Inflation and Housing Prices
What Fuels Housing Bubbles?*

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first version: April 2005
this version: May 7, 2005

Abstract

This paper shows that a reduction in inflation can fuel run-ups in housing prices. Agents that suffer from money illusion by not properly taking into account that inflation lowers future real mortgage payments, make systematic mistakes in evaluating real estate. After empirically decomposing the price-rent ratio in a rational component and implied mispricing, we find that (i) inflation and the nominal interest rate explain a large share of the time-series variation of the mispricing, (ii) the run-up in the housing prices starting in the late 1990s is reconcilable with the contemporaneous reduction in inflation and nominal interest rates, (iii) the tilt effect cannot rationalize these findings.

Keywords: Housing, Real Estate, Bubbles, Inflation, Inflation Illusion, Money Illusion, Behavioral Finance

JEL classification: G12, R2.

*We benefited from comments from Patrick Bolton, Albina Danilova, Filippos Papakonstantinou, Lasse Pedersen, and Haibin Zhu. We also thank the BIS for providing part of the housing data used in this analysis. Brunnermeier acknowledges financial support from the National Science Foundation and the Alfred P. Sloan Foundation.

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1 Introduction

Starting in the late 1990s, housing prices have experienced sharp run-ups, reaching unprecedented heights. The exponential increase of housing prices has been so striking that academics and non-academics alike have been talking about a housing bubble. Figure 1 illustrates different real house price indexes and shows that this phenomenon has been observed in several OECD countries.

![Figure 1: Residential property (real) price indices for a group of Anglo-Saxon countries (left panel) and for Scandinavian countries and other European countries (right panel). Base period is 1976, first quarter.](image)

All the countries for which we have data show a sharp increase in housing prices with the exception of Switzerland (CH). The figure also shows that previous sharp increases were typically followed by a sharp downturn. Shiller (2005) documents similar patterns for other countries and cities over shorter samples. This suggests the presence of an underlying common factor that causes these large swings in housing prices. Indeed, since these swings lead to large wealth effects, a thorough understanding of the underlying mechanism leading to these run-ups is needed.

Most of these countries have also experienced a decline in the nominal interest rate over the last decade. Since the real interest rate has been relatively stable over the last decade, inflation seems to play an important role that cannot be fully explained by rational reason.
In this paper we identify an empirical proxy for the mispricing in the housing market and show that it is largely explained by movements in inflation. Inflation matters and it matters in a particular way. Our analysis shows that these inflation effects (i) fuel run-ups in housing prices and (ii) arise in a setting in which agents are prone to money illusion.

To derive the mispricing we first have to isolate the rational component of price movements. Changes in economic fundamentals like land and construction costs, housing quality, property taxes, and demographic shifts (Mankiw and Weil (1989)) are all likely to have an impact on housing prices. Nevertheless, the relationship between these variables and housing prices has been highly unstable across subsamples (Poterba (1991)). Moreover, these variables alone are generally not able to capture the sharp run-ups in housing prices, so it has become common in the empirical literature to add cubic ‘frenzy’ terms in the housing price regressions to capture this feature of the data (see Hendry (1984) and Muellbauer and Murphy (1997)). Furthermore, the rational expectations hypothesis for the housing market has been rejected under formal testing (Clayton (1996)).

Changes in fundamentals should, at least in the medium and long run, affect housing prices and rents symmetrically. For this reason we use the price-rent ratio, which has the advantage – compared to the price-income ratio often used in the literature – of being less likely to increase dramatically due to changes in fundamentals. Moreover, households could in principle derive the same service flow by buying or renting a house. Thus, our analysis implicitly controls for both changes in fundamentals and for movements in the underlying service flow.

There are several rational channels through which inflation could in principle influence the price-rent ratio. First, inflation could be disruptive for the economy as a whole (like in the case of cost push shocks), lowering agents’ expectations of future real rent growth rates and therefore reducing today’s price-rent ratio. Second, an increase in inflation could make the economy riskier (or the agents more risk averse), therefore increasing the equilibrium risk-premium required on housing investment. This in turn would have to reduce the price-rent ratio. Third, as outlined in Poterba (1984), an increase in inflation reduces the after-tax user cost of housing, therefore potentially driving up housing demand and the price-rent ratio.

Nevertheless, even after controlling for these rational channels, inflation seems to have a substantial explanatory power for the sharp run-ups and downturns of the housing market. To demonstrate this we construct the mispricing using a generalized Campbell and Shiller (1988) method. Figure 2 depicts the standardized time series of the mispricing of the price-rent ratio in the U.K. housing market and the log gross-net nominal interest rate ratio \( \frac{\log ((1 + i_t) / i_t)}{\log r_t} \). The first thing to notice is that the mispricing shows sharp and persistent run-ups during the sample period. Moreover, the movements in the gross-net nominal interest ratio closely match the momentum of the mispricing, even though, as shown in Section 3.2 below, the real interest rate
does not seem to have any explanatory power for housing prices. The ability of the raw time series of the gross-net nominal interest rate ratio to track the trends in the mispricing is remarkable.

Figure 2: Mispricing and log gross-net nominal interest rate ratio in the U.K.

There are several departures from rationality that offer a potential explanation of the link between inflation and housing prices. First, as argued by Modigliani and Cohn (1979), if agents suffer from money illusion their evaluation of an asset will be inversely related to the overall level of inflation in the economy. Moreover, as shown in Section 3.1 below, the gross-net nominal interest ratio that tracks trends in the mispricing of the housing market surprisingly well in Figure 2, corresponds to the valuation of the price-rent ratio of an agent that suffers from money illusion. This explanation of house price run-ups would also be in line with the finding of McCarthy and Peach (2004) that the sharp run-up in the U.S. housing market since the late 1990s can be largely explained by taking into account the contemporaneous reduction of nominal mortgage costs. Second, in an inflationary environment, the nominal payments on a fixed-payment mortgage are higher by a factor that is roughly proportional to the gross-net nominal interest ratio, causing a large shift of the real financing cost toward the early periods of the mortgage, therefore causing a potential reduction in housing demand and prices – this
is the so called *tilt effect* of inflation (see Lessard and Modigliani (1975) and Tucker (1975)). Nevertheless, why the tilt effect should matter cannot be fully explained in a rational setting since financial instruments that are not affected by this shift in the real cost of financing, like the price level adjusted mortgage (PLAM) or the graduate payment mortgage (GPM), have been available to house buyers at least since the 1970s. Moreover, in Section 3.4 we show that the tilt effect is unlikely to be the driving force of the sharp run-ups in the housing market. Third, if agents are prone to speculation (as in Harrison and Kreps (1978)), a reduction of inflation in the presence of the tilt effect relaxes the borrowing constraints, therefore fueling speculative trade.

The balance of the paper is organized as follows. The next section reviews the most closely related literature on money illusion, borrowing constraint and speculative trading. Section 3 formally analyzes the link between inflation and housing prices using the U.K. housing market as a case study. In particular: Section 3.1 derives a proxy for the valuation of the price-rent ratio of an agent that is affected by money illusion; Section 3.2 provides a first assessment of the empirical link between housing prices and inflation; Section 3.3 provides a new method, based on the difference between the objective and subjective measure of the market, to identify the mispricing in the price-rent ratio, and shows that the estimated mispricing is largely explained by changes in the rate of inflation; Section 3.4 shows that it is unlikely that the tilt effect alone is the driving force of the link between inflation and mispricing on the housing market. In Section 4 we extend our empirical analysis to a cross-country setting and show that the strong link between housing price mispricing and inflation holds across countries. A final section concludes and a full description of the data sources is provided in the appendix.

# 2 Related Literature

## 2.1 Money Illusion

"An economic theorist can, of course, commit no greater crime than to assume money illusion." Tobin (1972)

"In fact, I am persuadable – indeed, pretty much persuaded – that money illusion is a fact of life." Blinder (2000)

In this section we sketch the links to the existing literature. In particular, we review previous definitions of money illusion, relate it to the psychology literature and summarize the empirical evidence on the effect of money illusion on the stock market.

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1 We first focus on the U.K. market since the longer sample period (1966:Q2–2004:Q4), the better quality of the data, and the availability of PLAM mortgage schemes, allow for sharper and more robust inference.
Definition of Money Illusion. Fisher (1928, p. 4) defines money illusion as “the failure to perceive that the dollar, or any other unit of money, expands or shrinks in value.” Patinkin (1965, p. 22) refers to money illusion as any deviation from decision making in purely real terms: “An individual will be said to be suffering from such an illusion if his excess-demand functions for commodities do not depend [...] solely on relative prices and real wealth...” Leontief (1936) is more formal in his definition by arguing that there is no money illusion if demand and supply functions are homogenous of degree zero in all nominal prices.

Related Psychological Biases. Money illusion is also very closely related to other psychological judgement and decision biases. In a perfect world money is a veil and only real prices matter. Individuals face the same situation after doubling all nominal prices and wages. The framing effect states that alternative representations (framing) of the same decision problem can lead to substantially different behavior (Tversky and Kahneman (1981)). Shafrir, Diamond, and Tversky (1997) document that agents’ preferences depend to a large degree on whether the problem is phrased in real terms or nominal terms. This framing effect has implications on (i) time preferences as well as on (ii) risk attitudes. For example, if the problem is phrased in nominal terms, agents prefer the nominally less risky option to the alternative which is in real terms more risky. If on the other hand the problem is stated in real terms, their preference ranking reverses. That is, they avoid nominal risk rather than real risk. The degree to which individuals ignore real terms depends on the relative saliency of the nominal versus real frame.

Anchoring is a special form of framing effect. It refers to a phenomenon that people tend to be unduly influenced by some arbitrary quantities when presented with a decision problem. This is the case even when the quantity is clearly uninformative. For example the nominal purchasing price of a house might serve as an anchor for a reference price even though the agents could have easily derived the real price.

While individuals understand well that inflation increases the prices of goods they buy, they often overlook inflation effects which work through indirect channels, e.g. general equilibrium effects. For example, Shiller (1997a) documents survey evidence that the public does not think that nominal wages and inflation comove over the long-run. Shiller (1997b) provides evidence that less than a third of the respondents in his survey study would have expected their nominal income to be higher if the U.S. had experienced higher inflation over the last five years. The impact of inflation on wages

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2 Most authors use the terms “money illusion” and “inflation illusion” interchangeably. Sometimes the latter is also used to refer to a situation where households ignore changes in inflation.

3 Fisher (1928) provides several interesting examples of inflation illusion due to anchoring. For example on pages 6-7 he writes about a conversation he had with a German shop woman during the German hyperinflation period in the 1920s: “That shirt I sold you will cost me just as much to replace as I am charging you [...] But I have made a profit on that shirt because I bought it for less.”
is more indirect. Inflation increases the nominal profits of the firm, therefore it will increase nominal wages. Similarly, the reduction in mortgage rates due to a decline in expected future inflation expectations is direct, while the fact that it will also lower future nominal income is indirect. This inattention to indirect effects can be related to two well known psychological judgement biases: mental accounting and cognitive dissonance. *Mental accounting* (Thaler (1980)) is a close cousin of narrow framing and refers to the phenomenon that people treat keep track of gains and losses in different mental accounts. By doing so, they overlook the links between them. In our case, they ignore that a higher inflation affects the interest rate of the mortgage and the labor income growth rate in a symmetric way. *Cognitive dissonance* might be another reason why individuals do not see that inflation increases future nominal income. They have a tendency to attribute increases in nominal income to their own achievements than simply to higher inflation.\(^4\)

**Inflation Illusion and the Stock Market.** To the best of our knowledge, we are the first who empirically assess the link between money illusion and house prices. However, there are a list of papers that empirically document the impact of money illusion on stock market prices, often referred to as the “Modigliani-Cohn” hypothesis. Modigliani and Cohn (1979) argue convincingly that prices significantly depart from fundamentals since investors make two inflation-induced judgement errors: (i) they tend to capitalize equity earnings at the nominal rate rather than the real rate and (ii) they fail to realize that firms’ corporate liabilities depreciate in real terms. Hence, stock prices are too low during high inflation periods. Ritter and Warr (2002) document that the value-price ratio is positively correlated with inflation and that this effect is more pronounced for leveraged firms. Moreover, they show that the inflation and the value-price ratios are negatively correlated with future market returns. Using the Campbell and Shiller (1988) dynamic log-linear evaluation method and subjective proxy for the equity risk premium, Campbell and Vuolteenaho (2004) show in the time-series that a large part of the mispricing in the dividend-price ratio can be explained by inflation illusion.\(^5\) Our methodology builds on their approach with the advantage that we do not have to arbitrarily specify a proxy for the risk premium on the housing investment. In contrast, Cohen, Polk, and Vuolteenaho (forthcoming) focus on the cross-sectional implications of money illusion on asset returns and find supportive evidence for the “Modigliani-Cohn” hypothesis.

Basak and Yan (2005) show, within a dynamic asset pricing model, that even though the utility cost of money illusion (and hence the incentive to monitor real values) is

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\(^4\) Shiller (1997a) also noted that “Not a single respondent volunteered anywhere on the questionnaire that he or she benefited from inflation. [...] There was little mention of the fact that inflation redistributes income from creditors to debtors.”

\(^5\) Additional evidence on the time-series link between market returns and inflation can be found in Asness (2000, 2003) and Sharpe (2002).
small, its effect on equilibrium asset prices can be substantial. In the same spirit, Fehr and Tyran (2001) show that (under strategic complementarity) even if only a small fraction of individuals suffer from money illusion, the aggregate effect can be large.

2.2 Borrowing Constraint and Speculation

Tilt effect. Lessard and Modigliani (1975) and Tucker (1975) show that under nominal fixed payment and fixed interest rate mortgages, inflation shifts the real burden of mortgage payments towards the earlier years of the financing contract. This limits the size of the mortgages agents can obtain. This tilt effect could lead to a reduction in housing demand. Kearl (1979) and Follain (1982) find an empirical link between inflation and housing prices and argue that liquidity constraints could rationalize their finding. Wheaton (1985) questions this simple argument in a life-cycle model and shows that several restrictive assumptions are needed for this to be the case.

Speculative Trading and Short-Sale Constraint. Borrowing constraints might also limit the amount of speculation. Harrison and Kreps (1978) show that speculative behavior can arise if agents have different opinions, i.e. non-common priors. Said differently, even if they could share all the available information, they would still disagree about the likelihood of outcomes. Scheinkman and Xiong (2003) put this model in a continuous-time setting and show that transaction costs dampen the speculative component of trading, but only have limited impact on the size of the bubble. Models of this type rely on the presence of short-sale constraints – which is a natural constraint in the housing market – to preempt the ability of rational agents to correct the mispricing. As in the stock market, there are also further reasons that limit arbitrage, like noise-trader risk (DeLong, Shleifer, Summers, and Waldmann (1990)) and synchronization risk (Abreu and Brunnermeier (2003)).

3 Housing Prices and Inflation

In this section we focus on the link between inflation and the price-rent ratio. We show that a simple non-linear function of the nominal interest rate is a proxy for the valuation of the price-rent ratio by an agent prone to money illusion. Empirically, we first document the correlation between nominal values and future price-rent ratios. To gain an understanding of this empirical link, we decompose the price-rent ratio into a rational component and an implied mispricing. We further show that the link between price-rent ratio and inflation is mostly driven by the mispricing component in a way that is consistent with money illusion. Finally, we show that the tilt effect is unlikely to explain our empirical findings. In this section we conduct our empirical analysis focusing on U.K. data because the longer sample period (1966:Q2–2004:Q4) and the
better quality of the data allow us to obtain a sharper and more robust inference. The subsequent section expands the analysis to a cross-country setting, confirming the results of the U.K. data.

3.1 Rent-Price Ratio and Gross-Net Interest Ratio

In principle an agent could either buy or rent a house to receive the same service flow. However, renting and buying a house are not perfect substitutes since households might derive extra utility from owning a house (e.g., ability to customize the interior, pride of ownership). Moreover, properties for rent might on average be different from properties for sale. Nevertheless, long-run movement in the rent level should capture long-run movements in the service flow. Moreover, changes in construction cost, demographic changes, and changes in housing quality should at least in the long-run affect house prices and rent symmetrically. As a consequence, in studying mispricing on the housing market, we focus on the price-rent ratio. Compared to the price-income ratio, the price-rent ratio has the advantage of being less likely to increase dramatically due to changes in fundamentals (e.g., in demography or property taxes). Studying the price-rent ratio is analogous to the commonly used price-dividend ratio to analyze the mispricing in the stock market.

More formally, in a dynamic optimization setting the equilibrium real price an agent is willing to pay for the house, \( P_t \), should be equal to the present discounted value of future real rents, \( \{L_t\} \), and the discounted resale value of the house.

\[
P_t = L_t + E_t \left[ \sum_{s=t+1}^{T-1} m_{t,s} L_s + m_{t,T} P_T \right]
\]

where \( m_{t,s} \) is the stochastic discount factor between \( t \) and \( s > t \), and \( T \) is the time of resale. Note, that \( L_t \) appears on the right hand side, because buying a house in period \( t \) one saves the rent payment in the same period.

Without uncertainty and constant real rent and real risk-free rate, the price-rent ratio becomes for \( T \rightarrow \infty \),

\[
\frac{P_t}{L_t} = \frac{1 + r}{r}, \tag{1}
\]

where \( r \) is the real risk-free rate.

Instead, if the agent suffers from money illusion, she treats the (constant) nominal risk-free rate as real. That is, she thinks that

\[
\frac{P_t}{L_t} = \frac{1 + i}{i} \tag{2}
\]

This derivation of inflation biased evaluation parallels the one in Modigliani and Cohn (1979) for the stock market. Equations (1) and (2) suggest to contrast regressors
(1 + i)/i and (1 + r)/r in addition to inflation \( \pi \). It is also worth emphasizing that the regressor is highly non-linear in \( i \), especially for low \( i \) – a fact we exploit.

Note that the tilt effect leads to the same regressor, since a mortgage with fixed nominal annual payment of 1 dollar forever is currently valued at \((1 + i)/i\). Hence, the maximum size of mortgage a household can afford is determined by \((1 + i)/i\). We devote Section 3.4 to discriminate between money illusion and tilt effect.

### 3.2 Housing Prices and Inflation - A First-Cut\(^6\)

In this section we take a first look at the empirical link between inflation, nominal interest rates and the price-rent ratio. In particular, we explore whether \( i_t, \pi_t, (1 + i_t)/i_t \) and \((1 + r_t)/r_t \) have forecasting power for the price-rent ratio. In assessing the forecasting performance of these variables, one faces several econometric issues. First, Ferson, Sarkissian, and Simin (2002) argue, with a simulation exercise, that if both the expected part of the regressand and the predictive variable are highly persistent, then the in-sample regression results may be spurious, and both \( R^2 \) and statistical significance of the regressor are biased upward (see also Torous, Valkanov, and Yan (2005)). Therefore, since \( P_t/L_t \) is highly persistent, this could lead to spurious results. Second, in exploring the forecastability of the price-rent ratio, the choice of the control variables is problematic and to some extent arbitrary since the literature on housing prices has suggested numerous predictors. Moreover, Poterba (1991) outlines that the relation between house prices and forecasting variables often used in the literature has not been stable across sub-samples.

We address both issues jointly. For the first problem, we remove the persistent component of the price-rent ratio by constructing the forecasting errors

\[
\hat{\eta}_{t+1,t+1-s} = P_{t+1}/L_{t+1} - 1_{\{s>0\}} \hat{E}_{t-s}[P_{t+1}/L_{t+1}]
\]

where \( s \) is the forecasting horizon and \( \hat{E}_{t-s}[P_t/L_t] \) is the (estimated) persistent component of the price-rent ratio. Second, we estimate \( \hat{E}_{t-s}[P_t/L_t] \) by fitting a reduced form vector auto regressive model (VAR) for \( P_t/L_t \), the log gross return on housing, \( r_{h,t} \), the rent growth rate \( \Delta l_t \) and the log real return on the twenty-year Government Bonds, \( r_t \). Following Campbell and Shiller (1988), for small perturbations around the steady state, the variables included in the VAR should capture most of the relevant information for the price-rent ratio. Indeed, the \( R^2 \) of the VAR equation for \( P_t/D_t \) is about 99 percent, which is consistent with previous studies that have outlined the high degree of predictability of housing prices (see, among others, Kearl (1979), Follain (1982) and Muellbauer and Murphy (1997)). This approach for constructing forecast errors, \( \hat{\eta}_{t+1,t+1-s} \), is parsimonious (since it allows us to remove persistency form the

\(^6\)Readers who are familiar with the empirical link between inflation and housing prices can skip this section without loss of continuity.
dependent variable without assuming a structural model) and also conservative since the reduced form VAR is likely to over-fit the price-rent ratio. We use quarterly data over the sample period 1966 third quarter to 2004 fourth quarter.\footnote{The VAR is estimated with one lag since this is the optimal lag length suggested by both the Bayesian and Akaike information criteria}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{\textit{t}-statistics and $R^2$ of univariate regressions of the forecast error $\hat{y}_{t+1,t+1-s}$ on interest rates and gross-net interest rate ratios (both nominal and real) as well as inflation.}
\end{figure}

Figure 3 summarizes the results about the predictability of the price-rent ratio. The figure plots the $t$-statistics\footnote{The $t$-statistics are constructed using Newey and West (1987) corrected standard errors.} (Panel A) and measures of fit (Panel B) of five univariate regressions of $\hat{y}_{t+1,t+1-s}$ on $r_t$, $i_t$, $\pi_t$, $(1+r_t)/r_t$ and $(1+i_t)/i_t$. In Figure 3 we introduce the convention that for $s = 0$, $\hat{y}_{t+1,t+1} = P_{t+1}/L_{t+1}$. That is, the first point in each of the plotted series corresponds to the regression output of a standard forecasting regression for the price-rent ratio.

Focusing first on $s = 0$ – the standard forecasting regression – it is apparent that the real interest rate, $r$, has no forecasting power for the price-rent ratio with a $t$-statistic (Panel A) of 0.741 and a $R^2$ (Panel B) of about 0 percent. This is consistent with the finding of Muellbauer and Murphy (1997) that the real interest rate has no explanatory power for movements in the real price of residential housing. The sign of the slope coefficient of the nominal interest rate, $i$, is negative suggesting that an increase in the nominal interest rate reduces the price-rent ratio. The regressor is statistically significant only at the 10 percent level and explains about 5 percent of the variation in the price-rent ratio. The figure also shows that lagged inflation is a significant predictor of the price-rent ratio and that the estimated slope coefficient has negative sign, which
is consistent with the Modigliani and Cohn (1979) argument that inflation causes a negative mispricing in assets. This is also consistent with the findings of Kearl (1979) and Follain (1982) that housing demand is reduced by greater inflation. The regressor explains about 7 percent of the time variation in \( P_t/L_t \). From the predictive regression of the price-rent ratio on \((1 + r_t)/r_t\) – as suggested by equation (1) – we learn that this variable is not significant nor has any forecasting power for the future price-rent ratio, reinforcing the conjecture that house prices do not tend to respond to changes in the real interest rate. Quite to the contrary, the money illusion proxy, \((1 + i_t)/i_t\), is highly statistically significant and has a positive sign implying that the price-rent ratio tends to comove with the valuation of agents prone to money illusion. Moreover, this regressor is able to explain about 9 percent of the time variation in the price-rent ratio. Consistently with money illusion, inflation \( \pi_t \) shows a significant negative correlation with housing prices.

Focusing on \( s > 0 \), we can assess whether the regressors considered have forecasting power for the unexpected component of price-rent changes. It is clear from Figure 3 that the real interest rate (both in terms of \( r \) and \((1 + r)/r\)) has generally no explanatory power for the unexpected movements in the price-rent ratio. On the contrary, the nominal interest rate, inflation and the illusion proxy, are statistically significant forecasting variables of unexpected movements in the price-rent ratio, and explain a substantial share of the time series variation of this variable.

These results suggest the presence of a strong empirical link between nominal values and the price-rent ratio but do not clarify whether this link is the consequence of a rational behavior or instead due to money illusion. Disentangling the role of money illusion for the price-rent ratio is the focus of the next subsection.

### 3.3 Decomposing the Inflation Effect

Inflation can affect the price-rent ratio for rational reasons. In this subsection we differentiate the rational effects of inflation on the price-rent ratio – through expected future rent growth rates and expected future returns on housing – from the effect of inflation on the mispricing. Note that inflation can influence expected future returns directly or through the taxation effect mentioned earlier.

We follow the Campbell and Shiller (1988) methodology, but also allow agents to have subjective beliefs. Letting \( P \) be the price of housing and \( L \) be the rental payment, the gross return on housing, \( R_h \), is given by the following accounting identity:

\[
R_{h,t+1} = \frac{P_{t+1} + L_{t+1}}{P_t}.
\]

Following Campbell and Shiller (1988), we log-linearize this relation around the steady state but, given our focus on mispricing, we allow traders to have a probability measure for the underlying stochastic process that is different from the objective one. As a
consequence, the steady state depends on the underlying measure of the traders. Under
the assumption that the steady state price-rent ratio is constant under the subjective
measure
\[ r_{h,t+1} = (1 - \hat{p}) \hat{k} + \hat{p} (p_{t+1} - l_{t+1}) - (p_t - l_t) + \Delta l_{t+1}, \]
where \( \hat{p} := 1/(1 + L/P) \), \( r_h := \log R_h \), \( p := \log P \), \( l := \log L \), \( \Delta l_{t+\tau} := l_{t+\tau} - l_{t+\tau-1} \), \( \hat{k} \) is a constant, subjective variables are denoted with a tilde and variables without
time subscript are evaluated at their steady state value under this measure.\(^9\) The log
price-rent ratio can be rewritten (disregarding a constant term) as a linear combination
of expected future rent growth, future returns on housing and a terminal value
\[
p_t - l_t = \lim_{T \to \infty} \left[ \sum_{\tau=1}^{T-1} \hat{\rho}^{\tau-1} (\Delta l_{t+\tau} - r_{h,t+\tau}) + \hat{\rho}^{T} (p_{t+T} - l_{t+T}) \right].
\]
Assume that the steady state price-rent ratio under the objective measure (denoted
without a tilde) is constant, that we can interchange the order of limit and expectation
under this measure, and also that \( E_t \left[ \lim_{T \to \infty} \rho^{T} (p_{t+T} - l_{t+T}) \right] = 0 \). Then, if agents
had the objective measure, we would have \( p_t - l_t = \sum_{\tau=1}^{\infty} \rho^{\tau-1} E_t [\Delta l_{t+\tau} - r_{h,t+\tau}] \). Hence,
the mispricing, \( \varepsilon_t \), given (up to a constant) by
\[
\varepsilon_t := (p_t - l_t) - \sum_{\tau=1}^{\infty} \rho^{\tau-1} E_t [\Delta l_{t+\tau} - r_{h,t+\tau}],
\]
captures the departure of the subjective measure from the objective one. If traders
have the objective measure then \( \varepsilon_t \) is always zero. Otherwise, this need not be the
case. Note that we assume that all traders have the same subjective measure. If
traders have heterogeneous measures and face short-sale constraints (as for example in
Harrison and Kreps (1978)), \( \varepsilon_t \) would also be affected by the speculative component.
The constant \( \rho \) can be inferred from historical data we have observed in the past, since
the realizations of the process we observe are generated by the objective measure.

Our specification can be considered a generalization of the Campbell and Vuolteenaho
(2004) approach. Like they do, we allow agents to have a measure that is different from
the objective one, but we do not restrict both measures to deliver \( \hat{p} = \rho \). Further, we
do not rule out explosive paths under the subjective measure. Third, our approach has
the advantage that we do not have to rely on an exogenously constructed risk factor to
construct subjective expectations. Finally, our measure of mispricing is conservative
since it depends only on the divergence of subjective and objective measures without
having to assume that the mispricing is solely due to wrong expectations about future
returns.

\(^9\)Note that if the subjective measure changes exogenously over time and agents are ex-ante unaware
of this fact, then \( \hat{p} \) could also change over time.
To re-frame the price-rent ratio in terms of risk premia, we rewrite equation (4) in terms of excess returns on housing, \( r_{h,t}^e = r_{h,t} - r_t \), and excess rent growth rates, \( \Delta l_{t+\tau}^e = \Delta l_t - r_t \), where \( r_t \) is the real return on the twenty-year Government bond.

\[
p_t - l_t = \sum_{\tau=1}^{\infty} \rho^{\tau-1} E_t \Delta l_{t+\tau}^e - \sum_{\tau=1}^{\infty} \rho^{\tau-1} E_t r_{h,t+\tau}^e + \varepsilon_t.
\]  

(5)

Following Campbell (1991) we compute the expected components of equation (5) using a VAR. The variables included in the VAR are the log excess return on housing, \( r_{h,t}^e \), the log price-rent ratio, \( p_t - l_t \), the excess rent growth rate, \( \Delta l_t^e \), and the exponentially smoothed moving average of inflation, \( \pi_t \).\(^{10}\) The VAR is estimated using quarterly data and the chosen lag length is one (both the Bayesian and the Akaike information criteria prefer this lag length for the estimated model).

With the estimated VAR at hand we then decompose the observed log price-rent ratio into three components: the implied pricing error, \( \hat{\varepsilon} \), the discounted expected future rent growth, and the discounted expected future returns

\[
p_t - l_t = \sum_{\tau=1}^{\infty} \rho^{\tau-1} \hat{E}_t \Delta l_{t+\tau}^e - \sum_{\tau=1}^{\infty} \rho^{\tau-1} \hat{E}_t r_{h,t+\tau}^e + \hat{\varepsilon}_t.
\]  

(6)

where \( \hat{E}_t \) denotes conditional expectations computed using the estimated VAR. Equation (6) allows us to break the economic link between inflation and the rent-price ratio into its rational part, given by the first two terms on the right hand side, and the mispricing, \( \hat{\varepsilon} \).

This decomposition is fundamental in assessing the role of inflation on housing prices, since the negative correlation between the price-rent ratio and inflation observed in the data could be solely the outcome of a fully rational behavior.

There are several rational channels through which inflation could affect housing prices. First, if inflation damages the real economy, \( \sum_{\tau=1}^{\infty} \rho^{\tau-1} \hat{E}_t \Delta l_{t+\tau}^e \) should be negatively related with inflation. This could be the case of stagflations caused by a cost-push shock. Second, \( \sum_{\tau=1}^{\infty} \rho^{\tau-1} \hat{E}_t r_{h,t+\tau}^e \) could tend to rise if inflation makes the economy riskier (or investors more risk averse), therefore driving up the required excess return on housing investment. If any of these were the case, the negative correlation between price-rent ratio and inflation could simply be the outcome of negative real effects of inflation or of time varying risk premia on the housing investment. Most importantly, if there were no inflation illusion, we would expect \( \hat{\varepsilon} \) to be uncorrelated with inflation, \( \log (1 + i_t) / i_t \), and \( i_t \) (unless reduction in inflation fuels speculative frenzies). Instead, the Modigliani and Cohn (1979) hypothesis of money illusion would predict a negative correlation between the mispricing, \( \hat{\varepsilon} \), and inflation (and the nominal interest rate), and a positive correlation between the mispricing and \( \log (1 + i_t) / i_t \).

\(^{10}\) Note that the measure of inflation we use is the CPI index without housing.
Table 1 reports the regression output of the three components of the log price-rent ratio in equation (6), on the exponentially smoothed moving average of inflation, $\pi_t$, the nominal interest rate, $i_t$, and the log of the Modigliani and Cohn (1979) inflation-biased evaluation, $\log (1 + i_t)/i_t$.

<table>
<thead>
<tr>
<th>Dependent Variables:</th>
<th>$i_t$</th>
<th>$\pi_t$</th>
<th>$\log (1 + i_t)/i_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slope coeff.</td>
<td>$R^2$</td>
<td>Slope coeff.</td>
</tr>
<tr>
<td>$\hat{\varepsilon}_t$</td>
<td>-6.295</td>
<td>.55</td>
<td>-3.904</td>
</tr>
<tr>
<td>$\sum_{\tau=1}^{\infty} \rho^{\tau-1} \hat{E}<em>t \Delta l</em>{t+\tau}^{i}$</td>
<td>-3.962</td>
<td>.09</td>
<td>-2.577</td>
</tr>
<tr>
<td>$\sum_{\tau=1}^{\infty} \rho^{\tau-1} \hat{E}<em>t l</em>{t+\tau}^{e}$</td>
<td>3.581</td>
<td>.04</td>
<td>1.949</td>
</tr>
</tbody>
</table>

Table 1: Univariate Regressions on nominal interest rate, inflation and illusion proxy.


The first row of Table 1 reports the univariate regression output of regressing the pricing errors on the proxies that are meant to capture inflation illusion. All the regressors are highly statistically significant and the estimated sign is the one we would expect under inflation illusion: the mispricing of the price-rent ratio tends to rise as inflation and nominal interest rates decrease and the Modigliani and Cohn (1979) inflation-biased evaluation rises. Moreover, our proxies for inflation bias are able to explain between one half and two thirds of the time series variation of the mispricing of the price-rent ratio.

The second row shows that expected future real rent growth rates seem to be negatively correlated with inflation and nominal interest rate (this last variable is significant only at the 10 percent level), and positively correlated with $\log (1 + i_t)/i_t$. Nevertheless, only a small share (between 9 percent and 12 percent) of the time variation in expected rent growth are explained by the regressors considered. These results are consistent with a view in which inflation influences the rent to price ratio partially due to the fact that an increase in inflation damages the real economy. On the other hand, this could simply be the outcome of housing rents being more sticky than the general price level.

The third row outlines that there is no significant link between inflation and risk premia on the housing investment. The regressors considered are not statistically significant and explain only between 2 percent and 4 percent of the time series variation in expected future returns on housing. Moreover, the estimated signs of the regressors imply that inflation is associated with a lower risk premium on housing investment, i.e. in times of high inflation the housing investment is considered to be less risky than investing in long-horizon Government bonds. Since we use a before-tax measure of
returns on housing, this result could also be due to the fact that an increase in inflation increases the after-tax return on housing (see Poterba (1984)), therefore requiring a lower before-tax risk premium.

The sum of the slope coefficients associated with each of the regressors in Table 1 is an estimate of the elasticity of the price-rent ratio with respect to that regressor. Our results therefore imply that, on average, a one percent increase in inflation (nominal interest rate) maps into a 4.5 (6.7) percent decrease in the price of housing relative to rent, and that the largest contribution to this negative elasticity is given by the effect of inflation (nominal interest rate) on the mispricing.

The results in Table 1 suggest that inflation illusion can explain a large share of the mispricing in the housing market and that the negative correlation between inflation and the rent-price ratio is mainly due to the effect of inflation illusion on the mispricing.

Figure 2 in the introduction plots the standardized series of estimated pricing errors $\hat{\epsilon}$ and illusion proxy $\log((1 + i_t) / i_t)$. It is apparent that movements in the gross-net nominal interest ratio closely tracks the changes in the pricing errors $\hat{\epsilon}$. Even though in the mid-eighties we do a poor job in capturing the level of mispricing, the overall apparent link between both series is remarkable.

To assess the robustness of these results, we next consider the uncertainty due to the fact that we do not directly observe expected future returns on housing and rent growth rates, but instead we use the estimated VAR to construct their proxies.

<table>
<thead>
<tr>
<th>Dependent Variables:</th>
<th>Regressors:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i_t$</td>
<td>$\pi_t$</td>
</tr>
<tr>
<td>$-6.28$</td>
<td>$-3.9$</td>
</tr>
<tr>
<td>$[-17.4,-0.68]$</td>
<td>$[-11.1,-1.85]$</td>
</tr>
<tr>
<td>$0.54$</td>
<td>$0.64$</td>
</tr>
<tr>
<td>$[0.05,0.75]$</td>
<td>$[0.019,0.356]$</td>
</tr>
</tbody>
</table>

Table 2: Median and 95 percent confidence intervals for slope coefficients and $R^2$.

Table 2 reports the results of a Monte Carlo exercise (described in Section A.2 of the Appendix) that formally addresses this issue. Each row of the table reports the median slope coefficient associated with the regressor, the median $R^2$ and (in squared brackets) their 95 percent confidence intervals. The first row of Table 2 shows that the relation between inflation illusion and the mispricing of the rent-price ratio is a robust one: inflation and nominal interest rate show a significantly negative correlation with the mispricing while the inflation-biased valuation shows a significantly positive correlation. Moreover, even tough the distribution of the estimated $R^2$ has a heavy left tail, there
seems to be a very high posterior probability that these variables explain a large share of the time series variation in the mispricing. The second and third row of Table 2 show instead that there is substantial uncertainty about the correlation between inflation, nominal interest rate and expected future returns on housing and expected future rent growth rates. Overall, these results confirm an empirically strong link between nominal values and the mispricing of the housing market, and suggest that this mechanism is the main source of the negative correlation between the price-rent ratio and inflation and the nominal interest rate.

3.4 Tilt effect

Our empirical results are consistent with money illusion. Nevertheless, we could also be capturing the tilt effect of inflation. Recall from Section 3.1 that the gross-net nominal interest ratio \((1 + i_t)/i_t\) is proportional to the amount agents can borrow under a fixed nominal payment mortgage. However, agents could use multiple alternative financing schemes available on the market, that are not affected by the tilt effect, like price level adjusted mortgage (PLAM) or the graduate payment mortgage (GPM). This is especially true in the United Kingdom, where PLAM and GPM were available at least since the early 1970’s. Furthermore, over the years, new more flexible mortgage products were introduced in all major countries. Hence, we would expect that the importance of the tilt effect – if it ever was there – declines over time. That is, the negative elasticity of the mispricing to inflation should become less negative over the sample period. We empirically assess this hypothesis. Figure 4 depicts point estimates and Newey and West (1987) 95 percent confidence intervals of the univariate regressions of the estimated mispricing on \(\pi_t\), \(i_t\), and \((1 + i_t)/i_t\) over a time-varying sample. We use the first ten years of data to obtain an initial estimate of the slope coefficient associated with each regressor, and we then add one data point at a time and update our estimates. That is, the point corresponding for example to 1992 first quarter is the estimated slope coefficient over the sample 1966 second quarter to 1992 first quarter. Figure 4 clearly reveals that the trend goes in the opposite direction. Over time the negative relation between mispricing and inflation (nominal interest rate) becomes even more negative. In addition, the relationship between mispricing and gross-net nominal interest ratio is clearly not decreasing over time. All three findings show that it is unlikely that the tilt effect is the driving force of the empirical link between housing mispricing and inflation.
4 US Evidence

In this section we examine the link between housing market mispricing and nominal values in the United States. Following the same procedure as in Section 3.3 we decompose the movements in the price-rent ratio into changes in expected future rent growth rates, $\sum_{\tau=1}^{\infty} \rho^{\tau-1} \tilde{E}_{t} \Delta l_{t+\tau}^{e}$, expected future excess returns, $-\sum_{\tau=1}^{\infty} \rho^{\tau-1} \tilde{E}_{t} r_{h,t+\tau}^{e}$, and implied mispricing, $\tilde{\varepsilon}_{t}$. We then regress these three components on the three proxies meant to capture the effect of inflation on the price-rent ratio. The sample period available runs form 1970 first quarter to 2004 third quarter. Univariate regression results are reported in Table 3. The first row shows that the proxies considered are all significant explanators of the mispricing. Moreover, the sign of the estimated elasticity is the one we would expect under inflation illusion: the mispricing of the price-rent ratio tends to rise as inflation and nominal interest rates decrease and the gross-net nominal interest ratio rises. The measures of fit are somehow smaller compared to the U.K. case, but this is likely to be due to the shorter sample period and poorer quality of U.S. data. For a review of the measurement problems in U.S. data on housing see McCarthy and Peach (2004). Nevertheless, the $R^{2}$ ranges form 15 percent when the explanatory variable is the nominal interest rate to 48 percent when we use inflation as the explanatory variable of the mispricing.

\footnote{We are currently in the process of extending the analysis to more OECD countries. We have already obtained housing price time series for the countries mentioned in Figure 1, and we are currently in the process of constructing time series of housing investment returns.}

<table>
<thead>
<tr>
<th>Dependent Variables:</th>
<th>Regressors:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$i_t$</td>
</tr>
<tr>
<td>$\hat{\pi}_t$</td>
<td>Slope coeff.</td>
</tr>
<tr>
<td></td>
<td>$R^2$</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sum_{\tau=1}^{\infty} \rho^{\tau-1} \hat{E}<em>t \Delta \pi^e</em>{t+\tau}$</td>
<td>Slope coeff.</td>
</tr>
<tr>
<td></td>
<td>$R^2$</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>$-\sum_{\tau=1}^{\infty} \rho^{\tau-1} \hat{E}<em>t \pi^e_t h</em>{t+\tau}$</td>
<td>Slope coeff.</td>
</tr>
<tr>
<td></td>
<td>$R^2$</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The second row shows that, as in the U.K., there is a significantly negative (positive) correlation between inflation and nominal interest rate (gross-net nominal interest ratio) and expected future rent excess growth rates. This could either be a consequence of a negative effect of inflation on the real economy or due to a higher degree of stickiness in housing rents than in the general price level. The regressors considered are able to explain between 56 percent and 62 percent of the time series variation in expected future growth rates. The last row shows that there is a statistically significant link between inflation and nominal interest rate and future risk premia on housing investment (but not between the gross-net nominal interest ratio and risk premia), which is consistent with the fact that, under distortionary taxes, an increase in inflation reduces the user cost of housing. These results imply a negative elasticity of the price-rent ratio to inflation (nominal interest rates) of about 8.6 (3.9) and that the largest contribution to this comes from the effect of inflation (nominal interest rate) on the mispricing.

Table 4 reports the results of a Monte Carlo exercise (described in Section A.2 of the Appendix) analogous to the one presented in Section 3.3 and which, as in the case of U.K. data, confirms the soundness of the empirical link between mispricing in the housing market and inflation, nominal interest rate and the gross-net nominal interest rate ratio. On the other hand, it shows that there is substantial uncertainty about the rational link between inflation (nominal interest rate) and the price-rent ratio, even though both variables show a significantly negative correlation with the risk premium on the housing investment.
5 Conclusion

This paper studies the close link between inflation and housing prices. It provides supportive evidence that agents are prone to money illusion since movements in the mispricing in the housing market are largely explained by changes in inflation, the nominal interest rate and a variable meant to capture money illusion. We also show that the tilt effect cannot explain our findings. These results hold for both the U.K. and the U.S. housing markets and help us understand the run-ups starting in the 1990’s.

References


A Appendix

A.1 Data Description

A.1.1 U.K. Data

The house price series is from the Nationwide Building Society, and covers the sample period 1966:Q2–2005:Q1. Over the subsample 1966:Q2–2005:Q5 the index is constructed as a weighted average using floor area, therefore allowing to control for the influence of house size. Over the periods 1974:Q1–1982:Q4, and 1983:Q1–1992:Q1 additional controls (for region, property type, etc.) have been added in the construction of the index. Since 1993 the index also takes into account changes in the neighborhood classification. The rent series is constructed combining several sources available through the Office of National Statistics. Over the period 1966:01–1987:01 we use the CTMK LA:HRA series of rents on dwellings paid by tenants in the UK and we combine it with the data on the stock of housing available through the Office of the Deputy Prime Minister. Over the period 1987:02–1987:12 we use the RPI-SGPE rent series of monthly percent changes over one month. Over the period 1988:01–2005:02 we use the CZCQ - RPI series of percent changes in rent over one year. The rent-free tenancies are...
excluded from the calculation of average rents. To obtain a series in levels for the price-
rent ratio we scale the index series to match the level of the average price-rent ratio in
1990. As interest rate we use the 20-year par yield on British Government Securities
available over the sample 1963:Q4–2004:Q4. All the results presented in the paper are
based on the longest possible sample given the data at hand (1966:Q2–2004:Q4).

A.1.2 U.S. Data

To construct the house price index series we use (i) the weighted repeat-sale housing
price index form the Office of Federal Housing Enterprise Oversight over the sub-sample
1976:01–2004:03 and the (ii) Census Bureau housing price index (obtained through the
Bank of International Settlements) over the period 1970:01–1975:04. To construct the
rent index we use the CPI-Rent from the Bureau of Labor Statistics. We re-scale the
indexes to levels to match the historical average of the U.S. price-rent ratio over the
same sample (as reported in Ayuso and Restoy (2003)). As long-run interest rate we
use the return on the 10-year Treasury bill. As measure of inflation we use the CPI
index without housing.

A.2 Assessing Uncertainty

To assess uncertainty in the regression results in Table 2, we report 95 percent con-
dence intervals for the estimated slope coefficients and $R^2$ constructed via Monte Carlo
integration by drawing form the posterior distribution of the estimated VAR coefficients.

Under a diffuse prior, the posterior distribution of the estimated VAR can be fac-
torized as the product of an inverse Wishart and, conditional on the covariance matrix,
a multivariate normal distribution

$$ \beta | \Sigma \sim N \left( \hat{\beta}, \Sigma \otimes (X'X)^{-1} \right) $$

$$ \Sigma^{-1} \sim \text{Wishart} \left( \left( n\hat{\Sigma} \right)^{-1}, n - m \right) $$

where $\beta$ is the vector of coefficients in the VAR system, $\Sigma$ is the covariance matrix
of the residuals, the variables with a hat are corresponding estimates, $X$ is the matrix
regressors, $n$ is the sample size and $m$ is the number of estimated parameters.

We therefore proceed as follows:

1. We draw covariance matrices $\tilde{\Sigma}$ from the inverse Wishart with parameters $\hat{\Sigma}, n$
   and $m$.

2. Conditional on $\tilde{\Sigma}$ we draw a vector of coefficients for the VAR from
   $\tilde{\beta} \sim N \left( \tilde{\beta}, \tilde{\Sigma} \otimes (X'X)^{-1} \right)$. 

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3. Using the draws for \( \hat{\beta} \) we construct expected discounted sums of rent growth \( \left( \sum_{\tau=1}^{\infty} \rho^{\tau-1} \hat{E}_t \Delta l_{t+\tau}^e \right) \) and returns to housing \( \left( \sum_{\tau=1}^{\infty} \rho^{\tau-1} \hat{E}_t r_{h,t+\tau}^e \right) \), and we compute pricing errors \( (\tilde{\varepsilon}) \) as

\[
\tilde{\varepsilon}_t = p_t - l_t - \sum_{\tau=1}^{\infty} \rho^{\tau-1} \hat{E}_t \Delta l_{t+\tau}^e + \sum_{\tau=1}^{\infty} \rho^{\tau-1} \hat{E}_t r_{h,t+\tau}^e
\]

We then regress \( \tilde{\varepsilon}_t, \sum_{\tau=1}^{\infty} \rho^{\tau-1} \hat{E}_t \Delta l_{t+\tau}^e \) and \( \sum_{\tau=1}^{\infty} \rho^{\tau-1} \hat{E}_t r_{h,t+\tau}^e \) on \( \pi_t, i_t \) and the log of the inflation-biased evaluation \( (1 + i_t) / i_t \), and we store the estimated slope coefficients and measures of fit.

4. We compute confidence intervals for the OLS slope coefficients associated with \( \pi_t, i_t \) and the log of \( (1 + i_t) / i_t \), and for the corresponding measures of fit, from the corresponding percentiles of the Monte Carlo iterations.