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by

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Abstract

MOMENTUM AND HOUSE PRICE GROWTH IN THE U.S:

ANATOMY OF A "BUBBLE"

This paper analyzes the bubble in property values in the U.S. in the period from 1999 through 2005. We define a bubble as a regime shift characterized by a change in the properties of house price deviations from underlying "fundamentals" that become more self-sustaining and/or more volatile than in other periods. We model the fundamentals of house price growth as lagged adjustments of prices to the expected present value of future service flows (imputed rent) from owner-occupied properties. We then study the autoregressive behavior of the errors generated from the estimated fundamentals equations with panel data from 44 Metropolitan Statistical Areas for the period of 1980-2005. We find evidence of momentum in house price growth throughout the period, but momentum increased after 1999. Breaking down the period further, we find that the bubble happened mostly after 2003; it was for a relatively short period and was characterized by a series of positive, seemingly random, shocks. Before that, price changes were reasonably well explained by the "fundamentals," such as a decline in long term real rates in the early part of the 1999-2005 period.

I. Introduction

The property market in the United States over the last decade has been widely perceived as having had a bubble. Figure 1 depicts the national rates of growth of house prices, ten-year Treasuries, an index of imputed homeowner rents, and the Consumer Price Index. The Figure shows acceleration in house prices after 1999 that is not consistent with the other data. We analyze post 1999 behavior of house price growth in the U.S. in order to characterize the change in price growth. We stop after 2005 when the price surge stopped. In particular, we look at the extent to which we can characterize the period as having a "bubble" relative to the "fundamentals" of price growth. We define a bubble as a regime shift that is characterized by a change in the properties of deviations of actual house price growth from its fundamentals. The fundamentals come from an estimated equation specifying house price growth as a function of lagged responses to the present value of expected future service flows (imputed rent). In a bubble, a shock to the growth rates is more self-sustaining (increased momentum) and/or more volatile than in other periods.

Various methods have been used to test for bubbles in financial markets. Early work relied on econometric methods such as variance-bound tests. Since then, tests for stationarity and cointegration as tests for absence of speculative bubbles have been proposed (see, for example, Diba and Grossman (1988) and Hamilton and Whiteman (1985)). Evans (1991), however, shows that these methods tend to reject the presence of the bubbles too often even if they are artificially induced in the Monte Carlo simulations. The literature on testing bubbles then moved on to the introduction of more effective regime switching models first presented by Blanchard and Watson (1982). These models look at bubbles as changes in regime, and then analyze properties of price processes in and out of the bubble regimes.[1] Our model is a variant of these regime shift models.

Apart from Roche (2001), who studied the Dublin market from 1976 to 1999, regime-switching models have not been widely applied in explaining house price bubbles. The structure of our model is similar to papers on housing bubbles by Black *et al.* (2006), Chan *et al.* (2001), Hwang *et al*. (2006) and Taipalus (2006). Wheaton and Nechayef (2007) address the same problem by looking at the extent to which price growth in the bubble period can be explained by a model of the fundamentals estimated from a previous period. Their approach is similar to a regime shift model. Coleman *et al* (2008) analyze a similar question from the standpoint of the role of the subprime market in the surge in house prices after 2003. Van Order and Dougherty (1991) test a rent-price model similar to the one developed in this paper. An alternative line of research looks at bubbles as coming from "overshooting" of estimated difference equations for house price (e.g., Capozza *et al* (2004))

Our principal result is that while we find evidence of momentum in the deviations from house price growth fundamentals throughout the period, momentum increased after 1999. We do not find much evidence of explosive momentum, although momentum after 1999 was close to explosive in some cities. We do not find evidence of an increase in volatility in the disturbances of the error process. We also find that momentum operates with a long lag. Breaking down the period further, we find that 2003 was a watershed year. The bubble happened mostly after 2003; that is, it was for a relatively short period and a period that was associated with big changes in markets, such as the rise of the subprime market and subprime securtization and a sharp decline in short term interest rates. Before that price changes were

[1] In a recent study, Baddeley (2005) incorporates destabilizing effects from bubbles, herding, and frenzies in the study of regime shifts conditional on institutional and political changes. She argues that in a less informed market such as real estate, thence where herding can be serious, and where financing and uncertainty are crucial factors in determining the time to invest, market booms and busts tend to be more pronounced.

by and large "explained" by the fundamentals, for instance the decline in long term real rates in the early part of the 1999-2005 period.

The next section provides a discussion on bubbles and regime switching models that have been widely applied in financial markets. Section III presents our model of house price growth. In particular, we develop the fundamental equation from which bubbles in the market are tested. Section IV describes the data employed, while Section V presents the results. Section VI discusses the robustness of our tests, and Section VII analyses the momentum phenomenon further. Section VIII concludes the study.

II. Bubbles and Regime Switching

There has been considerable research on modeling the price movements of stock markets in order to model deviations from the fundamental values.[2] Two versions of these models are the fads model proposed by Summers (1986) and the stochastic bubbles model suggested by Blanchard and Watson (1982). The latter type was subsequently extended by Van Norden and Schaller (1993, 1996), and Van Norden, (1996), who use switching regressions to describe the time-varying relationship between returns and deviations from the fundamentals.

The Fads model

Borrowing from Fama and French (1988) and Cutler, Poterba and Summers (1991), the logarithm of the market price of an asset is divided into (1) a non-stationary part that describes the fundamental price and (2) a stationary component that implies the returns are predictable (from previous returns). Both components are autoregressive and subject to

[2] Other proposed sources of bubbles are, for example, overconfidence of speculators coming from two different groups such that the deviations in price expectations create trading (Scheinkman and Xiong (2003)), and money illusion as a result of reduction in inflation, and hence nominal mortgage costs (Brunnermeier and Julliard (2006)).

different white noises with their own distributions. Given a proxy for the fundamental price subject to measurement error, all these imply

(1) $p_{t+1} - p_t = \beta_0 + \beta_1 \left(p_t - p^x{}_t \right) + e_t$

where p_t is the log of the market price at time *t*, p^x_t is the available proxy of the fundamental price, and $e_t \sim iid\left(0, \sigma_\omega{}^2\right)$.

This regression equation gives the excess returns as a function of differences between the log of the proxy for the fundamental and the log of the observed price. In finance models a commonly used proxy is the dividend, while the explanatory variable in the equation is the lagged log dividend/price ratio. Hence, price growth is a function of current price and lagged fundamentals. Because the current price (via equation (1)) depends on the dividend/price ratio lagged again, iterating equation (1) implies that price appreciation depends on a long lagged function of the proxy for fundamentals.

However, in this model, the assumptions that the fundamentals follow a random walk and that the fads part is stationary are not likely to hold. This is because of obvious inefficiencies in real estate markets: (1) transaction costs in real estate are high, (2) owner-occupiers are only in the market occasionally, and (3) the tax benefits accrued to homeowners reduce their costs but not costs for speculators, thus making arbitrage difficult. Hence, some modification is required in order to apply the model.

The Regime Switching Model

When the regression error term, e_t, is heteroscedastic, the fads model can lead to regime-switching for stochastic bubbles (they are stochastic because they either survive or collapse, subject to some probabilities). The existence of two possible outcomes of the bubbles means that there are two regimes generating market returns. We extend the regime-switching model by relaxing the assumption that the error term in the autoregressive fundamental price process is white noise. We assume that e_t follows an autoregressive process. A regime shift is characterized by an increase in the volatility of the disturbance in the autoregressive process for e_t and an increase in "momentum," which is measured as increase in the sum of the coefficients of the lagged e_t in the process.

III. Modeling the Fundamentals of House Price Growth

Given an information set, Ω_t, the fundamental value of a property is assumed to be given by (in principle, this should be net rent and net of costs, similar to net operating income):

$$(2) \qquad P_t = \sum_{i=0}^{\infty} E(R_{t+i} / D_{t+i}^{i} | \Omega_t) + \lim E(P_{t+1+i} / D_{t+1+i}^{i} | \Omega_t)$$

where *R* is the rental income, in this case imputed services of the property, and *D* is the risk-adjusted discount factor. In addition, the transversality condition that the second term approach zero gives

$$(3) \qquad P_t = \sum_{i=0}^{\infty} E\left(R_{t+i} / D_{t+i}^{i} | \Omega_t\right).$$

For this to be applicable to owner-occupied housing, imputed rent must be measurable by some form of market rent. We take this to be the actual market rent of comparable properties, which holds if the equation is applied to an owner who is just indifferent between owning and renting. In that case, the first order conditions for owners and renters will be the same; and the present value formulation that applies to landlords' valuation will apply to owner-occupiers' valuation. The advantage of this approach is that it saves having to develop a complicated model of housing demand and supply, which is not likely to be stable. For instance, Glaeser *et al* (2005) emphasize the role of inelastic supply in house price growth, especially due to local policy variation; our rent variable captures this effect without having to estimate, directly or indirectly, supply elasticities across cities and time.

Estimated Equations

Equation (3) is potentially quite complicated because of the covariance among the variables such as those coming from stock-flow adjustments of rents and prices over time. For instance, we should expect interest rates and future rents to be correlated because a rise in interest rates will, given rents, lower property values. On the other hand, it induces less production in the future, and thus higher rents. Indeed, if supply is perfectly elastic in the long run, a rise in interest rates will eventually produce a decline in rents without long run price change.

We consider first a simple model with constant interest rates and a steady growth rate of expected rents. We can adopt the Gordon model for stock prices to property value as

(4) $$P_t = R_t / (\alpha_i i_t - \alpha_\pi \pi_t * + \alpha)$$

where $(\alpha_i i_t - \alpha_\pi \pi_t * + \alpha)$ is the "cap rate" for housing, *i*, the interest rate, and $\pi *$ is the expected rates of growth of rent. The coefficients α_i and α_π do not necessarily equal one, as they are in the standard Gordon model, because of tax and other effects (such as cash flow effects from high nominal rates and lack of price indexed mortgages).

Taking first differences and logarithms of equation (4), we have

(5) $$GP_t = \pi_t - \Delta \ln(\alpha_i i_t - \alpha_\pi \pi_t *)$$

where GP_t is the growth rate of house prices and π_t is the current growth rate of rents, all at time *t*. Equation (5) can be approximated by

(6) $$\rho_t = GP_t - \pi_t = \alpha - \beta_i \Delta i_t + \beta_\pi \Delta \pi_t *$$

where ρ_t is the rate of growth of house prices minus the rate of growth of rent. The βs should be positive. This can be estimated by assuming that $\Delta\pi *$ is a function of past levels of $\Delta\pi$.

Preliminary estimates of equation (6) do not work well; longer lags in the adjustment process are necessary for the model to fit well and/or make sense. We therefore consider adjustment of the form:

$$(7) \qquad \rho_t = \alpha - \sum_{j=1}^{T} (\gamma_{t-j}^{i} \Delta i_{t-j} + \gamma_{t-j}^{\pi} \Delta \pi_{t-j}).$$

Equation (7) imposes the constraint that an increase in growth rate of rent of 1% will increase house price growth by 1% in the long run. The presence of α allows rents and prices to have different trends, for instance, because of measurement errors.

Estimates of equation (7) generate residuals, e_t, which are assumed to follow the autoregressive process

$$(8) \qquad e_t = \sum_{j=1}^{T} \omega_{t-j} e_{t-j} + \upsilon_t$$

where υ_t is *iid.* The sum of coefficients of lagged error terms must be greater than one for an explosive bubble. Our tests are thus on (1) the amount of, and changes in, momentum as measured by $\sum_t^T \omega_{t-j}$, and (2) changes in the variance of υ_t, during the post 1999 period.

IV. Data and Estimation

Our measure of house price is the quarterly house price index released by the Office of Federal Housing Enterprise Oversight (OFHEO),[3] which provides a repeat sales house price index for over 100 individual Metropolitan Statistical Areas (MSAs) since 1980. The rent series is the "owner's equivalent rent of primary residence" obtained from the Bureau of Labor Statistics, from which we also acquire the local Consumer Price Indices. After matching these three series, data for 44 MSAs can be used. We use the 10-year Treasury as a measure of nominal risk-free rate.[4]

[3] OFHEO has recently been restructured as the Federal Housing Finance Administration (FHFA).
[4] We have tried to proxy the real interest rate by the ten-year Treasury Inflation-Protected Securities (TIPS). However, since the earliest available TIPs begin listing in 1997, we are not able to obtain a reliable real interest

We have three main data concerns:

First, the repeat sales methodology price index may not hold quality constant. The OFHEO index looks at the same house twice without adjusting for home improvement between observations, and hence may overestimate growth in house prices. This may be offset by similar errors in the rent index.

Second, measured rent may grow too slowly because of the agency cost of renting and measurement errors in the rental index. That is, even if we have matched prices and rents for owners indifferent between owning and renting, there is always reason to believe that renters take less good care of property than owners do. Both Crone *et al* (2006) and Gordon and van Goethem (2004) discuss the extent to which the CPI rental index has underestimated rent growth over time (especially before 1985). If any of the above is the case, then there will be a tendency for our measure of P to grow faster than our measure of R (that is, for α in equation (6) to be positive), which is indeed what we find.

Third, the price and rent series do not necessarily match up in the sense of the price series representing price growth for a household that is indifferent between owning and renting, which is probably a household in a relatively low tax bracket. We note here that the OFHEO index only covers prices of houses whose mortgages are eligible for purchase by Fannie Mae or Freddie Mac. This imposes a limit, which is indexed to house prices over time, and thereby excludes approximately the top 10% of the market (by number of loans). Hence, the price data does at least exclude those owners who for tax reasons are the furthest from being

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rate series. We do not use mortgage rates because, among other things, they include premia for prepayment risk. There is a risk premium attached to i, which we assume is a part of D, the discount factor.

indifferent between owning and renting. We have not chosen to use the widely used Case-Shiller Indexes because of the wider coverage of the OFHEO Indexes.

With these data, we first estimate variants of the fundamentals of price growth from the specifications of ρ in equation (7) over the entire period, varying the models by changing lag lengths. From each fundamental equation, residuals are generated and modeled as given by equation (8), for various lag lengths. For each residual equation of particular lag length, four versions are estimated by dividing the MSA sample into two groups: fast growing (bubble candidate) MSAs (those that grew on average at a 2% per year faster rate than rents grew), and the rest (non bubble MSAs), and dividing both bubble and non bubble samples into pre and post 1999. The bubble MSAs are denoted by asterisks in Appendix 1. A regime change is characterized by a change in the error process. We test for changes in the sum of the coefficients in estimates of equation (8) and changes in the variance of the residuals in the error regression in (8).

V. Results

Estimates of the Fundamentals

Table 1 summarizes the estimates of our fundamental equation (7), using the entire panel of data across MSAs for the entire sample period and with exogenous variables lagged 12, 16, 20, and 24 quarters. The variables mostly have the expected signs. The signs within groups are also consistent, generally negative for interest rate and positive for past rent growth. The model implies a significant lag in the effect of an interest rate change on house prices. Table 2 presents a summary of the results of the coefficients for various lag lengths of the fundamentals. Longer lag specifications fit better, and their coefficients make more economic sense.[5] The nonbubble MSAs tend to have smaller constant terms, averaging close to zero vs. around 1.5% per year in the bubble MSAs.

The coefficients suggest overshooting. For instance, looking at the longer lags, rent increases are initially associated with price acceleration, as expected; but the sign turns negative after around four years. This implies that an interest rate shock is associated with positive effects on price growth which turn negative in a year or so. Note that there is a sharp turn to positive coefficients after five years in the longest lagged equation, leading to small but positive long run effect (see Table 2). Hence, the model suggests the possibility of a small long run effect of interest rate changes, perhaps because of a long run supply adjustment, but only after a long adjustment period.

Error Equations

We use the fundamental equations to generate errors equations, and then examine autoregressive properties of these errors as given by equation (8). As described above, we divide the available data into bubble and nonbubble MSAs, and we produce separate estimates of the error model by these MSA divisions in the pre- and post-1999 period. Results for the residuals from the 12-lag fundamental equation are shown in Appendix 2. Appendix 3 depicts the corresponding findings for the 16-lag model[6], while the sums of the residual coefficients are provided in Table 3. We also estimated error equations from the fundamental equation with 8 lags and 12 lags with lagged ρ on the right hand side, which give similar results as shown in Appendices 4 and 5. We therefore focus on the fundamental equation without lagged ρ.

[5] We initially tried to establish the fundamental model with local CPI to capture the MSA specific inflation, and in a way, deduce the real interest rate. However, adding the variable does not increase the explanatory power and intuition of the model significantly. We therefore maintain the current model for parsimony.
[6] Results on 20-lag and 24-lag models are available upon request.

From Table 3, the sums of coefficients in all of the specifications are positive; and in all cases, the sum increased after 1999. On average, the increase in sums was around 0.2 or 0.3; the bubble MSAs mostly have higher sums, averaging around 0.8.

Basic results for the coefficient sums are that momentum exists throughout the period, an increase in momentum after 1999, long adjustment lags, and general agreement about the increase in momentum across different estimates (varying by lag) of the fundamentals. The latter provides evidence of a regime shift in the post-1999 period. However, there is no evidence of an explosive bubble associated with the regime shift; coefficient sums are always significantly less than one (see footnote to Table 2).[7] The change in momentum is economically significant; the sums in bubble cities went from around 0.5 to around 0.8. Consider a 1% shock in one quarter. In the pre bubble case the long run effect of the shocks on price relative to rent is 1%/(1 - 0.5) or 2%, but becomes 1%/(1 - 0.8) or 5% in the post bubble period.

It is possible that the bubbles became bigger in the later part of the post-bubble period. We changed the cutoffs for the bubble period to later periods. For both 2002 through 2005 and 2003 through 2005, the coefficient sums are either the same as those in the post-1999 period as a whole or, in the case of the bubble MSAs, lower. We discuss this second period below.

Volatility

Table 4 presents results for testing the changes in the volatility of the errors in equation (8). We apply the Goldfield-Quandt test for the differences in variances. The results of the tests can be read from the "Pre/Post-1999 Test" rows. Bold face numbers show cases where the hypothesis that the variances are different is not rejected. In the nonbubble MSAs, the

[7] We have also performed unit root test on all the MSAs to reinforce the argument.

hypothesis is mostly rejected (except the one with the fundamental equation of 16 lags and 12 lags on the error equation). In the bubble MSAs, the hypothesis is almost never rejected; and the variance fell after 1999 in all those cases. Hence, there is some evidence of a regime shift in the bubble MSAs; however, the shift is toward a somewhat more stable regime after 1999.[8]

In order to verify that the cutoff year of 1999 is robust, we also tried various cutoff years such as 2002 and 2003. While results are not shown here, we find that variances did go up in both the post-1999 versus 2002-2005 and post-1999 versus the 2003-2005 periods, but differences are not statistically significant. We can thus conclude that our results are not sensitive to the cutoff point at 1999. Overall volatility did go up, due the increased momentum, but not because of increase in the (conditional) volatility of the white noise part.

VI. Robustness of the Fundamentals

We estimated variations of the fundamentals to see if the error equations still lead to findings that are similar to the ones we obtained in the previous section. We first separated the data set for the fundamentals into those for bubble MSAs and non-bubble MSAs and estimated separate panel regressions (regression results depicted in Appendix 6). The rationale is that, assuming bubble and non-bubble markets are separate groups, intra-group markets might share identical effects from the factors in the fundamental equation, but not inter-group markets. As expected, the error equations (with 8, 12, and 16 lags), shown in Appendix 7, are different between the two groups of MSAs. The test results of differences in variances between pre-bubble and post-bubble periods are depicted in Panel A of Appendix 9. The sensitivity to a change in the regression does not however alter our previous conclusions about changes in momentum.

[8] We have also tested the variances of the 44 individual MSAs. There are on average one or two MSAs that have statistically significant change in variance between the pre- and post-bubble periods in all of the cases. We therefore omit the results here for purpose of simplicity.

Our second variation included the inflation rate into the fundamental equation. This allows the discount rate to be thought of composed of a real rate plus real rent growth, and these might not have the same coefficients (e.g., because of different measurement errors). Furthermore, local inflation may contain information about rent, or its determinants that is not in the rental equivalent index (e.g., the rental data series might be too smooth or grow too slowly relative to the true numbers). The error equation results are in Appendix 8, and the comparison of variances in the pre- and post-1999 period is exhibited in Panel B of Appendix 9. The basic results are about the same.

VII. How much is explained by Fundamentals?

We do not get a significantly separate regime shift after 2002. Nonetheless, that period is problematic. It is probably too short to be able to differentiate statistically from the entire bubble period. However, it does show sharp acceleration in house prices (see Figure 1). This period coincided with the sudden decrease in short term interest rates, a sudden increase in the share of subprime loans and subprime securitization in the market and a sharp increase in the use of Adjustable rate mortgages (ARMs) in this market. This was at a time when short-term rates were unusually low relative to long-term rates. Appeal to the Modigliani Irrelevance Theorem suggests that while the use of ARMs is fine, it should be largely irrelevant; the rate for discounting cash flows of long-term assets like housing is still a long-term rate. To the extent that the advent of subprime ARMs stimulated purchase of housing because a new class of homeowners discounted at low short term ARM rates (along with poor underwriting of subprime loans), we have a potentially large shock to the fundamentals, which should in turn generate momentum.

To get a finer picture of the period, we simulated the fundamentals models to see how much of the actual change in prices, by MSA and nationally, was “explained” by the predictions of the estimated fundamentals models during the first part of the period (1999-2002) and the second (2002-2005). Table 5 depicts results using the version of the fundamental equation in Table 1 with 20 lags (results are similar for the 24 lag model). The second column gives the actual cumulative price change over the period. The third column is the actual cumulative rent increase. The fourth column is to have the third column divided by the second, i.e., the share of price growth “explained” by rent growth alone. The fifth column is the cumulative increase in the price to rent ratio. The sixth is the percentage of increase that is explained by the model (the ratio of predicted to actual). The last column is the fraction of overall change in price explained both rent growth and the model.

For instance, in the rows for the period of 2003-2005 in Panel A (that is, for non bubble MSAs), the actual average cumulative price change for 20 quarters was 0.18913 (about 19%) while the actual average cumulative rent change amounts to 0.04505, which accounts for 23.82% of the total price change (the fourth column). The price to rent ratio grew by 0.14408. The fundamental equation explained 41.26% of this, and rent growth and the model explained 54.44% of the overall change in prices.

The table suggests that the fundamentals did a reasonably good job of explaining the first part of the bubble period, and the estimated equation explained over half of the increase in prices relative to rents. This was probably due to the decline in long term Treasury rates over the period. However, very little is explained, especially in the bubble MSAs, in the second part of the period. This suggests that there was not much of a bubble before 2003 and that most of the high house price growth was explained by low long term rates. However, the long term rates did not fall at the end of the period and that appears as the main part of the bubble.

Figures 2a and 2b depict the average (across MSAs) levels of the white noise part of the error process. In both Figures the high levels of the errors is striking. There was clearly a major shift at the end of the period. From mid 2002 until the end of 2005 (10 quarters) the sum of the disturbances in the nonbubble MSAs was 9.3 %, and 16.8% in the bubble MSAs. Hence, while the increase in momentum mattered, a very large part of the bubble happened in the later part of the period, did not last very long, and was seemingly random.

VIII. Conclusions

Perhaps the best way to characterize housing markets during our sample period is that (1) there were always bubbles in the sense of disturbances generating momentum, (2) while the post-1999 period experienced a regime shift with increased momentum, (3) but not conditional volatility. Although our equations for the fundamentals of house price growth changed under different assumptions, the errors from those equations consistently show that momentum increased after 1999 and volatility did not change much. The regime shift was weaker in the bubble candidate cities, which had shown high growth throughout the period and higher post-1999 momentum. The increase in momentum is economically significant.

When we break the bubble period into pre and post 2002, we see a sharp change in that the fundamentals do a much worse job after 2002. Apparently 2003 was a watershed year. Going into that year there was a strong housing market, fueled by low long term real interest rates. It was not obvious at that time that there was going to be a bubble. The bubble appears to have begun in the second half of 2003. And it had less to do with momentum than with random changes in house price growth, which are associated with the decline in short rates and the rise of the subprime and ARM business. Breaking out cause and effect during this period (e.g., was the subprime surge exogenous or caused by the decline in short rates and good housing market?) is difficult (see Coleman *et al.* (2008)). However, it looks like something important happened during that relatively short period, which caused a strong market to become a bubble market.

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Figure One Growth Rates of House Price Index, Ten-year Treasury Bonds, Consumer Price Index, and Rent Index, at the National Level

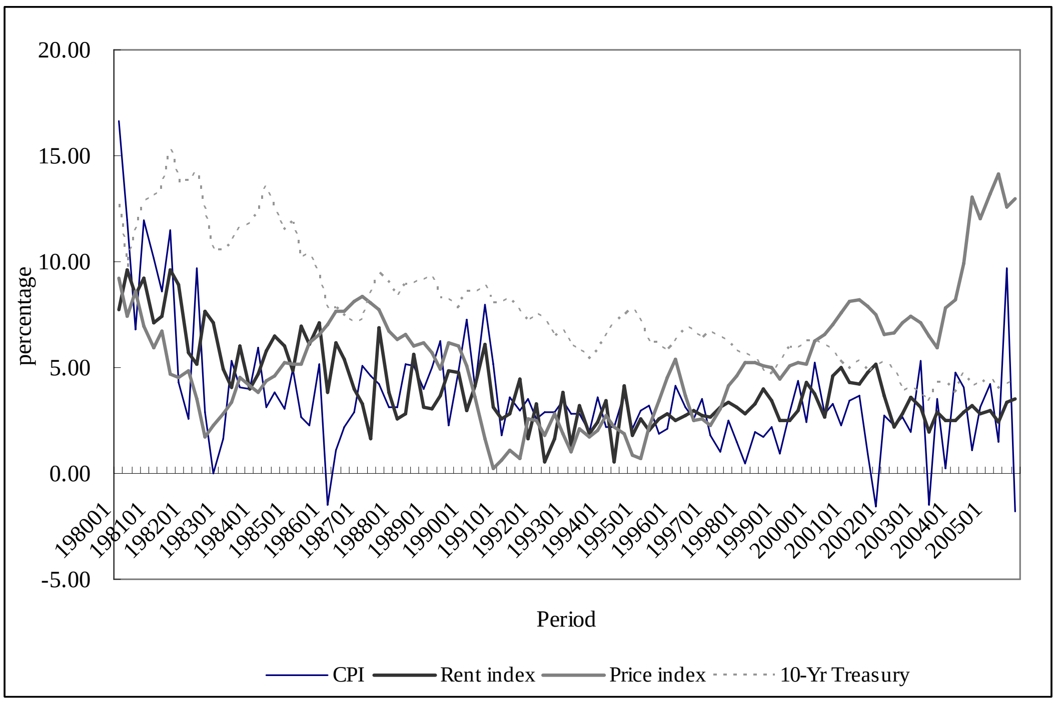

Figure 2: White Noise, using 8 lag error equations and 20 lag fundamentals equations

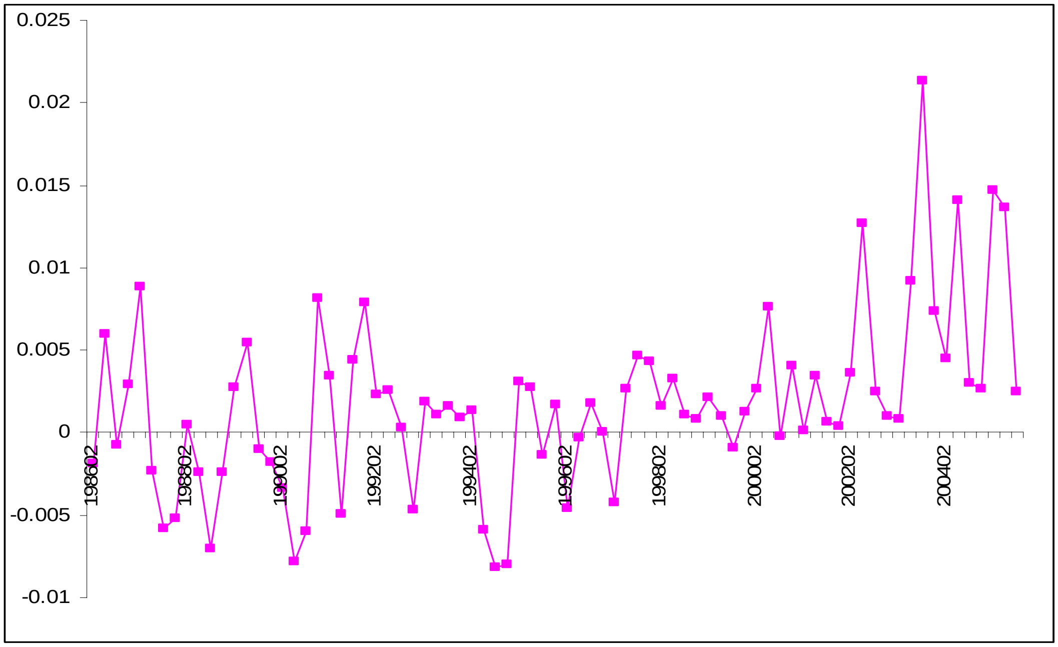

Figure 2a: White Noise from Fundamental Equation and 8-lag Error Equation for Non-bubble MSAs

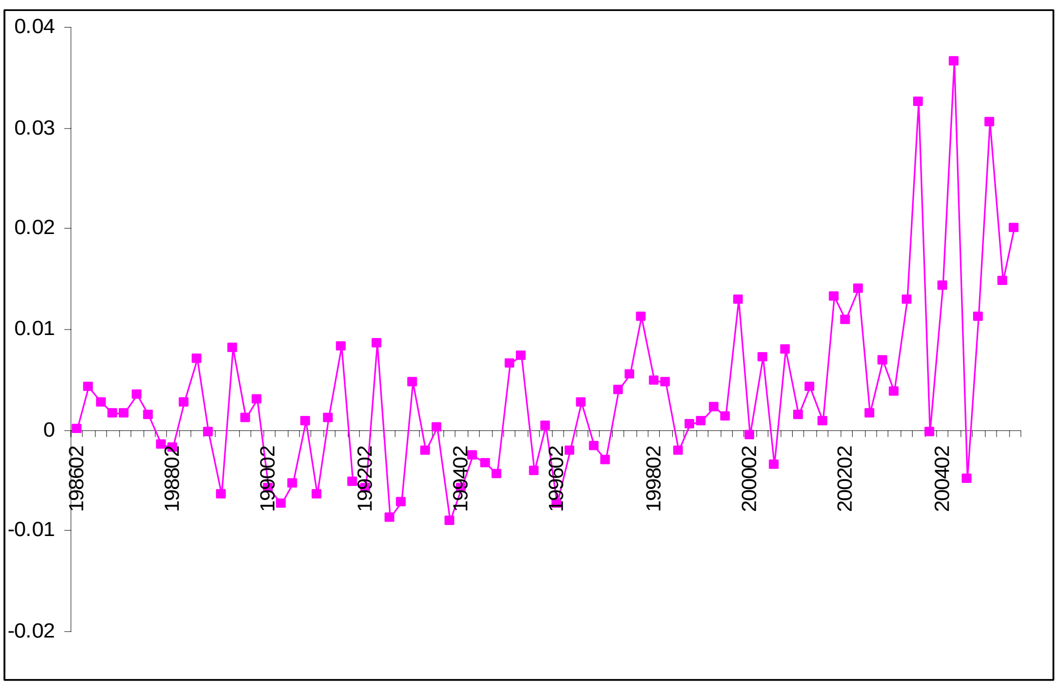

Figure 2b: White Noise from Fundamental Equation and 8-lag Error Equation for Bubble MSAs

Table 1 Basic Regression Results for the Fundamental Equation (Various Lags)

Equation being Difference between Growth Rates of House Prices versus Rent on Lagged Changes in 10-year Treasury and Local Rent Growth (MSA Fixed Effects Omitted)

Variables	12 Lags	16 Lags	20 Lags	24 Lags
Panel A: Coefficients of Nominal Interest				
Lag 1	0.3084	0.6500 ***	0.8360***	0.9408***
2	0.1308	0.1152	0.1056	0.1696
3	0.1220	-0.0240	-0.1080	0.2328
4	0.4172 *	-0.0160	0.5108**	0.7460***
5	0.3088	0.3340	0.5940**	0.9840***
6	0.0080	-0.2880	-0.2800	0.0300
7	0.2140	-0.1800	-0.8640***	-0.7160***
8	-0.4960 **	-1.2040 ***	-1.2560***	-1.1400***
9	-0.0440	-0.8600 ***	-0.8360***	-0.6720***
10	-0.1840	-0.5680 ***	-0.6360***	-0.6640***
11	0.1128	-0.0680	-0.1800	-0.2360
12	-0.1480	-0.3280	-0.5520**	-0.1800
13		-0.8880 ***	-0.9800***	-0.8040***
14		-1.6320 ***	-1.5840***	-1.1240***
15		-0.3880 **	0.0808	0.4784**
16		-0.8040 ***	-0.6960***	-0.0840
17			-0.8120***	-0.1560
18			-0.5840***	-0.1200
19			0.0408	0.3864*
20			0.4996**	0.5624***
21				1.0080***
22				0.6584***
23				0.4632**
24				0.7228***

Continue…

Table 1 Continued

Panel B: Coefficients of Rent Growth				
Lag 1	0.1618 ***	0.1778 ***	0.1924***	0.1965***
2	0.1869 ***	0.2254 ***	0.2314***	0.2440***
3	0.2290 ***	0.2588 ***	0.2508***	0.2659***
4	0.2449 ***	0.1969 ***	0.1881***	0.2101***
5	0.2773 ***	0.1888 ***	0.1832***	0.2024***
6	0.3448 ***	0.2311 ***	0.2225***	0.2340***
7	0.3439 ***	0.2623 ***	0.2393***	0.2459***
8	-0.0071	0.0860	0.0446	0.0438
9	-0.0681	0.0678	0.0215	0.0102
10	-0.1065 **	0.0731	0.0240	0.0015
11	-0.0543	0.1531 ***	0.1021*	0.0697
12	0.0351	0.3122 ***	0.2595***	0.2174***
13		0.3224 ***	0.2697***	0.2150***
14		0.3574 ***	0.3005***	0.2327***
15		0.3367 ***	0.2826***	0.2009***
16		0.1046 ***	0.0597*	-0.0362
17			-0.0452***	-0.1477***
18			-0.0545***	-0.1502***
19			-0.0301***	-0.1174***
20			-0.0086	-0.0871***
21				-0.0644***
22				-0.0419***
23				-0.0122
24				-0.0044
Adjusted *R*-square	0.079149	0.101218	0.1375	0.1562

"***", "**", "*" represent significance at 1%, 5% and 10% respectively.

Table 2 Comparison of Sum of Coefficients from the Fundamental Equation (7)

Coefficients are from Table 1

	Lag Length			
Variables	**Lag = 12**	**Lag = 16**	**Lag = 20**	**Lag =24**
Change in Interest Rate	0.7500	-6.1488	-6.7004	1.4868
Change in Rent Growth	1.5876	3.3543	2.7333	1.9287
LR effect of Change in Interest rate 100bp	0.1875	-1.5372	-1.6751	0.3717
Adjusted *R*-squared	0.0791	0.1012	0.1375	0.1562

Table 3 Comparison of Sums of Coefficients of the Error Equation from the Fundamental Equation

Panel A: Fundamental Model with 12 and 16 lags						
	Fundamental Lag = 12			**Fundamental Lag = 16**		
Category	**Lag =8**	**Lag=12**	**Lag=16**	**Lag =8**	**Lag=12**	**Lag=16**
Non-Bubble MSA Pre-1999	0.2862 (646.17)	0.3793 (825.19)	0.3567 (674.79)	0.5651 (508.12)	0.7056 (591.55)	0.7239 (509.46)
Non-Bubble MSA Post-1999	0.7440 (259.64)	0.7742 (168.22)	0.8805 (56.48)	0.8277 (132.28)	0.8715 (118.08)	0.9912 (80.24)
Differences	**0.4578**	**0.3949**	**0.5238**	**0.2626**	**0.1659**	**0.2673**
Bubble MSA Pre-1999	0.5699 (169.09)	0.5507 (191.43)	0.4806 (221.50)	0.5708 (128.89)	0.5397 (220.74)	0.4781 (144.18)
Bubble MSA Post-1999	0.8502 (79.60)	0.7293 (54.93)	0.6270 (37.77)	0.9028 (97.39)	0.7951 (54.44)	0.6677 (38.47)
Difference	**0.2803**	**0.1786**	**0.1464**	**0.332**	**0.2554**	**0.1896**
Panel B: Fundamental Model with 20 and 24 lags						
	Fundamental Lag = 20			**Fundamental Lag = 24**		
Category	**Lag =8**	**Lag=12**	**Lag=16**	**Lag =8**	**Lag=12**	**Lag=16**
Non-Bubble MSA Pre-1999	0.6071 (529.26)	0.7110 (547.24)	0.7315 (476.22)	0.6360 (530.64)	0.7364 (559.39)	0.7537 (471.01)
Non-Bubble MSA Post-1999	0.8072 (123.82)	0.8708 (102.41)	0.9566 (51.91)	0.7759 (128.47)	0.8702 (97.57)	0.8883 (54.02)
Differences	**0.2001**	**0.1598**	**0.2251**	**0.1399**	**0.1338**	**0.1346**
Bubble MSA Pre-1999	0.5757 (129.93)	0.5450 (227.52)	0.5022 (146.30)	0.6006 (128.62)	0.5722 (231.14)	0.5347 (149.40)
Bubble MSA Post-1999	0.8983 (81.89)	0.8139 (53.76)	0.6498 (28.76)	0.8810 (79.78)	0.8133 (55.65)	0.6703 (29.12)
Difference	**0.3226**	**0.2689**	**0.1476**	**0.2804**	**0.2411**	**0.1356**

Note: Numbers within parentheses are the *F*-values for testing the hypothesis that the sum of the coefficients equals 1. All the above results indicate the null hypothesis is rejected, or the coefficients do not sum to unity.

Table 4 Test of Differences in Variance between the Pre- and Post-Bubble Period in the Bubble and Non-Bubble MSAs with Various Lags in the Fundamental Equation (7)

Panel A: Comparing 12-lag versus 16-lag Fundamental Equations

	Non-Bubble MSAs			Bubble MSAs		
	12-lag Fundamental	**16-lag Fundamental**	**GQ Test [2]**	**12-lag Fundamental**	**16-lag Fundamental**	**GQ Test [2]**
8-lag residuals						
Pre-1999	1.61×10^{-4}	1.50×10^{-4}	1.07520	3.61×10^{-4}	2.98×10^{-4}	1.20986
Post-1999	1.65×10^{-4}	1.09×10^{-4}	**1.51334***	1.91×10^{-4}	1.70×10^{-4}	1.12224
Pre/Post-1999 Test [1]	1.02281	1.37610		**1.89082***	**1.75388***	
12-lag residuals						
Pre-1999	1.46×10^{-4}	1.44×10^{-4}	1.01623	3.02×10^{-4}	2.49×10^{-4}	1.21276
Post-1999	1.27×10^{-4}	1.05×10^{-4}	1.21158	1.70×10^{-4}	1.57×10^{-4}	1.07893
Pre/Post-1999 Test [1]	1.15196	**1.37340***		**1.78437***	**1.58746***	
16-lag residuals						
Pre-1999	1.41×10^{-4}	1.23×10^{-4}	1.15406	2.52×10^{-4}	2.18×10^{-4}	1.15502
Post-1999	1.22×10^{-4}	1.02×10^{-4}	1.19612	1.92×10^{-4}	1.76×10^{-4}	1.09422
Pre/Post-1999 Test [1]	1.15831	1.20053		**1.31256***	1.24346	

Panel B: Comparing 20-lag versus 24-lag Fundamental Equations

	Non-Bubble MSAs			Bubble MSAs		
	20-lag Fundamental	**24-lag Fundamental**	**GQ Test [2]**	**20-lag Fundamental**	**24-lag Fundamental**	**GQ Test [2]**
8-lag residuals						
Pre-1999	1.45×10^{-4}	1.44×10^{-4}	1.00520	2.95×10^{-4}	2.90×10^{-4}	1.01513
Post-1999	1.15×10^{-4}	1.12×10^{-4}	1.02077	1.73×10^{-4}	1.69×10^{-4}	1.02275
Pre/Post-1999 Test [1]	1.26526	1.28485		**1.70605***	**1.71886***	
12-lag residuals						
Pre-1999	1.40×10^{-4}	1.39×10^{-4}	1.00345	2.44×10^{-4}	2.40×10^{-4}	1.01880
Post-1999	1.12×10^{-4}	1.10×10^{-4}	1.01870	$1.62 \times 10^{-4}4$	1.56×10^{-4}	1.03465
Pre/Post-1999 Test [1]	1.24361	1.26250		**1.50958***	**1.53305***	
16-lag residuals						
Pre-1999	1.22×10^{-4}	1.19×10^{-4}	1.02404	2.16×10^{-4}	2.09×10^{-4}	1.03103
Post-1999	1.09×10^{-4}	1.06×10^{-4}	1.02478	1.81×10^{-4}	1.77×10^{-4}	1.02488
Pre/Post-1999 Test [1]	1.11998	1.12078		1.18985	1.18275	

1. The "Pre/Post- 1999 Test" is test for statistical difference between the pre- and post-bubble periods (Goldfeld-Quandt Test is used).
2. The "GQ Test" is test for statistical difference between two fundamental equations.
* implies that the Goldfeld-Quandt Test rejects the null hypothesis that the variances between the 8-lag and 12-lag fundamental equations are statistically the same at 5% significance level (compared to an *F*-value of 1.3)

Table 5 Explanatory Power of the Fundamental Model (without Error Equation) on the Cumulative Price Change for the Period 1995 – 2000

Panel A: Non Bubble MSAs

Period	**Cumulative Price Changes**	**Cumulative Rent Changes**	**% of Price Change Explained by Rent Change**	**Cumulative Growth Rate Difference**	**% of Growth Rate Difference Explained**	**Total % Price Changed Explained †**
1990 – 1995	0.23361	0.18770	80.35%	0.04590	281.90%	135.74%
1995 - 2000	0.22781	0.16358	71.80%	0.06423	171.22%	120.08%
2000 – 2005	0.37557	0.15113	40.24%	0.22444	55.65%	74.79%
2000 – 2002‡	0.18644	0.10609	56.90%	0.08036	81.45%	92.00%
2003 - 2005‡	0.18913	0.04505	23.82%	0.14408	41.26%	54.44%

Panel B: Bubble MSAs						
Period	**Cumulative Price Changes**	**Cumulative Rent Changes**	**% of Price Change Explained by Rent Change ***	**Cumulative Growth Rate Difference**	**% of Growth Rate Difference Explained**	**Total % Price Changed Explained †**
1990 – 1995	0.13553	0.18349	135.38%	-0.04796	-386.07%	271.99%
1995 – 2000	0.22763	0.14794	64.99%	0.07757	212.11%	139.24%
2000 – 2005	0.69539	0.21367	30.73%	0.48171	40.48%	58.18%
2000 – 2002 ‡	0.26657	0.12631	47.38%	0.14027	71.55%	85.03%
2003 –2005‡	0.42882	0.08737	20.37%	0.34145	27.72%	40.76%

"Average" is the percentage of Average Cumulative Rent Change constituting the Average Cumulative Price Change.

† "Total Price Changed Explained" refers to the proportion of price change explained by rent + fundamental model without error equation.

‡ Notice that the cumulative changes on price, rent and growth rate differences for the period of 2000-2002 and 2003-2005 do not add up to those for 2000-2005 because all the periods begin from one quarter prior to the period for the purpose of differencing. As such, adding the values of 2000-2002 and 2003-2005 double-counts quarter 4 of 2002.

Appendix

Appendix 1 Annualized Average Growth Rates (in percentage) of Price, Rent, Difference between Price and Rent, and Local CPI of Individual MSAs (Asterisk indicates MSAs separated as bubble candidates)

MSAs	No. of Obs.	Price Growth	Rent Growth	Price-Rent Growth	Local CPI
Akron, OH	103	3.9768	3.5016	0.4752	3.7448
Anchorage, AK*	96	3.1673	2.5849	0.5824	2.4593
Ann Arbor, MI	102	5.1890	3.4639	1.7251	3.5542
Atlanta-Sandy Springs-Marietta, GA	104	4.6340	3.8777	0.7563	7.1204
Atlantic City, NJ	87	6.5720	3.7304	2.8416	3.2089
Baltimore-Towson, MD	36	9.2178	4.1863	5.0315	2.5386
Boston-Quincy, MA *	104	8.2892	4.9242	3.3650	4.0825
Boulder, CO	104	5.8883	3.7984	2.0899	3.7073
Bremerton-Silverdale, WA	103	5.4960	3.4012	2.0948	3.6060
Chicago-Naperville-Joliet, IL	104	5.4657	4.3685	1.0972	3.6755
Cincinnati-Middletown, OH-KY-IN	104	3.8449	3.3949	0.4501	3.4088
Cleveland-Elyria-Mentor, OH	104	3.9130	3.5016	0.4114	3.7448
Dallas-Plano-Irving, TX	104	3.0029	3.3065	-0.3036	3.5913
Denver-Aurora, CO	104	4.9855	3.7984	1.1872	3.7073
Detroit-Livonia-Dearborn, MI	104	4.7089	3.3968	1.3120	3.4888
Flint, MI	104	4.6088	3.3968	1.2120	3.4888
Fort Lauderdale-Pompano Beach-Deerfield Beach, FL *	104	6.4542	3.9566	2.4976	3.8114
Fort Worth-Arlington, TX	104	2.7439	3.3065	-0.5626	3.5913
Gary, IN	104	3.7292	4.3685	-0.6393	3.6755
Greeley, CO	81	4.6503	2.9757	1.6746	2.8996
Honolulu, HI *	104	8.4394	4.0158	4.4236	3.6627
Houston-Sugar Land-Baytown, TX	104	2.4987	3.1129	-0.6142	3.2148
Kansas City, MO-KS	104	3.6772	3.6694	0.0078	3.3558
Lake County-Kenosha County, IL-WI	104	5.1801	4.3685	0.8116	3.6755
Los Angeles-Long *Beach-Glendale, CA	104	7.2382	4.7031	2.5351	3.7761
Miami-Miami Beach-Kendall, FL*	104	6.5227	3.9566	2.5661	3.8114

(Appendix 1 continued…)

MSAs	No. of Obs.	Price Growth	Rent Growth	Price-Rent Growth	Local CPI
Milwaukee-Waukesha-West Allis, WI	104	4.6754	3.6459	1.0295	3.5204
Minneapolis-St. Paul-Bloomington, MN-WI	104	5.2949	3.6892	1.6058	3.7092
New York-White Plains-Wayne, NY-NJ *	104	7.9851	4.6493	3.3358	3.9667
Philadelphia, PA	104	6.3239	4.3361	1.9878	3.7826
Pittsburgh, PA	104	3.8733	3.2084	0.6649	3.6355
Portland-Vancouver-Beaverton, OR-WA *	104	5.5337	3.3116	2.2221	3.4013
Racine, WI	90	5.0893	3.0796	2.0097	2.7917
Riverside-San Bernardino-Ontario, CA *	104	6.3798	4.7031	1.6767	3.7761
Salem, OR	98	5.1685	3.5155	1.6530	3.6083
San Diego-Carlsbad-San Marcos, CA *	104	7.0325	4.8219	2.2106	4.2708
San Francisco - San Mateo - Redwood City, CA *	104	7.7118	5.0223	2.6895	3.8847
San Jose-Sunnyvale-Santa Clara, CA *	104	7.9135	5.0223	2.8912	3.8847
Seattle-Bellevue-Everett, WA *	104	6.2482	3.7498	2.4983	3.8443
Tacoma, WA *	104	5.9906	3.7498	2.2407	3.8443
Tampa-St. Petersburg-Clearwater, FL *	32	11.0700	4.3738	6.6962	3.7665
Washington-Arlington-Alexandria, DC-VA-MD-WV*	36	10.8923	4.1863	6.7061	2.5386
Wilmington, DE-MD-NJ	103	6.1454	4.3271	1.8182	3.6888

Appendix 2 Results of Error Equations from 12-Lag Fundamental Equation *without* Lagged Regressands for Non-Bubble versus Bubble MSAs in Pre- and Post-Bubble Period (various lags)

Panel A: 8-lags

Number of Lags	Non-Bubble MSAs Pre-bubble Period	Non-Bubble MSAs Post-bubble Period	Bubble MSAs Pre-bubble Period	Bubble MSAs Post-bubble Period
Intercept	-0.00095**	0.00302***	-0.00172**	0.00516***
1	0.01573	0.22028***	0.25957***	0.43179***
2	0.07822***	-0.02568	0.20891***	0.00731
3	0.13859***	0.18798***	0.10497***	0.47637***
4	0.13204***	0.04012	0.03612	-0.16834***
5	-0.00521	0.02137	-0.17012***	-0.11031*
6	0.01905	0.11412***	0.10098***	0.03697
7	-0.00813	-0.07919*	0.12941***	-0.06612
8	-0.08406***	0.26500***	-0.09994***	0.24249***
Adjusted *R*-Square	0.0562	0.1626	0.2243	0.4187
Durbin-Watson	1.9850	1.9740	1.9730	2.0190

Panel B: 12-lags

Number of Lags	Non-Bubble MSAs Pre-bubble Period	Non-Bubble MSAs Post-bubble Period	Bubble MSAs Pre-bubble Period	Bubble MSAs Post-bubble Period
Intercept	-0.00062*	0.00297***	-0.00186***	0.00934***
1	0.05778**	0.28179***	0.36270***	0.27628***
2	0.08313***	-0.07906*	0.15478***	-0.06297
3	0.13069***	0.29794***	0.10197***	0.49151***
4	0.11801***	0.00786	0.01549	-0.19234***
5	0.00439	0.12202***	-0.14836***	-0.04563
6	0.00487	0.21256***	0.09097***	0.13734
7	0.00589	-0.04647	0.08549**	0.06448
8	-0.13712***	-0.09046	-0.11944***	0.11964
9	0.04381*	-0.01510	0.12586***	0.12166
10	-0.03215	0.02101	0.01270	-0.03208
11	0.01385	-0.05034	-0.08950***	-0.14664
12	0.08612***	0.11248**	-0.04193	-0.00194
Adjusted *R*-Square	0.0742	0.2542	0.2839	0.3866
Durbin-Watson	1.9780	1.8910	1.9370	2.0620

Continue…

(Appendix 2 continued)

Panel C: 16-lags

Number of Lags	Non-Bubble MSAs Pre-bubble Period	Non-Bubble MSAs Post-bubble Period	Bubble MSAs Pre-bubble Period	Bubble MSAs Post-bubble Period
Intercept	-0.00111***	0.00279***	-0.00235***	0.01138***
1	0.06315**	0.33134***	0.31679***	0.24775***
2	0.06294**	-0.13609**	0.11839***	-0.08545
3	0.13385***	0.49802***	0.17201***	0.56479***
4	0.10465***	-0.08921	-0.00149	-0.26032***
5	0.01641	0.17699***	-0.05945*	-0.00372
6	0.02158	0.06852	0.04641	0.03089
7	0.00586	-0.02039	0.08586***	0.18675*
8	-0.11524***	-0.16403**	-0.16078***	0.05888
9	0.06576**	0.01778	0.11310***	0.09942
10	-0.03653	-0.09035	0.02328	-0.02928
11	0.0351	0.17340**	-0.02989	-0.19359
12	0.0853***	0.16460**	-0.01163	-0.04324
13	0.00184	-0.00387	-0.06354**	0.04202
14	-0.06077**	0.09595	-0.00412	-0.02805
15	-0.0401*	-0.12370**	-0.03455	0.03175
16	0.01287	-0.01846	-0.02976	0.00835
Adjusted *R*-Square	0.0746	0.3411	0.3123	0.3377
Durbin-Watson	2.0280	1.9390	1.8700	2.0730

"***", "**", "*" represent significance at 1%, 5% and 10% respectively.

Appendix 3 Results of Error Equations from 16-Lag Fundamental Equation *without* Lagged Regressands for Non-Bubble versus Bubble MSAs in Pre- and Post-Bubble Period (various lags)

Panel A: 8-lags

Number of Lags	Non-Bubble MSAs		Bubble MSAs	
	Pre-bubble Period	**Post-bubble Period**	**Pre-bubble Period**	**Post-bubble Period**
Intercept	0.00084**	0.00215***	-0.00202***	0.00549***
1	0.09412***	0.20899***	0.34501***	0.40419***
2	0.13313***	-0.02702	0.16715***	0.02651
3	0.13181***	0.33066***	0.11373***	0.49836***
4	0.07433***	0.10850**	-0.03506	-0.14114**
5	0.02680	0.08167	-0.15655***	-0.17325***
6	0.06979***	0.20891***	0.10824***	0.02220
7	0.06678**	-0.07321	0.11624***	-0.05006
8	-0.03163	-0.01081	-0.08801***	0.31595***
Adjusted *R*-Square	0.1087	0.2813	0.2506	0.4516
Durbin-Watson	1.9620	1.9740	1.9050	2.0160

Panel B: 12-lags

Number of Lags	Non-Bubble MSAs		Bubble MSAs	
	Pre-bubble Period	**Post-bubble Period**	**Pre-bubble Period**	**Post-bubble Period**
Intercept	0.00070*	0.00292***	-0.00223***	0.00856***
1	0.11434***	0.27783***	0.31301***	0.29564***
2	0.09728***	-0.15511***	0.12204***	-0.08482
3	0.12082***	0.42720***	0.18639***	0.54866***
4	0.0622**	0.03272	-0.03692	-0.17027**
5	0.01641	0.12682**	-0.03713	-0.06366
6	0.06044**	0.23278***	0.01037	0.06923
7	0.04758*	-0.07155	0.09149***	0.06435
8	-0.03242	-0.02847	-0.11985***	0.25771***
9	0.08160***	-0.08045	0.08138**	0.00368
10	-0.00606	-0.07036	0.02606	0.04472
11	0.05132**	0.05390	-0.05979*	-0.18226**
12	0.09207***	0.12615**	-0.03732	0.01211
Adjusted *R*-Square	0.1391	0.3473	0.2900	0.3984
Durbin-Watson	2.0370	1.9640	1.8550	2.1110

Continue…

(Appendix 3 continued)

Panel C: 16-lags

Number of Lags	Non-Bubble MSAs Pre-bubble Period	Non-Bubble MSAs Post-bubble Period	Bubble MSAs Pre-bubble Period	Bubble MSAs Post-bubble Period
Intercept	0.00074**	0.00274***	-0.00300***	0.00966***
1	0.11734***	0.21694***	0.38154***	0.24951***
2	0.13043***	-0.17953***	0.08315**	-0.09332
3	0.10106***	0.47163***	0.15176***	0.60188***
4	0.04029	-0.02046	-0.00624	-0.18295**
5	0.08787***	0.22497***	0.00903	-0.00491
6	0.03283	0.17461**	-0.05900	0.01143
7	0.05080*	0.00971	0.13309***	0.15418
8	-0.06455**	-0.06212	-0.10831***	0.20048**
9	0.09494***	-0.07795	0.03103	-0.05940
10	0.00271	-0.04741	0.04059	0.09709
11	0.08873***	0.11900*	-0.03602	-0.26132*
12	0.08723***	0.24447***	0.02051	-0.01594
13	-0.01199	-0.01169	-0.06947**	0.05775
14	-0.05319**	0.11869*	-0.04291	-0.11895
15	0.00468	-0.13692**	0.00113	0.01714
16	0.01476	-0.05275	-0.05183*	0.01503
Adjusted *R*-Square	0.1752	0.4001	0.3173	0.3602
Durbin-Watson	2.0100	2.0120	2.0540	2.0200

"***", "**", "*" represent significance at 1%, 5% and 10% respectively.

Appendix 4 Results of Error Equations from Fundamental Equation *with* 8-Lag Regressands for Non-Bubble versus Bubble MSAs in Pre- and Post-Bubble Period (various lags)

Panel A: 8-lags

Number of Lags	Non-Bubble MSAs		Bubble MSAs	
	Pre-bubble Period	Post-bubble Period	Pre-bubble Period	Post-bubble Period
Intercept	-0.0012 ***	0.0024 ***	-0.0024 ***	0.0043 ***
1	-0.0689 **	0.1654 ***	0.1722 ***	0.3480 ***
2	-0.1032 ***	-0.1405 ***	0.0614 **	-0.0176
3	0.0918 ***	0.0553	0.1181 ***	0.4030 ***
4	-0.0144	-0.1233 ***	-0.1325 ***	-0.2591 ***
5	-0.0881***	-0.0114	-0.1060 ***	-0.0831
6	-0.0535 **	0.0328	0.0107	0.0343
7	-0.0705 ***	-0.0798 *	0.0796 ***	-0.0786
8	-0.0844 ***	0.2829 ***	-0.0920 ***	0.1306 **
Adjusted *R*-Square	0.0526	0.1297	0.0913	0.2537
Durbin-Watson	1.938	1.801	1.979	1.998

Panel B: 12-lags

Number of Lags	Non-Bubble MSAs		Bubble MSAs	
	Pre-bubble Period	Post-bubble Period	Pre-bubble Period	Post-bubble Period
Intercept	-0.0009 **	0.0034 ***	-0.0023 ***	0.0078 ***
1	-0.0429	0.3202 ***	0.2001 ***	0.2555 ***
2	-0.0910 ***	-0.2622 ***	0.0872 ***	-0.1513 ***
3	0.0798 ***	0.1869 ***	0.0680 **	0.4616 ***
4	-0.0161	-0.1998 ***	-0.1141 ***	-0.3444 ***
5	-0.0651 **	-0.0608	-0.1500 ***	-0.0200
6	-0.0148	-0.0118	0.0539 *	0.0850
7	-0.0427	-0.1642 ***	0.0745 ***	0.0279
8	-0.1360 ***	0.3332 ***	-0.1222 ***	0.0204
9	0.0142	-0.3454 ***	0.0540 **	0.0459
10	-0.0146	0.0991	0.0221	-0.0056
11	-0.0234	-0.2324 ***	-0.0441 *	-0.1428 **
12	-0.0226	0.0624	-0.0701 ***	-0.0965
Adjusted *R*-Square	0.0485	0.2119	0.1234	0.271
Durbin-Watson	1.960	1.931	1.989	2.05

Continue…

(Appendix 4 continued)

Panel C: 16-lags				
	Non-Bubble MSAs		**Bubble MSAs**	
Number of Lags	**Pre-bubble Period**	**Post-bubble Period**	**Pre-bubble Period**	**Post-bubble Period**
Intercept	-0.0008 **	0.0037 ***	-0.0024 ***	0.0098 ***
1	0.0085	0.2554 ***	0.2983 ***	0.1807 ***
2	-0.0940 ***	-0.2357 ***	0.0586 *	-0.1659 **
3	0.0977 ***	0.1932 ***	0.0728 **	0.5416 ***
4	-0.0287	-0.2203 ***	-0.1408 ***	-0.4077 ***
5	-0.0435	0.1398 **	-0.1351 ***	0.0075
6	-0.0249	0.0216	0.0642 **	-0.0191
7	-0.0395	-0.0684	0.0575 *	0.2096 **
8	-0.1643 ***	-0.1333 **	-0.1717 ***	-0.0494
9	0.0323	-0.1209 *	0.1211 ***	0.0100
10	-0.0193	0.0560	0.0004	-0.0143
11	-0.0097	-0.1708 ***	-0.0536 **	-0.1258
12	0.0252	0.1336 **	-0.0704 ***	-0.1899 **
13	0.0155	-0.0772	0.0180	0.0239
14	-0.0060	0.0502	-0.0037	0.0823
15	-0.0108	-0.0138	-0.0132	-0.0349
16	-0.0149	0.1534 **	-0.0348	0.0063
Adjusted *R*-Square	0.0565	0.1766	0.1959	0.3072
Durbin-Watson	1.965	1.892	1.927	2.086

"***", "**", "*" represent significance at 1%, 5% and 10% respectively.

Appendix 5 Results of Error Equations from Fundamental Equation with 12-Lag Regressands for Non-Bubble versus Bubble MSAs in Pre- and Post-Bubble Period (various lags)

Panel A: 8-lags

Number of Lags	**Non-Bubble MSAs**		**Bubble MSAs**	
	Pre-bubble Period	**Post-bubble Period**	**Pre-bubble Period**	**Post-bubble Period**
Intercept	-0.0012 ***	-0.0021 ***	0.0024 ***	0.0044 ***
1	-0.0689 **	0.0809 **	0.1077 ***	0.2113 ***
2	-0.1032 ***	0.0700 ***	-0.2137 **	-0.0267
3	0.0918 ***	0.0000	0.0151	0.3144 ***
4	-0.0144	-0.0197	-0.0748	-0.1263 **
5	-0.0881***	-0.1535	-0.0731 ***	-0.0999 *
6	-0.0535 **	0.0590	0.0141 **	0.0527
7	-0.0705 ***	0.0816 ***	-0.1310 ***	-0.1013
8	-0.0844 ***	-0.1127 ***	0.2376 ***	0.1135 *
Adjusted *R*-Square	0.0543	0.1002	0.0542	0.1304
Durbin-Watson	1.968	1.954	1.989	2.001

Panel B: 12-lags

Number of Lags	**Non-Bubble MSAs**		**Bubble MSAs**	
	Pre-bubble Period	**Post-bubble Period**	**Pre-bubble Period**	**Post-bubble Period**
Intercept	-0.0009 **	0.0026 ***	-0.0021 ***	0.0081 ***
1	-0.0767 **	0.1707 ***	0.1782 ***	0.1124 ***
2	-0.1100 ***	-0.2418 ***	0.0549 *	-0.1733 ***
3	0.0187	0.0938 *	0.0016	0.3327 ***
4	0.0198	-0.1221 **	-0.0339	-0.2205 ***
5	-0.0223	0.0261	-0.1384 ***	-0.0687
6	-0.0317	0.0830 *	0.0648 **	0.1342 **
7	-0.0337	-0.0999 **	0.0590 **	0.0148
8	-0.1948 ***	-0.1366 **	-0.1538 ***	0.0376
9	-0.0024	-0.1132 *	0.0901 ***	0.0593
10	-0.0667 **	-0.0220	0.0000	-0.0090
11	-0.0040	-0.0601	-0.0473 *	-0.0705
12	0.0693 ***	0.1289 **	-0.0439 *	-0.1080 *
Adjusted *R*-Square	0.0648	0.1406	0.0983	0.1078
Durbin-Watson	1.9650	1.8040	1.9380	2.0660

Continue…

(Appendix 5 continued)

Panel C: 16-lags

Number of Lags	Non-Bubble MSAs Pre-bubble Period	Non-Bubble MSAs Post-bubble Period	Bubble MSAs Pre-bubble Period	Bubble MSAs Post-bubble Period
Intercept	-0.0013 ***	0.0029 ***	-0.0022 ***	0.0097 ***
1	-0.0581 *	0.2730 ***	0.1449 ***	0.0532
2	-0.1234 ***	-0.3271 ***	0.0316	-0.2007 ***
3	0.0201	0.2929 ***	0.0495	0.4080 ***
4	0.0037	-0.1658 **	-0.0466	-0.2747 ***
5	-0.0340	0.1065 *	-0.0558 *	-0.0334
6	-0.0275	-0.0039	0.0307	0.0318
7	-0.0416	-0.0945 *	0.0585 **	0.1630*
8	-0.1852 ***	-0.2334 ***	-0.1732 ***	-0.0077
9	0.0182	0.0028	0.0691 *	0.0034
10	-0.0680 **	-0.2459 ***	-0.0057	-0.0235
11	-0.0156	0.2023 **	-0.0085	-0.0818
12	0.0652 **	0.1475 *	-0.0378	-0.1742 **
13	-0.0206	-0.0242	-0.0170	0.0311
14	-0.0355	0.0682	-0.0182	0.0299
15	-0.0263	-0.0734	-0.0251	-0.0579
16	0.0080	0.0327	-0.0185	0.0182
Adjusted *R*-Square	0.0618	0.2563	0.0765	0.2181
Durbin-Watson	2.0280	2.0210	1.8920	2.0640

"***", "**", "*" represent significance at 1%, 5% and 10% respectively.

Appendix 6 Regression Results for the Fundamental Equation for Bubble MSAs and Non-Bubble MSAs Separated

	Variables		
Variables	**Nominal Interests**	**Rent Growth**	**Regressand**
Panel A: Non-Bubble MSAs			
Lag 1	-0.65200 **	0.08545 *	-0.21947 ***
2	-0.85200 ***	0.13290 *	0.13028 ***
3	-1.02000 ***	0.10380	0.00696
4	-0.66000 ***	0.17795 **	0.22104 ***
5	-0.25600	0.10759	0.10375 ***
6	-1.00400 ***	0.14199 *	0.07580 ***
7	0.31960	0.22916 ***	0.13573 ***
8	-0.61600 **	0.11281 **	0.10386 ***
Adjusted *R*-	0.25247		
Panel B: Bubble MSAs			
Lag 1	0.28320	0.09866 **	0.11390 ***
2	-0.34800	0.16700 ***	0.13044 ***
3	0.07520	0.28606 ***	0.11596 ***
4	0.26560	0.49461 ***	0.21936 ***
5	-0.01200	0.44867 ***	0.02737
6	-0.42000	0.48665 ***	0.01126
7	-0.12400	0.44597 ***	0.01143
8	-0.96000 ***	-0.00880	0.02318
Adjusted *R*-	0.22687		

*"***", "**", "*" represent significance at 1%, 5% and 10% respectively.*

Appendix 7 Results of Error Equations with Separation of Non-Bubble and Bubble MSAs in Pre- and Post-Bubble Period (various lags)

Panel A: 8-lags				
Number of Lags	**Non-Bubble MSAs**		**Bubble MSAs**	
	Pre-bubble Period	**Post-bubble Period**	**Pre-bubble Period**	**Post-bubble Period**
Intercept	0.00099 ***	-0.00254 ***	0.00184 ***	0.00447 ***
1	0.13516 ***	0.07516 **	0.53786 ***	0.18425 ***
2	-0.12286 ***	0.07666 ***	-0.39784 ***	0.02370
3	0.17815 ***	0.07047 **	0.44936 ***	0.21641 ***
4	-0.05435 **	-0.12580 ***	-0.26742 ***	-0.14515 ***
5	-0.06125 **	-0.13983 ***	0.09191	-0.09551 **
6	-0.05020 **	0.01288	-0.02054	0.03616
7	-0.08117 ***	0.08362 ***	-0.09178	-0.09629 *
8	-0.04564 **	-0.09072 ***	-0.04692	0.31113 ***
Adjusted *R*-Square	0.0793	0.0664	0.2574	0.1591
Durbin-Watson	1.938	1.991	2.016	1.873
Sum of coefficients	-0.10216	-0.03756	0.25463	0.4347
Panel B: 12-lags				
Number of Lags	**Non-Bubble MSAs**		**Bubble MSAs**	
	Pre-bubble Period	**Post-bubble Period**	**Pre-bubble Period**	**Post-bubble Period**
Intercept	0.00080 **	-0.00226 ***	0.00279 ***	0.00790 ***
1	0.16613 ***	0.09914 ***	0.56779 ***	0.12394 **
2	-0.09202 ***	0.11065 ***	-0.48747 ***	-0.10439 **
3	0.15724 ***	0.02502	0.52716 ***	0.33279 ***
4	-0.05860 **	-0.10885 ***	-0.33241 ***	-0.21416 ***
5	-0.05823 **	-0.17418 ***	0.16204 **	-0.10847 **
6	-0.01653	0.05036 *	0.01328	0.01600
7	-0.07130 ***	0.08571 ***	-0.12262 *	-0.06672
8	-0.06464 **	-0.12261 ***	-0.06870	0.30957 ***
9	0.02814	0.04245	-0.05150	-0.11414 *
10	0.00740	0.03863	-0.13741 *	0.04662
11	-0.02684	-0.04562 *	0.04492	-0.24365 ***
12	-0.01764	-0.05812 **	0.04615	-0.05493
Adjusted *R*-Square	0.0706	0.098	0.3345	0.2134
Durbin-Watson	1.953	1.986	1.974	2.070
Sum of coefficients	-0.04689	-0.05742	0.16123	-0.07754

Continued…

(Appendix 7 continued)

Panel C: 16-lags

Number of Lags	Non-Bubble MSAs		Bubble MSAs	
	Pre-bubble Period	**Post-bubble Period**	**Pre-bubble Period**	**Post-bubble Period**
Intercept	0.00065 *	-0.00236 ***	0.00279 ***	0.00984 ***
1	0.21999 ***	0.19803 ***	0.54898 ***	0.03237
2	-0.10882 ***	0.09135 ***	-0.48642 ***	-0.12456 **
3	0.17832 ***	0.02455	0.54877 ***	0.32870 ***
4	-0.08917 ***	-0.13469 ***	-0.39248 ***	-0.21646 ***
5	-0.03099	-0.15524 ***	0.27316 ***	-0.07251
6	-0.02698	0.06678 **	-0.04320	0.08423
7	-0.07308 **	0.06640 **	-0.06925	0.04278
8	-0.08411 ***	-0.18035 ***	-0.10524	0.03212
9	0.04548	0.11070 ***	-0.01847	-0.00945
10	0.00160	0.02223	-0.16214 *	0.04346
11	-0.01198	-0.06224 **	0.04352	-0.27765 ***
12	0.01884	-0.06946 ***	0.12789	-0.08889
13	0.00486	0.01393	-0.19258 **	0.05007
14	-0.01384	0.00817	0.18351 **	0.01049
15	-0.02011	-0.01089	-0.10143	-0.09360
16	0.00288	-0.03854 *	0.25325 ***	0.04688
Adjusted *R*-Square	0.0942	0.1589	0.3568	0.2110
Durbin-Watson	1.963	1.937	2.031	2.004
Sum of coefficients	0.01289	-0.04927	0.40787	-0.21202

"***", "**", "*" represent significance at 1%, 5% and 10% respectively.

Appendix 8 Results of Error Equations with Local Inflation in the Fundamental (various lags)

Panel A: 8-lags

Number of Lags	Non-Bubble MSAs Pre-bubble Period	Non-Bubble MSAs Post-bubble Period	Bubble MSAs Pre-bubble Period	Bubble MSAs Post-bubble Period
Intercept	-0.00163 ***	0.00163 ***	-0.00254 ***	0.00450 ***
1	-0.05126 *	0.35149 ***	0.17341 ***	0.30734 ***
2	-0.11513 ***	-0.31355 ***	0.06033 ***	-0.02939
3	0.05640 **	0.32261 ***	0.08594 ***	0.22792 ***
4	-0.06002 **	-0.18798 ***	-0.13008 ***	-0.18111 ***
5	-0.07794 ***	0.08235	-0.12294 ***	-0.03666
6	-0.05090 **	0.02983	0.03482	0.01674
7	-0.04720 **	-0.04057	0.07411 ***	-0.10121 *
8	-0.09052 ***	-0.06091	-0.08169 ***	0.34916 ***
Adjusted *R*-Square	0.0446	0.0854	0.1917	0.2266
Durbin-Watson	1.9800	1.963	1.9890	1.951
Sum of coefficients	-0.43657	0.18327	0.0939	0.55279

Panel B: 12-lags

Number of Lags	Non-Bubble MSAs Pre-bubble Period	Non-Bubble MSAs Post-bubble Period	Bubble MSAs Pre-bubble Period	Bubble MSAs Post-bubble Period
Intercept	-0.00139 ***	0.00256 ***	-0.00242 ***	0.00841 ***
1	-0.03334	0.38500 ***	0.19820 ***	0.19789 ***
2	-0.08873 ***	-0.37852 ***	0.08625 ***	-0.15115 ***
3	0.04873 *	0.36500 ***	0.03407	0.36611 ***
4	-0.04623	-0.25366 ***	-0.11899 ***	-0.24821 ***
5	-0.06947 **	0.13173 **	-0.14020 ***	-0.03452
6	-0.01402	0.03573	0.06468 **	0.00068
7	-0.05271 **	-0.01728 **	0.05410 *	-0.06351
8	-0.11545 ***	-0.15394	-0.11180 ***	0.36649 ***
9	0.01773	0.10067	0.05457 *	-0.12022 *
10	-0.00812	-0.17881 **	0.02794	0.06897
11	-0.03055	0.08946	-0.04311	-0.27996 ***
12	-0.01969	0.00766	-0.07415 ***	-0.00499
Adjusted *R*-Square	0.0356	0.1122	0.2062	0.2496
Durbin-Watson	1.9940	1.9940	1.9520	2.0880
Sum of coefficients	-0.41185	0.13304	0.03156	0.09758

Continue…

(Appendix 8 continued)

Panel C: 16-lags

Number of Lags	**Non-Bubble MSAs**		**Bubble MSAs**	
	Pre-bubble Period	**Post-bubble Period**	**Pre-bubble Period**	**Post-bubble Period**
Intercept	-0.00135 ***	0.00287 ***	-0.00272 ***	0.01004 ***
1	0.01409	0.35994 ***	0.31673 ***	0.13401 **
2	-0.09413 ***	-0.34498 ***	-0.01439	-0.15430 **
3	0.07158 **	0.35902 ***	0.07945 ***	0.35390 ***
4	-0.07171 **	-0.28205 ***	-0.14695 ***	-0.25443 ***
5	-0.05146 *	0.18385 **	-0.11819 ***	-0.00621
6	-0.02238	0.00128	0.07680 **	0.09674
7	-0.04575	0.00041	0.04431	0.01795
8	-0.14399 ***	-0.20864 ***	-0.15929 ***	0.03153
9	0.05920 **	0.14061	0.10566 ***	0.14057
10	-0.03514	-0.25528 ***	-0.00720	-0.00722
11	-0.02240	0.10516	-0.03656	-0.31179 ***
12	-0.00498	0.00303	-0.06739 **	-0.01240
13	-0.00623	-0.10628	0.00562	0.02602
14	0.00366	0.04570	0.00054	-0.03296
15	-0.00429	-0.01619	-0.02032	-0.08671
16	0.01174	0.10674	-0.03923	0.06824
Adjusted *R*-Square	0.0469	0.2018	0.1824	0.2507
Durbin-Watson	1.9910	2.0060	1.9940	2.0350
Sum of coefficients	-0.34219	0.09232	0.01959	0.00294

"***", "**", "*" represent significance at 1%, 5% and 10% respectively

Appendix 9 Test of Differences in Variance between the Pre- and Post-Bubble Period in the Bubble and Non-Bubble MSAs in Fundamental Equations

Panel A: Separated Regressions on Non-Bubble and Bubble MSAs

Error Equation	Non-Bubble MSAs			Bubble MSAs		
	Pre-1999	**Post-1999**	**GQ Test [1]**	**Pre-1999**	**Post-1999**	**GQ Test [1]**
8-lag	1.72×10^{-4}	1.38×10^{-4}	1.2396	3.94×10^{-4}	2.94×10^{-4}	**1.3395 ***
12-lag	1.55×10^{-4}	1.44×10^{-4}	1.0791	3.90×10^{-4}	2.74×10^{-4}	**1.4236 ***
16-lag	1.51×10^{-4}	1.48×10^{-4}	1.0254	3.49×10^{-4}	2.53×10^{-4}	**1.3755 ***

Panel B: Local Inflation Added as Regressors

Error Equation	Non-Bubble MSAs			Bubble MSAs		
	Pre-1999	**Post-1999**	**GQ Test [1]**	**Pre-1999**	**Post-1999**	**GQ Test [1]**
8-lag	1.57×10^{-4}	1.18×10^{-4}	**1.33123 ***	3.90×10^{-4}	3.30×10^{-4}	1.18236
12-lag	1.50×10^{-4}	1.25×10^{-4}	1.20338	3.88×10^{-4}	2.94×10^{-4}	**1.31859 ***
16-lag	1.46×10^{-4}	1.30×10^{-4}	1.11997	3.48×10^{-4}	2.72×10^{-4}	1.27802

1. GQ Test compares the variances between the pre- and post-1999 period.

* implies that the Goldfeld-Quandt Test rejects the null hypothesis that the variances between the 8-lag and 12-lag fundamental equations are statistically the same at 5% significance level (compared to an *F*-value of 1.3)