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Five Themes of U.S. Home Price Cycles: A Unified Approach

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ABSTRACT

The U.S. housing market, after the Global Financial Crisis (GFC), has been extensively studied from several dimensions to assess the causes for the price crash. In this paper, we study and compare five themes related to house price behavior and identify common determinants that drive prices. The themes studied include the macroeconomic business cycle environment, monetary policy, the global saving glut, the fundamentals of the housing market, and lastly housing expectations which may be associated with bubbles. We employ a neural network methodology to capture and explore the relative importance of non-linear relationships not found in classical regression modeling using monthly data between key market features and house prices. Additionally, given bubble identification may be model dependent, we use the structure of model forecast errors (residuals) to identify the potential presence of bubbles. The potential presence of a bubble can be measured against the features within a model theme. CUSUM tests show potential structural breaks (bubbles) in two of our themes around the time of the GFC.

Key words: Housing prices, Great Recession, Business Cycles, Monetary Policy, Fiscal Policy, Housing Bubbles, Neural Network Methodology.

JEL Classification: E10, E32, E44, E58, E62, R31

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# Five Themes of U.S. Home Price Cycles: A Unified Approach

INTRODUCTION

Housing prices have reached levels double the previous high prior to the GFC which was considered by many a speculative bubble. The US housing market is seeing these high prices, even with new macro-prudential policies, a change in the structure of housing finances, and economic growth that has not trended higher than the pre-Global Financial Crisis (GFC) period. It is as if the housing history of booms and busts is repeating itself without any knowledge gained from the last speculative excess.

This paper contributes to our understanding of house price cycles by testing five themes that have been used to explain important aspects of housing cycles through applying them to the longer price dynamics before and after the GFC. Instead of testing a formal linear model, a neural network (NN) framework is employed to find those themes and features that have the greatest impact on housing variability. With a common modelling methodology and sample periods approximately equal, we can make comparisons among key independent variables driving housing prices and draw conclusions on the many strains of housing research applied to the GFC which may also be relevant for the more recent housing bubble of 2018-2022. Additionally, we can use the NN output to study the structure of forecast errors from our housing themes as a test for bubbles. Model errors trained on our data sets should have an expected value of zero and be iid. Systematic deviations of residuals can be a tool to identify potential bubbles. A visual inspection of residuals with CUSUM tests with formal tests allows us to identify potential bubbles as structured deviations from theme models. Across different model themes, we find some evidence surrounding the GFC for structural breaks which suggests that some models or themes cannot adequately describe housing cycle dynamics. Those who use these themes to describe the housing markets may misappropriately suggest a bubble that does not exist.

Graph 1 illustrates house prices represented by the S&P/Case-Shiller US National Home Price Index, a price index of matched sales that controls for the quality of sales. This index traces a cycle that began in 2001, grew slowly to 2004 and then accelerated until a peak in summer of 2006. The cyclical extreme declined until prices reached a low in 2012. This cycle has been viewed

as a key cause for the GFC and has been extensively studied as a unique one-off occurrence. A new cycle began slowly after 2012, until it accelerated after the COVID pandemic, starting in March 2020, and may be reversing during the second half of 2022. While many believe they have a good understanding of the housing bubble and GFC, our focus is on the extended period to 2021 and whether prominent explanations and features, what we will refer to as themes, from the GFC cycle are still applicable to the current housing price cycle. From training and testing theme features across extended housing data, we can draw inferences on: (1) the quality of the themes and features to describe housing prices, and (2) the potential presence of bubbles based on the structure of forecast errors.

Graph 1 S&P Case-Shiller US National Home Price Index

S&P/ Case-Shiller US National Home Price Index
(NSA) Index Jan 2000 =100 Monthly
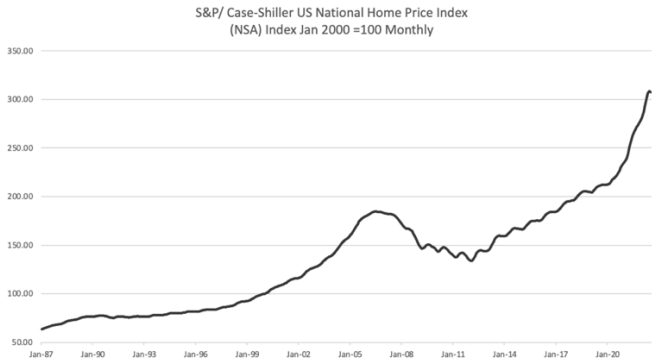
The severe housing price declines associated with the GFC caused economists to rethink both macro and micro housing relationships. For example, while macro variables such as low mortgage rates can drive housing markets, extrapolative market expectations can accentuate housing price extremes. Many policymakers view that any excess in prices were structural in nature caused by the "rules of the game" such as financing of subprime loans. Hence, changing the rules should eliminate or reduce the likelihood of another extreme housing price cycle. Nevertheless, despite structural and policy changes with respect to housing, prices over the post-GFC period and the pandemic have well exceeded the highs experienced during the pre-2008

housing boom which begs the question of what features or themes can explain another housing boom and potential bust that may exceed the amplitude and cyclicality surrounding the GFC.

This paper addresses the link between macro variables and the current US housing price dynamics through employing the economic features described in leading research articles on housing dynamics to formulate a set of alternative hypotheses. To allow for simple comparisons among these hypotheses, we use a neural network methodology to rank the independent variables or features by their relative importance. The range of standard errors across our different model themes are used to measure the relative value of themes and importance of features to explain housing prices. Additionally, the residual time series from our trained NN models are analyzed to identify potential periods when bubbles may exist.

By measuring the importance of key macro proxy variables for aggregate demand and credit that may interact in a non-linear manner, we address key issues on the link between the macro environment, housing, and the potential for bubbles. This work is suggestive of the complex impact of macro variables on housing prices. By varying the input features, and measuring the forecasting success, our neural network methodology can identify the set of inputs that best explain housing price variation. Feature inputs are assigned a relative importance value that rank orders them from greatest to smallest impact and sums to 1 for any network. This NN sensitivity analysis is useful for interpreting the importance of each input variable.

The US and international housing markets have been extensively studied since the GFC to explain the large boom and bust behavior surrounding the 2008 financial crisis and offer policy prescriptions on how to avoid another boom-bust cycle. While housing regulatory (macroprudential) policy and financial infrastructure have changed since the GFC, housing markets have now seen a new housing boom that has extended well beyond earlier highs. It is appropriate to again focus on macro fundamentals to look for key drivers in the housing cycle. Nevertheless, the link between macro variables and housing can be difficult to measure given a traditional key driver, interest rates, have been constrained by the zero bound.

Housing research has focused on the last boom and bust cycle during the GFC but has largely ignored the current boom cycle evolving during the QE and pandemic period. Housing

economic research has also centered on the micro foundations of localized household behavior and credit constraints. The housing and credit channel literature has been extensively reviewed by Glaeser and Gyourko (2018) Mian and Sufi (2018, 2019) and Duca, Muellbauer and Murphy (2021). Hence, we will not cite all the excellent research referenced in these papers especially in the Duca et al survey that has centered on finance and micro principles embedded in rent-arbitrage, inverse demand, user costs, and expectations models. These approaches do account for international spillovers and income as key drivers for housing, yet the link across a broad set of macro variables is less clear.

Overall housing research work has taken two different directions to explain the boom-bust nature of housing markets. One, macro financial work focuses on housing demand and the monetary/credit channel. Increases in income and credit will lead to increases in housing demand which pushes housing prices higher. Two, there has been an explosion of micro financial research which has focused on expectation generation, household credit conditions and constraints, and the relationship between housing and rents, an arbitrage theory, to explain the possibilities of bubbles and busts. This micro research centers on local issues to describe why some housing markets will differ markedly from others and argues that conventional macro views and policies do not properly account for the credit and household dynamics that can lead to housing boom-bust cycles.

Extracting the significant findings reported in such an enormous output of research is challenging. We propose the following: identify several important themes, generate several critical hypotheses for testing across a common testing period using monthly data, extract via a neural network methodology the relative value of different features and themes, and analyze residuals to make judgements on the potential presence of bubbles.

The themes chosen are: (1) the macro environment and how housing is related to US business cycles; (2) housing and economic policies, with special emphasis on monetary policy; (3) the global saving glut that connects US housing to the global economy; (4) the housing market environment with emphasis on supply and demand fundamentals; and finally (5) housing expectations and exuberance through extrapolative price behavior. A key conclusion is that the combination of low Fed funds and a large increase in the Fed balance sheet were critical drivers for the post-GFC boom; consequently, a reversal of monetary policy will have significant negative

effects. Nevertheless, the dominance of extrapolative expectations in the housing market creates an environment where bubbles are more likely. Bubbles, systematic deviations of model theme residuals, are often used as explanations for housing price cycles because a model may not effectively incorporate the extreme extrapolative nature of housing expectations.

The paper is divided into four sections: (1) a methodology for testing themes using a neural network, (2) a methodology for identifying potential bubbles, (3) the defining and testing of our five major housing themes and the analysis of residuals for potential bubbles, and (4) conclusions from our tests for explaining housing market price behavior.

1. <u>METHODOLOGY FOR TESTING THEMES – A NEURAL NETWORK FRAMEWORK</u>

We employ a supervised learning approach through using artificial neural networks as an alternative to linear regression to rank the importance of a set of macro and market specific variables which may have complex non-linear relationships with housing prices. Our objective is not to identify a single model to explain housing prices but to focus on the relative importance of features and themes on a complex market that has been viewed as potentially sensitive to bubbles and market crashes. By looking at the relative importance of themes, and the ability of specific features to explain housing prices, we can focus on the core macro issues associated with housing. We test specific hypotheses that have been offered to explain housing and measure relative validity of these macro housing themes through differences in model prediction errors.

We employ the IBM Modeler[1] neural network algorithm as a supervised network that feeds data forward through layers of nodes (also called neurons). The network is composed of three layers: a node for each input, an intermediary layer, referred to as a "hidden" layer that contains nodes connected to both the input and the output nodes, and a third layer consists of a single node for the output value. Each input node is connected to every node in the hidden layer with a weight.

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[1] IBM SPSS Modeler 18.0 Algorithms Guide, 2016, IBM Corporation. https://public.dhe.ibm.com/software/analytics/spss/documentation/modeler/18.0/en/AlgorithmsGuide.pdf. Tchuente and Nyawa (2022) present empirical results that show neural network methodologies outperform other techniques in real estate price estimations.

Each hidden layer node also has a weighted connection to the output node. Initial weights are assigned randomly and adjusted to minimize prediction error. The weighted connections that arrive at a node are summed and applied to a hyperbolic tangent function. The function output from each hidden layer node becomes an input into the final layer. The output from the third layer node becomes the model's target value prediction.

The model is trained through an error backpropagation algorithm to compute the first partial derivatives of the error function with respect to the weights. The weights are then adjusted based on the amount of the error, using the gradient descent method. This process is repeated until either the total error is below a specified level, or the number of data passes has exceeded a specified maximum.

Upon completing the training, a sensitivity analysis is conducted to determine the influence of each of the input variables on the output (housing prices) through varying the values of a single input variable while holding the others fixed. By observing the value of the mean squared error corresponding to each agitated input, the model can determine the sensitivity of the output to that input. The input variables are ranked by the effect of their changes on the output variable which generates a predictor importance ranking.

The sensitivity measure used to rank the predictors is $S_i = V_i/V(Y) = V(E(Y|X_i))/V(Y)$ where $V(Y)$ represents the output variance and X represents inputs. The predictor importance is the normalized sensitivity $VI_i = S_i / \sum S_j$.

2. <u>METHODOLOGY FOR TESTING BUBBLES</u>

For many, bubbles are in the eyes of the beholder which is unsatisfying for any serious economic discussion on the measurement of this phenomena. While significant work has focused on the times series of data, the unit root problem, a bubble cannot be divorced from the framework or model of the market. It is hard to say a bubble exists if there are exogeneous variables that can explain the rise or fall in price. A perceived bubble cannot be a bubble if we can find variables that drive the price behavior. A bubble can be identified or measured by the deviations (prediction errors) away from a model, a structural break from model behavior. Hence, bubble identification is conditional on the model used. Structured deviations away from a model's forecast should be suggestive of a bubble; consequently, the time series pattern of residuals can be used to test for

bubbles. CUSUM tests can measure structural breaks in a model at specific times. See Ploberger and Kramer (1992) for the testing of OLS residuals which can be used to identify and locate breaks.

The residuals for each of our theme models can be tested for structural breaks or potential bubbles; consequently, we can discuss the presence of bubbles based on different views of the world. We can observe breakage of atheoretical models through NN using different features to identify when bubbles may have occurred during training periods. Large deviations from the model in the training set is a strong test of bubbles because the model has all information prior and after the bubble. This is not a test of a model's ability to forecast out of sample, but a focus on whether a set of features can adequately find a fit that will generate forecast errors that are iid and have an expected value of zero. A model can have high forecast errors but have an expected mean of zero; however, a CUSUM, recursive residual test can be used to identify structural errors that can be viewed as bubbles. We also conducted CUSUMQ tests with results upon request.

We are not the first to associate the structure of forecast errors for the identification of bubbles Homm and Breitung (2012); however, most of this work has focused only on price series and not specific models using exogenous variables. We are the first to link an atheoretical machine learning framework across different set of features to tests the presence of bubbles in the housing market. From visual inspection of the CUSUM times series along with tests of critical values, we can identify whether model failure is consistent with when bubbles have been identified.

3. THEME TESTS

Table 1 provide an overview for all our five major themes, the test variations, and set of features. Theme 1 focuses on the business cycle and looks at seasonally and non-seasonally adjusted data. Theme 2 focuses on credit issues and monetary policy for both seasonally and non-seasonally adjusted data. Theme 3 centers on describing the savings glut story as an explanation of housing dynamics. Theme 4 looks at housing focused features, and Theme 5 accounts for expects and lags in housing prices which focus on extrapolative behavior that can lead to prices extremes or bubbles. All feature variables are scaled between 0 and 1, and we provide the ranked feature importance within each theme as well as statistics on model errors.

Table 1. Themes and features for neural network tests

Theme	Features
Housing and the business cylce	
H 1a NSA varaibles	Consumer Price Index All (CPI) annualized change, Consumer Price Index Rent annulaized chnage (CPIR), Non-Farm payroll number (NFP), Industrial Production annualized change (IP), 30-year Mortgage Rate (MORT), macro news (MACRO), and Economic Policy Uncertainty Index (EPU)
H 1b SA variables	Durable goods (DGOOD), Disposable income (DINC), Trade balance (TBAL), Employment/population ratio (EMRATIO), Unemployment level (UNEMPLOY), Industrial production (IP),
Housing driven by monetary policy	
H 2a NSA credit variables	30-year mortgage (MORT), Treasury 10-year / 2-year spread (TSREAD), Fed Funds (FFUND), EPU monetary index (EPUM).
H 2b NSA credit with Fed assets	30-year mortgage (MORT), Treasury 10-year / 2-year spread (TSPREAD), Fed Funds (FFUND), EPU monetary index (EPUM), FedAssets (FEDA).
Housing and global savings glut	
H 3a NSA variables	30-year mortgage (MORT), Treasury 10-year / 2-year spread, (TSPREAD) Fed Funds (FFUNDS) EPU monetary index (EPUM), Fed Assets. (FEDA).
H 3b SA variables	30-year mortgage (MORT), Trade Balance (TBAL) Fed funds (FFUND) EPUmonetary index (EPUM), FedAssets (FEDA).
Housing supply and demand	
H 4a NSA variables	Monthly supply of new houses (HSUPPLY), new single family houses sold (HSOLD), single family housing units completed (HCOMPL), industrial production (IP), and non-farm payroll (NFP). All NSA.
H 4b SA variables	Monthly supply of new houses (HSUPPLY), new single-family houses sold (HSOLD), single family housing units completed (HCOMPL), disposable income (DINC) durable goods (DGOOD), and trade balance (TBAL). ALL SA.
H 4c 4a plus expectations	Monthly supply of new houses (HSUPPLY), new single-family houses sold (HSOLD), single family housing units completed (HCOMPL), industrial production (IP), KC Fed stress index (STRESS), University of Michigan consumer sentiment (MCSENT), single-family units started /population level (HPOP), Houisng authorized but not started (HAUTH), and non-farm payroll (NFP All variables are NSA.
Housing and price extrapolation	
H 5a Price lags	Case Shiller prices lagged 1 period (CSLAG1) , Case Shiller prices lagged 6 periods (CSLAG6) with Fed funds (FFUND), housing units Authorized but not started (HAUTH), single family housing units completed (HCOMPL), Chicago Fed financial conditions (CFINCON), University of Michigan consumer sentiment (MCSENT), and Michigan inflation expectations (MINFEX).

3.1 FIRST THEME: HOUSING IS THE BUSINESS CYCLE

From 2001 to 2022, housing prices reached extreme levels twice, during 2003-07 and 2019-2022. At this time, we will not call these bubbles, yet many have used this term as an apt description. Leamer (2015) gives a detailed analysis of the role of housing both during the GFC, and after, arguing that "Housing really is the business cycle". He offers evidence that from 1950

to 2000, the housing cumulative contribution to GDP rose from 2% to 8%. More importantly, of the 11 recessions during this 50-year period, 9 were preceded by housing declines. Yet, the housing market over the post-GFC period seems divorced from the real economy given relative growth differences. Ziemba (2017) examines the US Housing Bubble during the GFC, the recession that followed the crash and the recovery up to 2015.

We first investigate the influence of macroeconomic variables on housing prices for the January 1992 to June 2022 period using monthly data. The independent and macro variables used are organized in two categories: features that are Not Seasonally Adjusted (NSA) and features that are Seasonally Adjusted (SA). There are both economic and statistical reasons for this distinction. All housing transactions occur with unadjusted prices. Anticipations and expectations are also not seasonally adjusted by builders, sellers, and buyers. Statistically mixing, NSA and SA impacts estimations since the SA data incorporate a filter with its own dynamics. By offering two sets of results, we enrich our understanding by testing the dynamics played by different independent variables. In several cases, when important variables are available in only one mode, only NSA or only SA, we allow for some mixing with some caution in interpreting results.[2]

Hypothesis 1a. Case Shiller National Home Price Index NSA is driven by macro variables. The non-seasonally adjusted (NSA) data set ranges from January 1987 through June 2022 and includes the consumer price all index NSA (CPI), consumer price rent index NSA (CPIR), Non-farm payroll NSA (NFP), industrial production NSA (IP), 30-year Mortgage Rate (MORT), macro news (MACRO), and the Economic Policy Uncertainty Index (EPU) to capture overall macro risk. These independent variables are chosen among a large set of macro data available to capture relationships between house prices and consumer prices, the consumer price index measuring rent as a relevant alternative opportunity cost to purchase, non-farm payroll, and industrial production are proxies for GDP. The 30-year mortgage rate is the primary variable that measures house financing and affordability. A macro news and the economic policy uncertainty index serves as proxies for the scope of financial conditions.

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[2] The data and detailed results are available from the authors.

Figure 1. H1a. Case-Shiller National Home Price Index NSA macro variable sensitivity
Period: 1987- June 2022

Source FRED database: Consumer price index all (CPI) annualized change, Consumer price index rent annualized change (CPIR), Non-Farm payroll number (NFP), Industrial Production annualized change (IP), 30-year mortgage rate (MORT), macro news (MACRO), and Economic policy uncertainty Index (EPU). Data scaled between 0 and 1 and sensitivities sum to 1

The results are generally expected but also surprising in that the most important variable with weight 0.341 is the CPI rent component that does not play a central role in business cycle aggregate demand analysis but proxies for the cost of overall housing. The other two important features, employment and industrial production, are key business cycles variables but play less importance in explaining housing variability.

Hypothesis 1b. Case Shiller National Home Price Index SA is driven by macro variables. Seasonally adjusted macroeconomic variables are introduced in this hypothesis for the period 1992 – June 2022, and the dependent variable is also seasonally adjusted. Disposable income (DINC), durable goods (DGOOD), industrial production (IP), trade balance (TBAL), and unemployment (UNEMPLOY) are all closely connected to business cycles; employment to population ratio (EMRATIO) is introduced to adjust employment relative to population size. The results show that durable goods, disposable income, and trade balance are the three most important drivers.

Figure 2. H1b. Case-Shiller National Home Price Index SA macro variable sensitivity
Period: 1987- June 2022.
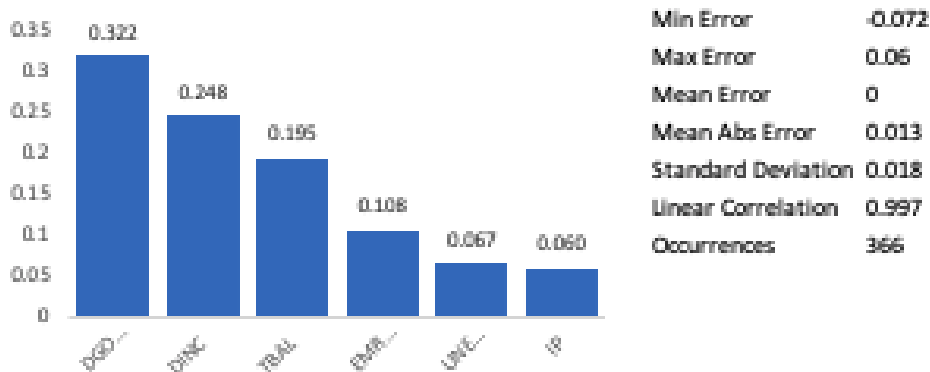
Source FRED database: Durable goods (DGOOD), Disposable income (DINC), Trade balance (TBAL), Employment/population ratio (EMRATIO), Unemployment level (UNEMPLOY), Industrial production (IP). Data scaled between 0 and 1 and sensitivities sum to 1.

Comparing the NSA and SA analysis, cyclical housing behavior is driven by traditional macroeconomic variables such as industrial production, durable goods, disposable income, non-Farm payroll and two special factors that are relevant to housing: CPI rent and trade balance. The SA tests notably have half the mean absolute error and half the standard deviation as the NSA test. There is a clear contemporaneous business cycle effect that includes a trade component. Housing cycles, as expected, are congruent with the business cycle.

The conclusion of these two hypotheses is that housing cycles play an important part in national US economic cycles and Leamer's core thesis extends beyond the GFC, with an implication that any current declines in housing prices may lead or be coincident to an economic recession. The use of both NSA and SA data with the two hypotheses confirm that different macroeconomic variables connect housing prices to cyclical macroeconomic variables. More specifically, for NSA data, the three most important cyclical variables are the CPI rent, industrial production, and non-farm payroll while for SA data, durable goods, disposable income, and trade balance emerge as most important.

3.2 SECOND THEME: HOUSING IS DRIVEN BY MONETARY POLICY

The second theme examines the impact of monetary policy on housing prices. A major debate arose soon after the GFC between Taylor and Bernanke as to the causes of the pre-GFC housing bubble and its bursting. Once housing prices started declining in late 2006 and continued their decline to 2008, several non-bank financial institutions experienced major drops in values of their housing and real estate investments, declines in their collateral values, and exposure to heavy debts. The bankruptcy of Lehman Brothers in September 2008 set the stage for a financial panic that exacerbated an economic recession that started December 2007 and ended in June 2009.
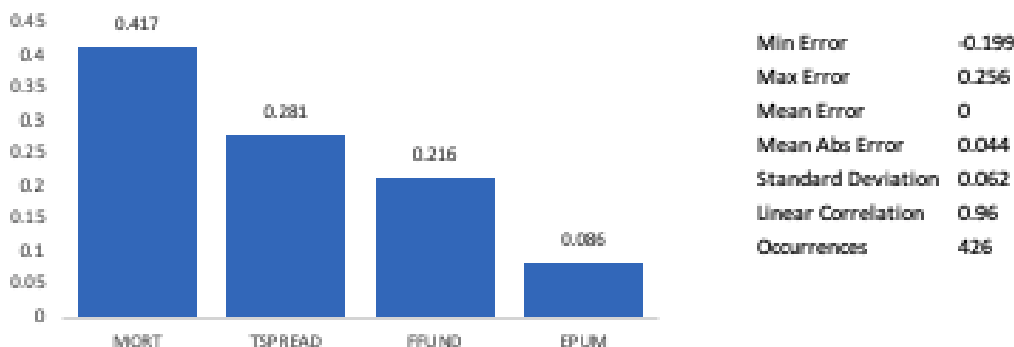
Taylor (2007, 2009) argued that US housing was stimulated by an easy monetary policy during the 2001-2004 period when the Fed kept Fed funds at very low levels for an extended period fueling a housing bubble. In view of Taylor's arguments, we propose to consider monetary policy as an important driver of housing prices. A detailed presentation of the role of monetary policy and housing is given in Bhar Ramaprasad and A. Malliaris, (2021).

While Taylor describes the Fed funds rate as the key tool of monetary policy, this tool was supplemented by QE. In Hypothesis 2a we test the role of Fed funds with other financial variables while in Hypothesis 2b we place an emphasis on Fed Assets accumulated via QE. Sample periods differ since there is little movement in Fed's balance sheet (no QE) prior to the GFC.

NSA housing prices for the longer sample (1987 to June 2022) are driven by the 30-year mortgage rate and the difference between the 10-year and 2-Year Treasury rate, which measure the slope of the yield curve while the Fed funds rate ranks as the third factor. However, when a similar exercise is performed for a shorter period of 2003 to June 2022, Fed assets becomes most important followed by Fed funds. These two variables together dominate the 30-year mortgage rate as the key drivers of housing behavior.

Hypothesis 2a <u>Housing prices NSA and monetary policy.</u> The Case Shiller National Home Price Index NSA is impacted by monetary policy expressed by the Fed funds, the 10-year Treasury minus 2-year spread, 30-year mortgage rate and an economic policy uncertainty index to capture the changes in policy expectations from 1987 to June 2022.

Figure 3. H2a. Case-Shiller National Home Price Index NSA monetary policy sensitivity
Period: 1987- June 2022

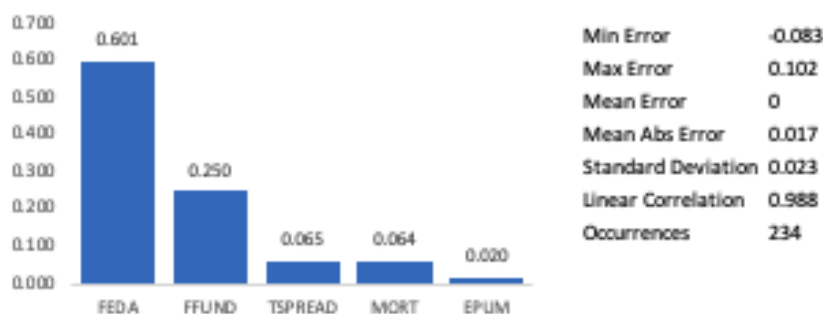|		
Min Error	-0.199
Max Error	0.256
Mean Error	0
Mean Abs Error	0.044
Standard Deviation	0.062
Linear Correlation	0.96
Occurrences	426

Source FRED database: 30-year mortgage (MORT), Treasury 10-year / 2-year spread
(TSREAD), Fed Funds (FFUND), EPU monetary index (EPUM). Data scaled between 0 and 1
and sensitivities sum to 1.

The results of this hypothesis support the conclusion that NSA house prices are driven by the 30-year mortgage rate, the term structure of interest rates represented by the 10-year less the 2-year spread, and Fed funds rate. However, the monetary policy variables as a theme have much less explanatory power then our business cycle theme models. The dispersion in errors is much higher.

Hypothesis 2b. Housing prices and monetary policy including Fed assets. When we study the behavior of the same dependent variable by introducing assets on the Fed balance sheet, this variable becomes the most important. What is especially notable is the low mean absolute error for the post-GFC monetary model theme with Fed assets even with the Fed funds rate tied closely to zero. Hypotheses 2a and 2b confirm that the housing market is impacted by monetary policy, initially and up to the GFC by rates and Fed funds policy and after the GFC by QE.

Figure 4. H2b. Case-Shiller National Home Price Index NSA monetary policy sensitivity
Period: 1992 - June 2022.

Min Error	-0.083
Max Error	0.102
Mean Error	0
Mean Abs Error	0.017
Standard Deviation	0.023
Linear Correlation	0.988
Occurrences	234

Source FRED database: 30-year mortgage (MORT), Treasury 10-year / 2-year spread
(TSPREAD), Fed Funds (FFUND), EPU monetary index (EPUM), Fed assets
(FEDA). Data scaled between 0 and 1 and sensitivities sum to 1.

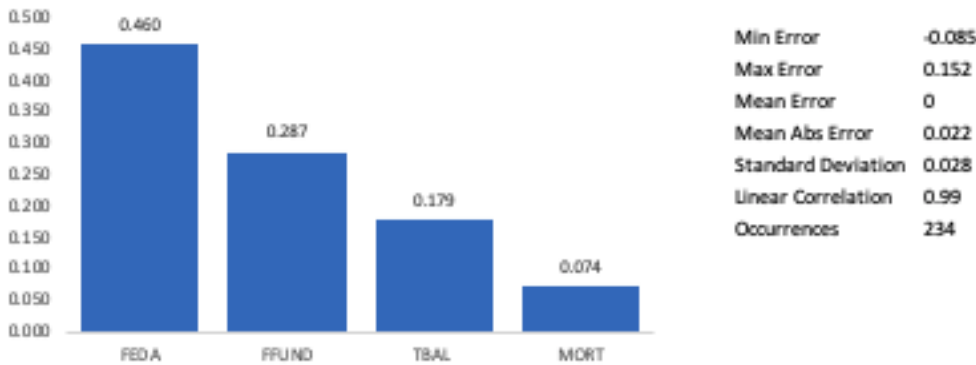## 3.3 THIRD THEME: HOUSING IS DRIVEN BY THE GLOBAL SAVING GLUT

Bernanke (2005, 2007a, 2007b, 2009, 2010) in a series of papers debated Taylor and argued that there was a global glut of savings that came to the US to be invested that strengthened the dollar and lowered mortgage rates. Several papers have evaluated these two competing theories and Sa, Filipa and Tomasz Wieladex. (2015) offer some evidence that it was the global saving glut that lowered longer term interest rates. Steiberg (2019) distinguishes between global saving glut and domestic saving drought. Recently, Evgenides and Malliaris (2022) re-evaluate the drivers of the pre-GFC housing boom and the 2019 to 2022 recent housing bubble and show that the global saving glut was more important in the first bubble, but QE played a much bigger role during the recent housing bubble.

This hypothesis is challenging because we compare drivers that are NSA as in Hypotheses 2a and 2b with the global savings glut using the trade balance as a proxy that is only available as SA. To moderate this statistical difficulty of mixing SA and NSA data, we use 2 models, expressed as H.3a and H3b. **Hypothesis 3a** Housing prices (NSA) with monetary policy and trade balance. **Hypothesis 3b** Housing prices (SA) and monetary policy and trade balance.

In the first case, Case Shiller NSA is explained by Fed funds, Fed total assets, the 30-year mortgage rate (all 3 NSA) and the trade balance. The second case considers the Case Shiller SA
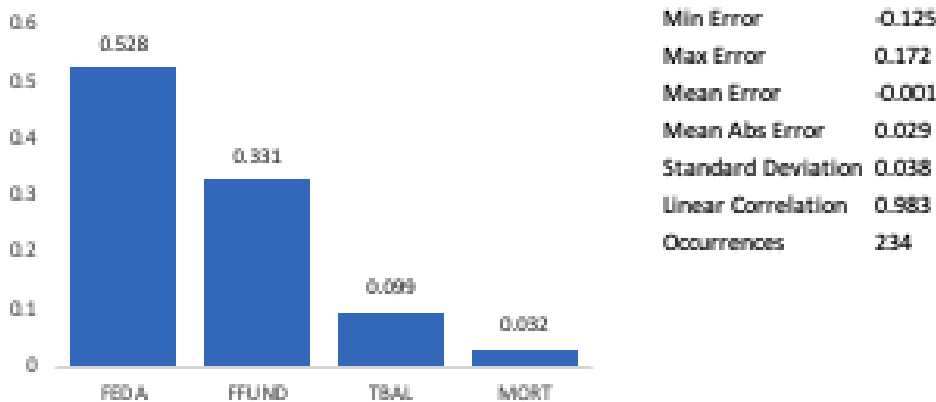
dependent variable with the same independent variables to see whether the global saving glut (trade balance) emerges as an important variable. Adjusting for seasonality does not influence the results.

Figure 5. H3a. Case-Shiller National Home Price Index NSA monetary policy sensitivity
Period: January 1987- June 2022

Min Error	-0.085
Max Error	0.152
Mean Error	0
Mean Abs Error	0.022
Standard Deviation	0.028
Linear Correlation	0.99
Occurrences	234

Source FRED database: 30-year mortgage (MORT), Trade Balance (TBAL) Fed Funds (FFUNDS) EPU monetary index (EPUM), Fed Assets. (FEDA) Data standardized and scaled between 0 and 1.

Figure 6. H3b Case-Shiller National Home Price Index NSA monetary policy sensitivity
Period: January 2003- June 2022.

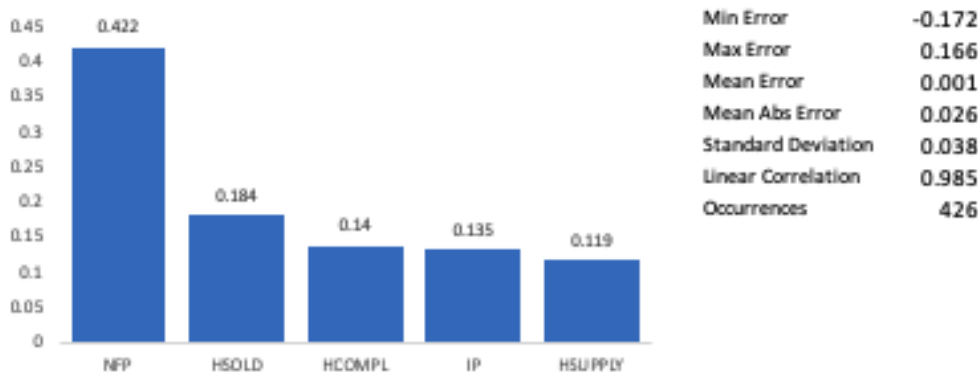|	
Min Error	-0.125
Max Error	0.172
Mean Error	-0.001
Mean Abs Error	0.029
Standard Deviation	0.038
Linear Correlation	0.983
Occurrences	234

Source FRED database: 30-year mortgage (MORT), Trade Balance (TBAL) Fed funds (FFUND) EPU monetary index (EPUM), Fed Assets (FEDA). Data

3.4 FOURTH THEME: HOUSING AS AN INDUSTRIAL SECTOR: SUPPLY AND DEMAND

Next, we examine the housing market with specific supply and demand information based on the recent broad housing research surveys of Glaeser and Gyourko (2018) and Duca et.al (2021). Erdman (2023) focuses on supply and demand fundamentals in metropolitan areas.

Hypothesis 4a Housing prices (NSA) and micro supply and macro demand factors. Case Shiller NSA housing prices are explained by supply variables: monthly supply of new houses, new single-family houses sold, single-family housing units completed as well as industrial production and non-farm payroll. Note we have no data for explicit housing demand other than proxies for aggregate demand which focus on business cycle.

Figure 7. H4a Housing prices and micro supply and macro demand factors
Period: 1987- June 2022

	Min Error	-0.172
	Max Error	0.166
	Mean Error	0.001
	Mean Abs Error	0.026
	Standard Deviation	0.038
	Linear Correlation	0.985
	Occurrences	426

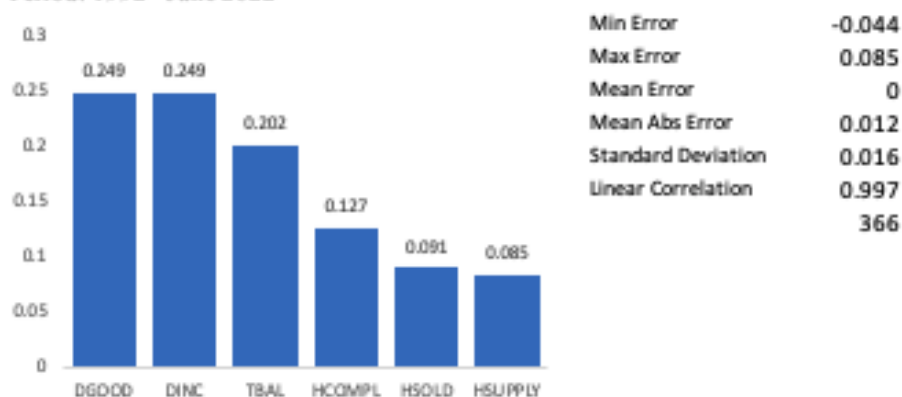Bar chart values: NFP 0.422, HSOLD 0.184, HCOMPL 0.14, IP 0.135, HSUPPLY 0.119

Source FRED database: Monthly supply of new houses (HSUPPLY), new single-family houses sold (HSOLD), single family housing units completed (HCOMPL), industrial production (IP), and non-farm payroll (NFP) Variables are NSA. Data standardized and scaled between 0 and 1.

For the case of NSA variables, these findings tell a story that the fundamentals of the housing markets such as houses completed, houses supplied, and houses sold have important influences on housing but also the demand side through employment and to a lesser extent industrial production are key drivers versus supply variables.

Hypothesis 4b <u>Housing prices (SA) and micro supply and demand factors</u>. For the Case-Shiller SA housing version test, we include data for demand. Case Shiller SA is explained by new single-family houses sold, single family housing completed, single-family housing started, disposable income, durable goods, and trade balance (demand by foreigners). Data extends from 1992 through June 2022.

Figure 8 H4b Housing Prices (SA) and micro supply and demand factors
Period: 1992 - June 2022

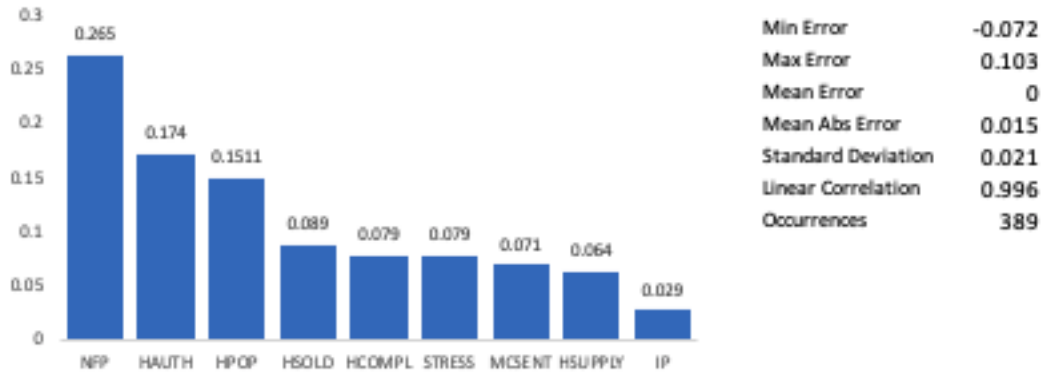| Min Error | -0.044 |
Max Error	0.085
Mean Error	0
Mean Abs Error	0.012
Standard Deviation	0.016
Linear Correlation	0.997
	366

Source FRED database: Monthly supply of new houses (HSUPPLY), new single-family houses sold (HSOLD), single family housing units completed (HCOMPL), disposable income (DINC) PCE durable goods (DGOOD), and trade balance (TBAL). Variables are SA. Data standardized and scaled between 0 and 1.

These results confirm earlier theme analysis where SA cyclical variables such as disposable income, trade balances, and durable goods spending drive housing prices. Supply variables represented by houses started, houses completed, and houses sold play a lesser role. One implication is that supply of housing appears less elastic and housing prices are driven by cyclical factors caused by demand shifts. Supply has little impact on price and only responds to demand through rising prices.

Hypothesis 4c <u>Housing prices and expectations</u>. This hypothesis is motivated by Piazzesi and Schneider (2016) and Kuchler, Piazzesi and Stroebel (2022) on housing expectation as measured by the Michigan Consumer Sentiment Index and its numerous components. We add to hypothesis 4a four new features: Housing units authorized but not started, single-family units

started/population level; Michigan consumer sentiment; and the Kansas City financial stress index. In this case, we find significant improvement based on a decline of standard error in the model versus 4a.

Figure 9 H4c Housing Prices micro supply and demand factors with expectations
Period: Feb 1990 - June 2022

Metric	Value
Min Error	-0.072
Max Error	0.103
Mean Error	0
Mean Abs Error	0.015
Standard Deviation	0.021
Linear Correlation	0.996
Occurrences	389

Bar chart values:
- NFP: 0.265
- HAUTH: 0.174
- HPOP: 0.1511
- HSOLD: 0.089
- HCOMPL: 0.079
- STRESS: 0.079
- MCSENT: 0.071
- HSUPPLY: 0.064
- IP: 0.029

Source FRED database: Monthly supply of new houses (HSUPPLY), new single-family houses sold (HSOLD), single family housing units completed (HCOMPL), industrial production (IP), KC Fed stress index (STRESS), University of Michigan consumer sentiment (MCSENT), single-family units started /population level (HPOP), Houisng authorized but not started (HAUTH), and non-farm payroll (NFP All variables are NSA. Data standardized and scaled between 0 and 1.

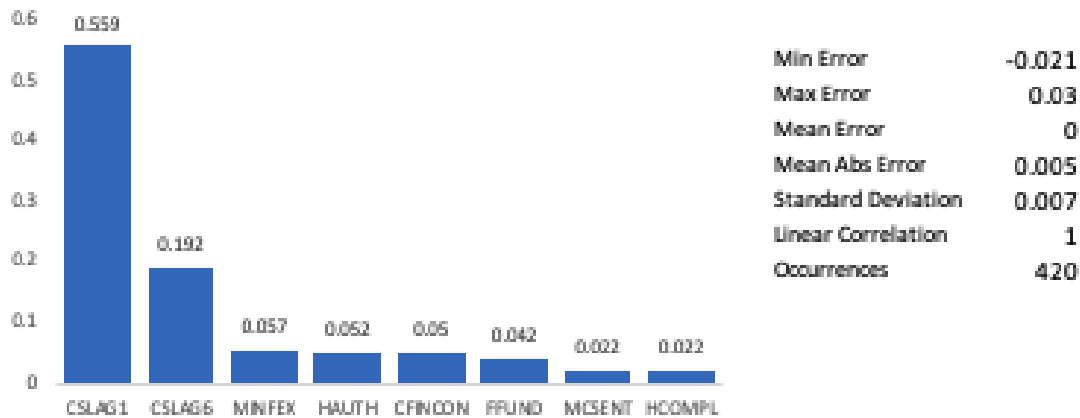## 3.5 FIFTH THEME: HOUSING BUBBLES BASED ON PRICE EXTRAPOLATION

The literature on asset bubbles essentially faces a major challenge: are bubbles truly bubbles if prices are driven by certain economic and financial variables? Specifically, we want to test the importance of past prices as a driver for housing price behavior relative to key exogenous macro and micro variables. If these key macro variables still represent most of the variation in housing prices than the question of a bubble becomes more complex. Housing prices are responding to changes in the business cycle, monetary policy, and sector specific variables. Housing is cyclical, but these cycles may not demonstrate bubble behavior. Alternatively, if extrapolative behavior explains most of the variation in housing prices, then we can say that the positive feedback loop from past trends drives price extremes and dominates any exogenous variables. This hypothesis is based on momentum and bubble work by the cumulative work developed by Piazzesi et al (2016, 2020), Meyer (2011), Glaeser et al (2018), and other surveys.

Basco and Schäfer-i-Paradís (2022) follow a different methodology by proposing a model free test of rational bubbles applied to US Housing and conclude that a bubble occurred only during 2002-06.

Hypothesis 5 <u>Price extrapolation as the key driver of housing prices.</u> Using all NSA data, Case Shiller lagged 1 period, Case Shiller lagged 6 periods, with Fed funds, housing units Authorized but not started, single Family Housing Completed, Chicago Fed financial conditions, Michigan consumer sentiment, and Michigan inflation expectations.

The 1-lag captures the momentum that may self-drive housing prices. The 6-lag measures the memory of past prices and its strength. Beyond these variables we also include some important variables for housing expectations, other past prices such as inflation expectations, indicators such as housing permits for housing not started, completed houses that may reduce or fuel current prices, financial conditions evaluated in surveys and other. The results show the core importance of extrapolative expectations as the key driver of housing market behavior.

Figure 10. H5 Housing prices with lags
Period 1992-June2022

Min Error	-0.021
Max Error	0.03
Mean Error	0
Mean Abs Error	0.005
Standard Deviation	0.007
Linear Correlation	1
Occurrences	420

Source FRED database: Case Shiller prices lagged 1 period (CSLAG1), Case Shiller prices lagged 6 periods (CSLAG6) with Fed funds (FFUND), housing units Authorized but not started (HAUTH), single-family housing units completed (HCOMPL), Chicago Fed financial conditions (CFINCON), University of Michigan consumer sentiment (MCSENT), and Michigan inflation expectations (MINFEX). Monthly Data standardized and scaled between 0 and 1.

The past price components with lag 1 and lag 6 dominate and explain about 80% of the housing variation. Outside of the lag effects, the other two important variables are inflation expectations, housing units authorized but not started, followed by Fed Funds and Financial conditions. A minor variation of H5a is to delete the weakest non-autoregressive variables to check if the neural network identifies any improvement. Fewer variables increase the importance of autoregressive modeling and shows overall improvement, results available from authors.

3.6 COMPARISON OF RESULTS AND BUBBLE TESTS

A comparison of our themes is included in Table 2 which breaks down the five themes across the two hypotheses for each. We find the themes have different explanatory power based on the mean absolute error, the maximum and minimum error and standard error. The price extrapolation theme which suggests the potential for bubble extremes dominates all models even when the set of features are restricted. On a relative basis, the theme that includes housing specific information outperforms themes that focus on macro variables, the business cycle, monetary policy, and the savings glut themes.

Table 2. Comparison of themes using neural network models

Figure X. Comparison of themes using neural network models

	Theme 1: Housing and the busness cycle		Theme 2: Housing driven by monetary policy		Theme 3: Housing and global savings glut		Theme 4: Housing supply and demand			Theme 5: Housing and price
	H1a NSA variables	H1b SA variables	H2a NSA variables	H2b Fed assets	H3a NSA variables	H3b Fed assets	H4a NSA variables	H4b SA Variables	H4c NSA variables	H5: price lags variables
Max error	0.106	0.06	0.256	0.102	0.152	0.172	0.166	0.085	0.103	0.03
Min error	-0.122	-0.072	-0.199	0.083	-0.085	-0.125	-0.172	-0.044	-0.072	-0.021
mean abs error	0.028	0.013	0.044	0.017	0.022	0.029	0.026	0.012	0.015	0.005
std dev	0.04	0.018	0.062	0.023	0.028	0.038	0.038	0.016	0.021	0.007
CUSUM test	reject *, **	accept	reject **	accept	accept	accept	accept	accept	accept	accept

* reject at .05 level, ** reject at .10 level of no structrual break (bubble) in the model

The investigation of the first theme clearly shows that housing is closely tied to business cycles. Among various NSA macro variables, CPI Rent, and industrial production dominant as drivers of housing variation while durable goods and disposable income are the SA macro variables that are most important.

An analysis of the role of credit and monetary policy shows that among the NSA variables, the 30-year mortgage rate and the 10-year 2-year Treasury rate spread are the leading variables. However, introducing Fed assets after the GFC, shows that it overtakes the 30-year mortgage rate as the explanation for housing prices. The extensive availability of money and credit drives the surge in housing prices over the last decade. When monetary policy is compared with the global saving glut, SA factors such as the trade balance and disposable income still emerge as important drivers of housing prices.

The fundamentals of supply and demand for housing such as durable goods and disposable income drive housing demand among SA variables. Employment, houses completed, and houses sold emerge among NSA variables as important features. Introducing new privately-owned housing units started to the population level becomes important as a measure of speculation; as housing prices increase, the number of single-family units started adjusted to population level also increases.

If, as some authors claim, that there is a persistent deficit of several million houses in the US (between 3 to 5 million homes assuming a certain level of population and a desired level of home ownership), the supply of housing is rather inelastic. The story that good macro conditions, a global saving glut, and easy monetary policies fuel increased housing demand can explain the bubble in housing prices during the past 25 years. The University of Michigan sentiment index and the Kansas City financial condition stress index do not play any special role in terms of housing expectations. Lastly, we introduced 1 and 6 period lags in house index to investigate the role of extrapolative forecasts and find strong empirical evidence that both lags dominate other features. Past prices play an important role in explaining the variation in housing prices. Extrapolative expectations fueled by quantitative easing which provides excess credit supply along with the story of a savings glut cause more extreme price moves in housing. While all our themes have some validity, the dominance of extrapolative expectations with easy credit provide a combined theme

consistent with bubble discussions. However, we want to look at dislocations from identified features as a further analysis of bubbles.

Graph 2. CUSUM chart examples for H1a and H4c with upper and lower bounds for critical .05 level
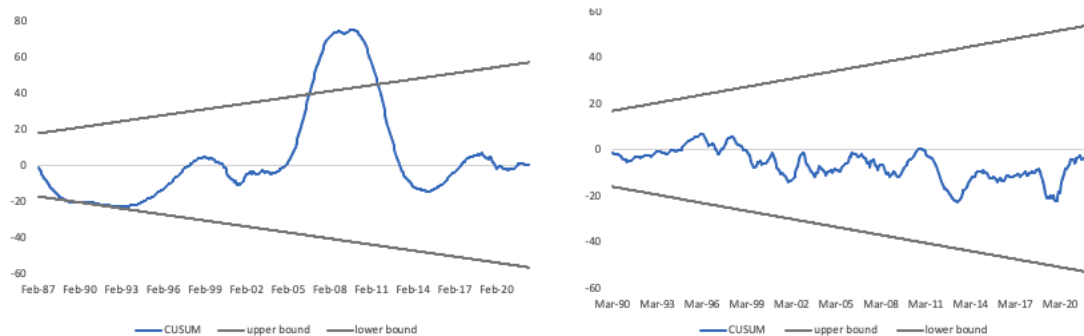
For illustrative purpose we show the CUSUM for two themes H1a and H4b. See Graph 2. We also test for whether residuals stay within the CUSUM bounds for all our themes and reported in Table 2. Notice the clear positive CUSUM, actual greater than predicted, for the period prior to the GFC and the switch to negative after the GFC, actual less than predicted, and then a return to normal only to reappear in the last two years. Different themes will have different CUSUM patterns which suggest the possibility of structural breaks. For example, our business cycle theme shows that actual standardized prices well exceeded the predicted value only then fall over the crisis. This pattern is not found when we use extrapolative price information in the model or in many of our other models. This suggests that bubble identification through structural breaks is model dependent. Price extremes may not represent a bubble without testing some form of fundamental model.

CONCLUSIONS

We have chosen 5 central themes to study US housing and for each one of these we have considered both non-seasonally adjusted (NSA) and seasonally adjusted (SA) data, when available. We have also considered similar periods for our samples and the same methodology. The purpose of our contribution is to help select some important features that can help explain cyclical behavior

of housing prices and the emergence of the 2004-06 first housing bubble and its bursting that led to the GFC; we also wish to understand the second housing boom surrounding the COVID pandemic which seems to be past its peak with a correction taking place.

Our tests for bubble using our five themes suggests that some themes will conclude there were housing bubbles (structural breaks) while a theme that focuses on extrapolative prices will not show the presence of a bubble (structural break) but confirms that the formation of expectations is a key driver for the housing market.

Any bubble is conditional on a model and the features used to describe the market environment. This concept of model specification and bubbles advances our understanding of the housing market and supports the identification of market themes. The wedding of themes through trained features using a machine learning (NN) approach with explicit tests of residuals can serve as an effective framework for more broadly analyzing market bubbles.

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