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ARTICLE

# Off-track monetary policy and housing

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**Abstract**

We find significant evidence of model misspecification, in the form of neglected serial correlation, in the econometric model of the U.S. housing market used by Taylor (2007) in his critique of monetary policy following the 2001 recession. When we account for that serial correlation, his model fails to replicate the historical paths of housing starts and house price inflation. Further modifications allow us to capture both the housing boom and the bust. Our results suggest that the counterfactual monetary policy proposed by Taylor (2007) would not have averted the pre-financial crisis collapse in the housing market. Additional analysis implies that the burst of house price inflation during the COVID-19 pandemic was not caused by the deviations from the Taylor rule that occurred during this period.

**Keywords:** Monetary policy; housing; Taylor rule; financial crisis

## 1. Introduction

Taylor (2007) employs simulations from an econometric model of the U.S. housing market he estimates to argue that the primary cause behind the housing boom and bust that preceded the 2007–2009 financial crisis was the Federal Open Market Committee's decision to keep the federal funds rate below the values implied by the Taylor rule from 2002 to 2006.[1] Taylor (2009, p. 4) amplifies this claim by asserting that this "off-track" monetary policy also caused the crisis itself. The number of citations for Taylor (2007) suggests that the paper's influence has been substantial.

Taylor's argument can be summarized by Figure 1, which reproduces Chart 1 of Taylor (2007), and the top-left graph in Figure 2, which—minus its 95% forecast bands—replicates Chart 3 of Taylor (2007).[2] Figure 1 shows the actual values of the federal funds rate as well as a counterfactual federal funds rate series, constructed using the Taylor rule, from the beginning of 2000 to the eve of the seizing up of credit markets in August of 2007. Taylor uses these two federal funds rate series in his model to compute the dynamic forecasts of U.S. housing starts shown in the top-left graph in Figure 2. Under the counterfactual monetary policy scenario, the housing boom and turnaround are far more moderate, from which Taylor concludes that the associated turbulence in financial markets would have been much less severe.[3]

Taylor's (2007) discussion uses housing starts as a proxy for the macroeconomic importance of the housing market. Interestingly, Taylor does not discuss his model's house price inflation forecasts; we provide these in the top-left graph in Figure 3.[4] We note that most of the literature on housing market-related causes of the financial crisis focuses on the behavior of house prices rather than housing starts; see, e.g., Adelino et al. (2018a), Berger et al. (2018), and Mian et al. (2013).

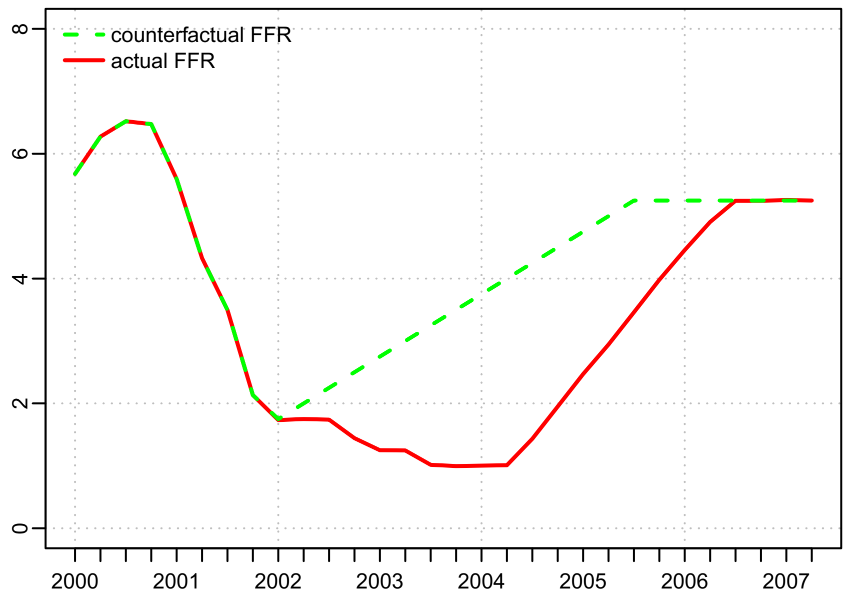


**Figure 1.** Taylor (2007) counterfactual Federal Funds Rate Scenario, 2000q1–2007q2.
Notes: The same two federal funds rate paths above are shown in Chart 1 of Taylor (2007). The counterfactual series was determined by the Taylor rule, but with smoothing of the Taylor rule-implied values so that increases are in 25 basis point increments; it is higher than the actual fed funds rate from 2002q2 until 2006q2.

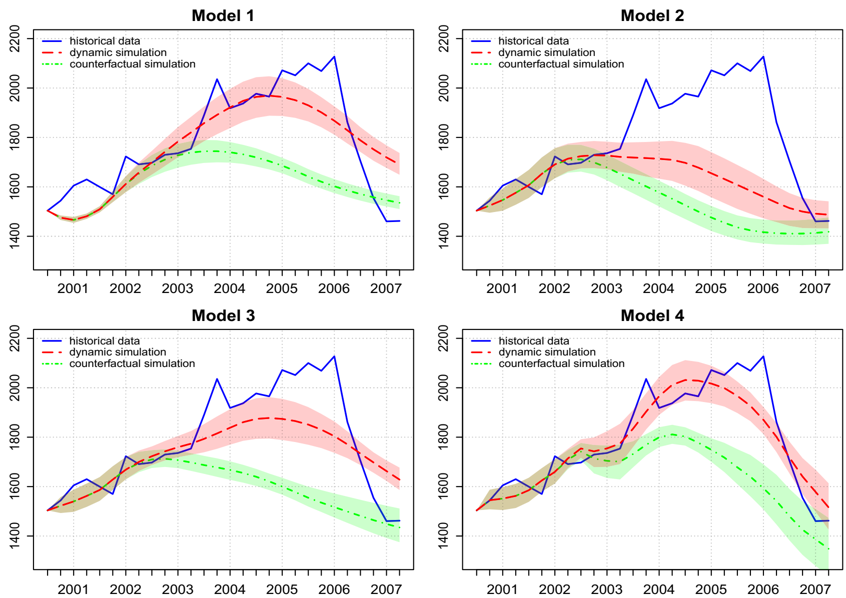


**Figure 2.** Housing starts simulations.
Notes: The housing starts series is measured in thousands of units. The dynamic simulations were generated by computing dynamic in-sample forecasts for 2000q4–2007q2 for each of the models in Table 1, using the actual values of the federal funds rate over this period; the simulated value for 2000q4 is the 1-step-ahead forecast, the simulated value for 2001q1 is the 2-step-ahead forecast, etc. The models in Table 1 were estimated using data for the 1987q1–2007q2 sample period. The counterfactual simulations were computed similarly, but using the counterfactual federal funds rate series shown in Figure 1. We follow Taylor (2007) in referring to these dynamic forecasts as "dynamic simulations" and "counterfactual simulations." The shaded areas represent bootstrapped 95% forecast bands.

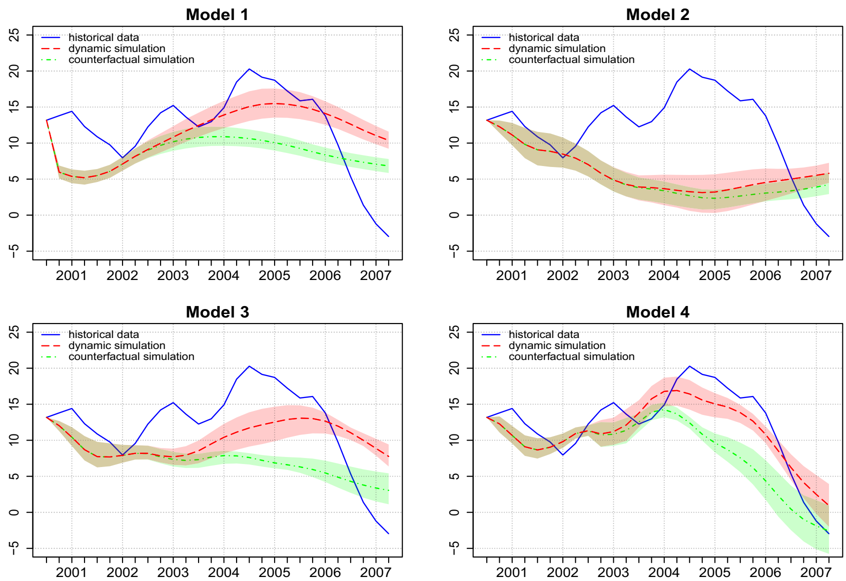


**Figure 3.** House price inflation simulations.
Notes: The house price inflation series is measured in percentages. The historical data are computed using the Case-Shiller U.S. National Home Price Index. Also, see the notes for Figure 2.

The main purpose of this paper is to examine the econometric specification Taylor (2007) uses and, within his framework, to revisit the policy question of whether an alternative path for the federal funds rate would have moderated the housing boom and bust. We find strong evidence of model misspecification in the form of neglected serial correlation. When we adjust the specification to remove this serial correlation, the fit of Taylor's model to the historical paths of both housing starts and house price inflation considerably worsens. We show that further modifications in the model's specification, such as including a financial uncertainty measure, produce economically significant changes in the dynamic forecasts. In particular, our preferred model captures the boom and its subsequent bust in both the housing starts and house price inflation series.[5]

This model yields the following policy implications. Under the counterfactual federal funds rate path, the housing starts boom would have indeed been moderated; but it would nonetheless have been followed by a precipitous decline. More importantly, the counterfactual policy scenario would have had a far weaker moderating effect on house price inflation. These results suggest that the role of federal funds rate deviations from Taylor-rule-implied values in setting the stage for the financial crisis was smaller than what Taylor (2007, 2009) claims.

When we extend our analysis to include the COVID-19 pandemic, we find that the then large deviations from the Taylor rule were not responsible for the burst of house price inflation in this period. Accordingly, while recent research has established a link between high house price growth and high overall inflation during the pandemic, e.g., Aladangady et al. (2022) and Liu et al. (2022), our results suggest that this link does not reflect monetary policy's failure to adhere sufficiently closely to the Taylor rule.

The theoretical foundation for Taylor's investigation of the relationship between the federal funds rate and the housing market is ambiguous. Interest rate changes in Poterba's (1984) user cost of housing model have a strong effect on house demand and prices. In this framework, the expected annual cost of owning a unit structure equals the cost of renting it. When monetary policy changes short-term interest rates, the user cost of housing changes and shifts occur in housing

**Table 1.** Model specifications and diagnostics

| Model | Specification | AIC, SIC | $Q(4)$, $Q(8)$ |
|---|---|---|---|
| 1 | $hs_t = \alpha_0 + \alpha_1 ffr_t + \alpha_2 hs_{t-1} + \alpha_3 \pi_t^h + \epsilon_t^{hs}$ | | 0.929, 0.773 |
| | $\pi_t^h = \beta_0 + \beta_1 hs_{t-1} + \epsilon_t^{\pi h}$ | | 0.000, 0.000 |
| 2 | $hs_t$ equation same as in Model 1 | | |
| | $\pi_t^h = \beta_0 + \beta_1 hs_{t-1} + \sum_{i=1}^{6} \gamma_i \pi_{t-i}^h + \epsilon_t^{\pi h}$ | 0.454, 0.493 | 0.550, 0.379 |
| 3 | $hs_t$ equation same as in Model 1 | | |
| | $\pi_t^h = \beta_0 + \beta_1 ffr_{t-1} + \sum_{i=1}^{6} \gamma_i \pi_{t-i}^h + \epsilon_t^{\pi h}$ | 0.441, 0.480 | 0.604, 0.336 |
| 4 | $hs_t = \alpha_0 + \alpha_1 ffr_t + \alpha_2 hs_{t-1} + \alpha_3 \pi_t^h + \alpha_4 vix_{t-1} + \epsilon_t^{hs}$ | 0.998, 1.000 | 0.962, 0.730 |
| | $\pi_t^h = \beta_0 + \beta_1 ffr_{t-1} + \sum_{i=1}^{6} \gamma_i \pi_{t-i}^h + \sum_{j=1}^{2} \theta_j vix_{t-j} + \epsilon_t^{\pi h}$ | 0.435, 0.484 | 0.271, 0.147 |

Notes: Variable definitions: $hs$ = housing starts, $\pi^h$ = house price inflation measured by Case-Shiller index, $ffr$ = Effective Federal Funds Rate, $vix$ = Chicago Board Options Exchange S&P 500 Volatility Index, $\epsilon^{hs}$ = error term in housing starts equation, and $\epsilon^{\pi h}$ = error term in house price inflation equation. The data on $hs$, $\pi^h$, and $ffr$ are the same as those used by Taylor (2007); the data on $vix$ were downloaded from the St. Louis FRED database. Sample period: 1987q1–2007q2. All models estimated by OLS. The column labeled 'AIC, SIC' shows the value of the Akaike Information Criterion and Schwarz Information Criterion for each equation in each model relative to the corresponding measures for Model 1; Model 1 values in the denominator. The column labeled '$Q(4)$, $Q(8)$' shows the $p$−values for the Ljung-Box $Q$−test of the white noise null hypothesis run on, respectively, the first four and eight residual autocorrelations.

demand.[6] However, in Glaeser et al. (2013) extended user cost model, the impact of interest rate changes on housing market activity is much weaker than in Poterba-like models.[7]

Further, the deposits channel of monetary policy of Drechsler et al. (2017) implies that federal funds rate increases of the sort that occurred in 2003–2006 would, all else equal, cause a shift of non-conforming mortgage funding out of the regulated banking system into the shadow banking system. Indeed, Drechsler et al. (2022) find that, while this Fed tightening led to a moderate decrease in overall pre-crisis mortgage lending, it accounts for most of the increase in the share of private-label securitization funding of non-GSE mortgages issued in this period. This raises the possibility that even higher increases in the federal funds rate of the sort Taylor (2007, 2009) argues should have occurred in this period would have led to an even larger shift to more run-prone mortgage funding, i.e., to an even larger buildup of macroeconomic risk.[8]

Results in the literature examining the impact of monetary policy on the US housing market in the run-up to the financial crisis are mixed.[9] Jarocinski and Smets (2008) and Eickmeier and Hofmann (2013) find that monetary policy played an important role in generating the pre-crisis housing boom and bust. Luciani (2015), however, concludes that the impact of monetary policy on that housing cycle was minor. Further, Greenwald (2018) shows that, relative to the loosening of credit standards (in particular, increases in the payment-to-income ratio for home mortgages), the role of interest rates in explaining this housing boom was small. Greenwald's (2018) result complements Bernanke's (2010) conclusion that regulatory policy, in comparison to monetary policy, was a more decisive driver of the expansion in the housing market before the financial crisis.

In Section 2, we carry out our main econometric analysis. We perform some robustness checks and extensions in Section 3. Section 4 concludes.

## 2. Models and simulations

Our main results are collected in Table 1, Figure 2, and Figure 3.[10] Table 1 presents the specifications of the models used and AIC, SIC, and Ljung-Box $Q$-test results for the estimated models; the sample period is 1987q1 to 2007q2. Our housing starts and house price inflation simulations are shown, respectively, in Figures 2 and 3; these simulations run from 2000q4 to 2007q2. In these figures, three time series are plotted in the graph associated with each estimated model: the historical data for the variable in question (solid blue line); the dynamic in-sample forecasts generated by the model using the historical data for the federal funds rate (dashed red line); and the dynamic in-sample forecasts obtained using the counterfactual federal funds rate series (dash-dotted green line) discussed above and displayed in Figure 1. We adopt Taylor's (2007) terminology and refer to these dynamic forecasts as, respectively, "dynamic simulations" and "counterfactual simulations." The shaded area around each simulation is a sequence of bootstrapped 95% forecast bands.

### 2.1 Model 1: Taylor's model

Model 1, which is the model Taylor (2007) uses to generate the simulations shown in his Chart 3, has two equations: a housing starts equation and a house price inflation equation. Each equation is estimated separately by ordinary least squares (OLS). The contemporaneous values of the federal funds rate ($ffr_t$) and house price inflation ($\pi_t^h$) are regressors in the housing starts equation, which also includes a lagged dependent variable ($\pi_{t-1}^h$).[11] The only regressor in the house price inflation equation is the lag-1 value of housing starts ($hs_{t-1}$). The Ljung-Box $Q$-test finds no evidence of residual serial correlation for the estimated housing starts equation. In contrast, the white noise null hypothesis is strongly rejected for the residuals of the estimated house price inflation equation.

As shown in Figure 2, Model 1's dynamic simulation for housing starts replicates well the behavior of the actual data through 2005; but it fails to capture the sharp drop in the series from 2006 to 2007.[12] The forecast bands around the dynamic and counterfactual housing starts simulations for Model 1 initially overlap. From 2003q4 through 2007q2, the counterfactual simulation is statistically significantly below the dynamic simulation.

Similar results in Figure 2 hold for Model 1's house price inflation simulations: the dynamic simulation misses the abrupt decrease at the end of the period; and the counterfactual forecast bands eventually move below the dynamic forecast bands. Further, house price inflation arguably remains quite high in the counterfactual simulation, e.g., in the range of 6% to 8% in the first half of 2007. This suggests that the deterioration in the quality of mortgage loans and associated underestimation of mortgage default risk would not have abated under the counterfactual federal funds rate policy; see, e.g., Demyanyk and Van Hemert (2011) and Adelino et al. (2018b).

### 2.2 Model 2: adjusting for serial correlation

Model 2 retains the housing starts equation from Model 1 and adjusts the specification of the house price inflation equation to obtain white noise residuals. This allows us to address the question of whether Model 1's simulations are driven by misspecified house price inflation dynamics. Here we do this by exploring if a richer lag structure using that equation's variables allows us to account for this residual serial correlation. We found it is necessary and sufficient to add six lags of $\pi_t^h$ in order for the $p$-value of the Ljung-Box $Q$-test to be pushed above conventional significance levels. This specification change leads to over a 50% decrease in the AIC and SIC relative to those for Model 1's estimated house price inflation equation.

The dynamic simulations for Model 2 shown in Figures 2 and 3 fail to replicate the post-2002 historical paths for both housing starts and house price inflation; they miss the housing market boom and, as a by-product, also miss the bust. The poor performance of the housing starts dynamic simulation is driven by the large bias of the house price inflation dynamic simulation. To see why, first note that Model 2's house price inflation counterfactual simulation is nearly identical to its dynamic simulation. This is due to the coefficient on $hs_{t-1}$ in Model 2's house price inflation equation being economically and statistically insignificant, such that this equation is approximately an autoregressive model of order 6 (AR(6)) and house price inflation is effectively

**Table 2.** Housing starts and house price inflation estimated equations

| Dependent variable: $hs_t$ | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| $ffr_t$ | −18.223*** | −18.223*** | −18.223*** | −17.875*** |
| | (4.221) | (4.221) | (4.221) | (4.139) |
| $hs_{t-1}$ | 0.734*** | 0.734*** | 0.734*** | 0.676*** |
| | (0.057) | (0.057) | (0.057) | (0.063) |
| $\pi_t^h$ | 7.761*** | 7.761*** | 7.761*** | 10.672*** |
| | (2.158) | (2.158) | (2.158) | (2.559) |
| $vix_{t-1}$ | | | | −2.933** |
| | | | | (1.453) |
| $\bar{R}^2$ | 0.929 | 0.929 | 0.929 | 0.932 |
| Observations | 78 | 78 | 78 | 78v |
| **Dependent variable: $\pi_t^h$** | **Model 1** | **Model 2** | **Model 3** | **Model 4** |
| $hs_{t-1}$ | 0.020*** | 0.000† | | |
| | (0.002) | (0.001) | | |
| $ffr_{t-1}$ | | | −0.135** | −0.138** |
| | | | (0.056) | (0.057) |
| $vix_{t-1}$ | | | | −0.022‡ |
| | | | | (0.035) |
| $vix_{t-2}$ | | | | 0.062*‡ |
| | | | | (0.034) |
| $\pi_{t-1}^h$ | | 1.964*** | 1.913*** | 1.917*** |
| | | (0.110) | (0.103) | (0.104) |
| $\pi_{t-2}^h$ | | −1.381*** | −1.316*** | −1.348*** |
| | | (0.219) | (0.211) | (0.207) |
| $\pi_{t-3}^h$ | | 0.711*** | 0.681*** | 0.680*** |
| | | (0.247) | (0.237) | (0.230) |
| $\pi_{t-4}^h$ | | −0.987*** | −0.957*** | −0.918*** |
| | | (0.245) | (0.235) | (0.230) |
| $\pi_{t-5}^h$ | | 1.228*** | 1.194*** | 1.171*** |
| | | (0.222) | (0.211) | (0.206) |
| $\pi_{t-6}^h$ | | −0.595*** | −0.573*** | −0.569*** |
| | | (0.112) | (0.106) | (0.103) |
| $\bar{R}^2$ | 0.671 | 0.983 | 0.985 | 0.986 |
| Observations | 78 | 72 | 72 | 72 |

Notes: The table reports OLS estimated coefficients; standard errors in parentheses. Regressions include a constant. See Table 1 for more details. ***, **, and * denotes statistical significance at 1%, 5%, and 10% level. †Less than $10^{-3}$. ‡When $vix_{t-1}$ is excluded from Model 4, the coefficient on $vix_{t-2}$ is significant at the 5% level and the associated simulations are almost identical to those obtained with Model 4.

exogenous. Next, the estimated AR(6) model is stationary and, insofar as its forecast bands contain the sample mean of 6.6% from 2003 onwards, its dynamic forecasts converge rather quickly to the sample mean. However, these forecasts are strongly biased down. Finally, these biased house price inflation forecasts are used to generate the housing starts dynamic simulation, which in turn is also downward biased.[13]

### 2.3 Model 3: incorporating federal funds rate

Model 3 also retains the housing starts equation from Model 1, but we change the specification of Model 2's house price inflation equation by replacing $hs_{t-1}$ with $ffr_{t-1}$. We do so because, in Model 2, house price inflation responds only indirectly to the federal funds rate via an estimated coefficient (on the lag-1 value of housing starts) that is indistinguishable from zero.[14] The coefficient on $ffr_{t-1}$ in Model 3's estimated house price inflation equation is negative and significant. This specification change leads to slightly lower AIC and SIC values relative to those for Model 2.

Model 3's housing starts dynamic simulation captures some of the housing boom and, like Model 1's housing starts dynamic simulation, misses the sharp 2006–2007 drop in the series. The forecast bands around Model 3's dynamic and counterfactual housing starts simulations do not overlap from late 2003 onwards.

The forecast bands for Model 3's house price inflation dynamic simulation intersect the historical data for only a single observation past 2002. While this simulation is an improvement over its analog from Model 2, it clearly is deficient. As in Model 1, house price inflation stays rather high in the counterfactual simulation.

### 2.4 Model 4: accounting for financial uncertainty

Finally, we consider the effect of introducing a standard measure of financial uncertainty in our econometric model. Our motivation for doing so is based on Bloom (2009), Ludvigson et al. (2021), and others, who have established the importance of financial uncertainty shocks for U.S. business cycle dynamics. Following Bloom (2009), Bloom (2014), and Carr and Wu (2006), we use the Chicago Board of Options Exchange VIX series as our proxy for uncertainty.[15] We modify our model by adding lags of VIX to both the housing starts and house price inflation equations.[16] The number of lags included is determined via the AIC and SIC and our decision, as per standard practice, to exclude specifications with subset distributed lag dynamics.[17] This specification change leads to a moderate improvement over Model 3's estimated equations as per the AIC.

When we model VIX as an AR(1) process, we obtain white noise residuals. Further, when we augment this AR(1) specification with lags of housing starts, house price inflation, and the federal funds rate, there is no improvement in fit. In addition, we find that housing starts, house price inflation, and the federal funds rate do not Granger cause VIX in bivariate Granger causality tests. Accordingly, we treat VIX as exogenous and do not introduce a separate VIX equation to Model 4. The apparent exogeneity of VIX in our model is consistent with Ludvigson et al.'s (2021) finding that financial market uncertainty, which they distinguish from macroeconomic and policy uncertainty, is a source of business cycle fluctuations.[18]

Figure 2 shows that the forecast bands for Model 4's housing starts dynamic simulation include the historical data for most of the observations. This stands in sharp contrast to our earlier models, especially with respect to the bust in the series. From mid 2003 on, the dynamic and counterfactual simulations' forecast bands do not overlap until the end of the sample. While Model 4 suggests that the housing starts boom would have been initially moderated under the alternative monetary policy rule, in both simulations the market collapses to the same level as found in the actual data. Insofar as the maximum-to-minimum drops in the dynamic and counterfactual simulated series are 25% and 26%, the busts are virtually identical in the two cases; the decrease in the historical data is 31%.

Model 4's house price inflation dynamic simulation also captures the boom and the bust in the actual data, as seen in Figure 3. At the peaks of the two simulated series, the associated forecast bands overlap. Following those peaks, the bands initially do not intersect; but they overlap at the end of the sample. The maximum-to-minimum drops in the dynamic and counterfactual simulated series are very similar, 16 and 17 percentage points, respectively; the historical house price inflation series decreases 23 percentage points during the bust.

Since Model 4's dynamic simulations replicate well the boom and the bust in both housing starts and house price inflation, it is our preferred model. Using this model, the collapse in the housing market is quite similar across the dynamic and counterfactual simulations. This implies that the associated fallout in financial markets would likely not have been significantly mitigated under the alternative monetary policy scenario.

## 3. Extensions

In this section, we consider three extensions of our analysis. First, we examine the robustness of our Model 4 results with respect to use of alternative financial uncertainty measures. Second, we employ a longer data set to explore the robustness of our Model 4 results to estimating the model with a sample that begins earlier than the one Taylor (2007) uses. Third, we analyze the extent to which Model 4 captures housing dynamics for other episodes of interest.

### *3.1 Alternative uncertainty measures*

In Section 2.4, we show that adding a financial uncertainty measure, the VIX index, to our model allows us to capture well the historical behavior of both housing starts and house price inflation. Many other (other than the VIX index) financial uncertainty proxies have received attention in the literature.[19] Here we analyze the effect on Model 4's simulations of substituting such alternative financial uncertainty measures, one at a time, for VIX.

The additional proxies for financial uncertainty we use are: the Ludvigson et al., (2021) 3-month-ahead financial uncertainty measure (LMN); the Baker et al. (2019) overall equity market volatility index (EMV); and the Chicago Fed's National Financial Conditions Index (NFCI). As with the VIX index, when each of these financial uncertainty measures is modeled as an AR($p$) process, we obtain white noise residuals and, accordingly, treat these series as exogenous.[20]

Our results are shown in Figure 4. The dynamic and counterfactual simulations for both housing starts and house price inflation generated by proxying financial uncertainty with LMN and EMV are very similar to those obtained with VIX in the following senses. First, the forecast bands overlap at the end of the sample. Second, the busts represented by the maximum-to-minimum percentage drops are nearly identical across both types of simulations for each financial uncertainty measure.

When we replace VIX with NFCI, two differences stand out. The forecast bands do not overlap by the end of the sample; the counterfactual bands lie below those for the dynamic simulations. However, the percentage maximum-to-minimum decreases are larger in the counterfactual simulations, i.e., the housing starts and house price inflation busts are more severe in the counterfactual scenarios.

To summarize, the crashes in housing starts and house price inflation we obtain using these VIX alternatives are quite similar to those generated by Model 4.

### *3.2 Extending the sample backward*

The Case-Shiller U.S. National Home Price Index begins in 1987, yielding arguably short samples for estimation of our (and Taylor's) equations. As a robustness check, we redo our analysis of Model 4 in Section 2.4 with a longer house price series, i.e., the Freddie Mac House Price Index (FMHPI) for the U.S. Since the Freddie Mac series begins in 1975, this gives us 48 additional quarterly observations. This requires that we use an alternative to VIX as a measure of financial

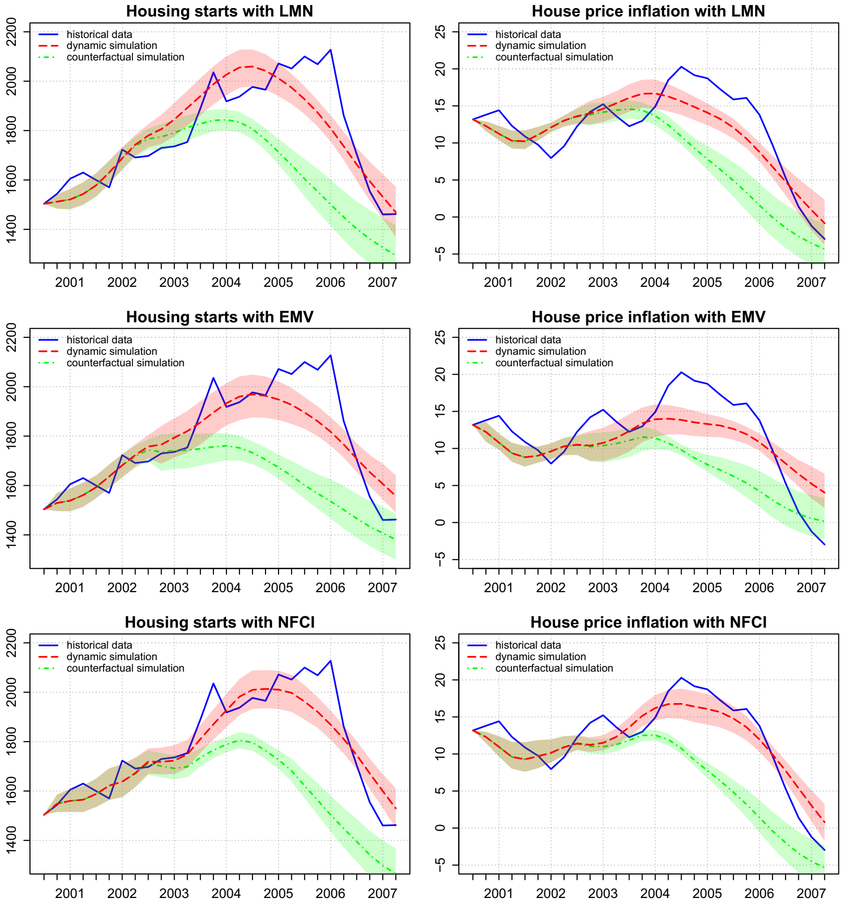


**Figure 4.** Robustness of model 4 to using alternative financial uncertainty measures.
Notes: The specifications of the models used for these simulations are identical to that of Model 4 with one change: these models replace the VIX index with an alternative measure of financial uncertainty. The acronyms "LMN," "EMV," and "NFCI" denote, respectively, the Ludvigson et al.'s (2021) 3-month-ahead financial uncertainty measure, the Baker et al.'s (2019) overall equity market volatility index, and the Chicago Fed's National Financial Conditions Index. Also, see the notes for Figure 2.

uncertainty, since our extended VIX series begins in 1986. We consider two such alternatives, LMN and NFCI, because both series extend back to 1975; the EMV series begins in 1985.

When we use Model 4's specification with FMHPI and, in turn, LMN and NFCI, there is significant serial correlation in the residuals of the housing starts equation of the model. Adding five additional of $hs_t$ to the housing starts equation leads to white noise residuals when we use NFCI as the financial uncertainty measure; with these additional lags of $hs_t$, we still obtain non-white noise residuals when LMN is used. Accordingly, below we discuss the dynamic and counterfactual simulations with financial uncertainty proxied by NFCI.

Our simulations are shown in Figure 5. For housing starts, use of the longer series leads to a 23% maximum-to-minimum drop in the dynamic simulation; this is quite close to the 25% drop in Model 4. In the counterfactual scenario with the extended estimation period, the associated decrease is 21%.

Using FMHPI, the historical bust in house price inflation is 13%. With the longer sample, the maximum-to-minimum drop in the dynamic simulation is 8%; so close to two–thirds of

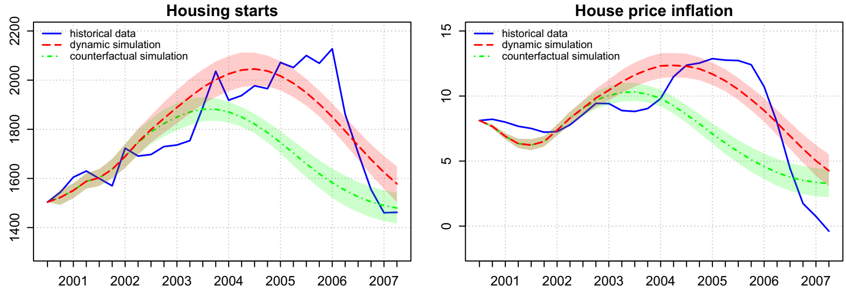


**Figure 5.** Robustness of model 4 to using estimation window with earlier start.
Notes: The model used for these simulations was estimated over a longer sample period, 1976q1–2007q2. Its specification is almost identical to that of Model 4 (our preferred model as per the discussion in Section 2.4). The differences with Model 4 are as follows: the housing starts equation features six lags of housing starts, instead of one lag, to obtain white noise residuals; house price inflation is measured by the Freddie Mac House Price index as opposed to the Case-Shiller National Home Price index; financial uncertainty is proxied by the Chicago Fed National Financial Conditions Index instead of VIX. Also, see the notes for Figure 2.

this historical drop is captured by the dynamic simulation. This is quite similar to the relative magnitudes of the house price inflation busts in the analogous simulations in Model 4. In the counterfactual simulation, the eventual drop in FMHPI inflation is 7%.

For both housing starts and house price inflation the forecast bands for the dynamic and counterfactual simulations overlap at the end of the sample when using the longer estimation window. This also occurs for Model 4.

### *3.3 Other episodes of interest*

Our primary motivation in Section 2 in moving from Model 2 to Model 4, our preferred model, is to explore whether we can develop an econometric specification capable of capturing the housing boom and bust that was a key cause of the financial crisis of 2007–2009. To provide further evidence in support of Model 4's specification, we demonstrate that it can replicate the historical data for some other periods of interest. We also consider counterfactual scenarios for these periods.[21] In this exercise, we focus on the housing market around the 1990–1991 recession (when the preceding bust in the housing market before the one that led to the Great Recession occurred) and after the Great Recession.

In the left panel of Figure 6, we plot the actual and counterfactual federal funds rate series in the top graph, and the dynamic and counterfactual simulations from Model 4 for housing starts and house price inflation over the 1989q2–1995q4 period in the middle and bottom graphs, respectively. We note that for the first three years of the simulation period, the actual and counterfactual federal reserve rate series are quite close; but from 1992q1 to 1993q4, the actual federal funds rate is 100 or more basis points below what is implied by the Taylor rule from 1992q1 to 1993q4.

The housing starts dynamic forecast bands encompass most of the historical data for the first three years; they do not capture the depth of the trough in 1991. They replicate the secular increase in the series that follows; but the lower limits of the bands are somewhat higher than the historical values. The performance of the house price inflation dynamic simulation is quite similar, with the exception that its forecast bands include the 1991 trough in the historical data. For both housing starts and house price inflation, the counterfactual forecast bands mostly overlap the dynamic forecast bands.

In the right panel of Figure 6, we plot the federal funds rate series and Model 4 simulations for the 2011q1–2023q4 period.[22] For most of the pre-COVID-19 pandemic period, the actual federal funds is below, at times by more than 100 basis points, the Taylor rule implied value. In the latter

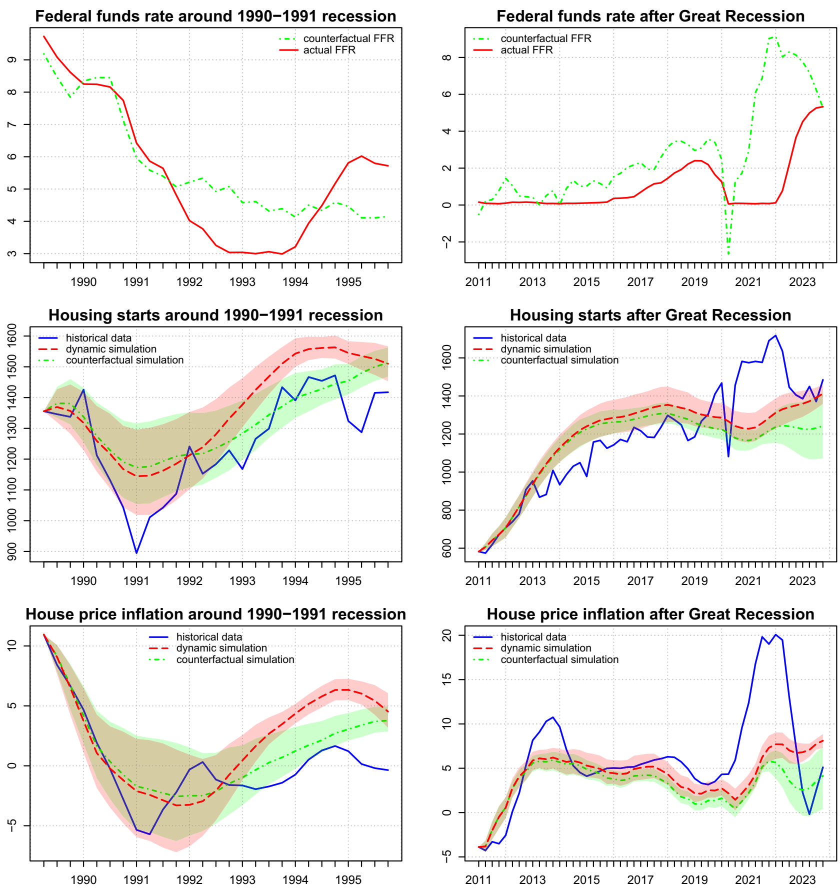


**Figure 6.** Model 4's simulations in other periods of interest.
Notes: Time series plots of the actual and counterfactual federal funds rates are shown in the top row for the two periods focused on; we use the *Taylor93GDP* series from the Federal Reserve Bank of Atlanta's Taylor Rule Utility as our measure of the counterfactual federal funds rate. The simulations in the left panel were generated by computing dynamic and counterfactual in-sample forecasts for 1989q2–1995q4 using Model 4 in Table 1. The simulations in the right panel were generated for 2011q1–2023q4 using Model 4 estimated over the 1988q1–2023q4 sample period.

part of the sample, the differences are much larger, i.e., after the NBER-identified trough of the pandemic recession, the average spread between the counterfactual and actual federal funds rate is 387 basis points.[23]

The housing starts dynamic simulation captures well the sustained increase in the historical data over this period. The narrow forecast bands for the first few years of the simulation include almost all of the historical housing starts data. Past this point, the forecast bands either cover or lie just above the historical values up to the onset of the pandemic. For most of 2020–2022, the dynamic simulation is biased downwards. For the last year of the sample, the historical housing starts values are mostly within the dynamic simulation's forecast bands. Throughout the 2011q1–2023q4 period, the dynamic and counterfactual simulations' forecast bands overlap.[24]

For house price inflation, the dynamic simulation forecast bands cover most of the historical data; but they undershoot the series around the 2013 peak and, to a much larger degree, during the pandemic period. The dynamic and counterfactual house price inflation simulations' forecast bands overlap for almost all observations during this period.

Why do Model 4's dynamic simulations strongly underpredict the historical data, for both housing starts and house price inflation, during most of the COVID-19 pandemic period? We speculate that this is due to our model missing the apparent increased demand for housing induced by the transition to remote work for many sectors of the U.S. labor force during this period; see, e.g., Mondragon and Wieland (2022).

## 4. Conclusions

There is strong evidence of dynamic misspecification in the house price inflation equation of Taylor's (2007) model that best simulates the behavior of the housing market in the buildup to the financial crisis of 2007–2009. His dynamic and counterfactual simulations are not robust to accounting for the residual serial correlation in that equation; see the discussion above of our Models 1 and 2.

In Taylor's model, house price inflation depends indirectly on the federal funds rate. When we allow house price inflation to directly respond to changes in the federal funds rate, the associated dynamic simulation provides an improved, but still deficient, fit to the historical data; see the discussion of our Model 3. We find that adding a measure of financial uncertainty to our Model 3 is helpful in modeling the historical paths of housing starts and house price inflation. This is done in our Model 4, which is our preferred model. In particular, through use of such a variable we are able to capture both the booms and the busts in these series; these results go through when we use alternative measures of financial uncertainty. We provide further support for Model 4's specification by using longer sample periods and by focusing on other periods of interest, i.e., the behavior of the housing market around the 1990–1991 recession and after the Great Recession.

Our main policy conclusion from Model 4 is that the pre-financial crisis housing bust would not have been averted under the counterfactual monetary policy advocated by Taylor (2007, 2009). By extension, we find that deviations from the Taylor rule were not a fundamental cause of the financial crisis of 2007–2009. As noted in our Introduction, other researchers, using different econometric approaches, have reported evidence both in favor of and against Taylor's critique of monetary policy from this period.

Dynamic simulations from Model 4 also replicate well housing market behavior during the long and slow recovery from the Great Recession up to the outbreak of the COVID-19 pandemic. During most of the pandemic period, the model's dynamic simulations are negatively biased. Conditional on the substantial overlap between the dynamic and counterfactual simulations, we conclude that the rapid acceleration of house price inflation during the pandemic period was not caused by deviations from Taylor rule implied values for the federal funds rate.

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## Notes

**1** We label this model 'Model 1' in Table 1.

**2** We focus on the model behind Taylor's Chart 3 since: (i) as Taylor (2007, p. 468) notes, it explains more of the housing bust than the initial model he considers; (ii) in contrast to that initial model, this model allows one to address the behavior of house price inflation; and (iii) inclusion of house price inflation in the model is supported by Granger causality testing.

**3** Objection can be raised against such an exercise along the lines of the Lucas (1976) critique. However, Rudebusch (2005) demonstrates that parameter estimates of reduced form coefficients can be quite stable in the presence of a change in the monetary policy rule under rational expectations.

**4** The Case-Shiller U.S. National Home Price index is used to compute the house price inflation series.

**5** We label this model 'Model 4' in Table 1.

**6** Mishkin (2001 p. 364) discusses the equivalence between two specifications of the user cost of housing equation: one uses a short-term interest rate and an alternative uses the long-term mortgage rate (which responds to expected future short-term rates).
**7** The model extensions that lead to this weaker impact include: (i) the possibility that personal discount rates are not equal to market interest rates; (ii) allowing housing supply to be highly elastic in the short run; and (iii) introducing household mobility and the ability to refinance in the presence of mean-reverting and volatile interest rates.
**8** Xiao's (2020) model also emphasizes the likely shift of funding from commercial banks to shadow banks in the wake of monetary tightening. Justiniano et al. (2022) identify a mortgage rate conundrum that occurred in the wake of the beginning of monetary policy tightening in 2003; they argue that this disconnect between mortgage rates and the steepening of the Treasury yield curve was due to a shift in the mortgage industry toward origination of non-conforming and riskier mortgages.
**9** Here we discuss a few salient examples from that literature; our discussion is not meant to be exhaustive. We note that the papers discussed in Kuttner's (2013) survey find, on the whole, that interest rates have a smaller impact on house prices than expected from the user cost model.
**10** The definitions of the variables we use are shown in the notes for Table 1. Coefficient estimates for these models are presented in Table 2.
**11** Use of the contemporaneous value of house price inflation raises concerns about an endogenous regressor. However, replacing this regressor by its lag-1 value leads to nearly identical simulated series. This is also the case for all of the other specifications we consider.
**12** Taylor (2007, p. 468) refers to this bust in housing starts as a "Shiller swoosh."
**13** Given this large downward bias, we do not focus on a comparison between Model 2's housing starts dynamic and counterfactual simulations.
**14** We find that while house price inflation Granger-causes housing starts, housing starts do not Granger-cause house price inflation. This is different from the two-way Granger causality between the two series that Taylor (2007, p. 468) reports. This difference is due to our use of six lags in testing whether housing starts Granger-cause house price inflation; as noted in Section 2.2, six lags of house price inflation are required in order to remove residual serial correlation. We also find that the federal funds rate Granger-causes house price inflation.
**15** In Section 3.1, we consider using alternatives to VIX as a measure of financial uncertainty.
**16** The VIX index commences in 1990q1. We extend it for the earlier part of our sample using the growth rates of a closely related series, VXO, which measures the option-implied volatility of the S&P 100 Index.
**17** In a subset distributed lag model, some of the intermediate coefficients are constrained to equal zero.
**18** When we endogenize VIX, the forecast bands for the dynamic and counterfactual simulations overlap those we obtain when we treat VIX as exogenous. In the equation we add, VIX is modeled as a function of lagged values of itself, house price inflation, and the federal funds rate.
**19** See, for example, Cascaldi-Garcia and Galvao (2021).
**20** As we do for the VIX index, when we treat these financial uncertainty measures as endogenous we obtain simulations whose forecast bands overlap the forecast bands generated when these variables are made exogenous.
**21** For the counterfactual scenarios, we use Taylor rule implied values of the federal funds rate from the Federal Reserve Bank of Atlanta's Taylor Rule Utility (https://www.atlantafed.org/cqer/research/taylor-rule); we use the series *Taylor93GDP*.
**22** These simulations are generated via Model 4 estimated over the 1988q1–2023q4 sample period.
**23** For two observations, 2011q1 and 2020q2, the counterfactual federal funds rate series is negative, violating the zero lower bound constraint for the policy rate. We note that the simulations in the right panel of Figure 6 we discuss below are robust to replacing those two negative values with zero.
**24** The Federal Reserve has actively used tools of unconventional monetary policy, e.g., forward guidance and large-scale asset purchases, from the outbreak of the financial crisis of 2007–2009 onward. As such, the actual federal funds might not provide an accurate measure of the stance of monetary policy during this period. To assess the sensitivity of the simulation results shown in the right panel of Figure 6 to our use of the actual federal funds rate, we generated analogous simulations using the Wu and Xia (2016) shadow federal funds rate and obtained nearly identical results. We ran the same type of robustness check for the Model 4 results in Figures 2 and 3 and the simulations in the left panel of Figure 6; the results are strongly similar to those we report in the paper.

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