Understanding Housing Market Volatility

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Abstract

The Campbell-Shiller present value formula implies a factor structure for the price-rent ratio of the housing market. Using a dynamic factor model, we decompose the price-rent ratios of 23 major housing markets into a national factor and independent local factors, and we link these factors to the economic fundamentals of the housing markets. We find that a large fraction of housing market volatility is local and that the national factor has become more important than local factors in driving housing market volatility since 1999, consistent with the findings in Del Negro and Otrok (2007). The local volatilities mostly are due to time-variations of idiosyncratic housing market risk premia, not local growth. At the aggregate level, the growth and interest rate factors jointly account for less than half of the total variation in the price-rent ratio. The rest is due to the aggregate housing market risk premium and a pricing error. We find evidence that the pricing error is related to money illusion, especially at the onset of the recent housing market bubble. The rapid rise in housing prices prior to the 2008 financial crisis was accompanied by both a large increase in the pricing error and a large decrease in the housing market risk premium.

Key words: dynamic factor model; housing market; price-rent ratio; risk premium; money illusion

JEL Classifications: C32, G12, R31

1 Introduction

Housing markets are partially segmented. There does not exist a centralized market for housing assets. Demographic changes, household preferences for geographic locations and climate plus inelastic land supply can lead to heterogeneous regional price dynamics. Some existing studies, such as Gyourko, Mayer and Sinai (2006) and Del Negro and Otrok (2007), have already observed the price level and growth rate vary drastically across major U.S. housing markets in the past few decades. As we can see in Table 1, for example, the average annual nominal price change was 5.4% in New York City but was only 2.7% in Kansas City during the period between 1979 to 2013. Moreover, the volatility of house prices also varies greatly across different cities. Table 1 shows the standard deviation of annual nominal price changes for the same period. It was 8.1% in New York City but was 3.6% in Kansas City. Table 2 reports similar statistics for the log price-rent ratios of the same cities. For example, in New York City the log price-rent ratio had an annual standard deviation of 24% while in Kansas City it was only 8.2% between 1979 to 2013.

On the other hand, all housing markets are obviously affected by a few aggregate variables such as the monetary policy, mortgage market innovations and national income. When the central bank lowers the key interest rate, it could stimulate the demand for houses in all markets and have a positive effect on housing prices. In fact Table 1 and Table 2 show that the correlation among some housing markets can be very high (e.g. New York City and Boston, Los Angles and Philadelphia).

In this study we use a dynamic factor model to decompose housing prices into a common national factor and idiosyncratic local factors in order to better understand the sources of housing market volatility. We treat a residential house as a dividend-paying asset and base our dynamic factor model on the Campbell-Shiller log-linear approximate present value formula for the price-dividend ratio (Campbell and Shiller, 1988). Such an approach allows us to link the unobservable factors to the economic fundamentals of the housing markets such as interest rates and expected rent growth.

Quantitatively distinguishing the national factor from local factors in the housing markets is important. From the perspective of policy makers, for instance, it is crucial to know if monetary policy was responsible for creating a national housing market bubble by keeping the short-term interest rate too low for too long, or if the increase in housing prices prior to the 2008 financial crisis instead reflected a collection of local bubbles. On the other hand, identifying a market "bubble" is intrinsically difficult. An increase in asset prices could be due to improved economic fundamentals as perceived by investors or due to purely speculative activities. By linking the unobserved price factors to economic fundamentals, our paper also seeks to distinguish between the part of housing market volatility attributable to changes in expected rent growth and the discount rate and the part that could be due to speculation or pricing errors.

Given the importance of the housing sector in the aggregate economy, there have been many studies on housing markets in recent years. For example, Fratantoni and Schuh (2003) uses a heterogeneous-agent VAR to examine the effect of monetary policy on regional housing markets. Davis and Heathcote (2005) points out that residential investment is more than twice as volatile as business investment and leads the business cycle. Iacoviello (2005) develops and estimates a monetary business cycle model with housing sector. Brunnermeier and Julliard (2008) finds evidence that money illusion can play an important role in fueling run-ups in housing prices. Stock and Watson (2009) estimates a dynamic factor model with stochastic volatility for building permits of the U.S. states from 1969-2007. Mian and Sufi (2009) uses detailed zip-code level data to examine the role of subprime mortgage credit expansion in fueling house price appreciation prior to the recent financial crisis. Kishor and Morley (2010) uses an unobserved component model to estimate expectations of housing market fundamentals and investigate the sources of aggregate housing market volatility. Ng and Moench (2011) estimates a hierarchical factor model of the housing market and examines the dynamic effects of housing market shocks on consumption. Favilukis et al. (2011) argues that international capital flows played a small role in driving the last house market bubble, and the key causal factor was instead the cheap supply of credit due to financial market liberalization. Recently, Sun and Tsang (2014) focus on the inference issues when studying sources to the housing market volatility. Our paper contributes to this growing literature that seeks to understand the fundamental driving forces of the housing market and its relationship to the aggregate economy.

Perhaps the closest studies to ours are Del Negro and Otrok (2007) and Campbell et al. (2009). Del Negro and Otrok (2007) was among the first to apply dynamic factor models to housing markets.[1] In their study state-level house price movements are decomposed into a common national component and local shocks via Bayesian methods. They find that historically the local factors have played a dominating role in driving the movement in house prices in different states. But a substantial fraction of the recent increases in house prices is due to the national factor. They further use a VAR to investigate the effect of monetary policy on housing markets. The key difference between our study and Del Negro and Otrok (2007) is that we treat a house as a dividend-paying asset and infer a factor structure for the price-rent ratio based on the Campbell-Shiller log-linear present value formula. As a result, we can explicitly link the unobserved factors to economic fundamentals of the housing markets. The Campbell-Shiller formula has been widely used to analyze the volatility of bond and equity markets. In an intriguing study, Campbell et al. (2009) applied the same method to price-rent ratio in housing markets.[2] The ratio is split into the expected present values of rent growth, the real interest rate and a housing risk premium. The study found that the housing risk premium accounts for a significant fraction of price-rent volatility. An important difference between our paper and Campbell et al (2009) is that we are able to disentangle the relative importance

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[1] Recent applications of dynamic factor models include Cicarelli and Mojon (2010) on global inflation, Ludvigson and Ng (2009) on bond risk premiums and Kose et al. (2003, 2008) on global business cycles among many others. Forni et al. (2000) provides a thorough analysis of the identification and estimation of generalized dynamic factor models.

[2] Brunnermeier and Julliard (2008) also uses the same approach to isolate the pricing error in the aggregate housing market due to money illusion.

of the common component in the price-rent ratios across individual markets from idiosyncratic local factors using a dynamic factor model. We show that this factor structure is an implication of the Campbell-Shiller present value formula and both factors have similar representations. Moreover, we show that a pricing error associated with money illusion is also important in driving housing market dynamics.

To implement the Campbell-Shiller formula, we need to estimate expected future rent growth and the real interest rate. Another innovation of our paper is that the forecasting vector auto-regression model (VAR) for future rent growth and the real interest rate is embedded in a dynamic factor model, and the two models are estimated jointly. The macro variables in the VAR are correlated with the national factor of rent growth but are independent of the local factors. Such a specification is important for appropriate identification of the national and the local factors.

The rest of the paper is organized as follows. Section 2 describes our model. Section 3 discusses the data and estimation strategy. Section 4 presents the main empirical results. Section 5 concludes.

2 Model

We treat a house as a dividend-paying asset and equate the house price to the present value of the expected future rental income under rational expectations.[3] Following Campbell and Shiller (1988), we can write the price-rent ratio as the sum of expected growth rate of rental income minus the expected rate of return on the housing asset.

In particular, if $P_{i,t}$ denotes the ex-dividend price of a housing asset in market i at time t, $D_{i,t+1}$ the rental income of the housing asset between t

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[3] Using rent as an approximation of the dividend income of a housing asset, we implicitly assume that individuals are indifferent between owning and renting. Glaeser and Gyourko (2007) points out that rental units in the housing markets tend to be very different from owner-occupied units.

and $t+1$, let $x_{i,t} = \log\left(\frac{P_{i,t}}{D_{i,t}}\right)$, $d_{i,t} = \log D_{i,t}$ and $r_{i,t+1} = \log\left(\frac{P_{i,t+1}+D_{i,t+1}}{P_{i,t}}\right)$. Under log-linear approximation, we have (ignoring constant terms):

$$x_{i,t} = E_t \sum_{\tau=0}^{\infty} \rho^{\tau} [\Delta d_{i,t+1+\tau} - r_{i,t+1+\tau}] \tag{1}$$

where $\rho = 1/(1+e^{-\bar{x}})$, and $\bar{x}$ is the steady state price/rent ratio. The house price today should equal the present value of expected future rent growth minus the weighted average of expected future rates of return.

We assume in this study that the growth rate of rent in one market consists of two components, a national factor that is common to all markets and an independent local factor that is specific to market i. We can now rewrite the standard Campbell-Shiller decomposition as

$$x_{i,t} = E_t \sum_{\tau=0}^{\infty} \rho^{\tau} \beta_{d,i} \Delta \bar{d}_{t+1+\tau} + E_t \sum_{\tau=0}^{\infty} \rho^{\tau} \Delta \tilde{d}_{i,t+1+\tau} - E_t \sum_{\tau=0}^{\infty} \rho^{\tau} r_{f,t+1+\tau} - E_t \sum_{\tau=0}^{\infty} \rho^{\tau} er_{i,t+1+\tau} \tag{2}$$

where $\Delta \bar{d}_t$ is the national factor of rent growth rate and $\beta_{d,i}$ is the factor loading for market i,[4] $\Delta \tilde{d}_{i,t}$ is the idiosyncratic rent growth rate in market i, $r_{f,t}$ is the real interest rate and $er_{i,t}$ is the excess rate of return in market i, $er_{i,t} = r_{i,t} - r_{f,t}$.

The last term in Equation (2) corresponds to the risk premium for investing in the housing market, which also can be written as the sum of two components

$$E_t \sum_{\tau=0}^{\infty} \rho^{\tau} er_{i,t+1+\tau} = E_t \sum_{\tau=0}^{\infty} \rho^{\tau} \beta_i \bar{er}_{t+1+\tau} + E_t \sum_{\tau=0}^{\infty} \rho^{\tau} \tilde{er}_{i,t+1+\tau} \tag{3}$$

The first part on the right side of the equation above can be thought of as the national housing market risk premium and the second part an idiosyncratic risk premium component that is specific to market i. This decomposition can be justified as follows: if housing markets were fully integrated without

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[4] For the purpose of identification we normalize the variance of the shock to the national factor to unity. See more discussions below.

transaction cost and other frictions, it would then follow from the standard asset pricing theory that $E_t(er_{i,t+1}) = \beta_i E_t(\bar{er}_{t+1})$, where $\bar{er}_{t+1}$ is the excess return on a portfolio of housing assets that is perfectly negatively correlated with the pricing kernel (or the stochastic discount factor).[5] Of course much evidence shows that housing markets are far from integrated and there are many kinds of frictions in each market such as transaction costs, liquidity constraints, etc. The second part on the right side of Equation (3) therefore captures the expected excess rate return that is orthogonal to the aggregate housing market risk premium. [6]

In summary, the log-linear Campbell-Shiller present value formula implies a factor structure for the price-rent ratios of the housing markets as follows:

$$x_{i,t} = \bar{x}_{i,t} + \tilde{x}_{i,t}, \quad i = 1, 2, ..., N \tag{4}$$

where

$$\bar{x}_{i,t} = \beta_{d,i} E_t \sum_{\tau=0}^{\infty} \rho^{\tau} \Delta \bar{d}_{t+1+\tau} - E_t \sum_{\tau=0}^{\infty} \rho^{\tau} r_{f,t+1+\tau} - \beta_i E_t \sum_{\tau=0}^{\infty} \rho^{\tau} \bar{er}_{t+1+\tau} \tag{5}$$

and

$$\tilde{x}_{i,t} = E_t \sum_{\tau=0}^{\infty} \rho^{\tau} \Delta \tilde{d}_{i,t+1+\tau} - E_t \sum_{\tau=0}^{\infty} \rho^{\tau} \tilde{er}_{i,t+1+\tau} \tag{6}$$

As we will further show in Section 4.3, there could be an additional pricing error term in Equation (5) if investors are not able to form rational expectations of future real rent growth or the real interest rate. For example, they may suffer from money illusion and mistakenly interpret a decline in

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[5] Since we will estimate the risk premium as the residual term in the Campbell-Shiller identity, we do not need to separately identify β_i and $E_t(\bar{er}_{t+1})$ but rather their product as a whole. Therefore as long as β_i is constant or its time variations, if there are any, are not related with local state variables, our decomposition in (3) will remain valid. In Table 3 we employ a quarterly data set for a small number of cities (due to limited data availability at the quarterly frequency) and report β_i estimates over different sample periods. The results indicate that, although there are some time variations in β_i for some cities, overall β_i remains quite stable for most cities during our sample periods.

[6] One implicit assumption is that investors in different housing markets share the same information set.

the nominal interest rate due to a change in inflation as a decrease in the real interest rate (or equivalently they extrapolate the historical nominal rent growth rate without taking into account changes in inflation). Under money illusion, the price-rent ratio, $\bar{x}_{i,t}$, will include an extra term (a pricing error) as follows,

$$\begin{aligned}\bar{x}_{i,t} =& \beta_{d,i} E_t \sum_{\tau=0}^{\infty} \rho^{\tau} \Delta \bar{d}_{t+1+\tau} - E_t \sum_{\tau=0}^{\infty} \rho^{\tau} r_{f,t+1+\tau} - \beta_i E_t \sum_{\tau=0}^{\infty} \rho^{\tau} \bar{er}_{t+1+\tau} \\ &+ (E_t - \tilde{E}_t) \sum_{\tau=0}^{\infty} \rho^{\tau} r_{f,t+1+\tau}\end{aligned} \tag{7}$$

where $\tilde{E}_t$ denotes people's subjective expectation under money illusion, E_t denotes the rational expectation. Investors perceive the real interest rate to be $\tilde{E}_t \sum_{\tau=0}^{\infty} \rho^{\tau} r_{f,t+1+\tau}$, while the actual real interest rate is $E_t \sum_{\tau=0}^{\infty} \rho^{\tau} r_{f,t+1+\tau}$. The first part of Equation (7) corresponds to the "correct" or "true" house value under rational expectations. If households underestimate the real interest rate, for example, the observed house price $\bar{x}_{i,t}$ will exceed its true value by $(E_t - \tilde{E}_t) \sum_{\tau=0}^{\infty} \rho^{\tau} r_{f,t+1+\tau}$. This pricing error will disappear if investors are able to correctly form rational expectations of future interest rates ($E_t = \tilde{E}_t$). In our decomposition exercise, we will need to distinguish empirically the pricing error from the risk premium term in the Campbell-Shiller formula.[7]

3 Data and Estimation

In our model specification there are two types of unobserved factors: the unobserved national and local factors for both rent growth and price-rent ratio, and the unobserved agent's expectations of future rent growth, future

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[7] We focus on money illusion in the national factor here because there is no appealing reason to assume only households in one or some particular markets make this mistake while others do not. However, it is possible that money illusion effects may vary in different markets due to different inflation experience. In Section 4.4 we will also explore the possibility of differential effects of the money illusion in different local markets.

interest rates and future excess returns or risk premiums. Typically the unobserved national and local factors can be extracted from the observed series by applying the type of Dynamic Factor Model (DFM) proposed in Stock and Watson (1991), and the unobserved expected future variables can be estimated by a VAR model that was first implemented in Campbell and Shiller (1988) to study sources of price-dividend variation. We combine these two lines of work and propose a novel VAR augmented DFM that allows us to simultaneously decompose the observed series into the national and local factors and obtain estimates of the expectations of future variables. Using the estimated expectations along with the Campbell-Shiller present-value accounting identity, we can further decompose the housing price variations into movements in different economic fundamentals including time-varying risk premiums.

Our data are semi-annual real rent growth and price-rent ratio of 23 metropolitan areas from 1979 to 2013. Real rent growth is obtained by deflating the nominal rent by the CPI. When applying the DFM to a real rent growth we augment the DFM with a multivariate VAR that includes several important macroeconomic variables (such as the interest rate) to allow for potential interactions between the national factor of real rent growth and observed macroeconomic variables. This is very important for several reasons. First it ensures the appropriate identification of the local factor of real rent growth in (6) which is supposed to be independent of the national factor of rent growth *and* the real interest rate in (5). Second, as pointed out by Engsted et al. (2012), a critical requirement for proper Campbell-Shiller VAR decompositions is that the forecasting state variables should include the current asset price. We address this issue by including the Case-Shiller home price index as one of the macro variables in our model. Third, the extra information contained in the macro variables can in principle improve the forecasts of national real rent growth as well as the future interest rate. More information on the data used in this paper can be found in the appendix A.

Denote the real rent growth in the 23 metropolitan areas by $\Delta d_{i,t}$. Assume a common national factor represented by $\Delta \bar{d}_t$ and the idiosyncratic local factors denoted by $\Delta \tilde{d}_{i,t}$. We use 2 lags for all dynamic factors since all data are semi-annual and 2 lags appear sufficient to capture potential dynamics. Notice that all variables are demeaned before being used to estimate the model. Specifically, the DFM part is set up as below:

$$\begin{aligned} \Delta d_{i,t} &= \beta_{d,i} \Delta \bar{d}_t + \Delta \tilde{d}_{i,t}, \quad i = 1, 2, ..., 23 && (8) \\ \Delta \bar{d}_t &= \phi_1 \Delta \bar{d}_{t-1} + \phi_2 \Delta \bar{d}_{t-2} + \omega_t && (9) \\ \Delta \tilde{d}_{i,t} &= \psi_1 \Delta \tilde{d}_{i,t-1} + \psi_2 \Delta \tilde{d}_{i,t-2} + \nu_{i,t}, \quad i = 1, 2, ..., 23 && (10) \end{aligned}$$

where ω_t and $\nu_{i,t}$ are independent Gaussian shocks.

We augment the above DFM with a VAR to allow the latent national factor $\Delta \bar{d}_t$ to interact with four macroeconomic variables including the real interest rate, r_t, real GDP growth, g_t, log changes in the Case-Shiller home price index, s_t, and CPI inflation rate, π_t:

$$\mathbf{Z}_t = \mathbf{\Phi}(L) \mathbf{Z}_{t-1} + \xi_t \tag{11}$$

where $\mathbf{Z}_t = (\Delta \bar{d}_t, r_t, g_t, s_t, \pi_t)'$ and $\xi_t = (\omega_t, \varepsilon_{r,t}, \varepsilon_{g,t}, \varepsilon_{s,t}, \varepsilon_{\pi,t})'$. The variance matrix of the innovations to the VAR is given by Σ. We also use 2 lags in the VAR specification.

To estimate this VAR-DFM model we cast it in a state-space form. The state-space representation of our model can be found in the appendix B. The Kalman filter then is conveniently employed to obtain maximum likelihood estimates of the hyper-parameters as in Kim and Nelson (1999). Once the hyper-parameter estimates are found the flitering algorithm is invoked to calculate the filtered estimates of the national and local factors: $\mathrm{E}[\Delta \bar{d}_t | I_t]$ and $\mathrm{E}[\Delta \tilde{d}_t | I_t]$, $i = 1, 2, \ldots, 23$. We rely on the filtered estimates in our calculations of various pricing components since agents can only know the information up to time t when pricing the housing assets. Iterating forward the dynamics of the unobserved national factor and observed macroeconomic variables, we can derive the growth component and interest rate component in the Campbell-Shiller decomposition (5) as follows:

$$\mathrm{E}_t \sum_{\tau=0}^{\infty} \rho^{\tau} \Delta \bar{d}_{t+1+\tau} = e_1' \cdot F \cdot (I - \rho F)^{-1} \cdot W_t \tag{12}$$

$$\mathrm{E}_t \sum_{\tau=0}^{\infty} \rho^{\tau} r_{t+1+\tau} = e_3' \cdot F \cdot (I - \rho F)^{-1} \cdot W_t \tag{13}$$

where $W_t = (\Delta \bar{d}_t, \Delta \bar{d}_{t-1}, r_t, r_{t-1}, g_t, g_{t-1}, s_t, s_{t-1}, \pi_t, \pi_{t-1})'$, i.e., the second half of the state variables in the transition equation (22) in Appendix B; F is the corresponding companion matrix in the VAR model. e_j is a selection column vector which has 1 as the j-th element and zero elsewhere. In the same way, the idiosyncratic local growth component $\mathrm{E}_t \sum_{\tau=0}^{\infty} \rho^{\tau} \Delta \tilde{d}_{i,t+1+\tau}$ can be computed relatively easily since it is by construction independent of the macroeconomic variables.

The aggregate and local risk premium components are obtained as the residual terms in the Campbell-Shiller accounting identity (5) and (6), respectively. We first apply the DFM to the log price-rent ratio and extract the national and local factors from this series.[8] Assume each price-rent ratio is the sum of the unobserved national factor and local factor:

$$x_{i,t} = \beta_{x,i} \bar{x}_t + \tilde{x}_{i,t}, \quad i = 1, 2, \ldots, 23 \tag{14}$$

and the national and local price-rent ratios both follow the stationary AR(2) processes:

$$\bar{x}_t = \alpha_1 \bar{x}_{t-1} + \alpha_2 \bar{x}_{t-2} + e_t, \quad e_t \sim \text{i.i.d. } N(0, \sigma_e^2) \tag{15}$$

$$\tilde{x}_{i,t} = \gamma_{i,1} \tilde{x}_{i,t-1} + \gamma_{i,2} \tilde{x}_{i,t-2} + \varsigma_{i,t}, \quad \varsigma_{i,t} \sim \text{i.i.d. } N(0, \sigma_{\varsigma,i}^2) \tag{16}$$

Again, the national and local factors are orthogonal to each other for identification purposes following Stock and Watson (1991). This model

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[8] Before applying the DFM to the log price-rent ratio data, we ran a panel unit root test and rejected the unit root hypothesis. This is consistent with the finding in Ambros et al (2011) that house price and rent are cointegrated.

again can be put into its state-space form and the estimation is done by following Kim and Nelson (1999). The risk premium term is then obtained by subtracting the rent growth and interest rate components from the price-rent ratio.

Also notice that in the dynamic factor models, the scale of the common factor and the factor loading are not identified independently. We normalize the standard deviation of the shocks to the common factor to be 1 to achieve identification.

4 Results

4.1 Factor Decomposition

We first estimate a dynamic factor model of the semi-annual log price-rent ratios of the 23 cities in our sample. The model decomposes each price-rent ratio into a common national factor and a local factor. The model is estimated for three sample periods, 1979 - 2013, 1979 - 1999S1 and 1999S2 - 2013. Table 4 summarizes the fractions of housing market volatility due to local factors. We measure the volatility of a housing market by the standard deviation of the semi-annual log price-rent ratio. We find that across the 23 cities local factors drive a significant portion of the total volatility in the housing markets. As Table 4 shows, for the whole sample period of 1979 - 2013, an average of 37% of the total volatility of the housing markets is attributable to local factors. In some cities, the local factor shares are more than 60%. Across the two sub-sample periods, while local factors account for more than half of housing market volatility during 1979 - 1999S1, local factor's impact has become much smaller since 1999. Almost 65% of the volatility of the housing markets can be attributable to a common national factor during 1999S2 - 2013. These results are consistent with those of Del Negro and Otrok (2007), which finds that historically movements in house prices were mainly driven by local components and that national factor has played a bigger role in recent years. Figure 1 plots the estimated national factor of the price-rent ratio together with the Case-Shiller house price index (normalized by the CPI index).[9] We can see that these two series track each other closely with a correlation coefficient of over 80%. Our series of the national factor of the price-rent ratio is also very similar to the one estimated by Davis et al. (2008). This confirms that the dynamic factor model provides a good summary of housing market movements.

4.2 Local Factor Shares

Table 4 also shows that the local factor shares vary greatly from city to city. For example, while local factor contributes more than 60% of the total volatility of the price-rent ratio in Houston, the local factor share is only around 15% in St Louis. The log-linearized Campbell-Shiller present value formula provides insights about what drives these local volatilities. The Campbell-Shiller formula is an accounting identity that expresses log price-rent ratio as a sum of two components: the present value of expected future rent growth rates and the present value of expected future discount rates. House prices increase today either because people expect higher future rent growth or a lower discount rate or both. As we have demonstrated in Section 2, the growth component can be further decomposed into a common national growth factor and an independent local growth factor. The discount rate component can be thought of as consisting of three factors, a risk-free interest rate, an aggregate or national risk premium which is common to all cities, and an idiosyncratic local risk premium. Therefore, in cites where local factors contribute a large share to housing market volatility there must be either volatile local growth or volatile local risk premiums or both. In Table 5 we report the standard deviations of local rent growth and local risk premiums (see below for more on the estimation of different components in the Campbell-Shiller accounting identity). We can see that on average local risk premiums are about 2 times more volatile than local rent growth between 1979 and 2013. We have very similar results for the two sub-sample

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[9] The semi-annual data of Case-Shiller index started from 1987.

periods (1979-1999S1 and 1999S2-2013). Notice that the lower volatilities of local growth and local risk premium in the second half of the sample (1999S2-2013) are consistent with declining local factor shares of price/rent volatility documented in Table 4. In Figure 2 we plot the scatter graph of local factor shares of the volatility of price-rent ratio against the standard deviations of local risk premiums. In Figure 3 we plot a similar graph with the standard deviations of local rent growth instead. We can clearly see from these two figures that the local factor shares are closely associated with the volatility of local risk premiums. Variation in the local growth volatility has some, but very limited, explanatory power for the local factor shares. Simple regressions of local factor shares on the volatility of local growth and the volatility of local risk premium (Table 6) confirm these results. During the whole sample period as well as the two sub-sample periods, the regression coefficient on the volatility of local risk premium is highly significant and R^2 is high. The coefficient on local growth is not significant (except in the first sample period) with low R^2. Cities with high local factor shares are those with large time variations in local risk premiums.

To study potential sources of local factor share variations across cities, in Table 7 we report the results of regressing the volatility of local risk premium on an index of local regulations. We use two indexes for local regulation. One is the Wharton Residential Land Use Regulation Index (WRLURI) and other is the index of housing supply regulation created by Sakes (2008). Both index are standardized to have a mean of zero and a standard deviation of one and are increasing in the degree of regulation. The two indexes have a positive correlation of 0.60 (see more in the Data appendix). Table 7 shows that variations in local risk premiums are negatively correlated with the degree of local regulations. Cities have higher level of regulation tend to have less volatile housing market risk premiums. And this negative relation is especially strong in the second half of the sample period (1999-2013). Since time variations in risk premium must be due to either time-varying risk of housing markets or time-varying risk aversion of investors, the results in Table 7 suggest that more stingent local regulations may have helped mitigate speculative activities in some housing markets during the 1999-2013 sample period.

4.3 Economic Fundamentals of Housing Markets

We next examine the economic fundamentals that underlie the national and local factors of house price-rent ratios. Using the Campbell-Shiller log-linear present-value formula, we are able to equate the national factor of the log price-rent ratio to the sum of the present value of the expected national growth rate in rent, the present value of the expected real interest rate and an aggregate risk-premium term. Similarly, the local factor of a price-rent ratio can be written as the sum of the present value of the expected local growth rate in rent and a local risk premium term. We embed a vector regression model into a dynamic factor model of rent growth rates. This allows us to obtain joint estimates of the national and local factors of rent growth as well as expected future interest rates. The national and local risk premium terms are then obtained as residuals in the Campbell-Shiller accounting identity using our previous estimates of the national and local factors of the log price-rent ratios.

Table 8 shows the volatilities of different components of the national housing market.[10] For the whole sample period of 1979 - 2013, the interest rate term has the largest standard deviation of 22.49% among the three economic variables underlying the national housing market. The risk premium term has a standard deviation of 15.66%, indicating strong evidence of time-varying risk premiums in the aggregate housing market. The growth term is the least volatile variable with a standard deviation of 7.87%. These three variables are laso highly correlated. The growth term and real interest rate are positively correlated. The risk premium is negatively correlated

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[10] Since dynamic factor models can't independently identify the variance of a common factor and the factor loadings, we report in Table 8 the cross-section average of the national factors of rent growth and risk premium, $\left(\frac{\sum_i \beta_{d,i}}{N}\right) E_t \sum_{\tau=0}^{\infty} \rho^{\tau} \Delta \bar{d}_{t+1+\tau}$ and $\left(\frac{\sum_i \beta_i}{N}\right) E_t \sum_{\tau=0}^{\infty} \rho^{\tau} \Delta \bar{er}_{t+1+\tau}$

with both the growth term and real interest rate.[11] Across the two subsample periods (1979 - 1999S1 and 1999S2 - 2103), however, there are some major differences. In particular, risk premium becomes the most volatile component of the aggregate housing market relative to the interest rate and the growth components during 1999-2013 and is (weakly) positively correlated with the growth component. The interest rate term became much less volatile during 1999-2013 probably due to long period of zero interest rate policy since the financial crisis of 2008.

To assess the impact of the economic fundamentals on housing markets, we report in Table 9 the results from simple regressions of log price-rent ratios on the growth and interest rate variables during 1979-2013. Notice that our estimates of the national growth factor and the real interest rate term are obtained from a separate dynamic factor model than the one for price-rent ratio, and the risk premium is obtained as the residual term in the Campbell-Shiller accounting identity. Therefore a meaningful regression is one that only includes the growth and interest rate variables. Table 9 shows that the growth component has little explanatory power for the variations of the aggregate housing market. The interest rate alone accounts for about 42% of the variation in the aggregate log price-rent ratios, and the growth and interest rate variables jointly explain up to 44% of the total variation in the aggregate log price-rent ratios. Moreover, consistent with standard economic theory, a higher expected real interest has a significantly negative effect on house prices. In contrast, the regression coefficient on the growth component is not significant and has the "wrong" sign. The regression result indicates that a large portion (more than 50%) of the variation in the national house market is due to changes in the aggregate risk premium term.

Table 9 also reports the results from regressing local price-rent ratios on local growth variables. In contrast to the aggregate housing market,

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[11] The negative correlation between the housing market risk premium and growth is consistent with the counter-cyclical risk premiums in the stock market documented in many studies such as Campbell and Cochrane (1999).

local growth does have some explanatory power for local price/rent ratios in a few cities such as New York City and Houston. The R^2 of these local regressions, however, are on average very small. This suggests that the idiosyncratic volatilities in local housing markets are mostly due to time-variation in local risk premiums, consistent with the result on the local factor shares in the previous section. Combining the results from local and national regressions, it seems safe to conclude that variation in risk premiums is the most important factor that drives housing market volatility. Changes in the interest rate have the expected, but limited, direct effect on housing market volatility. Regressions based sub-sample data yield a similar conclusion.[12]

4.4 Housing Market Risk Premiums and the Pricing Error

The residual term from the Campbell-Shiller present value formula (5) is the expected excess return or risk premium in the aggregate housing market, $E_t \sum_{\tau=0}^{\infty} \rho^{\tau} \bar{er}_{t+1+\tau}$. This is a valid decomposition if investors have rational expectations and the transversality condition holds, i.e., $\lim_{T\to\infty} \rho^T \mathrm{E}_t \bar{x}_{t+T} = 0$, where $\bar{x}_t$ is the national factor of log price-rent ratio. In general, however, the residual term from the Campbell-Shiller formula may include a pricing error. This pricing error can arise because either investors hold irrational expectations or there is a speculative bubble that violates the transversality condition. We now rewrite the Campbell-Shiller present value formula as

$$\bar{x}_{i,t} = \beta_{d,i} E_t \sum_{\tau=0}^{\infty} \rho^{\tau} \Delta \bar{d}_{t+1+\tau} - E_t \sum_{\tau=0}^{\infty} \rho^{\tau} r_{f,t+1+\tau} - \beta_i E_t \sum_{\tau=0}^{\infty} \rho^{\tau} \bar{er}_{t+1+\tau} + \lim_{T\to\infty} \rho^T \mathrm{E}_t \bar{x}_{i,t+T} \tag{17}$$

or

$$\bar{x}_{i,t} = \beta_{d,i} y_t - l_t - \beta_i \eta_t + \nu_{i,t} \tag{18}$$

where y_t, l_t and η_t are, respectively, the expected rent growth, the real interest rate and the risk premium, and $\nu_{i,t}$ denotes a possible pricing error

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[12] Kishor and Morley (2010) reports a similar finding that variation in risk premiums explains a large fraction of housing market volatility. Cochrane (2011) argues that most asset market puzzles and anomalies are related to large discount-rate/risk premium variation.

in the housing market. Our dynamic factor models produce estimates of $\bar{x}_{i,t}$, $\beta_{d,i}y_t$ and l_t, and the residual term from the account identity (18) now contains two components, the risk premium and the pricing error, $\beta_i\eta_t$ and $\nu_{i,t}$.

It is well documented that the excess return in the equity market can be predicted by some state variables such as yield spread and dividend yield. To distinguish between the risk premium and the pricing error in the aggregate housing market, we project via OLS regression the residual term from the Campbell-Shiller formula (18) onto the same state variables that are known to predict stock market returns as well as the national house price/rent ratio. We interpret the fitted value as the national housing market risk premium and the OLS residual as the aggregate pricing error. Notice that in dynamic factor models we can not separately identify the factor loadings and the standard deviation of a national factor. We again use the cross-section average of the Campbell-Shiller residuals from the 23 cities in the OLS regression. The results are reported in upper panel of Table 10. We can see that both the yield spread (the difference between the yield on Treasury bonds and that on Treasury bills), S&P 500 price/dividend (or price/earning) ratio and housing market price/rent ratio are significant predictors of the housing market returns. The R^2 from the OLS regression is high, indicating a large part of the Campbell-Shiller residual is the housing market risk premium that varies over time. Nonetheless the pricing error is also significant. The estimated housing market risk premium and pricing error are plotted in Figure 4. We can clearly see that during the housing market frenzy between 2000 and 2007, there was a large increase in the pricing error, ν_t, and an even larger decrease in the risk premium, η_t, both contributing to the sharp increase housing market prices before the 2008 financial crisis. In contrast, during the early sample period (1979 to 1985), the risk premium was increasing while the pricing error remains roughly the same. As a result, housing prices declined during that period (Figure 1).

It is interesting to notice that in the risk premium regression (the upper panel of Table 10), the coefficients on the yield spread and S&P 500 log price/dividend ratio both are positive while the coefficient on log house price/rent ratio is negative. The negative coefficient on house price/rent ratio implies that a higher house price must signal lower excess returns on housing asset. A large positive yield spread indicates that interest rates are likely to rise in the future, and rising interest rates decrease values of long-term assets such as houses. Therefore a large yield spread increases the risk to participate in the housing market, resulting in a higher risk premiums. On the other hand, it is well known that the dividend yield has strong forecasting power for future stock returns. For example Cochrane (2011) shows that a one percentage point increase in the dividend yield forecasts a nearly four percentage point higher excess return in the stock market. In states where the dividend yield is high (hence log price/dividend ratio is low), investors perceive a larger risk in the stock market and demand a higher expected return. As a result they are more willing to accept a lower expected return in the housing market. A higher dividend yield (or a lower price/dividend ratio) in the stock market predicts lower returns in the housing market. Housing assets seem to provide a hedge against stock market risk. Of course, such interpretations are subject to the caveat that part of the estimated risk premium may actually be the projection of the pricing error on the state variables or that the three state variables fail to capture all the variation of the housing market risk premium.

The orthogonal residual term from the above OLS regression can be interpreted as an estimate of the aggregate housing market pricing error. One possible source of the pricing error is money illusion. For example, Modigliani and Cohn (1979) argues that investors may fail to distinguish between the real interest rate and nominal interest rate. They may interpret a decline in the nominal interest rate due to changes in inflation as a decline in the real interest rate, and therefore bid up the real housing price. As pointed out by Brunnermeier and Julliard (2008), in the simplest case with constant real rents and real interest rates, the price-rent ratio will be simply determined as:

$$\frac{P}{D} = \sum_{\tau=1}^{\infty} \frac{1}{(1+r)^{\tau}} = \frac{1}{r} \tag{19}$$

where r is the real interest rate. Under money illusion, however, investors would value the housing asset as

$$\frac{P}{D} = \sum_{\tau=1}^{\infty} \frac{1}{(1+i)^{\tau}} = \frac{1}{i} \tag{20}$$

where i is the nominal interest rate. And if i declines due to a reduction in inflation, the price-rent ratio will increase even if the real interest rate remains constant.

To see if the estimated pricing error is indeed related to money illusion, we run an OLS regression of the pricing error on the inverse of the nominal interest rate. The results are reported in the second panel of Table 10. We can see that the estimated pricing error is indeed positively related to the inverse of the nominal interest rate. The regression coefficient is highly significant and R^2 is above 20%. We also control for inflation or change in inflation in the regression and we obtain the same result. Notice that the R^2 of the regressions are not very high, suggesting that money illusion may not be the only source of the pricing error. This is in contrast to the result in Brunnermeier and Julliard (2008) where the pricing error is almost entirely explained by money illusion.

The results of our dynamic factor model suggest a potential change of the factor share structure around 1999 (see Table 4) and this may affect the results about risk premium and pricing error above. To address this issue, we estimate the dynamic factor model using data from 1999 to 2013 only and repeat the same risk premium/pricing error regressions as above. We report the results in Table 11. We can see that all the coefficients from the risk premium and the pricing error regressions remain similar as before. Both stock market price dividend ratio and housing market price rent ratio have significant forecasting power for future excess returns in housing market. Pricing error is still positively correlated with the inverse of nominal interest rate, suggesting a money illusion effect. If we plot the fitted housing market risk premium we see a similar decrease prior to the financial crisis. The

R^2 from the risk premium regression, however, become much bigger than before. This implies that the pricing error may be smaller than what the whole-sample-estimation indicates. Another reason for the high R^2 is that the regression is run over a shorter sample period.

In local markets, local risk premiums are identified by the residuals of a similar local Campbell-Shiller identity (6), where local log price/rent ratio, $\tilde{x}_{i,t}$, and expected local real rent growth, $E_t \sum_{\tau=0}^{\infty} \rho^{\tau} \Delta \tilde{d}_{i,t+1+\tau}$, can be estimated based on our dynamic factor model and the forecasting VAR. It is possible that the residual term also includes a pricing error if the expectation of local *real* rent growth is distorted by local inflation. Separating local pricing errors from local risk premiums is more difficult because it is not obvious what local state variables are appropriate for identifying local risk premium. We conjecture that investors in cities that experience higher local inflation are more likely to have distorted expectation of *real* rent growth and the presence of such pricing errors will increase the volatility of the local Campbell-Shiller residual term (or the estimated local risk premiums). In Table 12 we report the results from regressing the cross-section of volatilities of the estimated local risk premiums on the levels of local CPI inflation (excluding shelter) for three periods respectively, 1979 - 2013, 1979-1999 and 1999-2013. In all three periods, the volatility of the estimated local risk premium is indeed positively correlated with the level of local inflation, although the regression coefficient is not significant for the whole or the second half of the sample period. During 1979-1999 where the average inflation is much higher than the latter period, however, the regression coefficient is significant and the R^2 is more than 13%. These results indicate that pricing errors from money illusion may be present at local level as well and investors' past experience may play an important role in shaping their expectations of future growth or discount rate.

5 Conclusions

This paper is an empirical analysis of housing market dynamics. The housing asset is probably the single most important component of an average household's financial portfolio. Housing market movements also have great impacts on macroeconomic fluctuations. Compared to equity and bond markets, however, there have been relatively fewer studies on the nature and sources of housing market volatility. We contribute to a growing literature on housing markets by estimating a dynamic factor model of the price-rent ratios of 23 major metropolitan areas of the U.S. The model allows us to disentangle the common and idiosyncratic local components of housing market volatility. We find that a large fraction of housing market volatility is local, although the impact of local factors has become smaller after 1999. Our dynamic factor model is based on a present-value representation of the price-rent ratio of the housing asset and is jointly estimated with a forecasting VAR that includes important macroeconomic variables. This approach enables us to relate otherwise unobservable latent factors to economic fundamentals of the housing markets. Our results indicate that at both the local and the aggregate levels time-variation in risk premiums is the most important source of housing market volatility. Interest rates play a smaller role in driving the movements of the housing markets. Nonetheless, changes in the interest rate can have a direct and indirect impact on the housing market. A decrease in the interest rate directly lowers the discount rate, and therefore pushes up home prices. Moreover, a sharp decline in the interest rate can also fuel housing market speculation through a money illusion effect. We find evidence that the housing market bubble leading to the 2008 financial crisis was indeed accompanied by both a large decrease in the housing market risk premium and a large increase in the pricing error associated with money illusion.

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A Data

Rent growth. Nominal rent indexes are the rent of primary residence for major U.S. metropolitan areas from the Bureau of Labor Statistics (BLS).[13] The beginning periods and the reporting frequencies of these indexes vary substantially for different cities and also over time for the same city. To include as much data as possible in the time dimension and to include as many cities as possible to span wide geographic regions, we follow Campbell et al. (2009) and focus on the semi-annual frequency. For many cities included in our study due to the inconsistency of reporting frequency of the rent data over time and across cities we take averages of monthly observations when necessary to convert to the semi-annual observations. Our sample period starts from 1979S1 and ends in 2013S1. This leaves us with a set of 23 cities: New York City, Philadelphia, Boston, Pittsburgh, Chicago, Cincinnati, Cleveland, Detroit, Kansas City, Milwaukee, Minnesota, Atlanta, Houston, Los Angeles, Portland, San Francisco, Seattle, St.Louis, Dallas, Miami, Denver, Honolulu, and San Diego. Evidently the data covers most major cities ranging from the east coast to the midwest and west coast. The nominal rent then is deflated by the consumer price index (CPI). Real rent growth is the difference of the logarithms of real rent index.

Log price-rent. Nominal housing price indexes are the repeat-transaction house price indexes from the Federal Housing Finance Agency (FHFA). We take averages of monthly observations to convert to semi-annual ones. We then divide the nominal housing price by the nominal rent and take the logarithm to get the log price-rent ratio. Notice that since both price and rent are indexes, the log price-ratio deviates from its true value by a constant. This caveat, however, won't affect our analysis of housing market volatility.

Other macroeconomic variables. Real GDP growth rate and the consumer price index are from the FRED website. The Case-Shiller home price

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[13] These indexes are the Consumer Price Index (CPI) rent components whose construction has been criticized by a number of studies such as the Boskin Commission Report. While we are aware of this problem, these indexes are the only rent series available and are often used in studies such as Campbell et al. (2009).

index is taken from Robert Shiller's book *Irrational Exuberance*, available on Shiller's website. The real interest rate used in our estimation is the short rate minus the CPI inflation rate. The short rate is the one-year Treasury bill rate and the long rate is the ten-year Treasury bond rate, and both are from the FRED website. For all series, we convert either quarterly or monthly observations of the macroeconomic variables to semi-annual ones by taking the average.

Indexes of local regulation used in our study are Wharton Residential Land Use Regulation Index (WRLURI) based on a 2005 survey and the index of housing supply regulation created by Sakes (2008) for the late 1970s and 1980s. Both indexes have a mean zero and a standard deviation of one. A larger index value indicates a higher degree of regulation. A market with an index value of positive one is one standard deviation above the national mean.

B The State Space Representation

In this appendix, we describe the state-space representation of our model for rent growth. We cast the model as specified by Equations (8), (9), (10), and (11) in a state-space representation with the measurement and transition equations as follows.

Measurement equation:

$$\mathbf{U}_t = \mathbf{M}\mathbf{Y}_t \tag{21}$$

where

$$\mathbf{U}_t = \begin{bmatrix} \Delta d_{1,t} \\ \vdots \\ \Delta d_{23,t} \\ r_t \\ g_t \\ s_t \\ \pi_t \end{bmatrix}, \quad \mathbf{M} = \begin{bmatrix} 1 & 0 & \cdots & 0 & 0 & \beta_{d,1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \vdots & & & & \vdots & \vdots & & & & & \vdots & & & & \\ 0 & 0 & \cdots & 1 & 0 & \beta_{d,23} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}$$

Transition equation:

$$\mathbf{Y}_t = \mathbf{\Lambda} \mathbf{Y}_{t-1} + \mathbf{\Theta}_t \tag{22}$$

where

$$\mathbf{Y}_t = \begin{bmatrix} \Delta \tilde{d}_{1,t} \\ \Delta \tilde{d}_{1,t-1} \\ \vdots \\ \Delta \tilde{d}_{23,t} \\ \Delta \tilde{d}_{23,t-1} \\ \Delta \bar{d}_t \\ \Delta \bar{d}_{t-1} \\ r_t \\ r_{t-1} \\ g_t \\ g_{t-1} \\ s_t \\ s_{t-1} \\ \pi_t \\ \pi_{t-1} \end{bmatrix}, \quad \mathbf{\Theta}_t = \begin{bmatrix} \nu_{1,t} \\ 0 \\ \vdots \\ \nu_{23,t} \\ 0 \\ \omega_t \\ 0 \\ \varepsilon_{r,t} \\ 0 \\ \varepsilon_{g,t} \\ 0 \\ \varepsilon_{s,t} \\ 0 \\ \varepsilon_{\pi,t} \\ 0 \end{bmatrix}$$

and

$$\mathbf{\Lambda} = \begin{bmatrix}
\psi_{1,1} & \psi_{1,2} & & & & & & & & & & & & & \\
1 & 0 & & & & & & & & & & & & & \\
 & & \vdots & & & & & & & & & & & & \\
 & & \cdots & \psi_{23,1} & \psi_{23,2} & & & & & & & & & & \\
 & & & 1 & 0 & & & & & & & & & & \\
 & & & & & \phi_{1,1} & \cdots & & & & & & & & \phi_{1,10} \\
 & & & & & 1 & 0 & & & & & & & & 0 \\
 & & & & & \phi_{2,1} & \cdots & & & & & & & & \phi_{2,10} \\
 & & & & & & & 1 & 0 & & & & & & \\
 & & & & & \phi_{3,1} & \cdots & & & & & & & & \phi_{3,10} \\
 & & & & & & & & & 1 & 0 & & & & \\
 & & & & & \phi_{4,1} & \cdots & & & & & & & & \phi_{4,10} \\
 & & & & & & & & & & & 1 & 0 & & \\
 & & & & & \phi_{5,1} & \cdots & & & & & & & & \phi_{5,10} \\
 & & & & & & & & & & & & & 1 & 0
\end{bmatrix}$$

Table1 Summary Statistics of Housing Markets, Price Changes 1979-2013

	NYC	PHIL	BOST	PITT	CHIC	CINC	CLEV	DET	KC	MILW	MINN	ATL	HOUS	LA	PORTL	SFR	SEA	stl	dal	mia	den	hon	sd
Log Price Change	0.0538	0.0475	0.0586	0.0322	0.0346	0.0271	0.0232	0.0239	0.0265	0.0307	0.0345	0.0312	0.0254	0.0494	0.0411	0.0606	0.0473	0.0294	0.0271	0.0429	0.0394	0.0539	0.0453
Std Dev	0.0810	0.0604	0.0831	0.0441	0.0579	0.0340	0.0513	0.0840	0.0363	0.0473	0.0555	0.0514	0.0505	0.1052	0.0706	0.0925	0.0740	0.0474	0.0414	0.1109	0.0500	0.2644	0.1017
Correlation	1.0000	0.7611	0.8720	0.1546	0.6581	0.3750	0.2712	0.3929	0.4961	0.3607	0.5359	0.6298	-0.1695	0.6019	0.0338	0.5847	0.2296	0.6580	0.2480	0.4441	0.0914	0.0765	0.5269
		1.0000	0.5860	0.3493	0.6759	0.5696	0.3833	0.2446	0.4599	0.4697	0.4592	0.4792	-0.1014	0.7184	0.2846	0.6076	0.3981	0.4784	0.0731	0.5639	-0.1031	0.3584	0.5851
			1.0000	0.0490	0.5280	0.3428	0.2865	0.3812	0.5265	0.2102	0.4774	0.6144	-0.2463	0.4716	-0.1356	0.5563	0.1147	0.5112	0.4165	0.2988	0.1659	-0.0261	0.4748
				1.0000	0.3973	0.3972	0.1027	0.3445	0.0462	0.3262	0.0952	0.1762	0.0908	0.1624	0.2212	0.2125	0.1766	0.2156	-0.1320	0.2306	-0.0552	0.7142	0.3748
					1.0000	0.5877	0.6218	0.6119	0.5160	0.6873	0.5812	0.6351	-0.0341	0.6440	0.4310	0.6013	0.6211	0.5879	0.0834	0.5719	0.1709	0.0829	0.7024
						1.0000	0.5727	0.5596	0.7731	0.4158	0.6227	0.5631	-0.0783	0.4191	0.5314	0.4944	0.4592	0.2014	0.0371	0.5663	0.2146	0.2844	0.3652
							1.0000	0.3296	0.6207	0.6602	0.4659	0.3779	-0.2136	0.3216	0.4526	0.3144	0.4225	0.3270	0.1401	0.2925	0.2198	-0.2631	0.3637
								1.0000	0.4671	0.2709	0.5540	0.5381	0.0135	0.4489	0.2889	0.5387	0.4160	0.3307	-0.0207	0.4481	0.2067	0.1144	0.4029
									1.0000	0.4383	0.7807	0.7053	0.0258	0.4223	0.4665	0.4948	0.3887	0.3755	0.4368	0.6019	0.4722	-0.0605	0.3414
										1.0000	0.5347	0.3371	0.0250	0.4224	0.5713	0.3964	0.4909	0.6895	0.0505	0.3952	0.3538	0.1591	0.5359
											1.0000	0.7491	0.2528	0.5843	0.5516	0.5702	0.4859	0.5199	0.3748	0.6564	0.6181	0.0367	0.4883
												1.0000	0.2290	0.5008	0.3620	0.5592	0.4658	0.4477	0.5608	0.6139	0.5027	0.0463	0.4463
													1.0000	0.1590	0.2328	0.0824	0.2662	0.0276	0.4248	0.2844	0.5026	0.1286	0.1458
														1.0000	0.3624	0.8134	0.6152	0.3999	0.1091	0.7247	0.0512	0.1695	0.8178
															1.0000	0.2606	0.6937	0.1988	0.1213	0.6550	0.3316	0.2528	0.2256
																1.0000	0.5402	0.4216	0.1269	0.5536	0.1500	0.2125	0.7046
																	1.0000	0.2639	0.1946	0.6092	0.2058	0.1252	0.5161
																		1.0000	0.1626	0.2488	0.2163	0.1379	0.4381
																			1.0000	0.3211	0.6300	-0.1482	0.1269
																				1.0000	0.3675	0.2603	0.5868
																					1.0000	-0.0921	0.1895
																						1.0000	0.2010
																							1.0000

Table2 Summary Statistics of Housing Markets, Log Price/Rent Ratios 1979-2013

	NYC	PHIL	BOST	PITT	CHIC	CINC	CLEV	DET	KC	MILW	MINN	ATL	HOUS	LA	PORTL	SFR	SEA	stl	dal	mia	den	hon	sd
Log Price /Rent	-0.3772	-0.3914	-0.3280	-0.3373	-0.5021	-0.3871	-0.4314	-0.3785	-0.2771	-0.3855	-0.2331	-0.3454	-0.0766	-0.2624	-0.4173	-0.3658	-0.3874	-0.2485	-0.1465	-0.1966	-0.2254	-0.6318	-0.3143
Std Dev	0.2425	0.1739	0.2161	0.1105	0.1258	0.0854	0.0912	0.2120	0.0824	0.1617	0.1816	0.0880	0.1012	0.2163	0.2571	0.2410	0.2445	0.1291	0.0822	0.2333	0.1406	0.2489	0.2029
Correlation	1.0000	0.6169	0.6187	0.4982	0.6130	0.5102	0.3757	0.3383	0.4418	0.4894	0.5537	0.5853	0.0775	0.6089	0.4482	0.6074	0.5164	0.5936	0.1455	0.5876	0.4197	0.5302	0.5754
		1.0000	0.8257	0.7979	0.7379	0.5675	0.3187	0.3054	0.4313	0.7675	0.7811	0.7041	0.0845	0.8735	0.8024	0.9284	0.8732	0.8373	-0.0003	0.7932	0.7181	0.8768	0.7697
			1.0000	0.6487	0.6851	0.5448	0.3682	0.4469	0.2754	0.6102	0.7012	0.6087	-0.1899	0.7243	0.6563	0.8157	0.7621	0.7561	-0.1476	0.7018	0.6323	0.6987	0.6618
				1.0000	0.7627	0.8233	0.6323	0.6425	0.5740	0.9225	0.8569	0.6728	-0.0953	0.7613	0.9191	0.8608	0.9211	0.9154	-0.2728	0.7633	0.8891	0.8326	0.8088
					1.0000	0.8766	0.8268	0.7769	0.6951	0.8279	0.8708	0.8559	-0.0565	0.8882	0.7913	0.8483	0.8518	0.8549	-0.0616	0.9088	0.7559	0.7157	0.9167
						1.0000	0.8816	0.8909	0.8290	0.9093	0.9090	0.8220	-0.0130	0.7333	0.8386	0.7405	0.8033	0.8846	-0.0953	0.8486	0.8770	0.5788	0.8566
							1.0000	0.9417	0.6329	0.6711	0.6663	0.5947	-0.2922	0.5747	0.6017	0.5460	0.6210	0.6403	-0.3081	0.6471	0.6110	0.4276	0.7218
								1.0000	0.6090	0.6747	0.6975	0.5996	-0.2984	0.5734	0.6073	0.5699	0.6290	0.6554	-0.3352	0.6589	0.6691	0.3934	0.7340
									1.0000	0.8073	0.8093	0.8542	0.4940	0.6128	0.6559	0.5445	0.5394	0.7455	0.4166	0.7733	0.7577	0.3145	0.7162
										1.0000	0.9670	0.8534	0.1538	0.8018	0.9587	0.8442	0.9030	0.9694	0.0086	0.8942	0.9704	0.7096	0.8667
											1.0000	0.9300	0.1727	0.8522	0.9313	0.8609	0.8979	0.9657	0.0864	0.9594	0.9627	0.6861	0.9079
												1.0000	0.3758	0.8505	0.7728	0.7727	0.7543	0.8614	0.3626	0.9465	0.8291	0.5718	0.8861
													1.0000	0.1308	0.0161	0.0228	-0.0973	0.1013	0.9092	0.1874	0.1377	-0.1381	0.0929
														1.0000	0.7710	0.9490	0.8706	0.8314	0.0635	0.9139	0.7409	0.8130	0.9585
															1.0000	0.8399	0.9529	0.9396	-0.1229	0.8667	0.9458	0.7642	0.8047
																1.0000	0.9335	0.8916	-0.1025	0.8603	0.7998	0.8633	0.9039
																	1.0000	0.9175	-0.2207	0.8686	0.8802	0.8570	0.8674
																		1.0000	-0.0007	0.9012	0.9377	0.7590	0.8620
																			1.0000	0.1609	-0.0065	-0.2388	0.0214
																				1.0000	0.8705	0.7024	0.9367
																					1.0000	0.6396	0.8262
																						1.0000	0.7493
																							1.0000

Table 3 The βs of Local Housing Markets

	1979 - 2013	1979 - 1999S1	1999S2 - 2013
NYC	1.1658	0.9903	1.2294
	(0.9308, 1.4008)	(0.4217, 1.5588)	(1.0952, 1.3637)
PHIL	1.1484	1.4173	1.0494
	(0.9553, 1.3416)	(0.9780, 1.8566)	(0.8956, 1.2031)
BOST	0.9908	0.7059	1.0772
	(0.7138, 1.2678)	(0.0765, 1.3354)	(0.8732, 1.2811)
CHIC	1.0227	0.7519	1.1246
	(0.8557, 1.1898)	(0.3437, 1.1601)	(1.0520, 1.1972)
CLEV	0.7318	0.9278	0.6612
	(0.4983, 0.9652)	(0.3722, 1.4834)	(0.5102, 0.8122)
DET	1.3227	1.8555	1.0977
	(1.0252, 1.6202)	(1.2929, 2.4182)	(0.7689, 1.4264)
HOUS	0.4896	0.8162	0.4090
	(0.2287, 0.7505)	(0.2368, 1.3956)	(0.3114, 0.50067)
LA	1.7775	1.2009	2.0002
	(1.5252, 2.0297)	(0.6688, 1.7330)	(1.7652, 2.2352)
SFR	1.4806	1.4172	1.4896
	(1.2033, 1.7579)	(0.8199, 2.0144)	(1.2245, 1.7547)
DAL	0.5141	0.7902	0.4427
	(0.2159, 0.7122)	(0.3675, 1.2130)	(0.3315, 0.5539)
MIA	1.7879	0.5181	2.2556
	(1.3415, 2.2342)	(-0.4970, 1.5333)	(1.9712, 2.5400)

Note: this table reports the βs of local housing markets in different sample periods. The βs are obtained by regressing quarterly excess return of a local housing market on the excess return of the aggregate housing market. Numbers in parentheses give the 95% confidence intervals of the regression coefficients.

Table 4 Volatility Share of Local Factors

	1979 - 2013	1979 - 1999S1	1999S2 - 2013
NYC	0.5114	0.7529	0.4860
PHIL	0.4127	0.6697	0.5568
BOST	0.5079	0.6910	0.2574
PITT	0.4039	0.2453	0.4090
CHIC	0.3186	0.3867	0.1940
CINC	0.2895	0.2740	0.3329
CLEV	0.4262	0.1662	0.5153
DET	0.4759	0.2350	0.6073
KC	0.3844	0.5545	0.2286
MILW	0.1669	0.3220	0.1925
MINN	0.1405	0.3829	0.0277
ATL	0.3083	0.6339	0.1171
HOUS	0.6717	0.8918	0.5971
LA	0.3494	0.6407	0.3443
PORTL	0.3596	0.4689	0.4184
SFR	0.3514	0.5606	0.3529
SEA	0.3493	0.5089	0.4450
STL	0.1558	0.3505	0.2078
DAL	0.6102	0.9520	0.3440
MIA	0.2557	0.3486	0.2095
DEN	0.3908	0.5531	0.1510
HON	0.4622	0.6433	0.8216
SD	0.2857	0.4814	0.3198
Average	0.3734	0.5093	0.3537

Note: this table reports fractions of the standard deviation of log price/rent ratio attributable to local factors.

Table 5 Volatility of Local Housing Markets

	1979 - 2013		1979 - 1999S1		1999S2 - 2013	
	Local Growth	Risk Premium	Local Growth	Risk Premium	Local Growth	Risk Premium
NYC	0.0283	0.1316	0.0090	0.1773	0.0196	0.0599
PHIL	0.0363	0.0963	0.0340	0.0819	0.0310	0.1177
BOST	0.0560	0.1516	0.0612	0.1899	0.0894	0.1007
PITT	0.0126	0.0504	0.0049	0.0241	0.0177	0.0314
CHIC	0.0021	0.0778	0.0009	0.0365	0.0031	0.0304
CINC	0.0038	0.0343	0.0045	0.0217	0.0040	0.0373
CLEV	0.0012	0.0791	0.0014	0.0149	0.0019	0.0662
DET	0.0069	0.1529	0.0124	0.0446	0.0023	0.1845
KC	0.0149	0.0629	0.0307	0.0766	0.0044	0.0190
MILW	0.0030	0.0305	0.0031	0.0445	0.0072	0.0225
MINN	0.0336	0.0453	0.0950	0.0876	0.0347	0.0351
ATL	0.0259	0.0495	0.0233	0.0410	0.0096	0.0174
HOUS	0.1203	0.1777	0.1519	0.2212	0.0019	0.0440
LA	0.2000	0.2190	0.2234	0.2530	0.0895	0.0923
PORTL	0.0625	0.1030	0.0554	0.0958	0.0631	0.0459
SFR	0.0882	0.1570	0.1698	0.2454	0.0337	0.0660
SEA	0.0384	0.0894	0.0353	0.0756	0.0325	0.0701
STL	0.0243	0.0315	0.0445	0.0482	0.0007	0.0227
DAL	0.0416	0.1160	0.0570	0.1197	0.0189	0.0298
MIA	0.0743	0.0892	0.0257	0.0297	0.0763	0.0684
DEN	0.1402	0.1330	0.1975	0.1681	0.0426	0.0435
HON	0.1092	0.1643	0.1101	0.1639	0.1410	0.0855
SD	0.1298	0.1652	0.1307	0.1606	0.1017	0.1066
Average	0.0545	0.1047	0.0644	0.1053	0.0360	0.0607

Note: this table reports the standard deviations of the expected local rent growth and the standard deviations of the local risk premiums.

Table 6 What explain local factor shares of price/rent volatility?

	Local Rent Growth	Local Risk Premium	R^2
1979 - 2013	0.4365		0.0310
	(0.5328)		
		1.4240**	0.3319
		(0.4409)	
1979 - 1999S1	1.1312**		0.1811
	(0.6089)		
		1.8717**	0.4676
		(0.4359)	
1999S2 - 2013	1.0530		0.0488
	(1.0145)		
		2.4717**	0.2816
		(0.8614)	

Note: this table reports the regression results of local factor shares on the volatility of local rent growth and the volatility of local risk premium, respectively. Numbers in parentheses are standard errors. An $**$ indicates the regression coefficient is significant at 5% level.

Table 7 Volatility of Local Risk Premiums and Regulation

	WRLURI	Saks-Index	R^2
1979 - 2013	-0.0671		0.0998
	(0.0440)		
		-0.0355	0.0537
		(0.0325)	
1979 - 1999S1	-0.0380		0.0312
	(0.0462)		
		-0.0053	0.0011
		(0.0338)	
1999S2 - 2013	-0.1687^{**}		0.3993
	(0.0452)		
		-0.0787^{**}	0.1675
		(0.0383)	

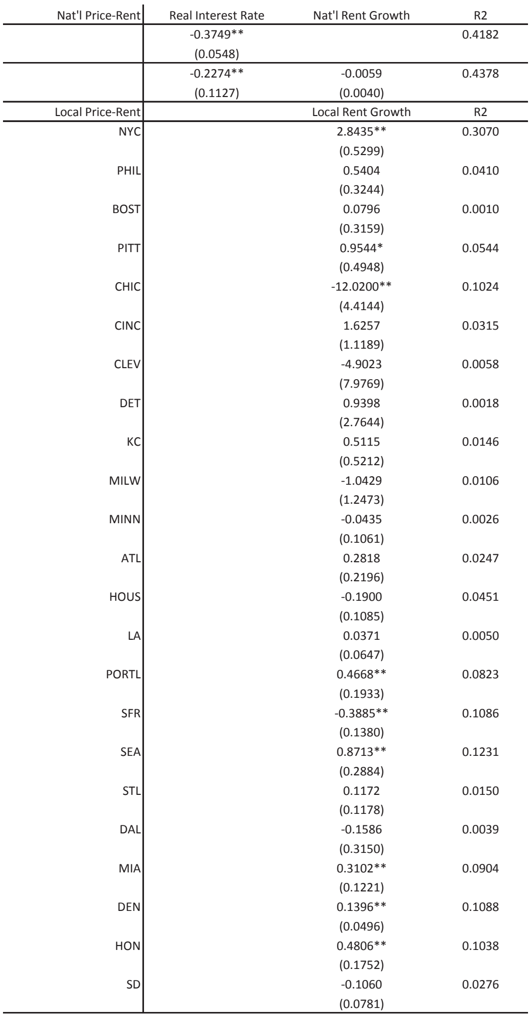
Note: this table reports results from regressing the volatilities of local risk premiums (normalized by local price/rent volatility) on local regulation indexes. Numbers in parentheses are standard errors. An $**$ indicates the regression coefficient is significant at 5% level.

Table 8 Volatility of National Housing Market

1979 - 2013	Nat'l Growth	Interest Rate	Nat'l Risk Premium
Std	0.0787	0.2249	0.1566
Correlation	1.0000		
	0.8760	1.0000	
	-0.2228	-0.4874	1.0000
1979 - 1999S1	Nat'l Growth	Interest Rate	Nat'l Risk Premium
Std	0.0291	0.0897	0.0903
Correlation	1.0000		
	0.6626	1.0000	
	-0.0382	-0.5791	1.0000
1999S2 - 2013	Nat'l Growth	Interest Rate	Nat'l Risk Premium
Std	0.0146	0.0192	0.0968
Correlation	1.0000		
	0.9616	1.0000	
	0.0403	-0.0204	1.0000

Note: this table reports the standard deviations of the expected national rent growth, real interest rate and the aggregate housing market risk premium.

Table 9 Price-Rent Ratio and Economic Fundamentals



Nat'l Price-Rent	Real Interest Rate	Nat'l Rent Growth	R2
	-0.3749**		0.4182
	(0.0548)		
	-0.2274**	-0.0059	0.4378
	(0.1127)	(0.0040)	
Local Price-Rent		Local Rent Growth	R2
NYC		2.8435**	0.3070
		(0.5299)	
PHIL		0.5404	0.0410
		(0.3244)	
BOST		0.0796	0.0010
		(0.3159)	
PITT		0.9544*	0.0544
		(0.4948)	
CHIC		-12.0200**	0.1024
		(4.4144)	
CINC		1.6257	0.0315
		(1.1189)	
CLEV		-4.9023	0.0058
		(7.9769)	
DET		0.9398	0.0018
		(2.7644)	
KC		0.5115	0.0146
		(0.5212)	
MILW		-1.0429	0.0106
		(1.2473)	
MINN		-0.0435	0.0026
		(0.1061)	
ATL		0.2818	0.0247
		(0.2196)	
HOUS		-0.1900	0.0451
		(0.1085)	
LA		0.0371	0.0050
		(0.0647)	
PORTL		0.4668**	0.0823
		(0.1933)	
SFR		-0.3885**	0.1086
		(0.1380)	
SEA		0.8713**	0.1231
		(0.2884)	
STL		0.1172	0.0150
		(0.1178)	
DAL		-0.1586	0.0039
		(0.3150)	
MIA		0.3102**	0.0904
		(0.1221)	
DEN		0.1396**	0.1088
		(0.0496)	
HON		0.4806**	0.1038
		(0.1752)	
SD		-0.1060	0.0276
		(0.0781)	

Note: this table reports the regression results of price-rent ratios on economic fundamentals for the national (the upper panel) and local markets (the lower panel) respectively. The numbers in parentheses are standard errors. $*$ indicates an estimate is significant at either 10% or 5% level.

Table 10 Aggregate Housing Market Risk Premium and Pricing Error

Risk Premium	Yield Spread	Price/Earning	Price/Dividend	House Price/Rent	R2
	0.0567**	0.1289**		-0.4765**	0.4929
	(0.0121)	(0.0348)		(0.1200)	
	0.0722**		0.0960**	-0.4541**	0.4285
	(0.0123)		(0.0427)	(0.1415)	

Pricing Error	1/Rate	1/inflation	Inflation - inflation(-1)		R2
	0.4159**				0.2074
	(0.1009)				
	0.4213**	0.0056			0.2127
	(0.1016)	(0.0085)			
	0.4193**	0.0055	0.0073		0.2192
	(0.1021)	(0.0085)	(0.0101)		

Note: the upper panel of this table contains the results of an OLS regression of the Campbell-Shiller residuals on yield spread, S&P 500 price/dividend and price/earning ratios, national house price/rent ratio. The lower panel reports the results of an OLS regression of the regression residual from the first OLS on inverse interest rate and inflation, changes in inflation. Numbers in parentheses are standard errors. An $**$ indicates the regression coefficient is significant at 5% level.

Table 11 Housing Market Risk Premium and Pricing Error: 1999-2013

Risk Premium	Yield Spread	Price/Deivdend	House Price/Rent	R^2
	0.0008	0.0543^{**}	-0.5732^{**}	0.9251
	(0.0054)	(0.0264)	(0.0373)	
Pricing Error	1/Interest Rate			R^2
	0.0784			0.0885
	(0.0503)			

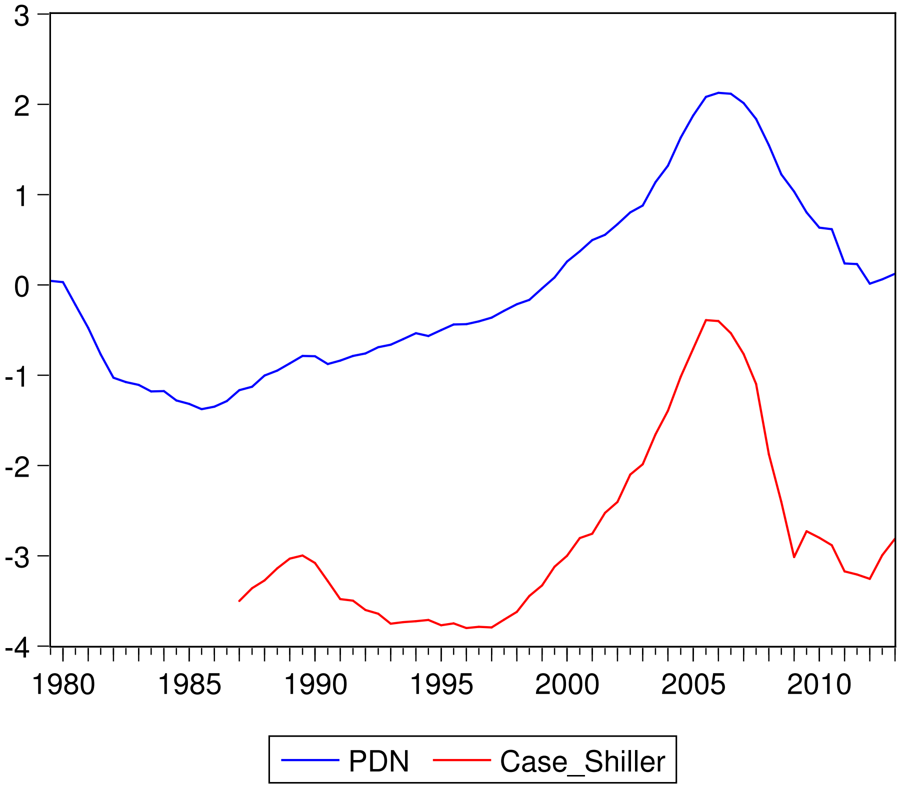
Note: the upper panel of this table contains the results of an OLS regression of the Campbell-Shiller residuals on yield spread, S&P 500 price/dividend and national house price/rent ratio. The lower panel reports the results of an OLS regression of the regression residual from the first OLS on inverse interest rate. Numbers in parentheses are standard errors. An $**$ indicates the regression coefficient is significant at 5% level. The regressions are based on data from 1999 to 2013.

Table 12 Volatility of Local Risk Premiums and Local Inflation

	1979-2013	1979-1999S1	1999S2-2013
Local ΔCPI	0.0970	0.17737*	0.0080
	(0.085)	(0.0995)	(0.0539)
R^2	0.0553	0.1315	0.0010

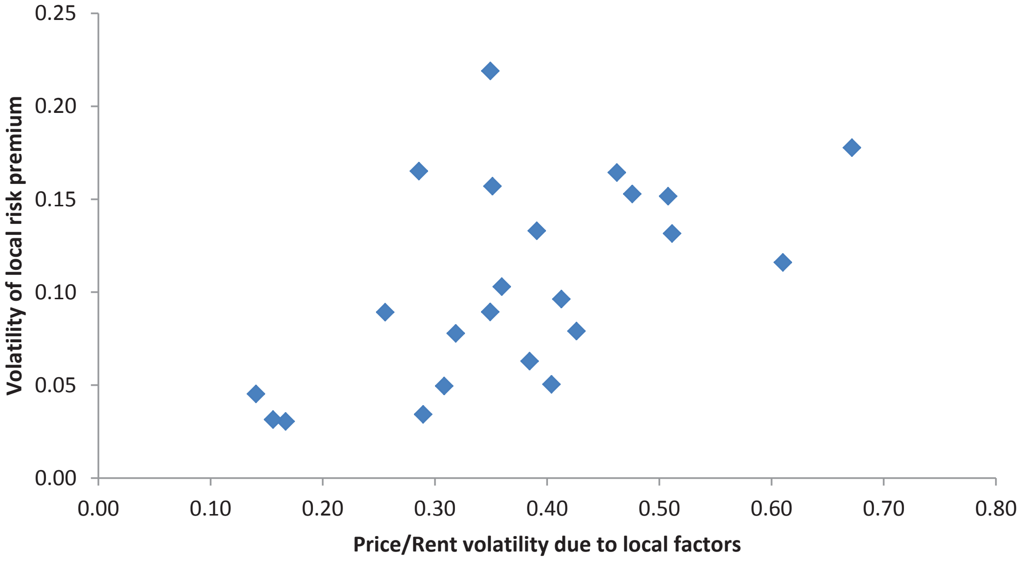
Note: this table reports results from regressing the volatilities of local risk premiums on local CPI inflation (excluding shelter). Numbers in parentheses are standard errors. An $*$ indicates the regression coefficient is significant at 10% level.

Figure 1: National Factor of Price-Rent Ratio and House Price Index



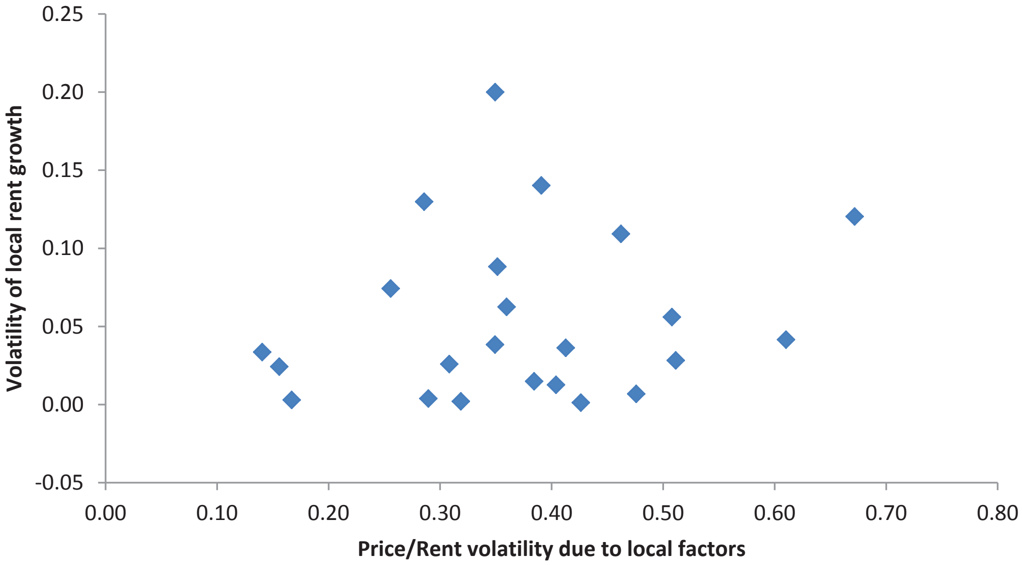
This figure plots the estimated national factor of log price-rent ratio, PDN, 1979-2013, and log Case-Shiller house price index over national rent index, Case-Shiller, 1987 - 2013. Both series are semi-annual.

Figure 2: Local Factor Share vs Local Market Risk Premium Volatility



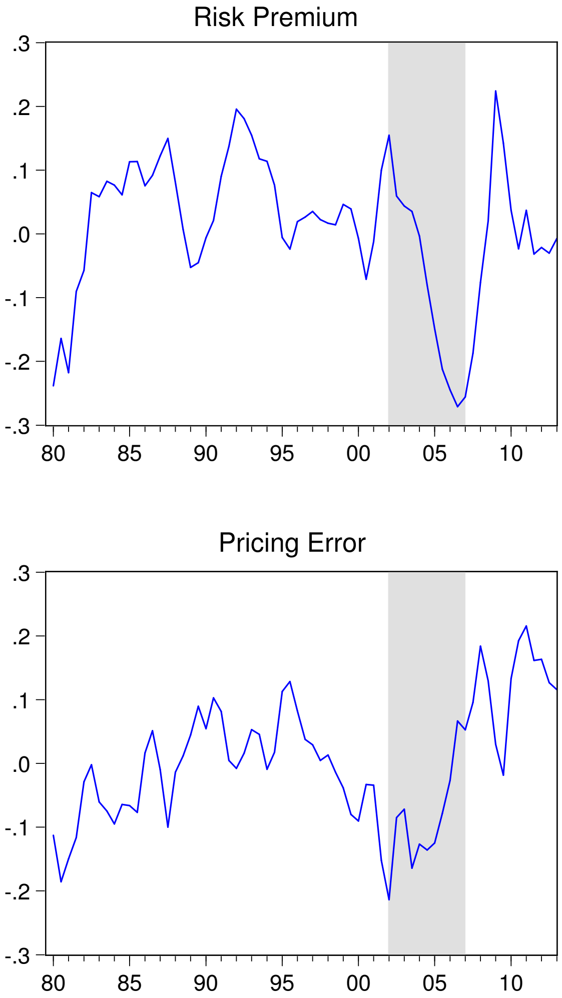
This figure plots the fraction of the total volatility in the house price-rent ratio due to the local factor (the horizontal axis) versus the volatility of local risk premium (the vertical axis) across the 17 housing markets.

Figure 3: Local Factor Share vs Local Growth Volatility



This figure plots the fraction of the total volatility in the house price-rent ratio due to the local factor (the horizontal axis) versus the volatility of local rent growth (the vertical axis) across the 17 housing markets.

Figure 4: Aggregate Housing Market Risk Premium and Pricing Error



This figure plots the estimated aggregate housing market risk premium (upper panel) and the pricing error (lower panel). The shaded area includes the period between 2002 and 2007.