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Is There an Asymmetric Impact of Housing on Output?

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Abstract

Numerous papers have tried to understand housing's role in the economy and have not reached an agreement. In this paper we turn to the asymmetric relationship between housing and the overall economic activity. We find that the relation between building permits and GDP is regime-dependent. Causality analysis suggests that the housing variable leads output only in the regime associated with periods when the housing and business cycles are experiencing contractions. Our findings not only echo the argument that housing leads the business cycles, but also show that it has time-varying effect on the overall economic activity.

Keywords: Housing, Business Cycles, Regime-switching, Causality

JEL classification: C32, C34, E32

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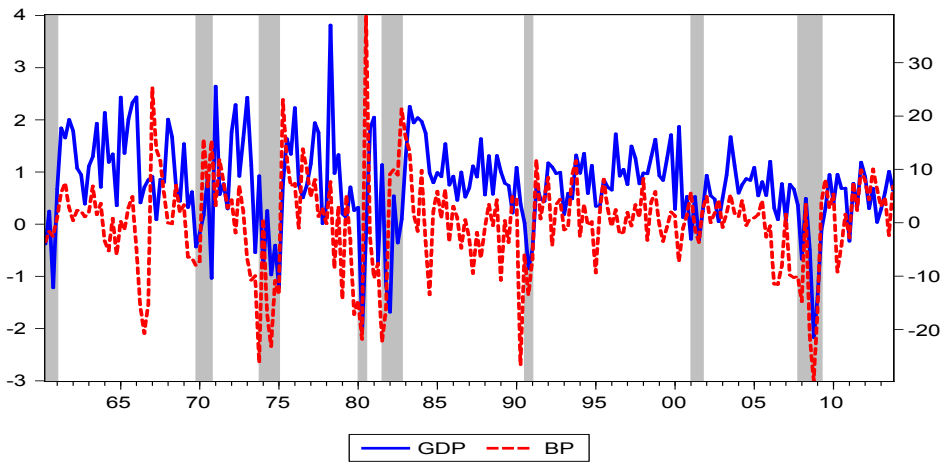
1 Introduction

Since the beginning of the financial crisis, housing has gained more attention from academics and practitioners than ever. In fact, there has long been a discussion about housing's role in the overall economy[1]. One of the main questions is whether there is a lead-lag relation between housing and the business cycles.

Figure 1 plots the growth rates of US real GDP and total building permits (BP). The low-frequency components of the two series share a striking resemblance. For the most part of the period, peaks/troughs in the permit series corresponds closely to the expansion/recession dates defined by the National Bureau of Economic Research (NBER). More noteworthy is when housing slumps, it is likely that there will be economic contractions in the following quarters. The procyclical feature of permit growth rates explains why housing is potentially an important candidate for understanding the dynamics of the business cycles.

Figure 1: US quarterly real GDP and building permit (BP) growth rates



Notes: Shaded areas correspond to the NBER recession dates.

[1]On the theoretical side, studies have investigated housing's role in the business cycles (e.g., Iacoviello (2005), Davis and Heathcote (2005) and Fisher (2007)). On the empirical side, researchers examine housing's leading effect on the economy (e.g., Green (1997), Coulson and Kim (2000), Leamer (2007), Ghent and Owyang (2010) and Strauss (2013))

However, empirical results of housing's leading role in the economy are mixed. Leamer (2007) provides evidence that housing downturns are reliable signals of incoming national recessions. This finding is echoed by the conclusion of Strauss (2013), who shows that building permits can be used to predict to a large extent the emergence of recessionary events at state-level. On the contrary, Ghent and Owyang (2010), using linear VAR approach, find no consistent statistical relationship displaying housing's leading effect on business cycles at city-level. One explanation of the disagreement among these studies is that the relation between housing and economic activity is time-varying[2].

This is the first paper to study the US housing-output link by exploiting the Markov-Switching Vector Autoregressive (MS-VAR) approach. First, this approach enables us to examine whether the housing-output relation changes over time. If such asymmetry exists, the predictive content of one variable on the other cannot be fully exploited in a linear model. Second, regime-dependent Granger causality analysis of the MS-VAR model is capable of revealing different causal patterns between building permits and GDP in each regime[3].

The findings of the current research shed new light on the housing-output link. Our empirical results suggest that the bivariate system of BP and GDP is subject to shifts in regime. Notably, the identification of high-volatility regime captures most of the NBER recession dates. Results from Granger causality tests show that BP Granger causes GDP only in the regime associated with downturn phases in both the housing and business cycles. Our findings not only confirm the argument that housing leads the business cycles, but also finds evidence of time-varying leading effect of housing on the overall economic activity.

The rest of the paper is organized as follows. In section 2, we introduce the data and provide a preliminary evidence of time-varying housing-output relation. Section 3 introduces the MS-VAR model and the regime-dependent Granger

[2]Recently there has been a growing literature on housing's asymmetric impact on macroeconomic aggregates (see, e.g., Chen, Chen, and Chou (2010), Márquez, Martínez-Cañete, and Pérez-Soba (2013), Case, Quigley, and Shiller (2013), Guerrieri and Iacoviello (2013) and Aye, Balcilar, Bosch, and Gupta (2014)).

[3]To account for the fact that the relation between BP and GDP may be due to the omission of monetary variables (see Smets (2007)), the MS-VAR model controls for interest rates or, in the robustness section, other variables.

causality test. Section 4 presents the empirical results. Section 5 concludes.

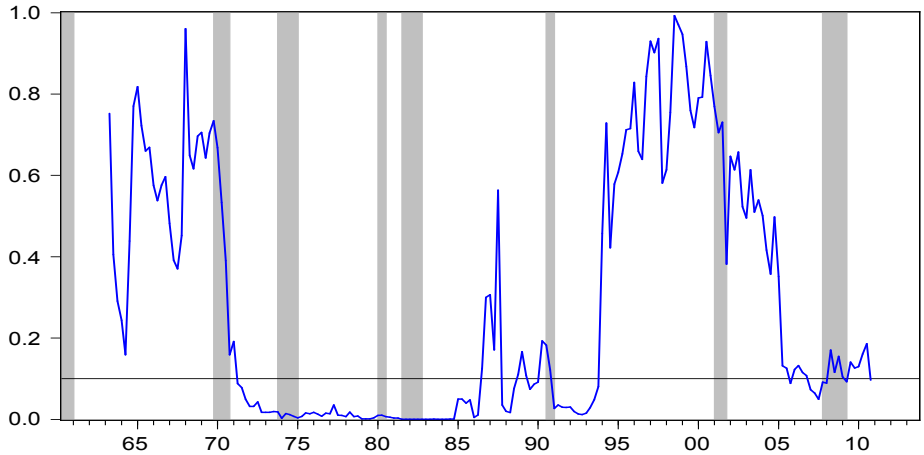
2 Data and Preliminary Analysis

Our analysis is based on quarterly observations of US real GDP and total building permits over the period 1960 Q1 to 2013 Q4 (216 observations), covering a total of eight recessions. We use BP as housing variable because Leamer (2007) concludes that it is the housing volume that matters for the US economy. House prices, on the other hand, are sticky downward and can barely exhibit housing cycles. Moreover, BP lead residential investment since money is poured into construction project after approval is obtained from local authorities, and thus are better at disclosing first-hand housing condition. Indeed, we find a lead of about 3 quarters for the BP. To control for the effect of monetary policy, we further include federal funds rates. All data are obtained from the Federal Reserve Bank of St. Louis.

Our study uses the growth rates of GDP and BP obtained by taking log difference of the respective variables. The Augmented Dickey-Fuller (ADF) test suggests both growth rates to be stationary. To provide a preliminary evidence of housing's time-varying leading effect on output, we use F-tests for Granger causality computed from rolling 6-year (24 observations) fixed windows. Based on a single equation that regresses GDP growth rate on the lagged values of itself and lagged permit growth rates, we test the null hypothesis that there is no Granger causality from BP to GDP.

Figure 2 shows the p-values of the rolling test statistics. The causal pattern changes over the sample period. There are three sub-periods when the p-values are below 0.1 line (10% significance level) and thus the housing variable has predictive contents for output. The first sub-period, 1971-1986, reflects the times when the US was plagued with recessions, while the latter two, 1991-1993 and 2007-2008, are in fairly close proximity to recession dates, suggesting that housing's leading role is linked to the emergence of recessions. On the other hand, there are two sub-periods, 1963-1970 and 1994-2005, when housing did not have significant leading effects. These findings indicate that the housing-output causal link may vary over time and the asymmetry is related to the state of the economy.

Figure 2: p-values of rolling Granger non-causality F-tests from BP to GDP



Notes: Null hypothesis: BP does not Granger cause GDP. The horizontal line indicates 10% significance level. Shaded areas correspond to the NBER recession dates.

3 Econometric Methodology

3.1 Markov-Switching Vector Autoregressive Model

To investigate the relation between housing and aggregate economic activity, we consider the following Markov-Switching Vector Autoregressive Model:

$$\begin{aligned} \Delta bp_t &= a_{bp}^{(s_t)} + \sum_{k=1}^{p} a_{bp,bp,k}^{(s_t)} \Delta bp_{t-k} + \sum_{k=1}^{p} a_{bp,y,k}^{(s_t)} \Delta y_{t-k} + \sum_{k=0}^{p} \beta_{bp,r,k}^{(s_t)} r_{t-k} + u_{bp,t} \ , \\ \Delta y_t &= a_{y}^{(s_t)} + \sum_{k=1}^{p} a_{y,bp,k}^{(s_t)} \Delta bp_{t-k} + \sum_{k=1}^{p} a_{y,y,k}^{(s_t)} \Delta y_{t-k} + \sum_{k=0}^{p} \beta_{y,r,k}^{(s_t)} r_{t-k} + u_{y,t} \ , \end{aligned} \tag{1}$$

where Δy_t and Δbp_t denote the growth rates of real GDP and building permits. Smets (2007) suggests the causal properties from housing to output might result from the omission of some important monetary variables that simultaneously affect both housing and output, therefore we consider federal funds rate, r_t, as an exogenous variable. Note that we allow monetary stance to have instantaneous effects on the housing variable and GDP. $[u_{bp,t}, u_{y,t}]'$ is the error term that follows

normal distribution with regime-dependent covariance matrix, $\Sigma^{(s_t)}$. The latent variable, s_t, is assumed to follow a M-regime Markov chain with transition probabilities given by

$$p_{ij} = Pr(s_{t+1} = j | s_t = i), \;\; i, j \in \{1, ..., M\}, \tag{2}$$

with $\sum_{j=1}^{M} p_{ij} = 1$. p_{ij} is interpreted as the probability of being in regime j at time $t+1$ given that the system is in regime i at time t. Using the transition probabilities, the expected duration of each regime can be computed as:

$$E[D|s_t = m] = \frac{1}{1 - p_{mm}}, \tag{3}$$

where $m \in \{1, ..., M\}$.

The identification of regimes rests on smoothed probabilities, which provide an inference about the likelihood of the system being in certain regime at time t conditioned on the full sample period. If two regimes are assumed, the system would be considered being in regime i at time t whenever $Pr(s_t = i|Y_T) > 0.5$, where $Y_T = \{y_1, ..., y_T\}$ and $i \in \{1, 2\}$.

Following Hamilton (1990) and Krolzig (1997), the ML estimation of the model is based on the Expectation-Maximization (EM) algorithm. The first step (Expectation) makes optimal inference about hidden Markov chain conditional on a given set of parameters. The second step (Maximization) re-estimates the parameters given the inferred hidden Markov chain. These steps are repeated until convergence.

3.2 Regime-Dependent Granger Causality

Unlike standard Granger causality analysis that reveals permanent causal patterns among the variables, regime-dependent Granger causality analysis of the currently studied MS-VAR model is capable of capturing time-varying relationship among the variables, allowing us to fully explore the causal links between housing and output. This is done by testing the following null hypothesis:

$$H_0 : a_{y,bp,1}^{(s_t=i)} = a_{y,bp,2}^{(s_t=i)} = ... = a_{y,bp,p}^{(s_t=i)} = 0, \tag{4}$$

which is equivalent to testing that BP does not Granger cause GDP in regime i. By imposing the above restrictions, we estimate a MS-VAR model with the

coefficients of all lag permit terms in GDP equation in regime i equal to zero and obtain the restricted log likelihood value (L_R). Together with the log likelihood value from the unrestricted model (L_U), we conduct a Likelihood Ratio (LR) test, $LR = 2(L_U - L_R)$, which follows a χ^2_k distribution with k equal to the number of restrictions. In a similar fashion, we can test the null hypothesis that GDP does not Granger cause the housing variable in regime i.

4 Empirical Results on Housing-Output Relation

4.1 Model Specifications

In the current study we assume that the latent variable, s_t, follows a two-regime Markov chain. One regime is associated with downturns in housing market and overall economy, while the other is associated with upturns in housing market and overall economy. Therefore, we are able to examine how variables of interest interact when housing and the economy are simultaneously in contraction or expansion phases. To determine the lag length of MS-VAR model while keeping the parsimonious principle in mind, we rely on the suggestions (2 lags) from the Schwarz information criterion (SIC) and Hannan-Quinn Criterion (HQC) for linear VAR model.

To see whether the data is supportive of the non-linear modeling, we test the null hypothesis of time-invariant VAR model against the alternative hypothesis of MS-VAR model. Due to the presence of nuisance parameters under the null, LR test statistic does not have standard asymptotic distribution. However, Davies (1977) proposes a method which derives an upper bound for the significance level of the LR test statistic. We therefore apply the bounded likelihood ratio test to test the null of no regime dependence. Panel A in Table 1 shows that the Davies' test (largest p-value) is smaller than any significance level. The result suggests that the time series of the growth rates of BP and GDP are subject to shifts in regime, thus we should reject the linear VAR model which has the feature of invariant parameters. By using the MS-VAR model, we are able to explore different dynamic interactions, which might be disguised under a linear VAR framework that presumes parameter constancy, between BP and GDP in each regime.

Next we examine which parts, either the autoregressive parameters or the covariance matrix or both, of the MS-VAR model are conditional on the regime of the Markov chain. The hypothesis tests below are conducted using standard LR test. This is because when the number of regimes is unaltered under the null, LR test statistic derived from a MS-VAR model has asymptotic properties similar to those of its counterpart derived from linear VAR model (see Krolzig (1997)).

Table 1: Tests for the specification of MS-VAR model

(A)	H_0: No regime-switching in the model (linear-VAR) H_a: Regime-switching in the model (MS-VAR)	Davies=0.00***
(B)	H_0: Only the covariance matrix is regime-dependent H_a: All parameters are regime-dependent	LR=28.08**
(C)	H_0: Only the autoregressive parameters are regime-dependent H_a: All parameters are regime-dependent	LR=20.33***

Notes: Davies means Davies' test, which is an upper bound for the significance level of the LR test statistic under the null. LR denotes the likelihood ratio test. $*$, $**$ and $***$ denote statistical significance at the 10%, 5% and 1% level.

We first test the null hypothesis that only the covariance matrix is regime-dependent and the autoregressive parameters are regime-independent against the alternative hypothesis that both parts are conditional on the regime of the Markov chain. Panel B in Table 1 displays the result which indicates rejection of the null at 5% significance level. Therefore, the MS-VAR model considered in our study encompasses time-varying autoregressive parameters. Suppose the model is built on the assumption of m Markov regimes, it is then instructive to think that there are m sets of autoregressive parameters. Each set describes the dynamic relationship between variables of interest in the corresponding regime.

In a similar fashion, we test the null hypothesis that only the autoregressive parameters are regime-dependent and the covariance matrix is regime-independent against the alternative hypothesis that both parts are conditional on the regime of

the Markov chain. Panel C in Table 1 displays the result which indicates rejection of the null at any significance level. In other words, the data is in favor of a MS-VAR model with heteroskedastic error term rather than one with homoskedastic error term. To sum up, the empirical analysis and the following estimation results are based on a MS-VAR model with the number of regime and also the autoregressive order equal to two. Furthermore, the model's autoregressive parameters and covariance matrix are all subject to shifts in the regime.

4.2 Is There an Asymmetric Impact of Housing on Output?

Table 2 summarizes the estimation results on the regime-dependent effect of BP on GDP. [4] In regime 1, the estimates of the permit growth rates at lag 1 and 2 from the GDP growth equation, $a^{(1)}_{\Delta gdp,\Delta bp,1} = 0.0028$ and $a^{(1)}_{\Delta gdp,\Delta bp,2} = 0.0096$, are small and statistically insignificant at any level. On the contrary, in regime 2, the coefficients of permit growth rates at lag 1 and 2 ($a^{(2)}_{\Delta gdp,\Delta bp,1} = 0.0481$ and $a^{(2)}_{\Delta gdp,\Delta bp,2} = 0.0172$) are about 17 and 1.8 times larger than their respective counterparts in regime 1, with the first coefficient being significant at 5% level while the latter insignificant. This finding is the first indication of the asymmetric leading effect of BP on GDP.

We identify regime 1 as low volatility regime and regime 2 as high volatility regime, because the standard deviations of permit and GDP growth rates are higher in regime 2 than in regime 1. As can be seen, the estimated transition probabilities, $p_{11} = 0.95$ and $p_{22} = 0.88$, imply that the two regimes are very persistent. The expected duration of the low volatility regime (18.31 quarters or, equivalently, 4.58 years), in which the housing variable does not have leading effect on output, is longer than that of the high volatility regime (8.57 quarters or, equivalently, 2.14 years).

[4] The complete results can be found in Table 5 in the appendix.

Table 2: Estimated parameters from the MS-VAR model

	Regime 1	(low volatility)	Regime 2	(high volatility)
$a_{\Delta gdp,\Delta bp,1}$	0.0028	(0.24)	0.0481^{**}	(2.56)
$a_{\Delta gdp,\Delta bp,2}$	0.0096	(1.01)	0.0172	(1.12)
$\sigma_{\Delta bp}$	17.96^{***}	(5.97)	123.05^{***}	(4.17)
$\sigma_{\Delta gdp}$	0.29^{***}	(7.44)	0.7^{***}	(4.03)
p_{11}	0.95			
p_{22}	0.88			

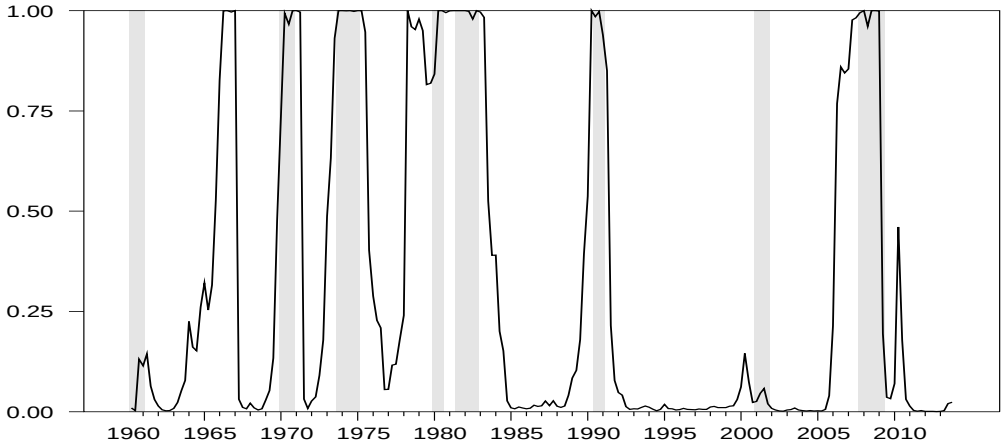
Notes: $a_{equation,variable,lag}$. t-statistics are reported in parentheses. $*$, $**$ and $***$ denote statistical significance at the 10%, 5% and 1% level.

The estimated smoothed probabilities of being in high volatility regime (regime 2), shown in Figure 3, display patterns of ups and downs, revealing the fact that the system of BP and GDP switches between the two regimes repeatedly. Notably, the period of high volatility regime appears to correspond to six of the eight NBER-identified recessions over the past 50 years; namely, recessions of 1960-61, 1969-70, 1973-75, 1980, 1981-1982, 1990-1991 and 2007-2009[5]. Over the same period housing market has also experienced declines in construction activity. In fact, 73% of the quarters with negative GDP growth rates are covered in the high volatility regime, and 77% of the quarters with positive GDP growth rates are covered in the low volatility regime. Analogously, 93% of the quarters with permit growth rates smaller than -10 percent are covered in the high volatility regime[6], and 80% of the quarters with positive permit growth rates are covered in the low volatility regime. As a result, it is reasonable to relate model-identified high/low volatility regime to downturn/upturn phases in both the housing and business cycles.

[5] Recall that the main purpose of this study is to examine the links between building permits and GDP under different regimes, rather than to provide a delineation of the dates at which the turning points in the business cycles take place (see Hamilton (1989) and Chauvet and Piger (2003))

[6] Since it is not uncommon for permit growth rates to fluctuate around 0 percent, we choose -10 percent rather than 0 percent as a threshold so that any quarter with permit growth rate smaller than -10 percent is considered as one with housing market downturn.

Figure 3: Smoothed probabilities of high volatility regime



Notes: Shaded areas correspond to the NBER recession dates.

Table 3: Regime-dependent Granger causality tests

(A)	H_0: Building permit does not Granger cause GDP in low volatility regime H_a: Building permit Granger causes GDP in low volatility regime	LR=1.62
(B)	H_0: Building permit does not Granger cause GDP in high volatility regime H_a: Building permit Granger causes GDP in high volatility regime	LR=27.33***
(C)	H_0: GDP does not Granger cause building permit in low volatility regime H_a: GDP Granger causes building permit in low volatility regime	LR=0.3
(D)	H_0: GDP does not Granger cause building permit in high volatility regime H_a: GDP Granger causes building permit in high volatility regime	LR=0.8

Notes: LR denotes the likelihood ratio test. $*$, $**$ and $***$ denote statistical significance at the 10%, 5% and 1% level.

Table 3 provides new evidence on the asymmetric leading effects of housing on the economy. In panel A and B, the null hypothesis that BP does not Granger cause GDP in low volatility regime cannot be rejected at any significance level, whereas the null hypothesis that BP does not Granger cause GDP in high volatility regime can be rejected at 1% significance level. In panel C and D, the null hypothesis of no Granger causality from GDP to BP cannot be rejected in any of the two regimes. These findings, together with the association between high/low volatility regime and downturn/upturn phases of the housing and business cycles, provide evidence that BP Granger causes GDP only when the housing and economic activity are experiencing contractions, and there is no reverse causality from GDP to BP in both regimes.

Regime-dependent causality shows the importance of modeling housing-output link in a nonlinear fashion. Based on linear VAR approach, Ghent and Owyang (2010) find no consistent statistical relationship showing that housing affects business cycles at city-level. We argue that the discrepancy between their findings and ours may be because the information content of BP cannot be fully exploited in a linear VAR model. Since the authors examine variables' correlation over the entire sample period (1983Q1-2008Q4), they rule out the possibility of structural breaks in the variables' relationship. Consequently, the leading effect of the housing variable on the business cycles during downturn phases may simply be averaged out by the inclusion of observations coming from periods when housing plays no leading role in the economy.

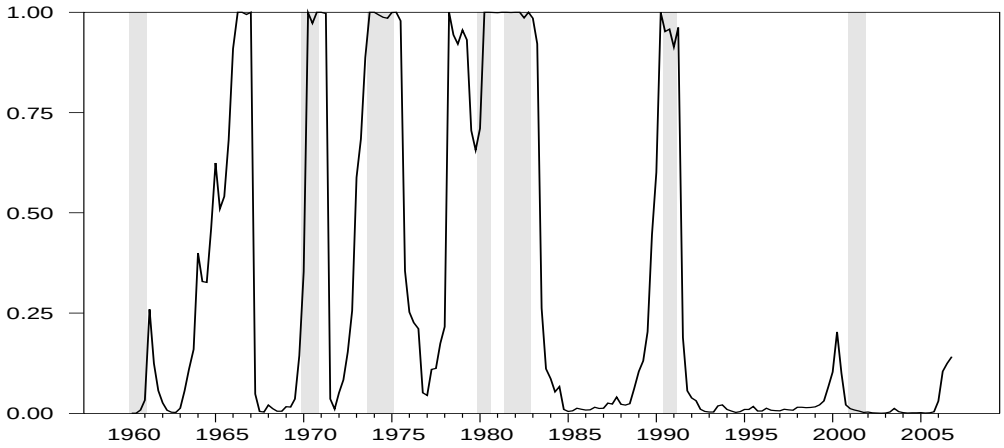
To summarize, our results from Granger causality tests are in line with previous works on housing's asymmetric impact on macroeconomic aggregates (e.g. Guerrieri and Iacoviello (2013) and Case, Quigley, and Shiller (2013)). Additionally, the results shed new light on the existing literature. Leamer (2007), Case and Quigley (2008) and Strauss (2013) provide evidence of housing's role as signal of imminent recessions. Our findings are not only consistent with theirs, confirming that housing downturns are closely linked to recessionary events in the economy, but also provide new evidence of time-varying effect of housing on the overall economic activity. Specifically, housing leads the business cycles only during the cycles' downward phases and plays little role in contributing to the growth of the economy during expansionary time. Last but not least, Smets (2007) raises the doubt that housing's leading effect may be due to the omission of several mon-

etary variables. Our results verify that housing continues to be a strong leading factor after interest rates are taken into consideration. To ensure robustness, in the next section we also examine the housing-output link after several monetary variables, i.e. term spreads, 10-year interest rates, real interest rates and inflation, are controlled for.

4.3 Robustness

In this section we demonstrate the robustness of our results by considering a shorter sample period and other control variables. First, since many believe that the recession of 2007 was triggered by problems in housing markets and, in particular, Case and Quigley (2008) indicate that the decline in housing construction is likely to have large direct impact on the economy, we consider a shorter sample period (1960 Q1 to 2006 Q4), which excludes the recession time (2007Q4 to 2009Q2) and pre-recession period, so as to see whether the asymmetric leading effect of BP on GDP remain the same. Second, Smets (2007) points out that housing's leading effect on the economy may disappear after several monetary factors are taken into consideration. We test this supposition by estimating the MS-VAR model using term spreads, 10-year interest rates, inflation and real interest rates separately as control variable.

Figure 4: Smoothed probabilities of high volatility regime



Notes: Shaded areas correspond to the NBER recession dates.

Figure 4 shows the estimated smoothed probabilities using the shorter sample period. As with the full sample case, high volatility regime (regime 2) refers to the regime with larger variances in both variables and is related to the downturn phases in both the housing and business cycles. Table 4 presents results of model specification and regime-dependent Granger causality tests in panel (A) and (B), respectively. The first column corresponds to the short sample period, denoted as SP. For the model specification, we see that the null hypotheses of linear VAR model and of regime-switching only in parts of the model (autoregressive parts or covariance matrix) are rejected at 1%, 1%, and 10% significance levels, thus the data is in support of a MS-VAR model with all parameters subject to regime changes. For the Granger causality tests, the causal pattern is the same as that found in the full sample case: BP Granger causes GDP only in the high-volatility regime and there is no reverse causality from GDP in both regimes.

Table 4: Results of robustness check

	SP	TS	INT10	INF	RFFR
(A) VAR vs MS-VAR (Davies)	0.000^{***}	0.000^{***}	0.000^{***}	0.000^{***}	0.000^{***}
A vs AC	43.02^{***}	38.03^{***}	51.59^{***}	13.34^{***}	49.24^{***}
C vs AC	25.61^{*}	26.43^{**}	36.93^{***}	18.47	24.71^{*}
(B) BP does not GC GDP (1)	3.65	2.3	4.08	5.26^{*}	3.66
BP does not GC GDP (2)	18.08^{***}	11.62^{***}	29.67^{***}	19.74^{***}	23.69^{***}
GDP does not GC BP (1)	4.05	2.63	5.87^{*}	3.71	0.79
GDP does not GC BP (2)	3.55	1.54	0.26	3.44	5.24^{*}

Notes: The first row of panel A tests the null hypothesis of linear VAR against the alternative hypothesis of MS-VAR. The second row of panel A tests the null hypothesis of regime-switching only in the autoregressive part (A) of the MS-VAR model against the alternative of regime-switching in all parameters (AC) . The third row of panel A tests the null hypothesis of regime-switching only in the covariance matrix (C) of the MS-VAR model against the alternative of regime-switching in all parameters (AC). Panel B displays the results of Granger causality (GC) tests. (1) indicates low-volatility regime and (2) high-volatility regime. All tests, except for the linearity test based on Davies' test (upper bound for the significance level of the LR test statistic) in the first row, are based on standard LR test; $*$, $**$ and $***$ denote statistical significance at the 10%, 5% and 1% level.

The estimation results of the MS-VAR models controlling for other monetary

variables are shown starting from the second column of table 4, in this order: term spreads (TS), 10-year interest rates (INT10), inflation (INF) and real interest rates (RFFR). We see that the MS-VAR model with regime-dependence in autoregressive parameters and covariance matrix is preferable to all other specifications in all cases except for INF, in which a MS-VAR model with regime-dependence only in autoregressive parameters seems to be preferred. In regard to the causality pattern, the evidence of BP Granger causing GDP in high-volatility regime (second row in panel B) remains the same as before in all cases. Note that all LR test statistics are relatively large and thus indicate strong rejection of the null hypothesis. Additionally, we find Granger causation from GDP to BP in low-volatility regime (in the case of INT10), from BP to GDP in low-volatility regime (in the case of INF) and from GDP to BP in high-volatility regime (in the case of RFFR). The overall results suggest that BP strongly lead GDP in the high-volatility regime; namely, when both the housing and aggregate activity are experiencing downturns.

5 Conclusions

This paper investigates housing's role in the overall economy by exploiting a regime-switching VAR framework. Previous works have provided mixed results of housing's leading effect on the business cycles. In particular, Leamer (2007) and Strauss (2013) claim housing to be strong leading indicator of the economy, while Ghent and Owyang (2010) find no consistent statistical relationship displaying housing's leading effect at city-level. We argue that the discrepancy may be due to the fact that housing has time-varying effect on the economy. Specifically, when a linear approach is applied, housing's leading effect on the business cycles during certain periods may be averaged out by the inclusion of observations coming from periods when housing plays no leading role in the economy. As a result, we propose to model the housing-output relation using MS-VAR approach, allowing the system of variables of interest to follow a stochastic regime-switching Markov chain. Consequently, we are able to see how variables affect each others in each regime.

Our empirical results show that the housing-output link is regime-dependent. The model-identified high-volatility regime corresponds to the downturn phases of

the housing and business cycles, while the model-identified low-volatility regime the upturn phases. Regime-dependent Granger causality tests suggest that the causal link exists from BP to GDP only in the high-volatility regime, and there is no reverse causation from GDP to BP in both regimes. In other words, housing leads the aggregate economy when both the housing and business cycles are experiencing contractions. The result remains unchanged when we consider a shorter sample period which excludes the recession of 2007 (when housing was deemed to be the source of the crisis), and when we take into account other monetary variables as control variables.

Our results from the Granger causality tests confirm the findings of previous works on housing's asymmetric impact on macroeconomic aggregates (e.g. Guerrieri and Iacoviello (2013) and Case, Quigley, and Shiller (2013)). Moreover, this paper provides new evidence on housing's role in the economy. We not only assert housing's role as signal of imminent recessions (Leamer (2007), Case and Quigley (2008) and Strauss (2013)), but also find that housing leads the business cycles only during the cycles' downward phases and has little effects in contributing to the growth of the economy during expansionary time. This regime-dependent leading effect is in line with findings by Stock and Watson (2003) that the predictive performance of leading indicators for output is in general unstable over time.

It remains an open question why BP leads GDP in an asymmetric fashion. However, it would be possible to attribute the causal effects of BP on GDP during recessions to the housing variable's high correlation with consumer expectation (Strauss (2013)). Consumer sentiment has long been thought to contain predictive information for GDP around the recession periods (Batchelor and Dua (1998) and Christiansen, Eriksen, and Møller (2014)).

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Appendix

A Tables

Table 5: Estimated parameters of the MS-VAR model with federal funds rates as control variable; $a_{equation,variable,lag}$; t-statistics are reported in parentheses; $*$, $**$ and $***$ denote statistical significance at the 10%, 5% and 1% level.

	Regime 1		Regime 2	(recessions)
$a_{\Delta bp}$	3.132***	(3.23)	-4.385	(-0.79)
$a_{\Delta bp,\Delta bp,1}$	0.216**	(2.37)	0.173	(0.66)
$a_{\Delta bp,\Delta bp,2}$	0.0151	(0.2)	0.349	(1.43)
$a_{\Delta bp,\Delta gdp,1}$	-0.78	(-1.07)	-1.018	(-0.42)
$a_{\Delta bp,\Delta gdp,2}$	1.003	(1.36)	0.019	(0.007)
$a_{\Delta bp,i}$	-2.505***	(-2.59)	-0.896	(-0.419)
$a_{\Delta bp,i,1}$	1.587	(0.9)	-3.665	(-0.98)
$a_{\Delta bp,i,2}$	0.444	(0.46)	4.938**	(2.23)
$a_{\Delta gdp}$	0.476***	(3.74)	1.111***	(2.85)
$a_{\Delta gdp,\Delta bp,1}$	0.0028	(0.24)	0.0481**	(2.56)
$a_{\Delta gdp,\Delta bp,2}$	0.0096	(1.01)	0.017	(1.12)
$a_{\Delta gdp,\Delta gdp,1}$	0.225**	(2.39)	-0.114	(-0.42)
$a_{\Delta gdp,\Delta gdp,2}$	0.204**	(2.56)	0.202	(1.02)
$a_{\Delta gdp,i}$	0.074	(1.06)	0.084	(0.42)
$a_{\Delta gdp,i,1}$	-0.224	(-1.48)	0.017	(0.07)
$a_{\Delta gdp,i,2}$	0.156	(1.42)	-0.153	(-0.94)
$\sigma_{\Delta bp}$	17.96***	(5.97)	123.05***	(4.17)
$\sigma_{\Delta gdp}$	0.29***	(7.44)	0.7***	(4.03)
p_{11}	0.95			
p_{22}	0.88			
Duration	18.31	(quarter)	8.57	

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