romer and Romer (2004) approach, but augmented with finance and housing specific controls. The reaction of real house prices to these shocks is estimated using local projections to accurately capture the timing of the reactions. The results show that there are no statistically significant or economically meaningful reactions of real house prices to monetary shocks within two months of a monetary shock. However IRFs show that there are statistically significant and economically meaningful responses at horizons greater than a year and are similar to IRFs in the existing literature. Therefore the results provide strong evidence that house prices are not consistent with always being equal to the fundamental value of housing, even after this fundamental value has been adjusted for search frictions and contractual rigidities.

Instead the results are consistent with explanations such as agents' inability to observe monetary shocks precisely in real time or agents expectations not reacting rationally to available information about monetary shocks. Monetary shocks are not necessarily harder to observe than other shocks, and may well be easier, as the Federal Reserve publishes a large amount of information on its aims, expectations and policy tools in quantitative form. No similar information is available for other shocks such as productivity or financial shocks, suggesting that agents are unlikely to precisely observe and adjust their expectations rationally to these shocks either.

As a result the many recent macroeconomic models that assume agents in housing markets use full information rational expectations may be seriously mis-specified and so may be of little practical relevance.

In additional work I also use a sign decomposition, suggested on the basis of the conceptual frameworks, to analyse the relative importance of different proximal drivers of US housing cycles. I implement this decomposition using linear and rank correlations between the cyclical components of different housing variables, where the cyclical components are extracted using an appropriately chosen band-pass filter. I find that the consumption demand channel has been the most important proximal driver of housing cycles, the asset demand channel has also been relatively important and the housing supply channel has been clearly the least important.

These results suggest that changes in house prices do not always result from changes in the fundamental value of housing, even after adjusting for the frictions in housing markets. The results are instead consistent with agents not observing many shocks and not adjusting their expectations rationally in reaction to information on shocks. Therefore housing cycles are likely to arise from the partially behavioural reaction of housing markets to shifts in the demand for housing consumption and housing assets.

Appendices

A Conceptual frameworks

This section of the Appendix introduces two conceptual frameworks that build on the expression for the fundamental value of housing[10] introduced in Section 2. One which uses the basic fundamental value expression in a system with housing consumption and housing supply and one which uses the fundamental value expression with search frictions and bargaining. The first of these demonstrates the transmission of monetary shocks through housing rents, and suggests a sign decomposition for the proximal drivers of house price fluctuations, while the second demonstrates the transmission of monetary shocks through search costs.

I start with the first framework, in which the housing market effectively consists of two interrelated areas: housing consumption and housing ownership. The real prices of housing consumption are real rents and the real prices of housing ownership are real house prices. The total quantity of houses that people desire to own and the total number of houses that people live in and so consume the housing services of are equal. Therefore there are three key variables in the market: real house prices, real housing rents and the quantity of housing. Clearly these are not the only relevant variables in reality, so I limit my analysis to the sign of likely effects and specify that this is under the assumption that no excluded variables have sufficiently large counteracting effects to change the signs implied here.

I initially consider the standard fundamental value condition and show that this is likely to be a special case of a more general expression of housing asset demand in this framework. The fundamental value condition is an expression for house prices that is a positive function of housing rents. However it is also likely to be a negative function of the quantity of housing agents choose to own, which I call housing asset demand. This is because as agents choose to own more housing they will have to bear more of the risks associated with housing, since asset classes are imperfect

[10] As discussed in the main text, throughout this paper house prices, housing values, housing rents and other related variables are all considered in real terms unless stated otherwise.

substitutes for one another, so the premia attached to the specific risks in housing are likely to rise. This in turn can be easily rearranged to give an expression for the quantity if housing owned, i.e. housing asset demand, that falls with real house prices and rises with real housing rents, as follows:

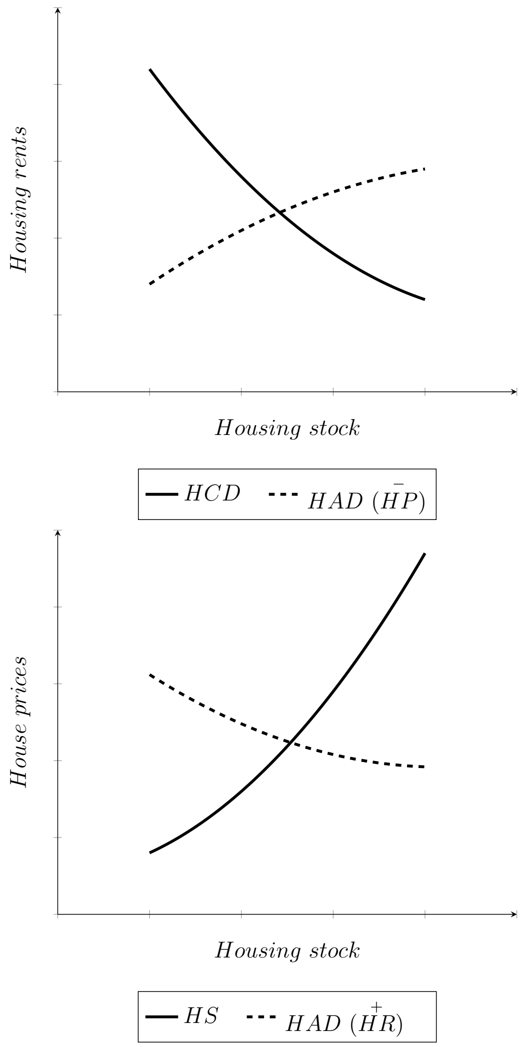
$$
\begin{aligned}
HP_t &= E_t \, (\sum_{k=0}^{\infty} \frac{HR_{t+k}}{DR_{t+k}}) \\
HP &= E \, (\sum \frac{HR}{DR(\overset{+}{HAD})}) \\
HP &= g(\overset{+}{HR}, \overset{-}{HAD}) \\
HAD &= f(\overset{-}{HP}, \overset{+}{HR})
\end{aligned}
\tag{5}
$$

where HP = real house prices, HR = real housing rents, DR = real discount rate, HAD = housing asset demand and f_x denotes a function with the sign of differentials given by + or - above variables.

This expression is sensible. Housing asset demand is very likely to increase in real housing rents, as these, or the ability to forgo paying them to others, are part of the real return of holding a housing investment along with expected price changes and non-monetary benefits. Housing asset demand is also very likely to decrease with real house prices, as this is the price of purchasing the expected stream of real returns.

I can then use similar logic to also construct equivalent signed expressions for housing consumption demand and housing supply. I start by considering the supply of housing. It will be more profitable for businesses and households to supply additional housing if the real price they receive for it is higher. Therefore housing supply is very likely to increase with real house prices. Whereas, I assume that housing supply only responds to real housing rents in so far as they affect real house prices. Next I consider the demand for housing consumption, which includes the consumption of housing services from houses that agents own. When real rents are high agents face a high price for housing consumption and are very likely to demand less of it. Therefore housing consumption demand is a negative function of real housing rents. Whereas, I assume that the demand for housing consumption supply only responds to real house prices in so far as they affect real housing rents.

Figure 7: Plots of housing ownership and consumption markets in the first framework



Notes: Plots of the conceptual functions for housing supply, housing consumption demand and housing asset demand, all measured in terms of the housing stock, as a function of either real housing rents or real house prices in the first conceptual framework. The upper panel shows the housing consumption market and the lower panel shows the housing ownership market. HS = housing supply, HCD = housing consumption demand, HAD = housing asset demand, HP = real house prices and HR = real housing rents.

Therefore the expressions for housing supply, housing consumption demand and housing asset demand, plotted in Figure D.1, can be summarised as:

$$\begin{aligned} HS &= f_1(\overset{+}{HP}) \\ HCD &= f_2(\overset{-}{HR}) \\ HAD &= f_3(\overset{-}{HP}, \overset{+}{HR}) \end{aligned} \tag{6}$$

where HS = housing supply, HCD = housing consumption demand, HAD = housing asset demand, HP = real house prices, HR = real housing rents and f_x denotes a function with the sign of differentials given by + or - above variables.

If the housing market clears, so demand equals supply, then shifts in each of the curves would have the effects in Table D.1, normalising the effect on real house prices to be positive. Shifts in housing supply, such as those generated by housing regulation or building cost changes will reduce the quantity of housing and increase real rents. Shifts in consumption demand, such as those generated by higher incomes or consumer confidence, will increase the quantity of housing and real rents. Shifts in housing asset demand, such as those generated by increased real house price expectations or easier housing credit will increase the quantity of housing and reduce real rents. This directly yields the correlation structures implied by the three shifts in Table 2. It is important to note that these three curves represent the main transmission mechanisms which underlie the housing market, rather than structural shocks. Structural shocks need to be independent of one another, which is not the case for transmission mechanisms.

The effects of an expansionary monetary shock on real house prices can then be analysed as follows. The reduction in expected base rates, risk and liquidity premia discussed in Section 2 will increase asset demand at any given levels of housing rents and house prices, shifting the asset demand curve to the right in the housing consumption and housing ownership diagrams in Figure D.1. This will place upwards pressure on house prices and downwards pressure on housing rents. The expected increase in housing consumption from expected increased economic and financial conditions discussed in Section 2 will increase consumption demand

Table 6: Signed effects of shifts in housing market curves

	HP	HQ	HR
Supply	+	-	+
Consumption demand	+	+	+
Asset demand	+	+	-

Notes: Effects implied by the conceptual framework of a shift in each of the three curves, normalised to increase house prices. HP = real house prices, HR = real housing rents and HQ = the quantity of housing. All effects are normalised to have a positive effect on house prices.

at any given level of housing rents, shifting the consumption demand curve to the right in the housing consumption diagram in Figure D.1. This will place upwards pressure on housing rents and so indirectly shift the asset demand curve to the right in the housing ownership diagram in Figure D.1, placing upwards pressure on house prices. Therefore the overall effect on real housing rents is ambiguous, as the effects through consumption demand and asset demand operate in opposing directions, so it is possible for real housing rents to fall in reaction to an expansionary monetary shock. However real house prices will unambiguously rise, once contractual rigidities allow them to change, as the asset demand and consumption demand channels will both drive increases in house prices.

I now move onto the second framework, in which I only consider the market for housing ownership but now introduce search frictions in this market. Specifically I assume that it takes time for buyers and sellers to match with one another and the probability of a successful match in any period for a buyer (seller) decreases (increases) with the market tightness, i.e. the number of buyers relative to the number of sellers. I therefore only consider two main variables in this setting: real house prices and the market tightness. As with the first conceptual framework, I acknowledge that these are not the only relevant variables in reality, so I limit my analysis to the sign of likely effects and again specify that this is under the assumption that no excluded variables have sufficiently large counteracting effects to change the signs implied here.

I initially consider the adjusted fundamental value condition, introduced in Section 2, with a particular focus on the adjustment for transaction costs, which in this setting will be driven by the search frictions. I treat the discounted sums of rents as exogenous valuations of owning a house for buyers and sellers. Since the time spent searching for a house will be costly, as it will imply reduced leisure or working time, the longer an agent expects to spend searching the higher their transaction costs are. This implies that if the market is tighter, so search time increases for buyers and decreases for sellers, then transaction costs increase for buyers and decrease for sellers. With exogenous valuations this implies that house prices must fall to stop it being profitable for a net increase in sellers in the market to occur. Therefore the adjusted fundamental value of housing implies that house prices are a negative function of market tightness in this setting, as follows:

$$\begin{aligned} E_{t-1}\,(\sum_{k=0}^{\infty}\frac{HR^s_{t+k}}{DR^s_{t+k}} + TC^s_t) = HP_t \; &= E_{t-1}\,(\sum_{k=0}^{\infty}\frac{HR^b_{t+k}}{DR^b_{t+k}} - TC^b_t) \\ E\,(HDS^s + TC^s(\frac{\overset{-}{HB}}{HS})) = HP \; &= E\,(HDS^b - TC^b(\frac{\overset{+}{HB}}{HS})) \\ HP =& m_1(\frac{\overset{-}{HB}}{HS}) \end{aligned} \tag{7}$$

where HP = real house prices, HR = real housing rents, DR = real discount rate, TC = real transaction costs, HDS = the real discounted sum of rents, $\frac{HB}{HS}$ = market tightness, ^{b} denotes for buyers, ^{s} denotes for sellers and m_x denotes a function with the sign of differentials given by + or - above variables.

After a match occurs then the buyer and the seller have to bargain over the price, as the buyers willingness to pay is greater than the sellers reservation price. Their relative bargaining strength will determine which level between these two values the agreed house price is set at. This bargaining strength will be affected by the value of each negotiators reserve option of returning to search, which will be lower for the buyer and higher for the seller if the market is tighter. Therefore house price bargaining implies that house prices are a positive function of market tightness, as follows:

$$
\begin{aligned}
HP &= HDS^s + \phi \ (HDS^b - HDS^s) \\
HP &= HDS^s + \phi(\overset{+}{\frac{HB}{HS}}) \ (HDS^b - HDS^s) \\
HP &= m_2(\overset{+}{\frac{HB}{HS}})
\end{aligned}
\tag{8}
$$

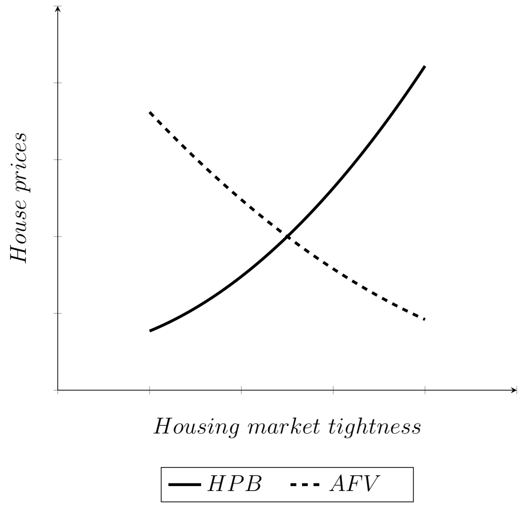
where HP = real house prices, HDS = the real discounted sum of rents, $\frac{HB}{HS}$ = market tightness, ϕ = sellers' relative bargaining strength between 0 and 1, ^{b} denotes for buyers, ^{s} denotes for sellers and m_x denotes a function with the sign of differentials given by + or - above variables.

Therefore the relationships between real house prices and housing market tightness implied by the conceptual functions for the adjusted fundamental value of housing and the house price bargaining condition have different signs. Since only the housing ownership market is considered and the discounted sum of rents is treated as exogenous in this conceptual framework these two functions are the only ones considered. They are plotted in Figure D.2.

The effects of an expansionary monetary shock in this framework can then be analysed as follows. The effects on base rates, premia and consumption demand would raise the discounted sum of housing rents for both buyers and sellers. This would cause both the adjusted fundamental value curve and the house price bargaining curve in Figure D.2 to shift upwards. Therefore the effect on market tightness is ambiguous, so it is possible that the response to the shock includes a change in market tightness. However both curves will place upwards pressure on house prices, so house prices will unambiguously rise regardless of the change in market tightness.

It is also worth noting that one could expand the first framework, which includes the housing ownership and consumption markets, to also include the search frictions from the second framework in the housing ownership market. In this case the estimated signed effects from the first framework would remain true as long as the

Figure 8: Plot of the housing ownership market in the second framework



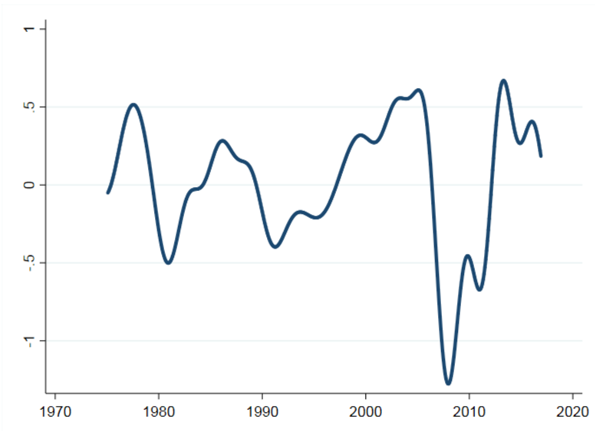
Notes: Plots of the relationships between real house prices and housing market tightness implied by the functions for the adjusted fundamental value of housing and the house price bargaining condition in the housing ownership market of the second conceptual framework. AFV = adjusted fundamental value of housing and HPB = house price bargaining condition.

original mechanisms were not entirely counteracted by changes in search costs from the response of market tightness. Such a change in market tightness in response to shifts in housing consumption demand, housing asset demand or housing supply shocks seem extremely unlikely to be compatible with both asset demand and house price bargaining behaviour, even if these are not exactly as described in the second framework. Therefore the signed effects of the shifts in Table D.1 are very likely to remain the same in such a setup.

B Cycle periodicity robustness

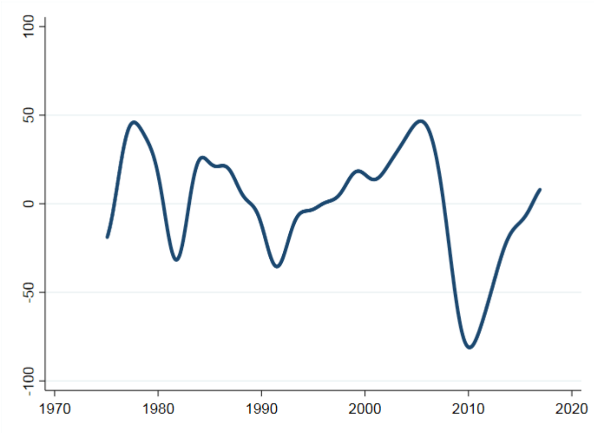
This section of the Appendix contains the robustness checks from increasing the maximum cycle length and reducing the minimum cycle length of the cyclical components extracted from the housing variables. The following graphs and tables show the cyclical components and the associations between them but either extend the maximum cycle length extracted to 50 years or reduce the minimum cycle length extracted to 1.5 years. In both cases the results are similar to those in the baseline case.

Figure 9: Cyclical element of real house price growth with longer cycles



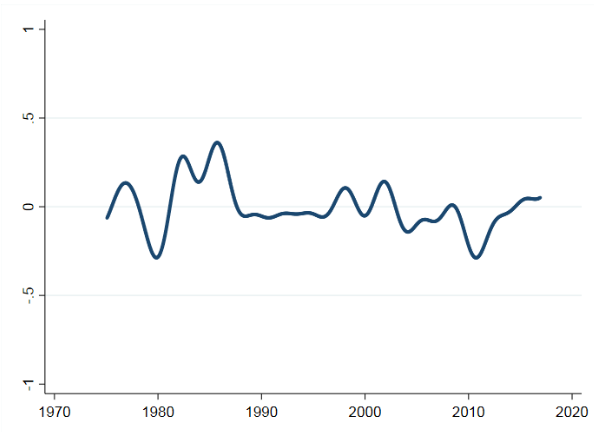
Notes: This repeats the graphs from Figure 4 but with frequencies that give cycles of between 3 and 50 years in length.

Figure 10: Cyclical element of housing starts with longer cycles



Notes: This repeats the graphs from Figure 5 but with frequencies that give cycles of between 3 and 50 years in length.

Figure 11: Cyclical element of real housing rental price growth with longer cycles



Notes: This repeats the graphs from Figure 6 but with frequencies that give cycles of between 3 and 50 years in length.

Table 7: Housing market cyclical linear correlations

	HP	HS	HR
HP	1		
HS	0.60*	1	
	(0.39 to 0.81)		
HR	0.26*	0.31	1
	(0.03 to 0.48)	(-0.01 to 0.62)	

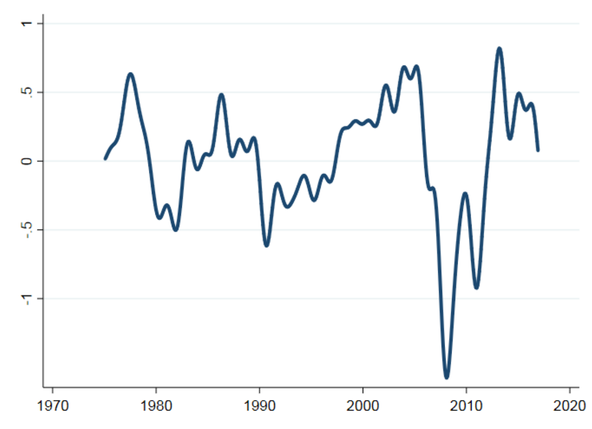
Notes: This repeats the results from Table 4 but with frequencies that give cycles of between 3 and 50 years in length.

Table 8: Housing market cyclical rank correlations

	HP	HS	HR
HP	1		
HS	0.61*	1	
	(0.37 to 0.85)		
HR	0.24	0.20	1
	(-0.03 to 0.51)	(-0.14 to 0.53)	

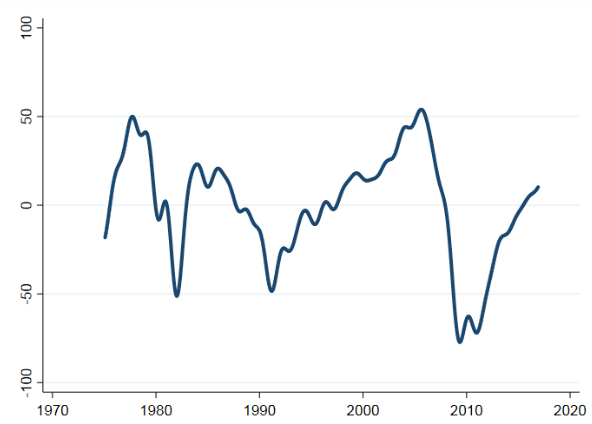
Notes: This repeats the results from Table 5 but with frequencies that give cycles of between 3 and 50 years in length.

Figure 12: Cyclical element of real house price growth with shorter cycles



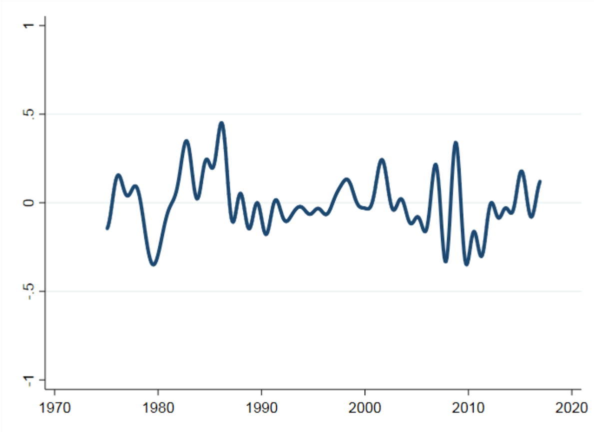
Notes: This repeats the graphs from Figure 4 but with frequencies that give cycles of between 1.5 and 40 years in length.

Figure 13: Cyclical element of housing sales with shorter cycles



Notes: This repeats the graphs from Figure 5 but with frequencies that give cycles of between 1.5 and 40 years in length.

Figure 14: Cyclical element of real housing rental price growth with shorter cycles



Notes: This repeats the graphs from Figure 6 but with frequencies that give cycles of between 1.5 and 40 years in length.

Table 9: Housing market cyclical linear correlations

	HP	HS	HR
HP	1		
HS	0.59*	1	
	(0.40 to 0.79)		
HR	0.26*	0.20	1
	(0.03 to 0.50)	(-0.08 to 0.47)	

Notes: This repeats the results from Table 4 but with frequencies that give cycles of between 1.5 and 40 years in length.

Table 10: Housing market cyclical rank correlations

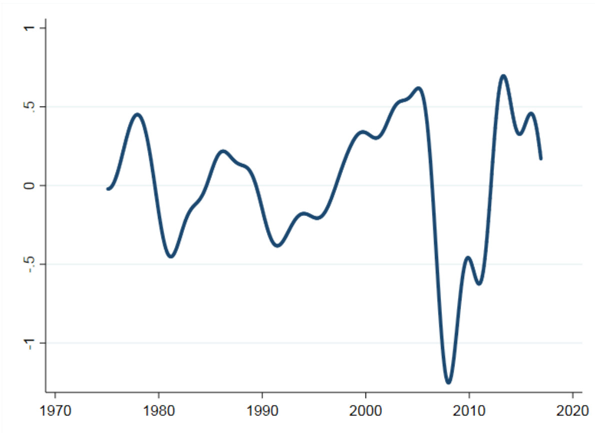
	HP	HS	HR
HP	1		
HS	0.62*	1	
	(0.40 to 0.84)		
HR	0.27*	0.23	1
	(0.03 to 0.50)	(-0.03 to 0.49)	

Notes: This repeats the results from Table 5 but with frequencies that give cycles of between 1.5 and 40 years in length.

C Housing data source robustness

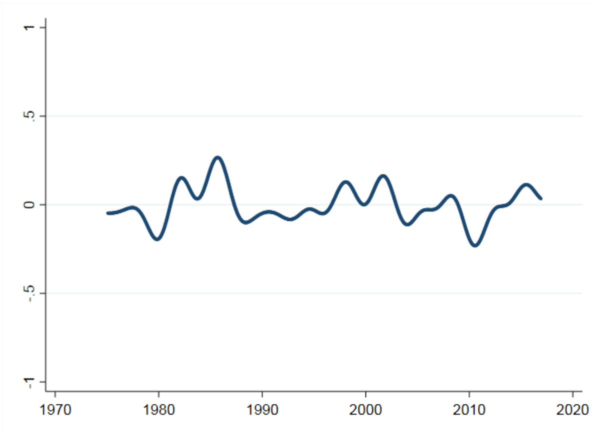
This section of the Appendix contains the robustness checks from using different real house price data. It repeats the analysis in Section 3 and Section 4 but using the Case-Shiller real house price index. The following graphs and tables show the cyclical components, the associations between them and the impulse response to a monetary shock. In all cases the results are similar to those in the main text.

Figure 15: Cyclical element of real house price growth



Notes: This repeats the graph from Figure 4 but uses the Case-Shiller real house price index.

Figure 16: Cyclical element of real housing rental price growth



Notes: This repeats the graph from Figure 6 but deflating rents in line with the deflator used in the Case-Shiller real house price index.

Table 11: Housing market cyclical linear correlations

	HP	HS	HR
HP	1		
HS	0.61*	1	
	(0.39 to 0.82)		
HR	0.21	0.25	1
	(-0.03 to 0.45)	(-0.05 to 0.55)	

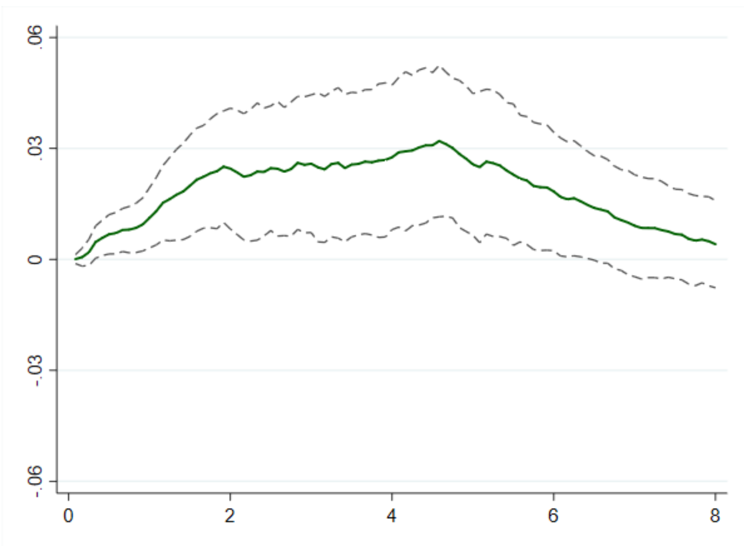
Notes: This repeats the results from Table 4 but with the Case-Shiller real house price index and deflator.

Table 12: Housing market cyclical rank correlations

	HP	HS	HR
HP	1		
HS	0.63*	1	
	(0.40 to 0.86)		
HR	0.24	0.20	1
	(-0.04 to 0.52)	(-0.10 to 0.49)	

Notes: This repeats the results from Table 5 but with the Case-Shiller real house price index and deflator.

Figure 17: Impulse response function of real house prices to a monetary shock



Notes: This repeats the graph from Figure 2 but uses the Case-Shiller real house price index.

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