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Working Paper

Monetary policy and the house price boom across US Staates

Working Paper, No. 2005-24

Provided in Cooperation with:

Federal Reserve Bank of Atlanta

Suggested Citation: del Negro, Marco; Otrok, Christopher (2005) : Monetary policy and the house price boom across US Staates, Working Paper, No. 2005-24, Federal Reserve Bank of Atlanta, Atlanta, GA

This Version is available at:

<https://hdl.handle.net/10419/101035>

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Monetary Policy and the House Price
Boom across U.S. States

Marco Del Negro and Christopher Otrok

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Abstract: The authors use a dynamic factor model estimated via Bayesian methods to disentangle the relative importance of the common component in the Office of Federal Housing Enterprise Oversight's house price movements from state- or region-specific shocks, estimated on quarterly state-level data from 1986 to 2004. The authors find that movements in house prices historically have mainly been driven by the local (state- or region-specific) component. The recent period (2001–04) has been different, however: “Local bubbles” have been important in some states, but overall the increase in house prices is a national phenomenon. The authors then use a VAR to investigate the extent to which expansionary monetary policy is responsible for the common component in house price movements. The authors find the impact of policy shocks on house prices to be very small.

JEL classification: C11, E58, R31

Key words: housing, monetary policy, Bayesian analysis

The authors thank, without implicating, Bob Eisenbeis, Scott Frame, and Dan Waggoner for helpful conversations and seminar participants at the Atlanta Fed, Bank of England, ECB, and the Federal Reserve Board of Governors for comments. The views expressed in this paper are the authors' and do not necessarily reflect those of the Federal Reserve Bank of Atlanta or the Federal Reserve System.

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”We don’t perceive that there is a national [housing] bubble but it’s hard not to see ... that there are a lot of local bubbles.”

Federal Reserve Chairman Alan Greenspan (*Economic Club of New York, May 20, 2005; CNN Money*)

1 Introduction

In some U.S. metropolitan areas house prices increased dramatically during the last few years. The increase in house prices is substantial even if one looks at the average state-level price, which smooths out the differences across local markets within each state. Figure 1 shows the annualized average growth rates from the first quarter of 2001 to the last quarter of 2004 in the OFHEO (Office of Federal Housing Enterprise Oversight) house price indexes, deflated by the U.S. core PCE inflation, for the forty-eight contiguous states. In this four-year period house price indexes increased more than ten percent per year in several states on both the East and the West Coasts, notably California, Florida, Nevada, Maryland and Rhode Island. The rise in house prices has been very uneven across the nation, with some states, like Texas and Ohio, growing barely above two percent per year. If we compare the growth in house prices in the last four years with the average growth since 1986, we find that states like Florida have grown three times their average, while other states, like Michigan, have grown twenty percent less than average.

From the perspective of the current debate, an important question is whether the widespread, but not homogeneous, increase in house prices reflects a national phenomenon or rather, in the words of Chairman Greenspan, a collection of “local bubbles.” The answer to this question has important policy implications. “Local bubbles” are most likely attributable to local factors, i.e., circumstances that are specific to each geographic market, rather than to monetary policy, which is the same for the entire nation. On the contrary, if the boom in house prices is a national phenomenon, monetary policy may well be a likely suspect.

To address the issue of a potential national housing cycle we estimate a dynamic factor model in the spirit of Geweke (1977), Sargent and Sims (1977), and Stock and Watson (1989), on state-level OFHEO house price indexes from the mid-eighties to the end of 2004. We then use the factor model to disentangle the component of the increase in the value of housing that is common to all states from the component that is idiosyncratic, i.e. specific to each state. The latter component is meant to capture the “local bubbles”, while the former

captures co-movement across all states, and therefore, potentially, what has been referred to as a “national bubble.” We find that historically movements in house prices have mainly been driven by the local (state- or region-specific) component. Indeed, growth rates in OFHEO house price index are far less synchronized across states than are the growth rates in real per capita income, which are a measure of the business cycle at the state level.

However, the recent period has been different in this regard. While for a number of states local factors are still very important, for many states that experienced large increases in house prices a substantial fraction of these increases is attributable to the national factor. How can we reconcile this finding with the fact that increases in house prices have been uneven across states? Of course, part of the cross-state heterogeneity is due to local factors. But about two third the heterogeneity is due to the fact that states have different exposures to the common cycle: Some states, like Iowa or Oklahoma, are barely affected by the common cycle, while others, for instance most states in the Northeast, are strongly affected.

Since in the recent period the common component of the growth in house prices across states has been sizable, we ask to what extent monetary policy is behind this co-movement. Of course there are many other potential causes of the house price boom, such as mortgage market innovations for instance, but here we focus on one of them only: monetary policy. We do so because by most accounts, including the Fed’s own FOMC statements, monetary policy has been expansionary in recent history. In the press, the boom in house prices has often been associated with loose monetary policy. We follow Bernanke and Boivin (2003) and estimate a VAR where the common factor in house prices is one of the variables, while the other variables measure the stance of monetary policy (the federal funds interest rate, money supply), aggregate U.S. inflation and output, and the thirty-year mortgage rate. We identify monetary policy shocks using sign restrictions á la Uhlig (2005) and Canova and De Nicoló (2002). Perhaps not surprisingly, we find that monetary policy has been expansionary in the recent period, in the sense that most deviations from the implied policy rule have been on the side of “loose” rather than “tight” monetary policy. The analysis of impulse responses shows that expansionary monetary policy shocks lead to increase in the housing factor. We then perform the following counterfactual thought experiment: What would have been the alternative path of the housing factor had there not been any monetary policy shocks from the first quarter of 2001 onward? And, in turn, what would have been the counterfactual growth in house prices across states? The results from this counterfactual experiment indicate that the impact of monetary policy shocks on house prices is non-negligible, but is small compared with the magnitude of the price increase over the last four

years. Therefore, our analysis suggests that expansionary monetary policy is not behind the recent boom in house prices.

While there are established literatures studying the effect of housing on asset pricing, portfolio choice, business cycles and consumption, the literature on the relationship between housing prices and monetary policy is fairly limited. Chirinko et. al. (2004) study the interrelationship between stock prices, house prices, and real activity in a thirteen country sample. Their primary focus is in determining the role asset prices play in formulating monetary policy. Iacoviello and Minetti (2005) document the role that the housing market plays in creating a credit channel for monetary policy. Their empirical analysis uses a sample of four countries that does not include the U.S. Perhaps the closest study to ours is Fratantoni and Schuh (2003) who study the effects of monetary policy on regions in the U.S. from 1966-1998. They find that the response of housing investment to monetary policy varies by region. Our paper differs from the previous literature both in terms of methodology and of focus. In terms of methodology, we use a factor model to extract the common cycle in house price fluctuations. In terms of focus, like Fratantoni and Schuh – and unlike Chirinko et. al. (2004) and Iacoviello and Minetti (2005) – we are interested in the regional differences in the response of house prices to policy shocks. Differently from all these papers, we are particularly interested in the role of monetary policy in the latest housing boom.

The remainder of the paper is as follows. Section (2) describes the dynamic factor model; section (3) describes the data, section (4) the empirical results, and section (5) concludes.

2 Model

Our approach consists of two steps. In the first step we use a purely statistical model to tell the common component of fluctuations in house prices apart from state or region-specific fluctuations. In this step we avoid making too many a-priori assumptions on the drivers of common fluctuations – that is, we let the common factor be latent instead of pre-specifying a number of regressors. Once we have obtained an estimate of the common factor from the statistical model, in the next step we investigate what lies behind it – and in particular, we focus on the role of monetary policy shocks.

Our statistical model is a dynamic factor model estimated via Bayesian methods, as in Kose, Otrok, and Whiteman (2005). The model postulates that the observable variables ($y_{n,t}$, $n = 1, \dots, N$, $t = 1, \dots, T$), the growth rates in state-level house price indexes, depend

on a number of latent factors, which capture comovement at the national (f_t^0) or at the regional (f_t^r) level, as well as on state-specific shocks $\epsilon_{n,t}$. Specifically, the model is:

$$y_{n,t} = \mu_n + \beta_n^0 f_t^0 + \sum_{r=1}^R \beta_n^r f_t^r + \epsilon_{n,t}, \quad (1)$$

where μ_n is the average growth rate, which is allowed to differ across states, and β_n^r represents the exposure of state n to factor r . The estimates μ_n may be of interest in themselves, as they reflect historical trends in terms of state-level demographics, economic growth, *etc cetera*, but are not the focus of this paper. This paper focuses on the deviations from the historical mean, and in particular on the decomposition of these deviations in the recent period. We impose the natural restriction that $\beta_n^r = 0$ if state n does not belong to region r . The section 3 discusses the definition of regions.

The law of motions for the factors is given by an $AR(q)$ process:

$$f_t^r = \phi_1^r f_{t-1}^r + \dots + \phi_q^r f_{t-q}^r + u_t^r, \quad u_t^r \rightsquigarrow N(0, 1), \quad r = 0, \dots, R., \quad (2)$$

where the variance of the innovations u_t^r is normalized to one. The law of motions for the state-specific shocks is given by an $AR(p_n)$ process:

$$\epsilon_{n,t} = \phi_{n,1} \epsilon_{n,t-1} + \dots + \phi_{n,p} \epsilon_{n,t-p} + u_{n,t}, \quad u_{n,t} \rightsquigarrow N(0, \sigma_n^2). \quad (3)$$

A key identification assumption which allows us to disentangle the factors from one another and from the state-specific shocks is that all innovations are mutually independent.

The paper will decompose movements in $y_{n,t}$ into fluctuations due to each of the three components: national, regional, and state-specific component. The statistic $v_n(t_0, t_1)$ computes the variance of fluctuations due to the national factor as the fraction of the sum of the variance of all three components over the sub-sample (t_0, t_1) :

$$v_n(t_0, t_1) = \frac{\sum_{t=t_0}^{t_1} (\beta_n^0 f_t^0)^2}{\sum_{t=t_0}^{t_1} (\beta_n^0 f_t^0)^2 + \sum_{t=t_0}^{t_1} (\beta_n^r f_t^r)^2 + \sum_{t=t_0}^{t_1} \epsilon_{n,t}^2}. \quad (4)$$

This variance decomposition is computed for each state n for the entire sample, as well as for sub-periods of interest, notably the last four years.

The Bayesian procedure used to obtain the posterior distribution of the parameters of interest, the Gibbs sampler, is straightforward for this model. We now give a brief description of it. The Gibbs sampler is a zig-zag procedure where a set of parameters is drawn conditional on another set of parameters, and vice-versa, exploiting the fact that the conditional posterior distributions have a known form, even if the joint posterior does

not. The Gibbs sampler for this problem has two steps. In the first step, we condition on the factors and draw all other parameters. Conditional on the factors, each equation (1) is a regression model with $\text{AR}(p_n)$ errors. The procedure developed by Chib and Greenberg (1994) makes it possible to draw $\mu_n, \beta_{n,t}^r, \phi_{n,j}, \sigma_n^2$ (see Otrok and Whiteman 1998). Since the errors are independent across n , the procedure can be applied equation by equation. The same procedure is applied to the parameters ϕ_j^r of the law of motion of the factors (2). In the second step we draw the factors, conditional on all other parameters. The model is already written in state-space form, equation (1) being the measurement equation, and equations (2) and (3) being the transition equation for the unobserved states, which include both the factors and the idiosyncratic shocks. We can then use the algorithm developed by Carter and Kohn (1994) (see Kim and Nelson 1999, Cogley and Sargent 2002, and Primiceri 2005) to obtain draws of the states. This approach leads to a curse of dimensionality however, as the number of states grows proportionally with the cross-sectional dimension N . A solution to this curse of dimensionality is to pre-whiten the data, that is, to pre-multiply each measurement equation by $1 - \sum_{j=1}^p \phi_{n,j} L^j$, so to get rid of the dynamics in the state-specific shocks (see Kim and Nelson 1999, and Quah and Sargent 1993), obtaining:

$$\left(1 - \sum_{j=1}^p \phi_{n,j} L^j\right) y_{n,t} = \left(1 - \sum_{j=1}^p \phi_{n,j}\right) \mu_n + \sum_{r=0}^R \beta_n^r \left(1 - \sum_{j=1}^p \phi_{n,j} L^j\right) f_t^r + u_{n,t}. \quad (5)$$

To our knowledge, the literature that followed this path has generally conditioned on the p observations $(y_{n,1}, \dots, y_{n,p})$. We use the full sample instead. The extra step required to this amounts to computing the expectation of the first p realizations of the factors conditional on the initial observations.

The priors used in this paper are quite standard, and similar to those used in Kose, Otrok, and Whiteman (2005). Importantly, we use identical priors for both the house price and the real income data sets, obtaining very different results in terms of the national/local factor decomposition, as we will see. This is indirect evidence that the priors do not drive the main results of the paper. The prior for constant μ_n is normal with 2 and precision (the inverse of the variance) 1. The prior for the loadings β_n^r is fairly loose: it is Gaussian with zero mean and precision equal to 1/100. The prior for the idiosyncratic innovation variance σ_n^2 is an inverted gamma with parameters 4 and 0.1. The priors for the parameters of the AR polynomial are Normal with mean zero and precision equal to 1 for the first lag, and then increasing geometrically at rate .75 for the subsequent lags. We choose a lag length equal to $q = 3$ for the factors and $p = 2$ for the idiosyncratic shocks. All priors are mutually independent.

3 The Data

Most of the data were obtained from Haver Analytics (Haver mnemonics are in italics). The Housing Price Index (HPI; *HPI@REGIONAL*) is published by the Office of Federal Housing Enterprise Oversight (OFHEO), and captures changes in the value of single-family homes. The HPI is a weighted repeat sales index: It measures average price changes in repeat sales or refinancings on the same properties and weights them (see Calhoun, 1996, for an in-depth description of how the HPI is constructed). The price information is obtained from repeat mortgage transactions on single-family properties whose mortgages have been purchased or securitized by Fannie Mae or Freddie Mac since January 1975.¹ While the housing price data has been criticized for its construction, to our knowledge it is the best data available to the public at the state (or more disaggregated) level.² Additionally, we will be working with growth rates of the housing price data so issues related to bias in the level estimates are not relevant.

We use state level data even though other levels of aggregation (e.g. Metropolitan Statistical Area) are available. We believe that the state level data is disaggregated enough to establish our main conclusions, and yet the cross-section is small enough for our computational approach to be feasible. We compute growth rates using annualized log-differences, in percent. The HPI data are nominal. We deflate the data using core PCE inflation (*JCXFEBM@USECON*), which measures inflation in the personal consumption expenditure basket less food and energy.

The HPI data are available from 1975, but in our estimation we use only data beginning in the first quarter of 1986. Figure 2 shows that state-level HPI data are extremely noisy for a number of states before the mid-eighties, with sharp appreciations immediately followed

¹An alternative measure that is available at the state level at quarterly frequency is the Conventional Mortgage Home Price Index (CMHPI), published by Freddie Mac. This measure is roughly based on the same data on which the OFHEO HPI is constructed. Indeed, we find that the correlation between the growth rates in the two price indexes is above .9 over the entire sample period.

²Some authors, notably Peach and McCarthy (2004), have emphasized the differences between the OFHEO house price and the constant quality house price index produced by the U.S. Bureau of the Census. They argue that home renovations and improvements lead to an overstatement of the average growth in the OFHEO house prices. The constant quality house price index is simply not available at the disaggregated level. We are aware that the potential mis-measurement of quality can lead to an upward bias in our estimated mean growth rate. However, the average growth rate in house prices is not the focus of the paper. The focus is on comovements in state-level house prices, especially during the recent boom. From this perspective, we think that taking home renovations and improvements into account makes little difference for our analysis.

by sharp depreciations. From the perspective of the dynamic factor model, the noise in the series is not necessarily a problem in terms of estimation, as it is captured by the idiosyncratic component. However, our methodology cannot deal with very large time variation in the importance of the noise component, particularly when the time variation is very large as it is for the HPI data. The noise abates considerably for most states after the mid-eighties. We choose the first quarter of 1986 as the starting date for our analysis (this date is indicated with a dashed vertical line in Figure 2). Large structural changes in the credit market, such as the end of regulation Q, provide another reason for leaving the first part of the sample out of the analysis. Additionally, this sample gives us a period with one monetary policy regime, which is convenient for the identification of monetary policy shocks. The sample ends in the last quarter of 2004. In summary, we have 19 years (76 quarters) of data for the 48 contiguous U.S. states. We have checked for the robustness of our results to moving the start date to the first quarter of 1985, and found that the results to be robust. The real per capita personal income data ($YPPHQ@PIQR$) are computed by deflating the nominal per capita income data from the Bureau of Economic Analysis using PCE inflation.

The regional factors are defined by geography. Our baseline specification includes five regions. The first three regions follow the Census definition. These are the North-East Region, which includes the New England and Middle Atlantic Divisions; the Mid-West Region, which includes the East- and West-North-Central Divisions (the former includes the Great Lakes regions, while the latter includes the Plains); the West Region, which includes the Mountains and the Pacific Divisions. We split the South Region, which includes the South Atlantic, the East-South-Central, and the West-South-Central Divisions, into two separate regions: South Atlantic and the East-South-Central (i.e., Alabama, Kentucky, Mississippi, and Tennessee) on one side, and the West-South-Central division (Arkansas, Louisiana, Oklahoma, Texas), which includes a number of oil-producing states, on the other. We have also tried a specification with nine regions, the nine Census Divisions, and obtained very similar results. The only difference is that for some of the Divisions with few states the regional factors were not well identified, hence we preferred the five regions specification.

The data used in the VAR include two measures of monetary policy, total reserves (in some specifications we use non-borrowed reserves as a robustness check) and the federal funds rate, inflation as measured by the GDP deflator and real output growth as measured by the growth in real GDP. All data were taken from the Federal Reserve Bank of St Louis database (FRED). The FRED mnemonics are *BOGNONBR*, *TOTRESNS*, *FEDFUNDS*, *GDPDEF*, and *GDPC1*, respectively. The 30 year mortgage rate is obtained from Haver

Analytics (FCM@USECON). All data are quarterly, and the time-period coincides with that used in the factor model.

4 Empirical Results

We have three sets of empirical results. The first set of results provides evidence on the relative importance of national versus regional or state-specific shocks in driving movements in house prices across US states over the past twenty years. We document that there is a large degree of heterogeneity across states in regard to relative importance of the national factors. Overall, however, we find that historically movements in housing prices are mainly driven by local factors, either regional or state-specific. The second set of results argues that the recent period has been different in this regard. While local factors have remained important, the increase in house prices that occurred in several states in the last four years is mainly driven by the national factor. Given the importance of the national factor, in the third sub-section we ask whether or not expansionary monetary policy lies behind the recent national housing boom. Specifically, we identify monetary policy shocks using a VAR with sign restriction, and investigate their impact on house prices. We find the impact of monetary policy on the housing boom to be non-negligible but small relative to the size of the housing boom.

4.1 House price fluctuations and business cycles across US states

We first want to establish the degree of comovement in housing prices across states. Figure 3 contains three charts. The top chart shows the data – the growth rate in house price indexes for the forty-eight contiguous states from QI-1986 to QIV-2004. The other two charts decompose movements in the growth rates into national and local factors. By national factor (middle chart) we mean the impact of national shocks on state n , that is, the component $\beta_n^0 f_t^0$ of equation (1). All lines in the middle chart are perfectly (sometimes negatively) correlated by construction, with the different amplitudes of fluctuations reflecting the size of the exposure β_n^0 to national shocks. By local factors (bottom chart) we mean the joint impact of regional and state specific shocks, that is, the $\beta_n^r f_t^r + \epsilon_{n,t}$ component of equation (1). The data show two periods of relatively high volatility in the growth rates. The first coincides with the early part of the sample – from 1986 to the early 1990s. The second coincides with the most recent period. A difference between these two episodes is in the role played by local

factors, as shown by the bottom chart. In the first episode local factors are behind most of the volatility.³ Simply eyeballing the data (top chart) it is very hard to tell whether there is a common component of house price movements in the late eighties and early nineties, for any co-movement is shadowed by the importance of local factors. In contrast, in the recent episode the common component is quite apparent. Except for a few states, notably Nevada and California, the volatility in local factors in the recent period (2001-2004) is no higher than it had been in the previous four years.

Figure 4 shows the same decomposition for state-level growth rate in real per capita income. Real per capita income can be seen as a proxy for state-level business cycles (output is not available at the quarterly level). The model used on the real income data is the same, including the specification of all the priors, as that used on the house price data. The data sets however are quite different, and so are the results of the decomposition. First, state-level real income growth rates are less volatile than the house price data, with some exceptions for rural states like North Dakota. Second, state-level business cycles appear to move more in step than fluctuations in house prices. Local factors are important, but appear to be largely short frequency deviations from the common component. Finally, for the income data there is no evidence of the two high volatility episodes that characterize the house price data. In particular, not much is happening toward the end of the sample.

Figure 5 quantifies the relative importance of the national factor for the house price and the income data over the entire sample. In particular, for each state the figure shows the magnitude $v_n(1, T)$ (see equation (4)), that is, the variance of fluctuations due to the national factor as a fraction of the variance of all components, for housing on the horizontal axis and for income on the vertical axis. For all states that are above the 45 degree line the common component of fluctuations is more important for income than it is for house prices. Three-quarter of states are above the 45 degree line. For the median state the national factor explains only fifteen percent of the variance of house price movements. Only for a quarter of states the national factor is the main driver of movements in house prices, meaning that the national component drives fifty percent or more of the fluctuations. This is in contrast with state-level business cycles. For the median state the national factor explains about fifty percent of the variance in real per-capita income growth.

Recent literature (see for instance McCarthy and Peach, 2004) tries to explain the recent increase in house prices by means of an affordability index, which measures the extent to

³Some of the local factors are correlated across subsets of states, as they represent regional shocks to the South West and Mid West regions.

which current house prices are “affordable” given the level of income and of mortgage interest rates. The underlying idea is that as income grows and interest rates decline, households bid up house prices because they simply can afford them (that is, the mortgage payments remain constant as a fraction of income). This theory posits a tight relationship between income and house prices. The state-level evidence presented here presents a challenge to this theory, as it shows that local factors dominate fluctuations in house prices, at least in the first part of the sample, but not in per-capita income. An interesting hypothesis, which we do not investigate further in this paper, is that segmentation in the mortgage markets up until the mid-nineties lies in part behind the importance of the local factors.

4.2 The recent housing price boom

Figure 6 plots the posterior median of estimated national housing factor f_t^0 (black, scale on the left axis), the ninety percent bands (dotted lines), as well as the OFHEO U.S. price index (gray, right axis). The figure shows that the recent period, particularly the last two years, has been one of unprecedented volatility at the national level. The questions we try to address in this section are twofold. First, are these shocks at the national level, or are local factors, behind the recent increase in house prices across many U.S. states? Quantitatively, what is the relative importance of the two? Second, to what extent can different exposures to national shocks explain the heterogeneity across states in the house price increases?

Figure 6 also shows that the estimated national factor and the OFHEO U.S. price index are very correlated, particularly in the second part of the sample. This finding may call into question the need to estimate a factor model to perform the exercise conducted in this paper: Can’t we simply use the U.S. price index? Moreover, doesn’t the fact that the U.S. price index grew so much in the last two years provide by itself evidence that the increase in house prices is a national phenomenon? The answer to both questions is that there is an identification problem behind the U.S. price index that makes it hard to solve the “local versus national factors” question just by staring at it. The U.S. price index is a weighted average of the state-level indexes, where the weights are proportional to the size of the states. A key issue in the debate is whether the increase in the national index reflects a national phenomenon, or local phenomena in a number of very highly populated (and therefore highly weighted) states, like Florida or California. In econometric terms, averages (such as the U.S. price index) are good estimates of factors only under the condition that the weights on each single component are negligible – a condition that is certainly not met in the case of the U.S. price index. The factor model is designed to address this identification problem. The

model tries to extract the common component of fluctuations across states, without having any information on the relative weight of each state: *ex ante*, all states weight the same in the factor model.

In order to quantify the importance of national shocks relative to local factors in the recent period we plot for each state the the magnitude $v_n(t_0, t_1)$ for the sub-sample 2001-2004 on the vertical axis, and 1986-2000 on the horizontal axis in Figure 7. Again, $v_n(\cdot, \cdot)$ represents the variance of house prices fluctuations in state n due to the national factor as a fraction of the variance of all components. For all states that are above the 45 degree line the common component of fluctuations is more important in the recent period than in the remainder of the sample. Figure 7 shows only the the median of the posterior distribution of $v_n(\text{QI-1986, QIV-2000})$ and $v_n(\text{QI-2001, QIV-2004})$, but in general these magnitudes are tightly estimated: The difference $v_n(\text{QI-1986, QIV-2000}) - v_n(\text{QI-2001, QIV-2004})$ is always statistically significant. Between 2001 and 2004 the relative importance of national shocks has increased for all but one state, Florida. For the median state the explanatory power of the national factor in terms of the variance of house price movements has increased three-fold, from 11 to 34 percent. Overall the figure provides evidence that the recent period is different from the rest of the sample, in that the relative importance of national shocks has increased substantially. Even in the recent period, heterogeneity across states is large – for a number of South-western and Mid-western states the importance of the national factor remains negligible even in the last four years. For many states local factors are still the dominant source of fluctuations. However, we now proceed to show that for many of the states that witnessed large increases in house prices, the national factor lies behind such increases.

Figure 8 shows two bars for each of the forty-eight contiguous states, one in dark and one in light gray. The dark gray bar represents the annualized average growth rates for the 2001-2004 period in the OFHEO house price index, expressed in real terms, which was also shown in Figure 1. The only difference is that in Figure 8 the growth rates are computed in excess of the historical (1986-2004) mean, that is, we show $\sum_{t=\text{QI-2001}}^{\text{QIV-2004}} (y_{n,t} - \mu_n) / 16$. The light gray bar represents the component of the average growth rates for the same period that can be attributed to the national factor. Specifically, for each state the figure shows the median of the posterior for the quantity $\sum_{t=\text{QI-2001}}^{\text{QIV-2004}} \beta_n^0 f_t^0 / 16$.⁴ The figure shows that a substantial fraction of the cross-state heterogeneity in the recent housing price boom is attributable

⁴To avoid cluttering the picture, we do not show the ninety percent bands for both the demeaned data and the component attributable to the national factor (the figure is available upon request). Taking estimation uncertainty into account does not alter the conclusions.

to the fact that states have different exposures to the national factor. Indeed, the cross-sectional variance in the component of house price growth explained by the common factor (light gray bars) amounts to about seventy percent of the cross-sectional variance in average house price growth (dark gray bars). Of course, local factors – shown by the distance between the dark and the light gray bars – are still important, especially for states like California and Nevada. But it is certainly not the case that all cross-state heterogeneity in the house price boom is driven by “local bubbles”.⁵

4.3 Expansionary monetary policy and the housing price boom

We have so far made a case that the national factor has been important in the 2001-2004 period. What economic forces are behind the common factor? The answer must lie in a common set of shocks or changes to the housing market. It is beyond the scope of this paper to analyze all possible explanations for the house price boom. Here, we focus on one of the most likely potential culprits, monetary policy shocks. By most accounts, including the Fed’s own FOMC statements, monetary policy has been expansionary in recent history. In the press, the boom in house prices has often been associated with loose monetary policy. This section uses a VAR to investigate the importance of monetary policy shocks in driving the common component of house price increases in the recent period.

The VAR includes standard macroeconomic data, as well as our estimates of the common house price factor. We use some newly developed VAR identification techniques that require minimal assumptions to identify and extract monetary shocks. We then use the identified shocks in a counterfactual experiment where we eliminate these shocks from Q1-2001 on to create a counterfactual housing price factor. Next, we are able to identify the effects of this shock on each state house price index via its factor loading or sensitivity to the national cycle. These calculations give us an idea on the magnitude of the importance of expansionary monetary policy on housing prices.

The virtue of our approach is that we can combine of a small number of national level variables and with a wide selection of regional variables capturing local economic conditions

⁵What state-specific characteristics drive the differences in exposures to the common factor is an interesting question which we leave for further research. We observe that the size of the light gray bars (that is, the magnitude of the exposures) has a clear geographical pattern: It is generally large for states on both the East and the West coasts – states where fluctuations in residential land prices are likely to be larger (see Davis and Heathcote 2004), possibly because of zoning and other land use controls (see Glaeser and Gyourko, 2002), and small for states in the center of the country.

without losing too many degrees of freedom (see Bernanke and Boivin 2003). The factor-augmented-VAR thus yields a parsimonious model that allows us to study the effects of national shocks on regional economies. A similar approach was developed by Otrok and Terrones (2004) to study the effects of US monetary policy shocks on global house prices.

The reduced form VAR is given by:

$$Y_t = A(L)Y_{t-1} + e_t, \quad e_t \rightsquigarrow N(0, \Sigma), \quad (6)$$

where Y_t is an $m \times 1$ vector that includes observable data as well as the housing factor and $A(L)$ is a matrix lag polynomial. Ideally, one would estimate the VAR coefficients as part of the MCMC algorithm and allow the uncertainty in the estimates of the factors to be captured in the uncertainty in the VAR parameters and the impulse response functions (see Bernanke, Boivin, Elias 2005). However, since estimating the dynamic factor model itself is computationally costly, combining this with estimating and identifying the VAR at each step of the MCMC algorithm would be computationally very costly.⁶ Given how tightly the latent factors are estimated (see Figure 6), we believe this to be a relatively minor issue.

The identification of monetary shocks is controversial. We identify monetary shocks using a sign restrictions approach introduced by Faust (1998) and further developed by Uhlig (2005) (see also Canova and DeNicoló 2002). Under this approach identification is achieved by placing restrictions on the sign of the impulse responses with respect to the shock(s) of interest for some variables for a number of periods in the future. For example, after a contractionary monetary policy shock we restrict the impulse response function of reserves to be non-positive, and that of interest rates to be non-negative. One advantage of Uhlig's procedure is that it allows one to identify only the innovation of interest (here as in Uhlig's work, monetary policy shocks), without making assumptions on the remainder of the system. A second advantage is that by changing the set of variables that are subject to the sign restrictions one can analyze the outcome of a variety of different identification approaches. We exploit this feature by exploring a number of them, which we describe below. We then pick the identification that gives the largest impact of monetary policy shocks on the house factor, thereby showing an upper bound on the importance of policy shocks.

Our VAR consists of six variables: the house factor, total reserves, CPI inflation, GDP growth, the thirty-year mortgage rate and the Federal Funds rate. The VAR is estimated

⁶Our identification procedure, described below, is based on sign restrictions. This procedure requires many draws of potential impulse response functions and is also computationally intensive procedure. It is the combination of this procedure with the dynamic factor model that is infeasible.

using quarterly data and has four lags. We use a standard Litterman prior for the VAR coefficients. The first four variables are in growth rates while the fed funds rate and mortgage rate are first differenced. We then identify the (contractionary) monetary shock as the shock that results in a set of impulse response functions consistent with 1) a increase in the Fed Funds rate, 2) a non-positive change in growth of total reserves, 3) a non-positive change in CPI growth, 4) a non-positive change in GDP growth. These restrictions hold for three quarters after the shock. We leave the responses to the house factor and the mortgage rate unrestricted. The restriction on the response of CPI inflation and GDP growth to be non-positive in response to a contractionary monetary shock is not without controversy. Indeed, the former is at the center of the 'price-puzzle' debate while the latter has generated controversy in the literature (Uhlig 2005). Among the alternatives identification schemes we study are: i) leaving CPI and GDP unrestricted, ii) constraining the impact on the mortgage rate to be non-negative, and iii) changing the number of quarters for which the restrictions have to hold to two. We also considered alternative model specifications, where we include non-borrowed reserves in place of total reserves, or alternatively include both measures of reserves. In another specification we use both the Fed Funds rate and mortgage rates in levels. Finally, we increased the lag lengths for the VAR to five and six lags. For none of these alternative identification schemes/model specifications is the impact of policy shocks on the house factor is larger than reported.

Figure 9 displays the impulse response function of all of the variables to the monetary policy shock, along with the 68 percent posterior coverage intervals. The house factor shows a significant and persistent drop following the contractionary monetary shock. This result confirms that monetary policy shocks can impact housing prices. The size of that response on states varies according to each state's exposure to the common cycle. States with larger exposure to the common factor will have a stronger response to the monetary shock than those with smaller factor loadings. The mortgage rate increases after the shock, although the uncertainty surrounding the size of the impact is large, and the posterior coverage intervals include zero. For all other variables the responses are constrained, at least for the first three period after impact, so little interpretation need be given to these responses.

Perhaps of greater interest than the shape and significance of the impulse response function for housing prices to the monetary shock is the quantitative importance of the recent policy choices on the housing price boom. To address this issue we construct a counterfactual where we create a new set of "data" for all variables in our VAR after setting the structural monetary shocks equal to zero from Q1-2001 until the end of the sample. This

experiment is in the same spirit of Uhlig (2001) who constructs a counterfactual to identify whether or not markets were surprised by the decline in interest rates. That is, he backs out the structural shocks to determine whether or not policy differed from the past in this period. Here we back out the monetary shocks to determine their effect on housing prices. Figure 10 shows the actual (solid line) and the counterfactual (dash-and-dotted line) paths for the Fed Funds rate and the housing factor from this procedure. The difference between the actual and the counterfactual Fed Funds rate is not very large, but is not negligible either. Toward the end of the sample, the counterfactual Fed Funds rate is about seventy basis points higher than the actual fed funds rate. Other multivariate models used in policy analysis that are estimated using a different sample and different variables, such as the Atlanta Fed BVAR for instance (see Zha 1998), produce a counterfactual Fed Funds rate that is not very different from the one shown here (if anything, closer to the actual path). Consistently with the results for the impulse response functions, the counterfactual housing factor is generally below the actual one, especially toward the end of the period where the difference between the two is about one percent. Visually, the actual and counterfactual housing factors are close to each other, suggesting that the impact of policy shocks on house prices is not large.

However, it is hard to get a quantitative sense of the importance of policy shocks from the Figure 10, both because the factor is scale-free and because the impact may cumulate over time. For this reason, Figure 11 shows the impact of policy shocks across the forty-eight states, relative to the overall impact of the national housing factor. Specifically, the dark gray bars in Figure 11 represent the component of the average growth rates in the 2001-2004 period that can be attributed to the national factor, namely the quantities $\sum_{t=Q1-2001}^{QIV-2004} \beta_n^0 f_t^0 / 16$ that were also shown in Figure 8. The light gray bars quantify the impact of policy shocks. For each state they show the quantity $\sum_{t=Q1-2001}^{QIV-2004} \beta_n^0 (f_t^0 - \tilde{f}_t^0) / 16$, where by \tilde{f}_t^0 we denote the counterfactual factor. In other words, the light gray bars show how smaller growth in house prices would have been in absence of policy shocks in state n (or larger, if state n has negative exposure to the national factor). Figure 11 shows that the impact of monetary policy shocks has been non-negligible, but fairly small: at most one percent in terms of average growth. Again, these figures are an upper bound among all the specifications/identification schemes we considered.

In summary, this section's findings are: i) the Fed, while following a slightly more expansionary policy than in the past did not deviate substantially from "business as usual" in the recent period; and ii) to the extent that the Fed did pursue an overly accommodative

policy, the impact of this policy on house prices has been small relative to the overall housing price increase of the last five years. Given that in the popular press loose monetary policy is sometimes blamed for the housing bubble, our findings may be relevant to the current debate. Our result that the impact of monetary policy shocks on house prices was small in the recent period does not of course imply that the low interest rate environment experienced by the US economy is not responsible for the housing boom. Here, we only consider the component of the low interest rate that is attributable to policy shocks – that is, to the Fed deviating from its historical policy rule in an expansionary way. Had the Fed reacted differently to the environment – had it followed a different rule – the results might have been quite different. This is a much more difficult question that (because of the Lucas’ critique) goes beyond the scope of this paper.

5 Conclusions

We use a dynamic factor model estimated via Bayesian methods to disentangle the relative importance of the common component in OFHEO house price movements from state- or region-specific shocks. Our sample consists of quarterly data from 1986 to 2004. We find that historically fluctuations in house prices have mainly been driven by the local (state- or region-specific) component. Indeed, growth rates in OFHEO house price index are less synchronized across states than are the growth rates in real per capita income, which are a measure of the business cycle at the state level. In the recent (2001-2004) period, however, “local bubbles” have been important in some states, but that overall the increase in house prices is a national phenomenon. We then use a VAR to investigate the extent to which expansionary monetary policy is responsible for the common component in house price movements. We find the impact of policy shocks on house prices to be small relative to the size of the recent housing price increase.

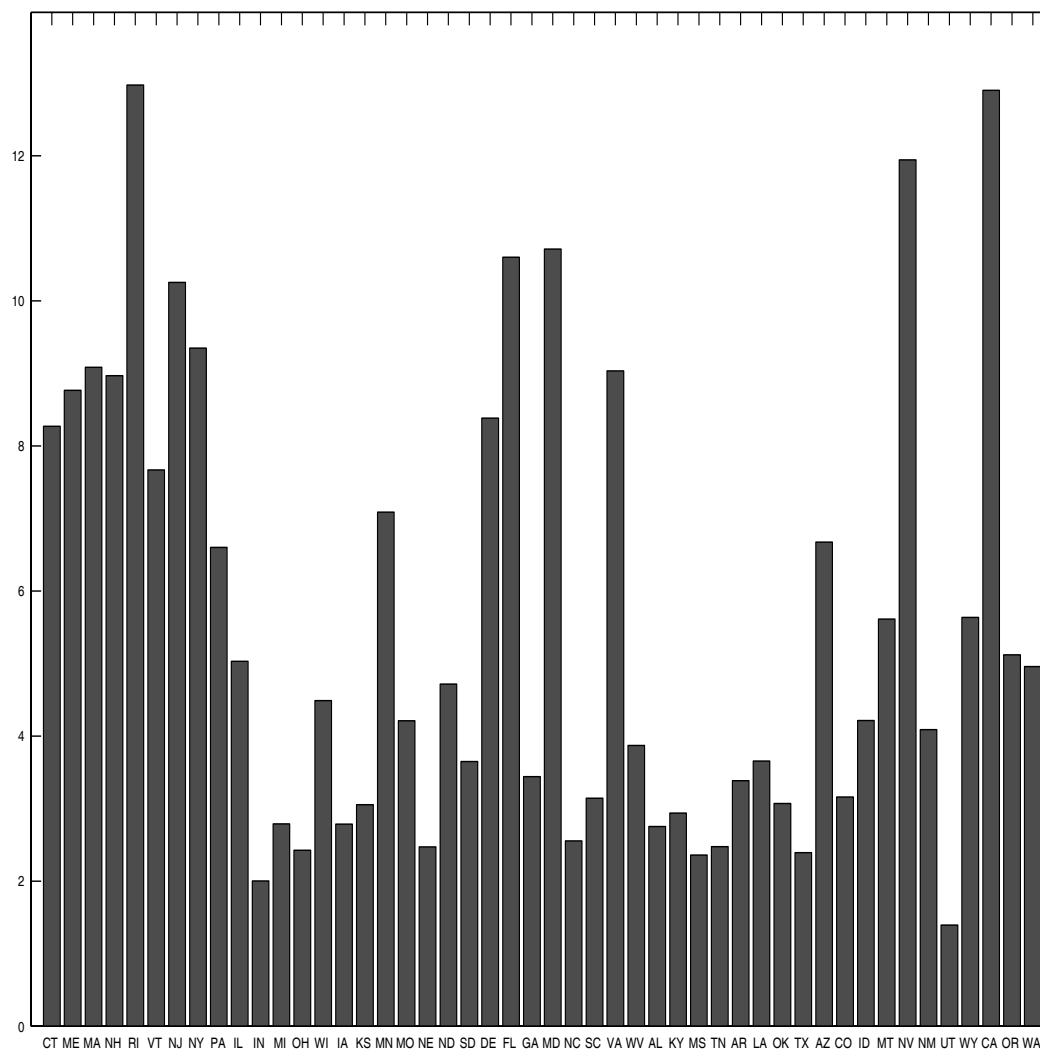
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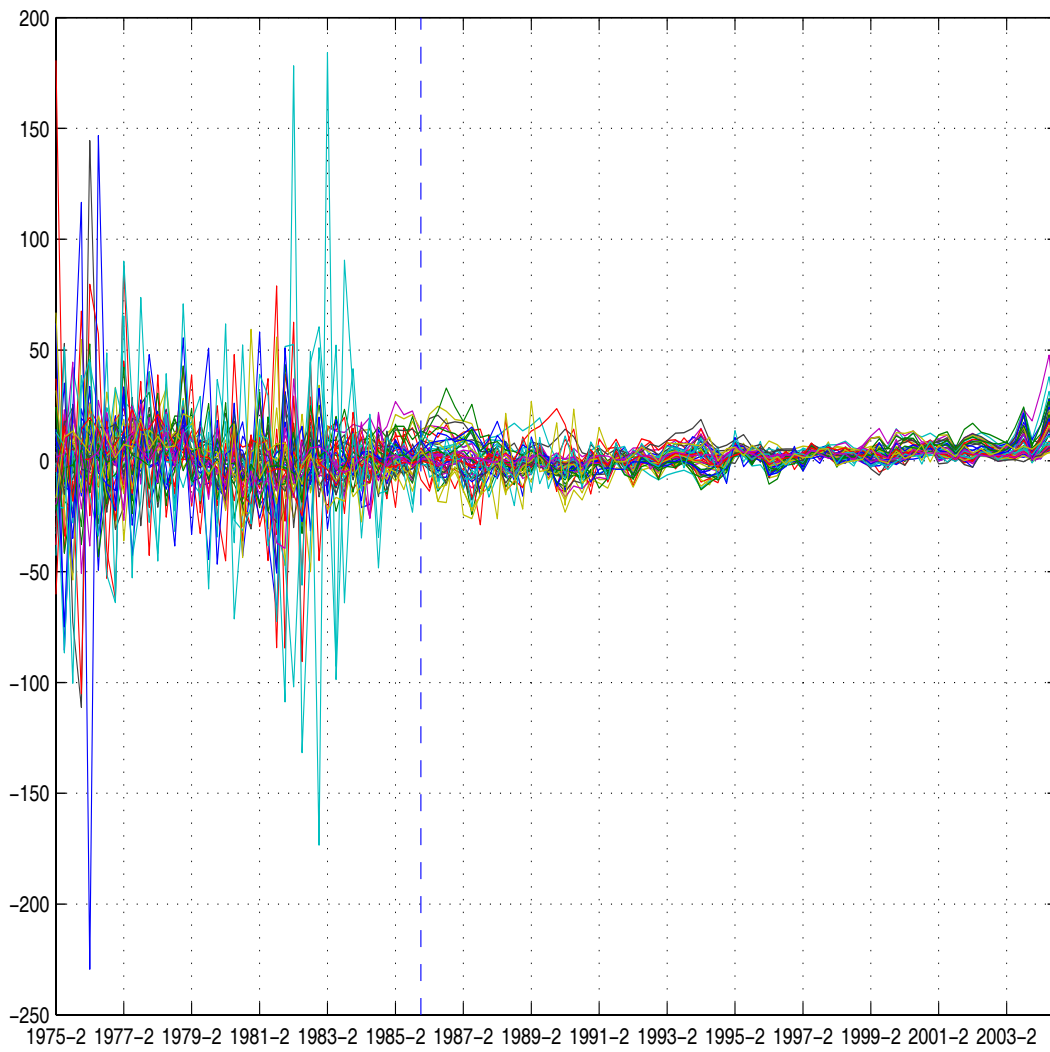
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Figure 1: CROSS-STATE HETEROGENEITY IN THE RECENT HOUSE PRICE BOOM



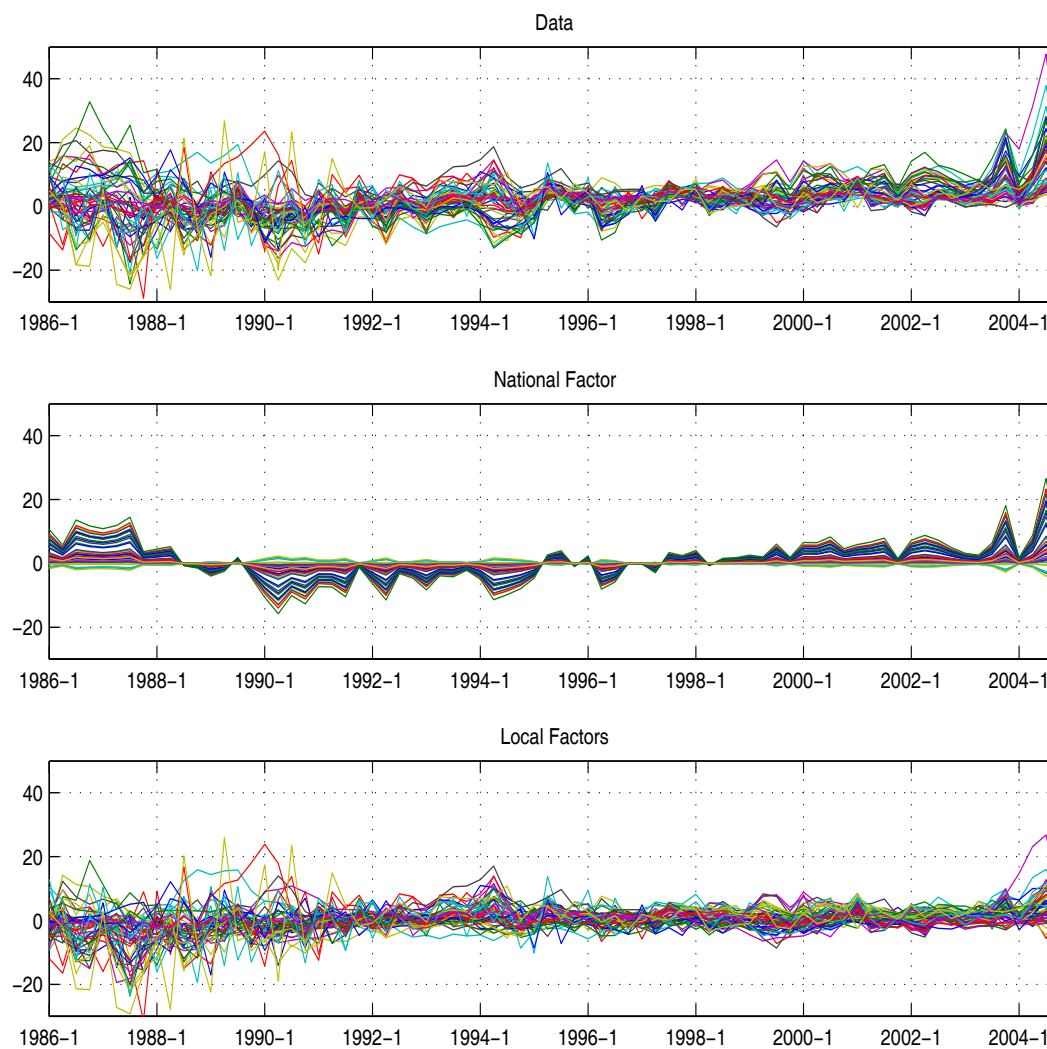
Notes: The figure shows shows the annualized average growth rates from the first quarter of 2001 to the last quarter of 2004 in the OFHEO (Office of Federal Housing Enterprise Oversight) house price indexes, deflated by the U.S. core PCE inflation, for the forty-eight contiguous states.

Figure 2: GROWTH RATES IN STATE-LEVEL HOUSE PRICES (REAL): 1975-2004



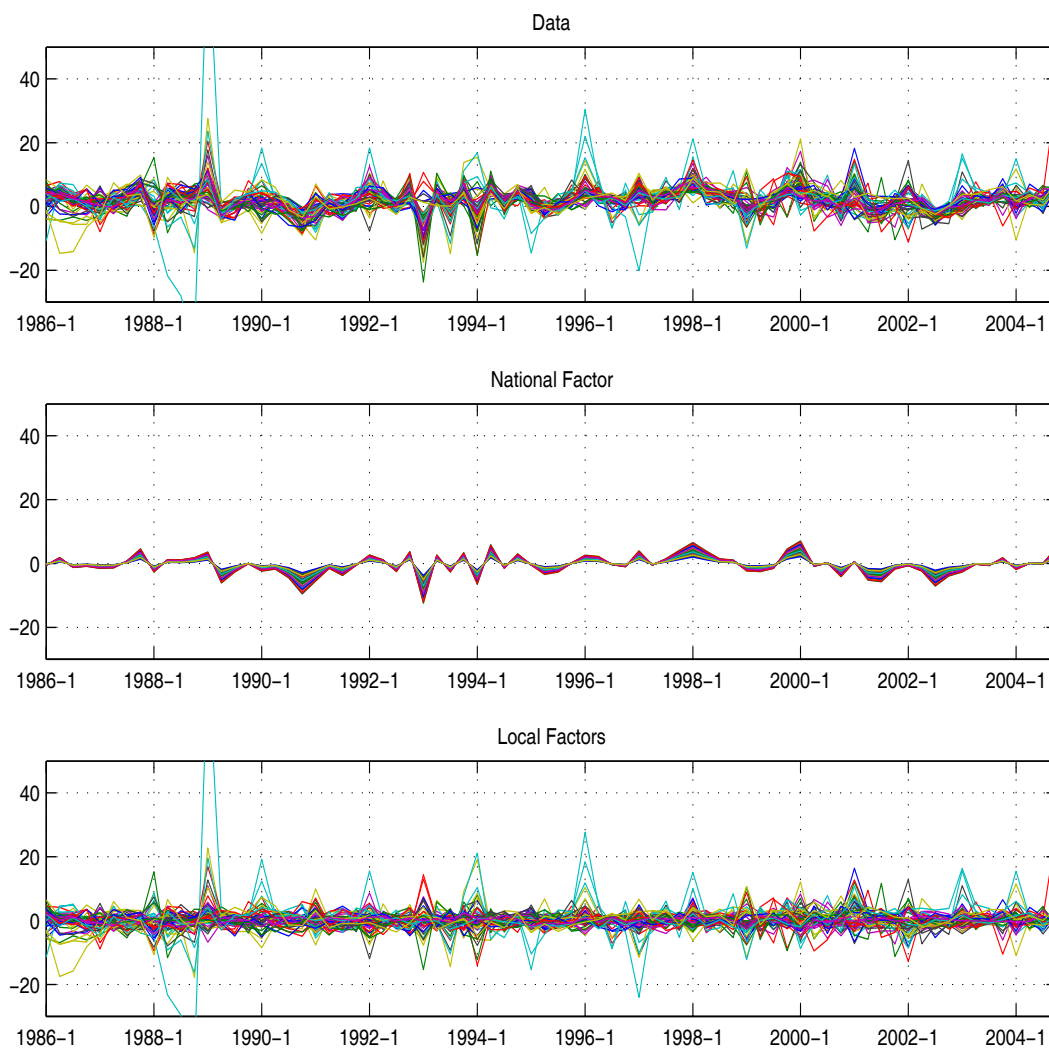
Notes: The figure shows the growth rates in OFHEO house price indexes for the forty-eight contiguous U.S. states for the period 1975-2004. The vertical line marks Q1-1986, the beginning of the sample period used in this paper. The nominal house price indexes are deflated using the core PCE inflation.

Figure 3: STATE-LEVEL REAL HOUSE PRICE GROWTH: NATIONAL AND LOCAL FACTORS



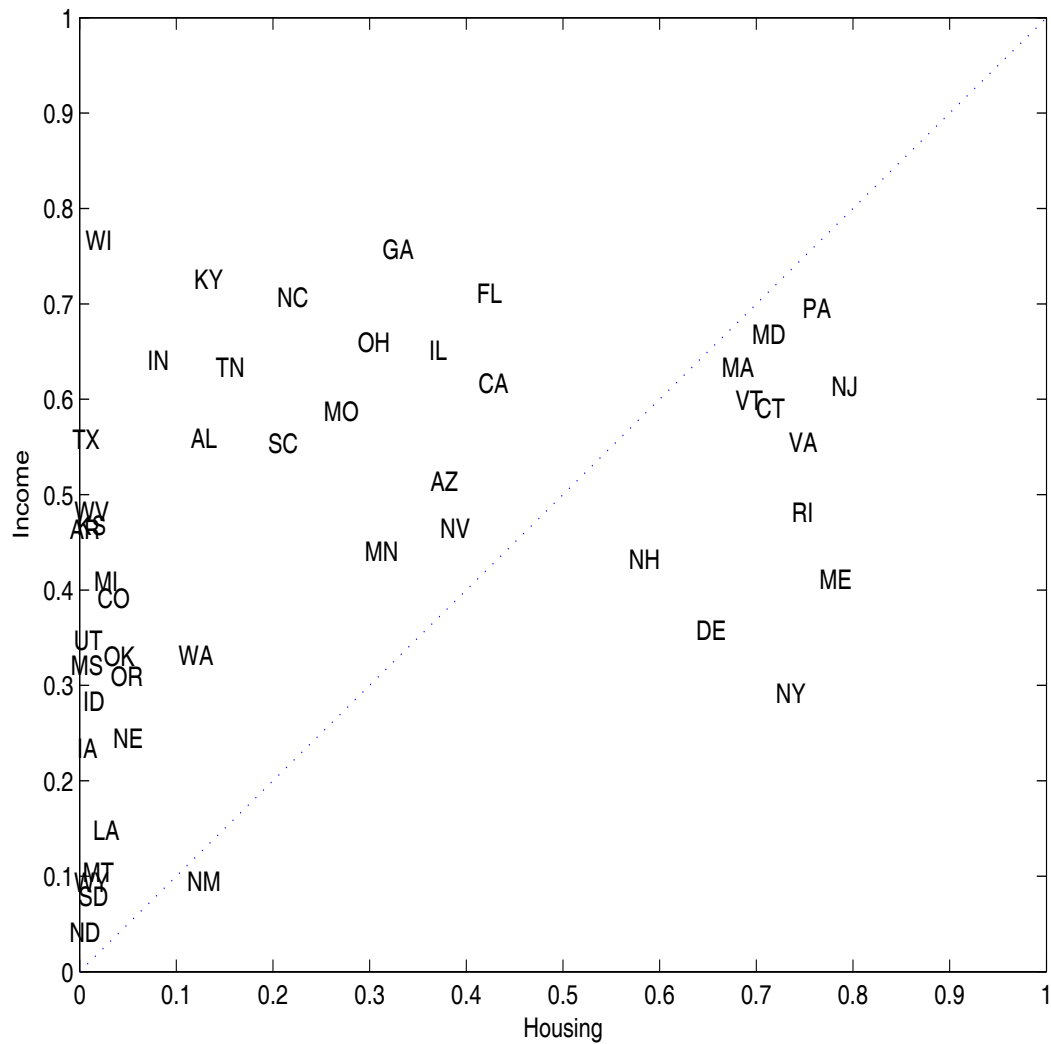
Notes: The top chart shows the growth rates in OFHEO house price indexes for the forty-eight contiguous U.S. states from QI-1986 to QIV-2004. The nominal house price indexes are deflated using the core PCE inflation. The middle chart (national factor) shows the impact of national shocks on state n , that is, the component $\beta_n^0 f_t^0$ of equation (1). The bottom chart (local factors) shows the joint impact of regional and state specific shocks, that is, the $\beta_n^r f_t^r + \epsilon_{n,t}$ component of equation (1). For all estimated quantities we show the median of the posterior distribution. See section 3 for a description of the data.

Figure 4: STATE-LEVEL BUSINESS CYCLES: NATIONAL AND LOCAL FACTORS



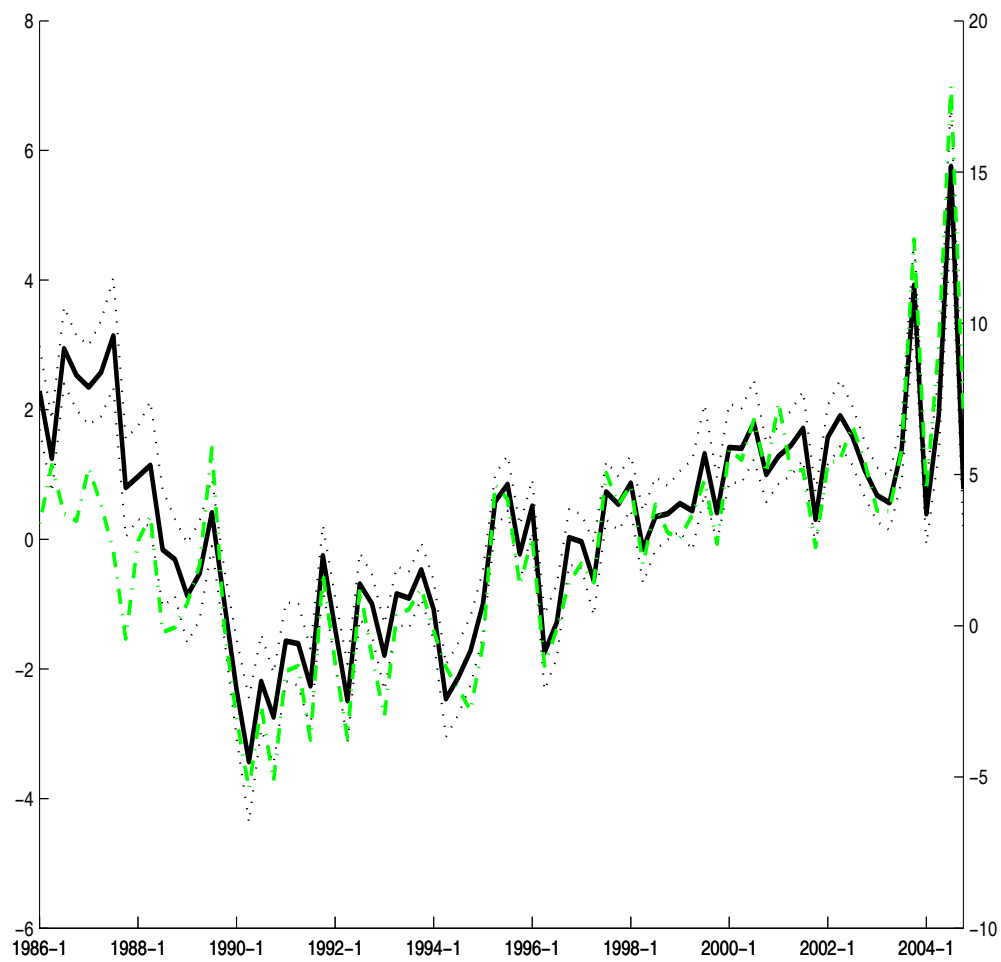
Notes: The top chart shows the growth rates in real per-capita income for the forty-eight contiguous U.S. states from QI-1986 to QIV-2004. The middle chart (national factor) shows the impact of national shocks on state n , that is, the component $\beta_n^0 f_t^0$ of equation (1). The bottom chart (local factors) shows the joint impact of regional and state specific shocks, that is, the $\beta_n^r f_t^r + \epsilon_{n,t}$ component of equation (1). For all estimated quantities we show the median of the posterior distribution. See section 3 for a description of the data.

Figure 5: VARIANCE DECOMPOSITION: HOUSING VS INCOME



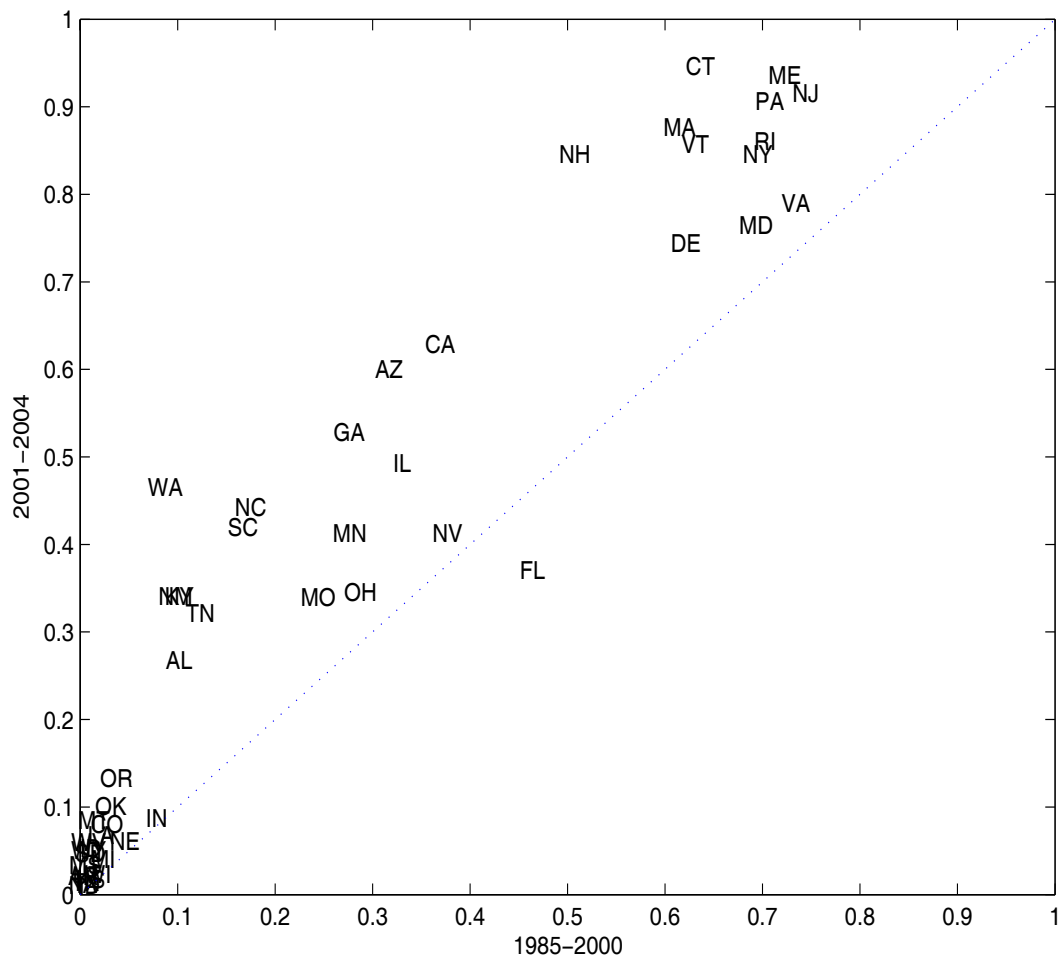
Notes: The figure shows the variance of fluctuations due to the national factor as a fraction of the variance of all components (referred to in the paper as $v_n(1, T)$, see equation (4)) for housing on the horizontal axis and for income on the vertical axis. The sample period is QI-1986 to QIV-2004. The figure shows the the median of the posterior distribution of $v_n(1, T)$.

Figure 6: THE NATIONAL HOUSE PRICE FACTOR AND THE U.S. OFHEO HOUSE PRICE INDEX



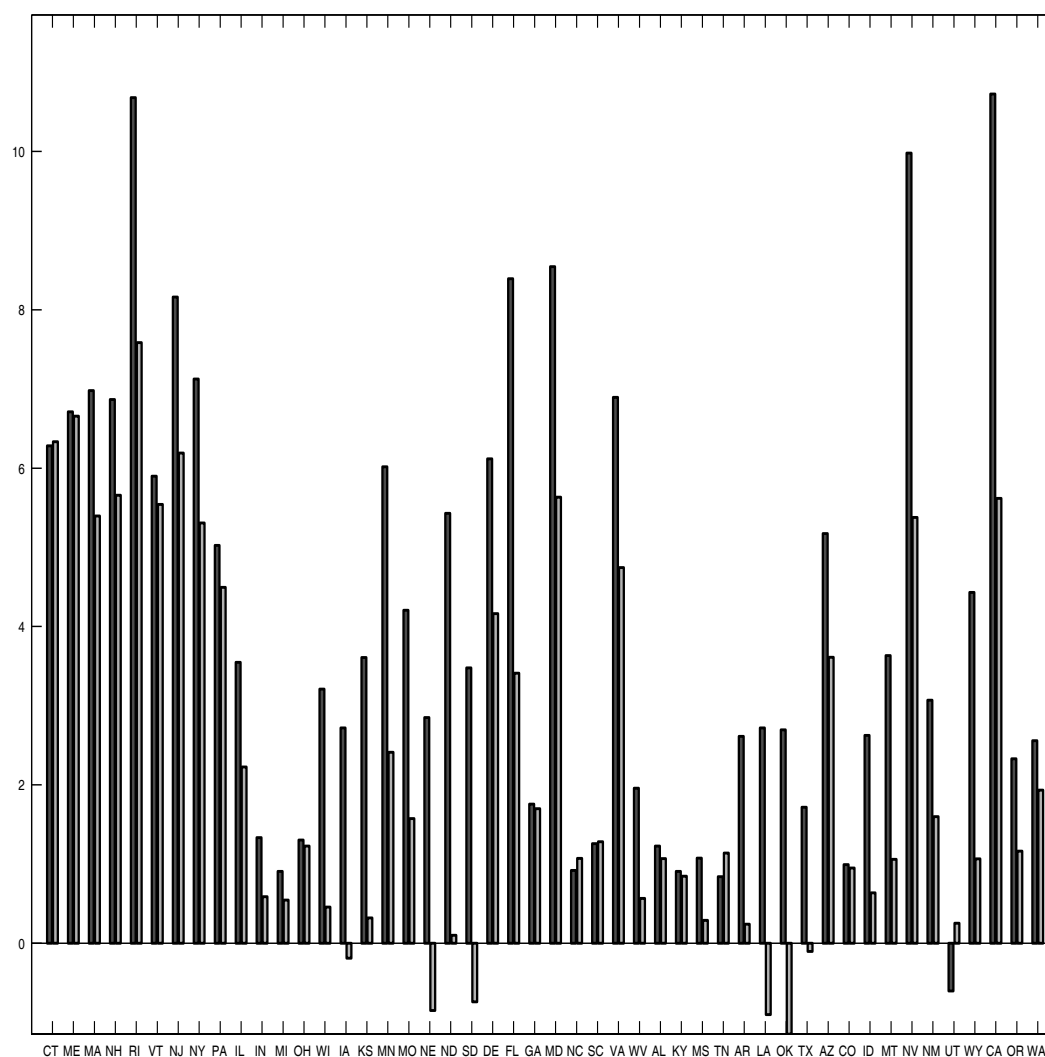
Notes: The figure plots the national housing factor f_t^0 (black, scale on the left axis), the ninety percent bands (dotted lines), as well as the OFHEO U.S. price index (gray, right axis). f_t^0 is the median posterior estimate of the factor from equation (1).

Figure 7: VARIANCE DECOMPOSITION, HOUSING: 1986-2000 vs 2001-2004



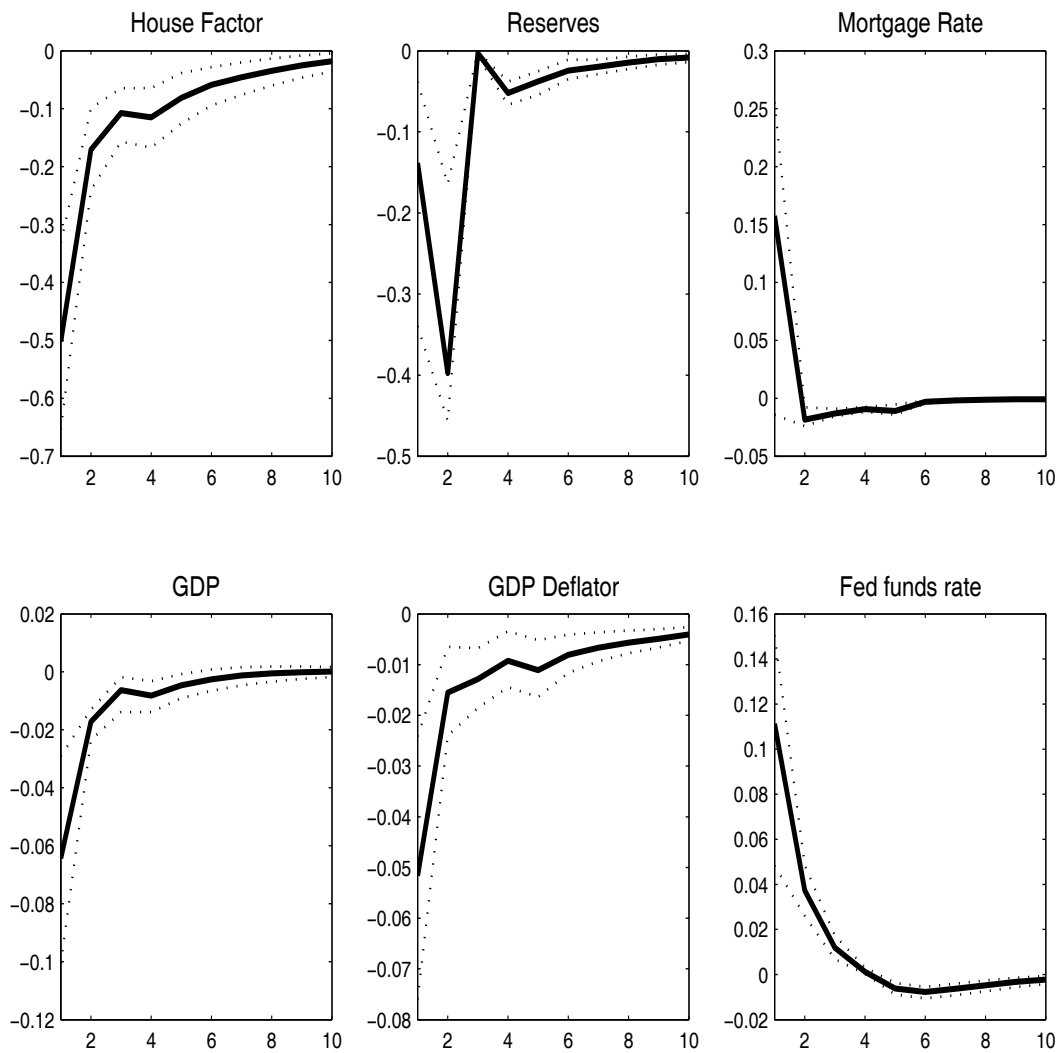
Notes: Figure 7 plots for each state the the magnitude $v_n(t_0, t_1)$ for the sub-sample 2001-2004 on the vertical axis, and 1986-2000 on the horizontal axis. $v_n(\cdot, \cdot)$ represents the variance of house prices fluctuations in state n due to the national factor as a fraction of the variance of all components. The figure shows the median of the posterior distribution of $v_n(t_0, t_1)$ obtained from estimating the model over the entire sample period.

Figure 8: CROSS-STATE HETEROGENEITY IN THE RECENT HOUSE PRICE BOOM: THE ROLE OF THE NATIONAL FACTOR



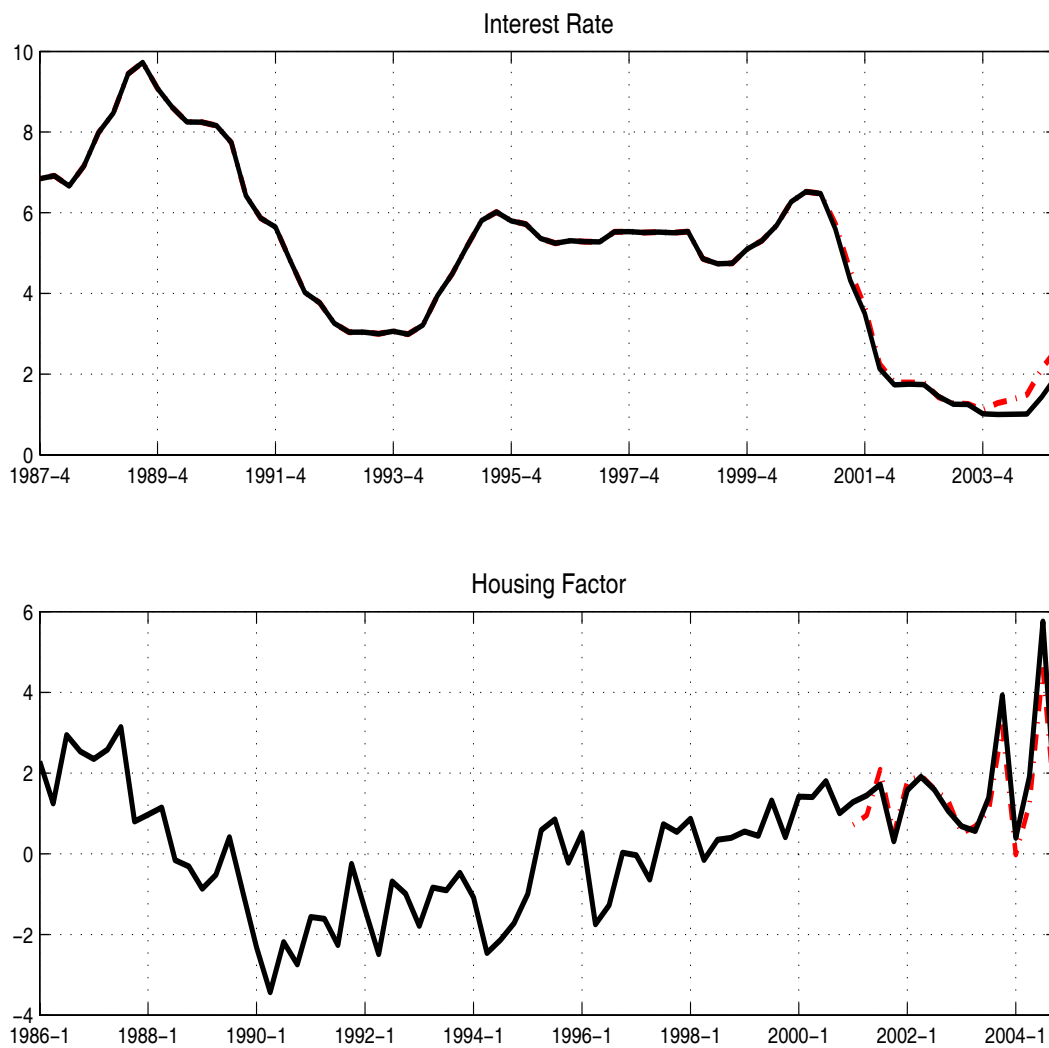
Notes: The figure shows for each of the forty-eight contiguous states the annualized average growth rates in real OFHEO house price index (dark gray bars) in excess of the historical (1986-2004) mean for the 2001-2004 period: $\sum_{t=Q1-2001}^{Q4-2004} (y_{n,t} - \mu_n) / 16$. The light gray bar represents the component of the average growth rates for the same period that can be attributed to the national factor: $\sum_{t=Q1-2001}^{Q4-2004} \beta_n^0 f_t^0 / 16$.

Figure 9: HOUSING AND MONETARY POLICY: IMPULSE RESPONSES



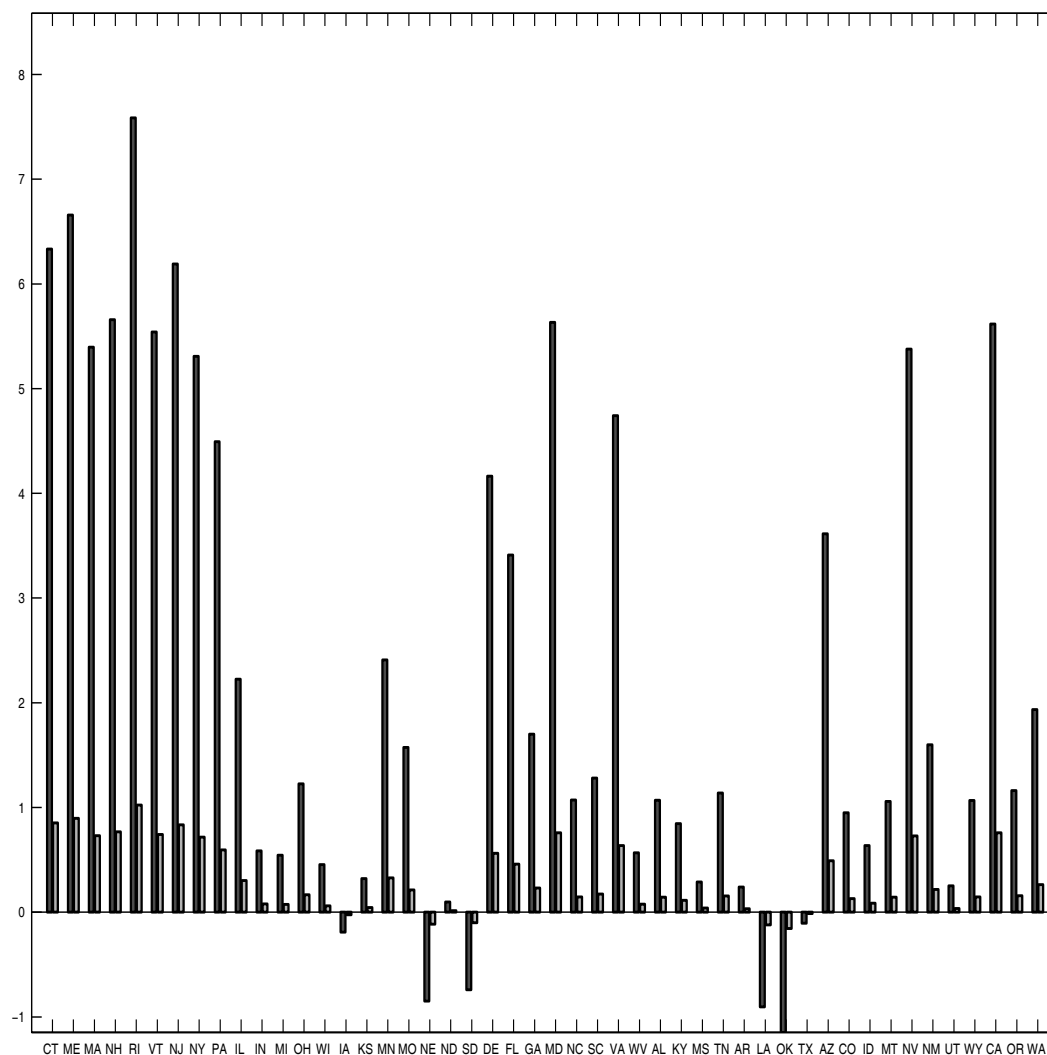
Notes: The figure displays the impulse response function of all of the variables to the monetary policy shock, along with the 68 percent posterior coverage intervals.

Figure 10: ACTUAL AND COUNTERFACTUAL INTEREST RATE AND HOUSING FACTOR



Notes: The figure shows the actual (solid line) and the counterfactual (dash-and-dotted line) paths for the Fed Funds rate and the housing factor. The counterfactual paths are obtained by shutting down monetary policy shocks from Q1-2004 to the end of the sample.

Figure 11: CROSS-STATE HETEROGENEITY IN THE RECENT HOUSE PRICE BOOM: ASSESSING THE ROLE OF MONETARY POLICY SHOCKS



Notes: The dark bars in the figure represent the component of the average growth rates in the 2001-2004 period that can be attributed to the national factor, namely the quantities $\sum_{t=Q1-2001}^{QIV-2004} \beta_n^0 f_t^0 / 16$, for each of the forty-eight contiguous states. These are the same quantities also shown in Figure 8. The light bars quantify the impact of policy shocks. For each state the figure shows the quantity $\sum_{t=Q1-2001}^{QIV-2004} \beta_n^0 (f_t^0 - \tilde{f}_t^0) / 16$, where by \tilde{f}_t^0 we denote the counterfactual factor.