US Regional Housing Markets and Monetary Policy

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October 15, 2020

Abstract

This paper studies the impact of monetary policy on eight regional housing markets in the U.S.. My focus is on the ability of monetary policy to stabilize the dynamics of the real economy, financial markets, and housing markets across the regions. A structural panel VAR-X with time-varying parameters (TVPs) and stochastic volatilities (SVs) is estimated on quarterly regional real personal income, real personal consumption expenditures, real loans, and real house prices across eight regions of the US from 1998Q2 to 2019Q3. Bayesian methods developed by Canova and Ciccarelli (2009, "Estimating multicountry VAR models," International Economic Review, 50, 929-959) are used to estimate the TVP-SV panel VAR-X. The estimates show several meaningful results. This paper finds that the transmission of shocks among the sectors are different across regions, as well as cross-region transmission of real and financial sectors' shocks to housing sectors. There are significant house price spillovers and the house price shocks from core regions are more influential to other regions. I also study the effectiveness and differences of monetary policy in stabilizing regional house prices by two sets of counterfactual analysis.

JEL codes: E21, E27, E51, G18, R31

Key words: Housing, Monetary policy, Regional, Bayesian panel VAR

*North Carolina State University Economics Department, e-mail: ylin23@ncsu.edu. The full text and supplementary appendix is downloadable at http://yiminglin.wordpress.ncsu.edu/research. I extend my gratitude to my dissertation advisor Jim Nason for his constant encouragement and guidance. I appreciate my dissertation committee members Douglas Pearce, Giuseppe Fiori, and Xiaoyong Zheng for their comments and support. I am also grateful to Bogdan Nikiforov of the Department of Agricultural and Resource Economics for providing computing support.

1 Introduction

The housing market in the US plays an important role in the economy and has been of central concern for conducting monetary policy. Since housing markets are locally characterized by its economic conditions, the transmission of shocks among the real economy, financial markets, and housing markets are various in different regions. Monetary policy also influence regional housing markets differently.

This paper provides more insights into the differences in the regional real, financial, and housing markets during 1998Q2-2019Q3. The economic regions in this paper are the eight Bureau of Economics Analysis (BEA) regions. This paper first evaluates the differences of regional real, financial, and housing markets by studying the dynamic responses of regional housing markets with respect to their own region's real economy and financial market shocks, as well as the repercussion effects of housing market shocks. It then studies the house price spillovers from region to region. Finally, this paper addresses the concern to monetary policy makers that how the monetary policies influence the housing markets differently across regions.

The Federal Reserve (Fed) conducts monetary policy by managing short-term interest rates to achieve maximum employment consistent with stable prices, and to moderate long-term interest rates. The target for federal funds rate in the open market are set by the Federal Open Market Committee (FOMC) in the Fed, and the changes of the target rate or range directly influences all short-term interest rates. The change of the short-term rates then influences the real economy, financial markets, and housing markets. However, the differences in the mix of industries, firms, and banks cause different regional sensitivities to the interest rate change (Bernanke and Blinder (1988), Kashyap and Stein (1995), and Carlino and DeFina (1999)). Regional housing markets are also different in responding to the shocks from the real economy and financial markets. This suggests monetary policy can influence regional housing markets differently.

I estimate a panel VAR-X to study the transmission of shocks among the real, financial, and housing sectors within and across regions, the interdependencies among regional housing markets, and counterfactual analysis following Sims and Zha (2006) for studying the effectiveness of monetary policy in stabilizing regional house prices.

The panel VAR-X is estimated on quarterly regional real per capita personal income growth, real per capita personal consumption expenditures growth, real per capita loan growth, and real house price growth from 1998Q2 to 2019Q3. The change in federal funds target rate or range (FFTR) is taken as predetermined monetary policy intervention. The panel VAR-X is mapped into a dynamic factor model and estimated by Bayesian methods that proposed by Canova and Ciccarelli (2009). The dynamic factor model reduces the computational demand by mapping the reduced-form parameters into structural factors. The posterior distributions of the panel VAR-X is estimated by a Metropolis-within-Gibbs Marcov chain Monte Carlo algorithm following Canova and Ciccarelli (2009) and Dieppe, Legrand, and van Roye (2016).

I identify regional income shocks, demand shocks, loan shocks, and house price shocks by recursively ordering the real, financial, and housing sectors. The IRFs with respect to these structural shocks give evidence of regional differences in real, financial, and housing markets and the transmission among the three sectors within and across regions.

I also report the effectiveness of monetary policy and the differences of the effects across regions by conducting two sets of counterfactual analysis. The first set is evaluated using parameters estimated from the panel VAR-X but conditional on unchanged monetary policy with the target change of federal funds rate equals to zero during the sample periods. The second set is using actual data but alternative parameters. I estimate variables in each region during the financial crisis with parameters of monetary policy before-crisis and after-crisis for comparing the effectiveness of monetary policy among before-, during-, and after-crisis periods.

This paper contributes to the literature that studies the effects of monetary policy on locally segmented housing markets. Cooper, Luengo-Prado, and Olivei (2016) assess the differential impact of monetary policy on state-level house prices. In addition to house prices, I also incorporate the regional real economy and financial markets, and studies their multidirectional links in this paper. Further, most of this research on the

US regional housing markets are based on state-level data or metropolitan statistically areas (MSAs). Fratantoni and Schuh (2003) quantify the differences in the impact of monetary policy on housing markets in different MSAs by using a nonstructural heterogeneous-agent VAR (HAVAR), and Beraja et al. (2017) find that the differences in regional housing equity have different influences on monetary policy effects based on data of MSAs. Different from this literature, the eight BEA regions used in this paper are more aggregated, and the coverage is more comprehensive than MSAs. This paper also contributes a new data set of quarterly region-level growth rates of real per capita personal income, real per capita personal consumption expenditures, real per capita loans, and real house prices.

To the best of my knowledge, this paper is the first to use counterfactual analysis that estimated from a TVP-SV panel VAR-X to study the effects of changes to the target fed funds rate on regional real, financial, and housing markets. There is rare literature taking the FFTR change as policy shocks. I measure policy shocks that are tied directly to the main monetary policy tool of the Fed. The counterfactual analysis gives useful results about the differences of effectiveness of monetary policy across regions.

The estimation of the panel VAR-X gives three main results. First, within-region transmission of shocks are different across regions. Three core regions NE, FW, and GL and a noncore region SE have significant within-region transmission of shocks. While other regions' house prices do not significantly respond to their own regions' real and financial sector shocks. Second, there are cross-region transmission of real and financial sectors' shocks to housing sectors, and they are different across regions. Third, there are house price spillovers across regions. All regions' house prices respond significantly and positively to other regions' house price shocks. The core regions spread more house price shocks over other regions than noncore regions. These results show regional housing markets are locally characterized, accepting house price spillovers from other regions, and influenced by other regions real and financial markets through limited direct channels.

The counterfactual analysis also gives meaningful results. [Material to come.]

The rest of the paper is organized as follows. Section 2 presents the TVP-SV panel

VAR-X estimator. Section 3 describes the data. Section 4 reports empirical results. Section 5 concludes.

2 The TVP-SV Panel VAR-X

This section introduces the TVP-SV panel VAR-X, and the dynamic factor approach that developed by Canova and Ciccarelli (2009). They reduce the dimension of the highly-parameterized TVP-SV panel VAR-X by factorizing the parameters and mapping the panel VAR-X into a state-space structure.

The panel VAR-X in this paper is estimated on four variables in each of the eight economic regions. The sample period is 1998Q2-2019Q3 ($T = 85$). The panel VAR-X is

$$Y_t = K_t + A_t Y_{t-1} + C_t D_t + e_t, \tag{2.1}$$

where $e_t \sim N(0_{32\times1}, \Sigma_{t(32\times32)})$ is a disturbance matrix, and $\Sigma_t \equiv exp(\zeta_t)\tilde{\Sigma}$ is the time-varying covariance matrix. The covariance matrix is composed of a heteroskedastic part and a homoskedastic part. The heteroskedastic part ζ_t captures the stochastic volatilities over time of the variance, and the homoskedastic part $\tilde{\Sigma}$ keeps constant during the sample period. The matrices A_t and C_t are matrices of time-varying lag and intervention response parameters of the reduced-form panel VAR. The intercept K_t is also time-varying.

The state-space structure of the dynamic factor model that proposed by Canova and Ciccarelli (2009) transform the reduced-form panel VAR into

$$Y_t = \chi_t \theta_t + e_t, \tag{2.2}$$

where χ_t is a matrix that reloads $I_{32} \otimes X_t^{'}$, with $X_t = (Y_{t-1}^{'}, K_t^{'}, D_t^{'})^{'}$. The factor loadings are $\theta_t \equiv (\theta_{1t}^{'}, \theta_{2t}^{'}, \theta_{3t}^{'}, \theta_{4t}^{'})^{'}$, where θ_{1t} is the component common to all variables in all regions, $\theta_{2t} = (\theta_{21t}, \theta_{22t}, ..., \theta_{28t})^{'}$ are components common to the corresponding regions, $\theta_{3t} = (\theta_{31t}, \theta_{32t}, \theta_{33t}, \theta_{34t})^{'}$ are components common to the corresponding endogenous variables, and $\theta_{4t} = (\theta_{41t}, \theta_{42t})'$ are common components comes from the intercept and the exogenous variable D_t to all other variables. By factorizing the parameters, each variable can be taken as a weighted average of all other variables.

The state equation is the law of motion of the factors,

$$\theta_t = (1-\rho)\bar{\theta} + \rho\theta_{t-1} + \eta_t, \tag{2.3}$$

where the error term $\eta_t \sim N(0, B)$, and B is a block diagonal matrix of variance of the factors b_i, $i = 1, ..., 4$. The long-run average of the factor, $\bar{\theta}$, is obtained from OLS estimation of the observation equation (2.2). The parameter $0 \leq \rho \leq 1$ decides the persistency of the factors over time.

Define the law of motion of the heteroskedastic part of the covariance matrix,

$$\zeta_t = \gamma\zeta_{t-1} + \nu_t, \tag{2.4}$$

where the error term $\nu_t \sim N(0, \varphi)$, with φ a time-invariant variance, and γ determines the persistency of the heteroskedasticity of this model.

Canova and Ciccarelli (2009) and Dieppe, Legrand, and van Roye (2016) estimate the parameters of interest in the panel VAR-X with Metropolis-within-Gibbs Bayesian MCMC algorithm. The parameters of interest are factors $\theta = \{\theta_t\}_{t=1}^{T=85}$, heteroskedastic component in variance, $\zeta = \{\zeta_t\}_{t=1}^{T=85}$, residual variance, φ, factor variance, $b = \{b_i\}_{i=1}^{4}$, and homoskedasiticity component in variance, $\tilde{\Sigma}$. Chan and Jeliazkov (2009) propose a sparse matrix approach for increasing the computational efficiency, and this approach is applied by Dieppe, Legrand, and van Roye (2016) in estimating θ and ζ in the panel VAR-X. The sparse matrix approach stacks θ and ζ over time into a compact matrix Θ and Z, and then map the law of motions over time into simultaneous equation form.

Table 1 reports the priors. Posterior distributions are obtained given the priors and likelihood of the data from the observation equation (2.2). The posterior distributions are listed in table 2.

The draws of the parameters $\tilde{\Sigma}$, φ, b_i, Σ, and θ are obtained by Gibbs sampler, while

Table 1: Priors for Parameters and Hyperparameters

Parameter	Interpretation	Prior Distribution
Θ	factors θ_t	$N(\Theta_0, B_0)$
Z	heteroskedasticity component ζ_t	$N(0, \Phi\{(K^{'}K)\}^{-1}$
φ	residual variance	$IG(\frac{\alpha_0}{2}, \frac{\delta_0}{2})$
b_i	factor variance	$IG(\frac{a_0}{2}, \frac{c_0}{2})$ for $i = 1, ..., 4$
$\tilde{\Sigma}$	homoskedasticity component	$\lvert\tilde{\Sigma}\rvert^{(32+1)/2}$
Hyperparameter	**Interpretation**	**Prior**
ρ	autoregressive coefficient in factors	0.6
γ	autoregressive coefficient in residual variance	0.75
a_0	inverse gamma shape in factor variance	10000
c_0	inverse gamma scale in factor variance	1
α_0	inverse gamma shape in residual variance	10000
δ_0	inverse gamma scale in residual variance	1

* This table summarizes the priors for parameters and hyperparameters needed in estimating the state-space model.

Table 2: Posterior Distributions of Parameters of Interest

Parameter	Interpretation	Posterior Distribution
Θ	factors θ_t	$N(\bar{\Theta}, \bar{B}_0)$, where $\bar{B} = (\xi^{'}(\Sigma)^{-1}\xi + B_0^{-1})^{-1}$, and $\bar{\Theta} = \bar{B}(\xi^{'}(\Sigma)^{-1}y + B_0^{-1}\Theta_0)$
ζ	heteroskedasticity component	$N(\bar{\zeta}, \bar{\varphi})$, where $\bar{\zeta} = \bar{\varphi}\frac{\gamma(\zeta_{t-1}+\zeta_{t+1})}{\varphi}$, and $\bar{\varphi} = \frac{\varphi}{1+\gamma^2}$
φ	residual variance	$IG(\frac{85+\alpha_0}{2}, \frac{Z^{'}G^{'}GZ+\delta_0}{2})$
b_i	factor variance	$IG(\frac{85d_i+a_0}{2}, \frac{\sum_{t=1}^{85}(\theta_{i,t}-\theta_{i,t-1})^{'}(\theta_{i,t}-\theta_{i,t-1})+c_0}{2})$
$\tilde{\Sigma}$	homoskedasticity component	$IW(\bar{S}^{(n)}, T)$, where $\bar{S}^{(n)} = \sum_{t=1}^{T}(e_t^{(n-1)})exp(-\zeta_t^{(n-1)})(\sum_{t=1}^{T}(e_t^{(n-1)})^{'}$

* This table summarizes the posterior distributions of the parameters.
** The Metropolis algorithm is applied in updating candidates of ζ_t.

a Metropolis step is used to estimate ζ. The M-G algorithm is summarized.

1. Set the starting values for the parameters. The starting value of factors θ_t is obtained from OLS estimation of the observation equation (2.2). The variance of factors $b_i^{(0)} = 10^5$. The homoskedasticity component $\tilde{\Sigma}^{(0)} = \frac{1}{T}\sum_{i=1}^{T} e_t e_t'$. The heteroskedasticity component $\zeta_t^{(0)} = 0$. The variance of the dynamic coefficient $\varphi^{(0)} = 0.001$.

2. Draw the parameters $\tilde{\Sigma}$, ζ, φ, b_i, Σ, and θ consequently from the posterior distribution.

   (a) The draws of $\tilde{\Sigma}$, φ, b_i, Σ, and θ are obtained from the Gibbs sampler. The priors of the sparse matrices Θ and Z are used for drawing θ and φ.

   (b) The heteroskedasticity component ζ is obtained from a Metropolis step. First, draw the candidate of ζ from the transition kernel $\zeta^{(n)} = \zeta^{(n-1)} + \omega$ in each iteration, where $\omega \sim N(0, \phi I_T)$ with $\phi = 10^5$ chosen to balance the variance and the acceptance rate. Then update the draws following the acceptance rule.

3. Repeat from step 2 until iterations end.

I draw 16,000 times from the posterior in total and drop the first 8,000 draws. I pick one from every 4 in the last 2000 draws.[1]

3 The Data

This section summarizes the construction of data. The sample is from 1998Q2 to 2019Q3.

The eight economic regions defined by the BEA are New England (NE), Far West (FW), Mideast (ME), Great Lakes (GL), Rocky Mountains (RM), Plains (PL), Southwest (SW), and Southeast (SE). Table 3 in appendix A lists states in each region.

[1]The Matlab program used in estimation is the Bayesian Estimation, Analysis, and Regression (BEAR) toolbox (version 4.0) that developed by the external developments division of the European Central Bank.

I label NE, FW, ME, and GL as core regions and RM, PL, SW, and SE as noncore regions. The grouping considers the classification in Carlino and DeFina (1999) and I update it according to regional economic development. Regional economic indicators[2] show core regions are more prosperous in housing markets and financial markets.

Each regional data set consists of four variables. The variables are annualized quarterly growth of real per capita personal income ($\Delta lnPI_t$), real per capita personal consumption expenditures of nondurable goods ($\Delta lnPCE_t$), real per capita loans ($\Delta lnLoan_t$), and real house prices ($\Delta lnHP_t$). The change in the target of federal funds rate ($\Delta FFTR_t$) is common to the eight regions. The following subsections describes the construction of the four variables. Appendix B provides more details for this section.

3.1 Real Personal Income Growth ($\Delta lnPI_t$)

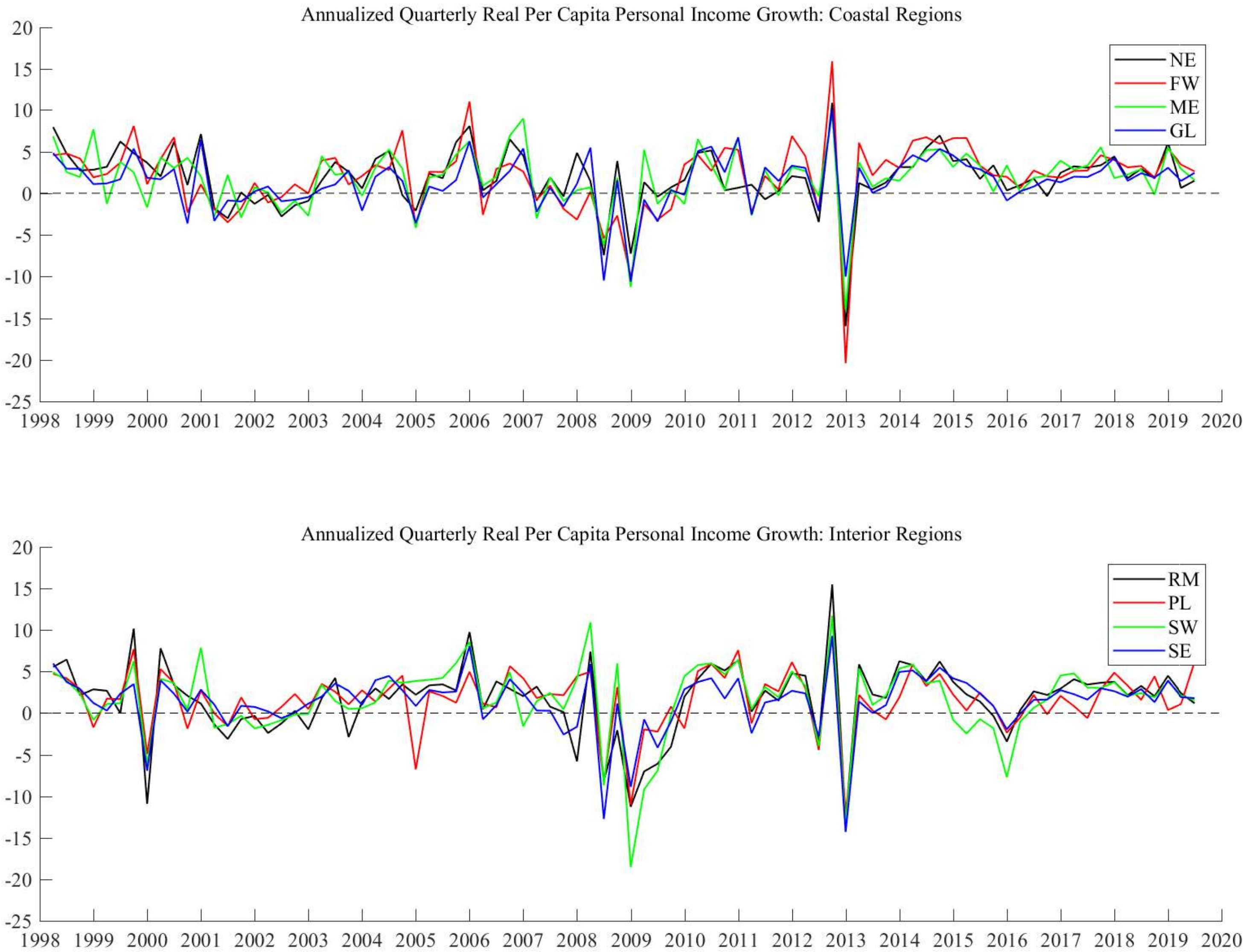
The real per capita personal income growth is one of the real sector variable. Figure 1 plots the movements of $\Delta lnPI_t$ from 1998Q2 to 2019Q3.

The real personal income growth rates were more volatile before 2002, during 2007-2009 financial crisis, and 2012-2013 for core and noncore regions. All regions fluctuate together in most of the period except 1999-2000 with an obvious difference between the core and noncore regions, while the synchronization of movements exists respectively within core and noncore regions.

The noncore regions RM, PL, SW and SE had higher growth rates of personal income on average than the core regions. While three of them, PL, SW, and SE, maintained more stable growth rates with smaller volatility. The growth rates in the core regions are more volatile than the noncore regions except RM.

[2]The two indicators are annually per capita personal consumption expenditures: housing and utilities, and per capita personal consumption expenditures: financial services and insurance, from 1998 to 2018. Data source: Bureau of Economic Analysis; see `https://apps.bea.gov/itable/iTable.cfm?ReqID=70&step=1`.

Figure 1: Annualized Quarterly Regional Real Per Capita Personal Income Growth Rate



Note: This figure plots the regional $\Delta lnPI_t$. The top panel plots the regional $\Delta lnPI_t$ in the core regions, and the bottom panel plots the regional $\Delta lnPI_t$ in the noncore regions. The sample period is 1998Q2 to 2019Q3.

3.2 Real Personal Consumption Expenditures Growth ($\Delta lnPCE_t$)

Another real sector variable is real per capita personal consumption expenditure growth for nondurable goods[3]. The nondurable goods PCE is an important indicator for studying the repercussions of house price shocks. Since regional and state-level PCEs are only available annually, I temporal disaggregate regional annual PCE to obtain quarterly PCE. The appendix reviews these temporal disaggregation methods. Figure 2 plots the movements of $\Delta lnPCE_t$ from 1998Q2 to 2019Q3 that constructed in this paper.

Real per capita PCE growth rates fluctuated around one percent during the sample period except during the financial crisis in 2007-2009. The eight regions reached their own minimum growth at the end of 2008 or at the beginning of 2009. The first-order autocorrelations reported in table 5 in appendix B shows that the $\Delta lnPCE_t$ series are much more persistent than $\Delta lnPI_t$ and $\Delta lnLoan_t$.

3.3 Real Loans Growth ($\Delta lnLoan_t$)

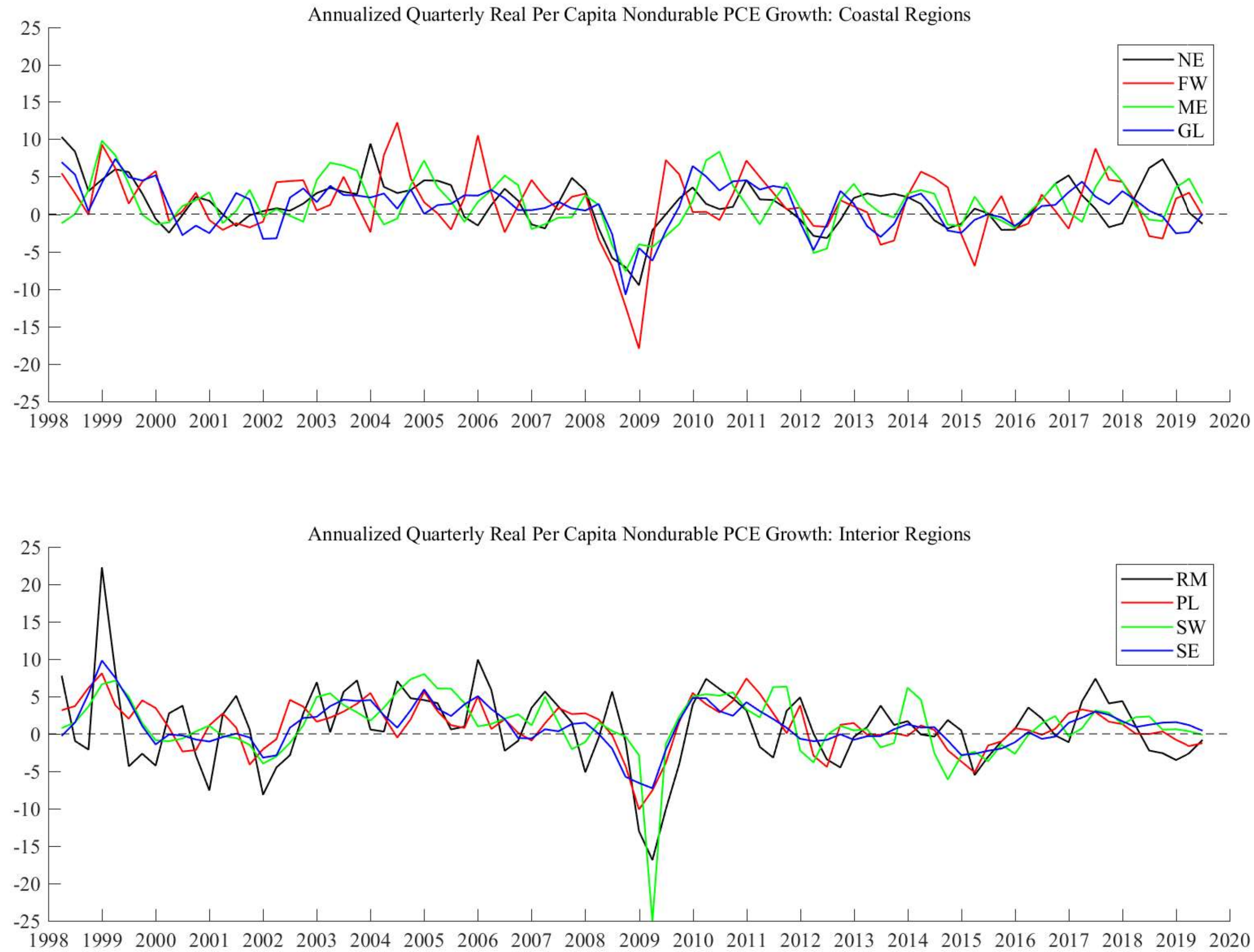
The financial sector variable in estimation is real per capita loan growth. The $\Delta lnLoan_t$ is constructed using total loans and leases net of unearned income[4] for commercial banks, which is taken as banks' assets in their balance sheets. Real estate loans take the biggest proportion in the total loans and leases. Figure 3 plots the movements of $\Delta lnLoan_t$ from 1998Q2 to 2019Q3 that constructed in this paper.

The regional real loan growths are the most volatile ones among all series. The maximum annualized quarterly growth are as high as 388 percent, and the minimum are as low as -347 percent. Both the maximum and the minimum are reached by the FW, while all regions are highly volatile, and there are not much synchronization of movements among the regions.

[3]NIPA Handbook, US Bureau of Economic Analysis, 2019, p5-4; see `https://www.bea.gov/system/files/2019-12/Chapter-5.pdf`

[4]Unearned income in accounting are interest income on loans that should be received from borrowers but not yet earned.

Figure 2: Annualized Quarterly Regional Real Per Capita PCE Growth Rate



Note: This figure plots the regional $\Delta lnPCE_t$. The top panel plots the regional $\Delta lnPCE_t$ in the core regions, and the bottom panel plots the regional $\Delta lnPCE_t$ in the noncore regions. The sample period is 1998Q2 to 2019Q3.

Figure 3: Annualized Quarterly Regional Real Per Capita Loan Growth Rate

Note: This figure plots the regional $\Delta lnLoan_t$. The top panel plots the regional $\Delta lnLoan_t$ in the core regions, and the bottom panel plots the regional $\Delta lnLoan_t$ in the noncore regions. The sample period is 1998Q2 to 2019Q3.

3.4 Real House Price Growth ($\Delta lnHP_t$)

This paper places more emphasis on the real house price growth. I obtain quarterly state-level house price index of all transactions from the Federal Housing Finance Agency for constructing $\Delta lnHP_t$. The index is estimated using actual sales prices and appraisal data. Figure 4 plots the movements of $\Delta lnHP_t$ from 1998Q2 to 2019Q3.

The real house price during the sample period experienced a smoothly growing period before 2003. It then entered a booming period in most of the regions during 2003-2006, and this is also the period that has the largest dispersion among regions. The house price growth dropped to negative since 2006-2007 and remains below zero for most of the time until 2013. Three of the core regions, NE, FW, and ME, are the three most volatile ones. The real house price growth in these three regions also have the highest persistence[5], as well as SW. Unlike $\Delta lnLoan_t$ and $\Delta lnPI_t$, the real house price growth in all regions are highly persistent.

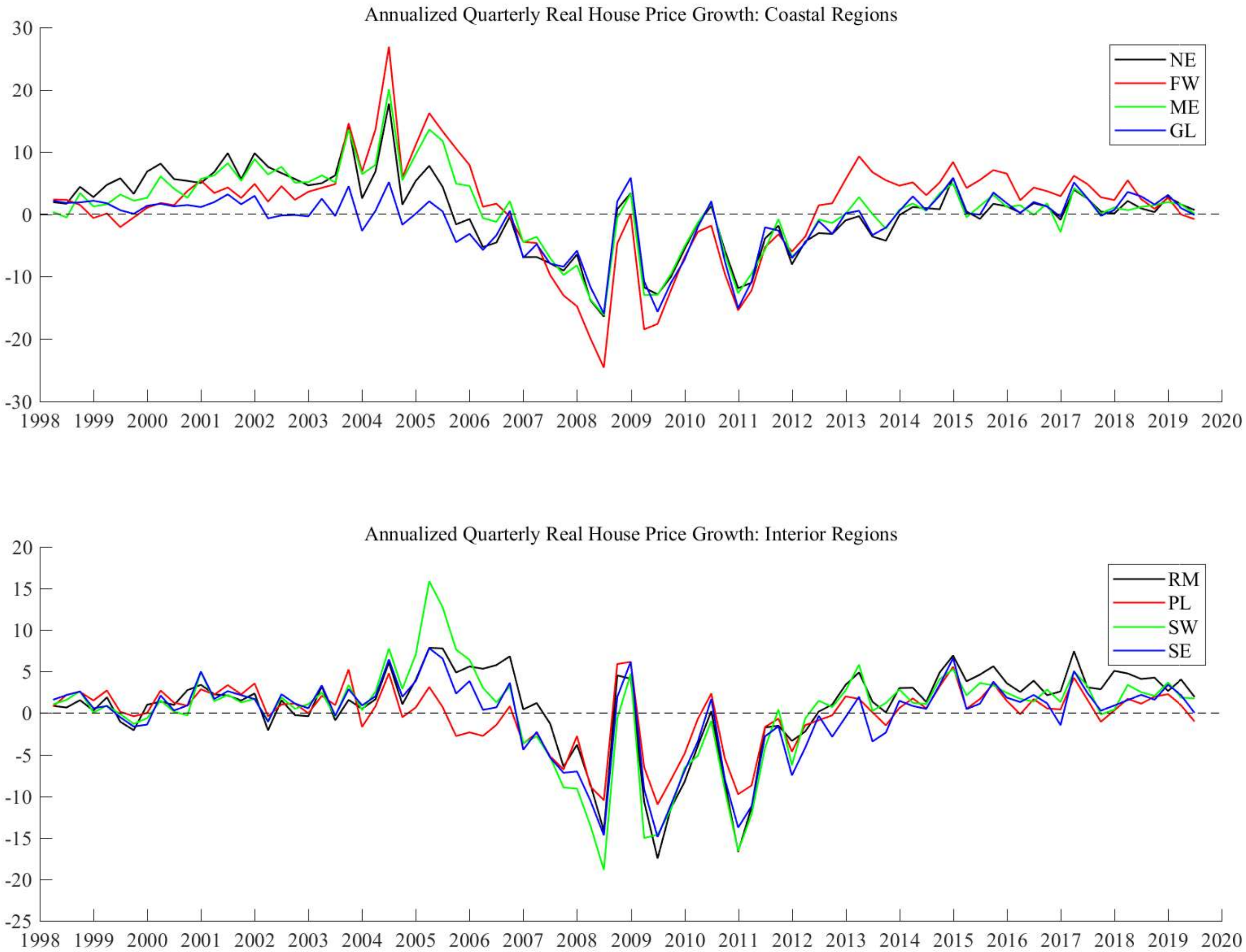
3.5 Target Change of Federal Funds Rate ($\Delta FFTR_t$)

The target change of the Federal funds rate is to measure the monetary policy. I treat the policy rate as a predetermined policy intervention that is common to all regions. The policy rate is set at each meeting of the Federal Open Market Committee (FOMC). At its eight meetings per year, the FOMC decides to change the target fed funds rate or to leave it unchanged. If the target rate is changed, most often the move is plus or minus 25 basis points. Figure 5 plots $\Delta FFTR_t$ from 1998Q2 to 2019Q3.

There are three contractionary policy periods that have positive $\Delta FFTR_t$ during the sample period. They are 1999Q2-2000Q2, 2004Q2-2006Q2, and 2015Q4-2018Q4. The two expansionary policy periods that have negative $\Delta FFTR_t$ are 2001Q1-2001Q4 and 2007Q3-2009Q1. There is no change in the target rate from 2009Q2 to 2015Q3. The target rate change during period 2001Q1-2001Q4 is more frequent than other periods, while the most intense policy was in 2008Q1 with a two percent drop in the target rate.

[5]See table 5 in appendix B for first-order autocorrelations.

Figure 4: Annualized Quarterly Regional Real House Price Growth Rate



Note: This figure plots the regional $\Delta lnHP_t$. The top panel plots the regional $\Delta lnHP_t$ in the core regions, and the bottom panel plots the regional $\Delta lnHP_t$ in the noncore regions. The sample period is 1998Q2 to 2019Q3.

Figure 5: Quarterly Change of Federal Funds Target Rate

Note: This figure plots the national $\Delta FFTR_t$. The sample period is 1998Q2 to 2019Q3.

4 Empirical Results

This section first describes the identification of the structural shocks. Next, I report estimates of the panel VAR-X during 1998Q2-2019Q3. These estimates include two sets of counterfactual analysis for studying the effectiveness of monetary policy.

4.1 Identification

The structural shocks are identified using a recursive scheme in each region. The ordering within a region is $\Delta lnPI$, $\Delta lnPCE$, $\Delta lnLoan$, and $\Delta lnHP$. The two real sector variables $\Delta lnPI$ and $\Delta lnPCE$ are placed first. Higher income increases the households' and firms' abilities to borrow and pay off debts through expanding their balance sheets, thus increases housing demand and house prices. Shocks to house prices cause repercussions on the real economy and financial markets through housing wealth and collateral effects on consumption and credit (for example, Steindel and Ludvigson (1999) and Jappelli and Pistaferri (2010)). Thus I place shocks from real sector first, then loan shock and house price shock within each region.

In the baseline model, I assume noncore regions respond later than core regions as the core regions are more prosperous in financial and housing markets. The ordering of the regions is NE, FW, ME, GL, RM, PL, SW, SE. According to the panel VAR-X in this paper, variables within a region respond to shocks from real economy, financial market and housing market with a lag, and contemporaneously respond to the monetary policy shock.

4.2 Differentiated Regional IRFs

This subsection reports the multidirectional linkages among regional real, financial, and housing sectors, and emphasizes on differentiated regional responses of house price growth with respect to income, demand, loan, and house price shocks from their own or other regions.

The IRFs show that the transmission of shocks to regional real, financial, and housing sectors have large differences among regions in both directions and magnitudes. Three core regions, NE, FW, and GL, and a noncore region, SE, have statistically and economically significant IRFs within region. The cross-region house price spillovers are also evident in the IRFs, while the transmission of shocks from other region's real and financial sectors to a region's housing sector is skim.

4.2.1 Transmissions Among Sectors

The IRFs in this section are summarized in a table. [Material to come.]

Figures 10 to 17 in appendix C.1 are within-region IRFs among all sectors based on the whole sample period. Three core regions NE, FW, GL, and a noncore region SE generally have significant responses among the sectors. These responses indicate there are transmission of shocks among the sectors within the regions. The house prices in these regions response positively to income, demand, and loan shocks, and there are significant repercussion effects from the housing sectors. The IRFs in ME, RM, PL, and SW are less significant, and they indicate impeded transmissions among the sectors or the transmission mechanisms changed over the sample period.

Different from other IRFs that are positive, the IRFs with respect to loan shocks are less determined. For example, the loan shock from NE generates significant positive impacts on income and nondurable consumption, and insignificant positive impacts on house prices. It indicates the loan shock is dominated by credit demand rather than supply. While loan shocks from GL, SW, and SE generate significant negative impacts on house prices, and ME, RM, PL generate insignificant negative impacts on house prices. It indicates the loan shocks in these regions are dominated by credit supply rather than demand shocks.

The cross-region transmission from real economy and financial market to housing market also exists in several regions. Figures 18 to 29 in appendix C.2 display the cross-regions IRFs of house price growth to income, demand, and loan shocks. The shocks from real and financial sectors in GL and SE, and demand shocks from SW and FW transmit to other regions' housing sectors positively and significantly. For example, a 1% increase in $\Delta lnPI$ in GL rises the house prices in core regions by about 2.5%, and rises the house prices in noncore regions by about 2%. While shocks from noncore regions generate larger impacts on noncore regions' house prices than on core regions' house prices. However, the persistence of the impacts from noncore regions are similar to those from core regions. The house prices reach at steady states in about ten quarters in both cases.

Almost all other regional shocks do not significantly transmit to housing markets in other regions. This is an evidence that regional housing markets are locally characterized. They depends on local economic fundamentals and influenced by other regions' fundamentals through skim direct channels. The house prices in other regions only positively and significantly respond to several other regions' shocks. However, there are plenty of cross-region transmissions through housing markets. The house price spillovers are discussed in the next subsection.

The next paragraph analyses cross-region transmission of shocks to real and financial sectors. [Material to come.]

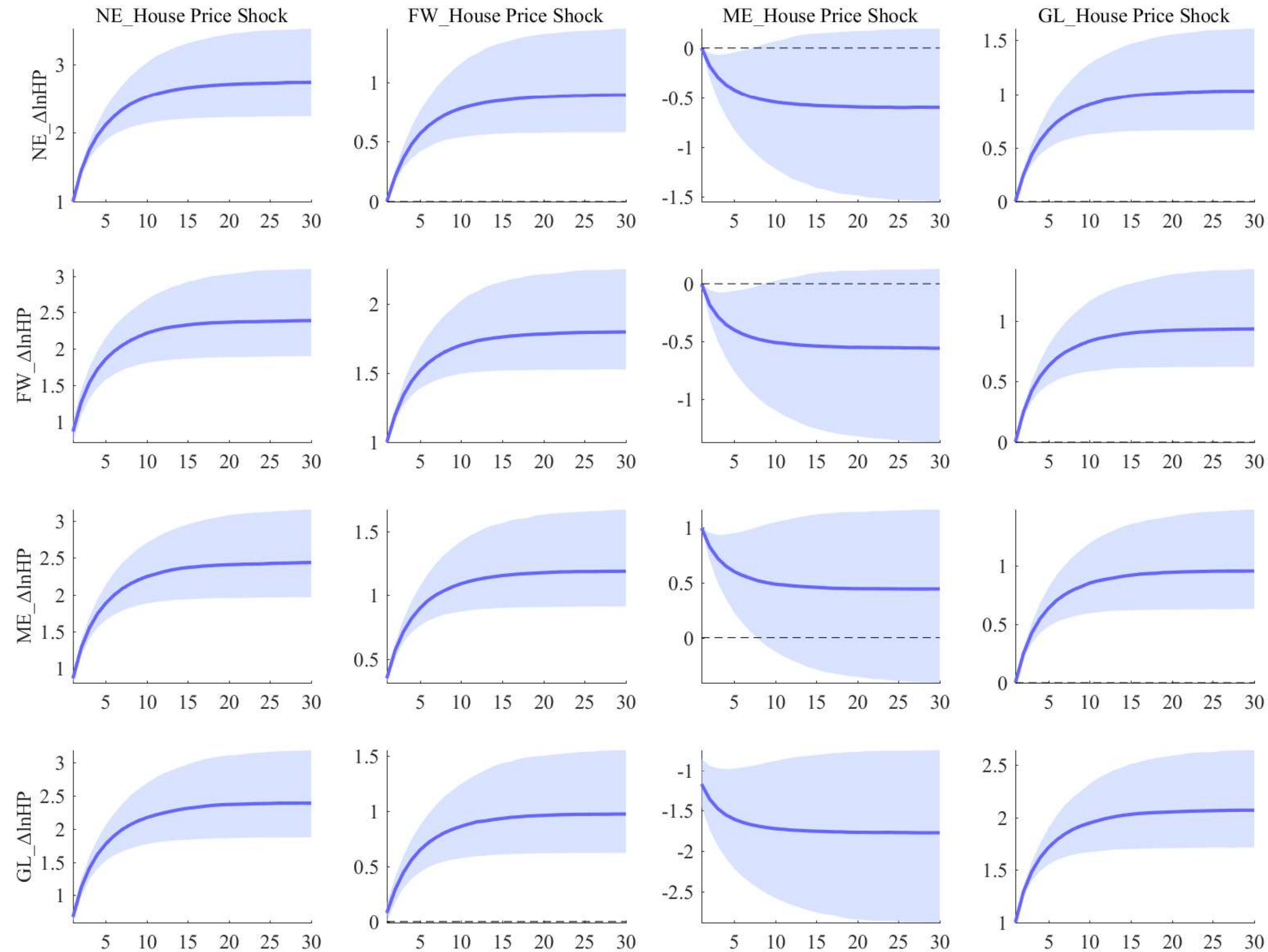
4.2.2 House Price Spillovers

Figures 6 to 7 display IRFs of $\Delta lnHP$ within the core and noncore regions. Figures 8 to 9 display IRFs of $\Delta lnHP$ across the core and noncore regions. The figures show that all regions respond positively to their own and other regions' house price shocks, and they generate positive IRFs of other regions' house prices except ME and PL. This is evidence of house price spillovers across regional house prices in the US. The evidence is supported by the 68% uncertainty bands. The spillovers suggest a transmission mechanism of housing markets that runs from the core regions to noncore regions.

Comparing figure 6 to figure 7, the core regions' house prices reach to steady states in longer periods than the house price shocks in noncore regions. The house prices in the core regions reach to steady states in about ten quarters, while they are about five to ten quarters in the noncore regions.

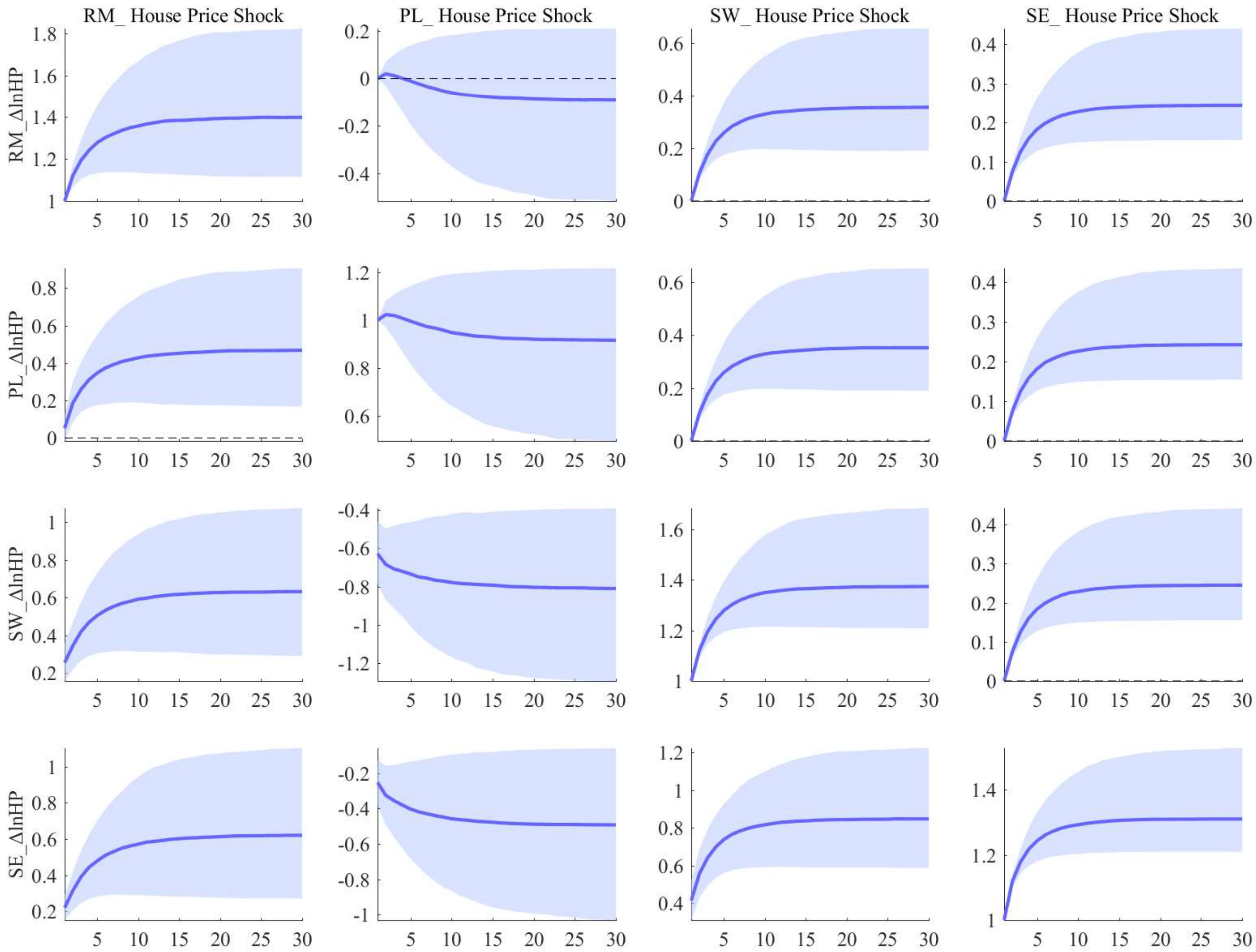
The four figures show that core regions' house price shocks are responsible for rela-

Figure 6: IRFs of $\Delta lnHP$ to House Price Shocks within Core Regions



Note: This figure displays IRFs of core regions' $\Delta lnHP$ to noncore regions' house price shocks in 24 quarters with 68% uncertainty bands.

Figure 7: IRFs of $\Delta lnHP$ to House Price Shocks within Noncore Regions



Note: This figure displays IRFs of core regions' $\Delta lnHP$ to noncore regions' house price shocks in 24 quarters with 68% uncertainty bands.

tively large and persistent responses of house price growth in all regions than the noncore regions' shocks. A 1% increase in house prices in the core regions can lead to increases in other regions' house prices by about 1%-2.5%. The dynamic responses after impact continue to increase until they reach to steady states in about 15 quarters. The noncore regions' house price shocks are less influential and persistent. A 1% increase in noncore regions' house prices have impacts of no more than 0.8% increase in other regions' house prices. The dynamic responses of these IRFs return to steady state in less than 15 quarters.

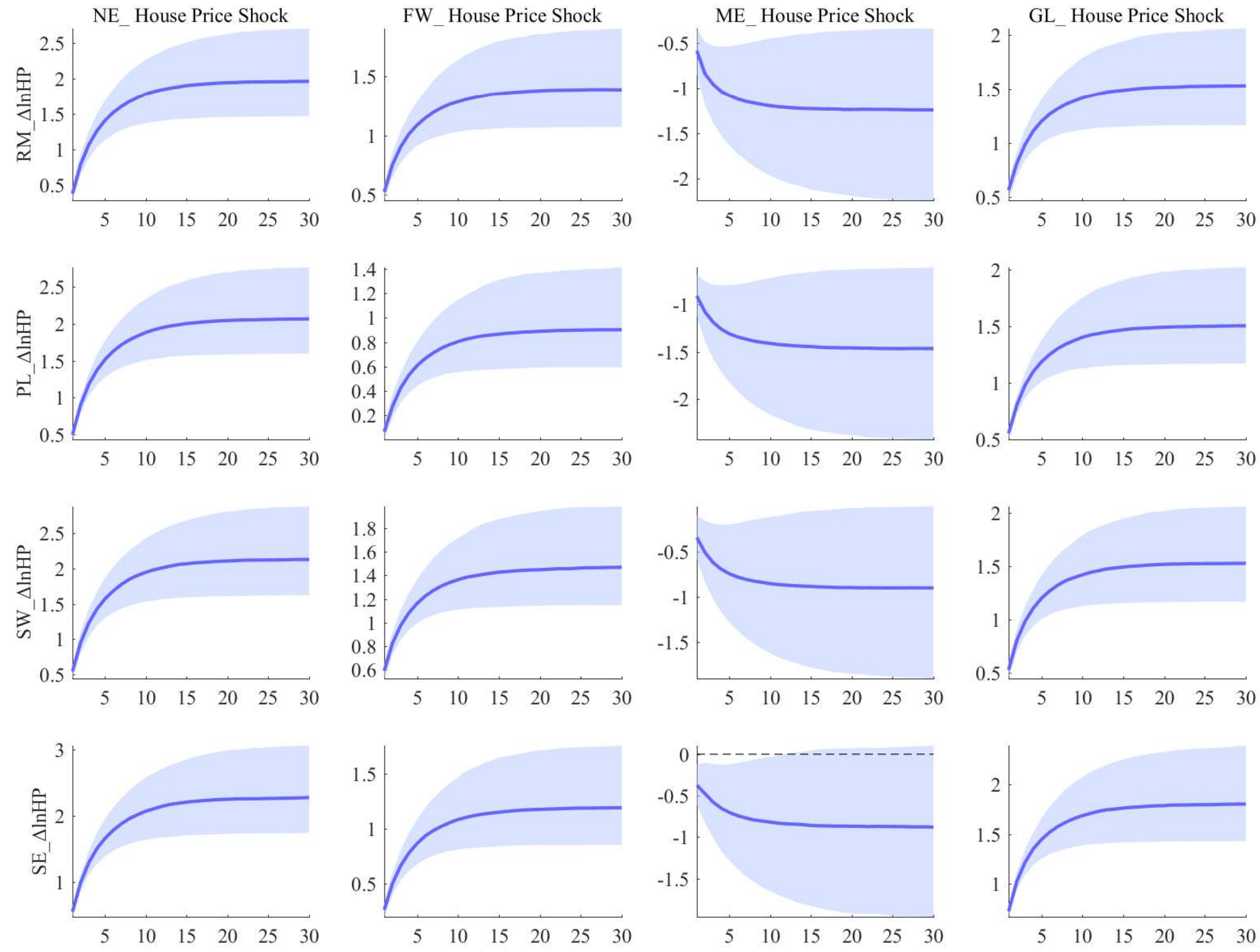
Two exceptions of the discussion above are the core region ME and the noncore region PL. Different from other regions, ME and PL do not significantly generate positive house price spillovers to other regions. However, they respond positively to other regions' house price shocks. The impacts of a 1% increase in house prices in ME to other regions' house prices are around -1.5% to -0.5%. The impacts are significant in some regions. One possible explanation is that the investment demand of housing in ME suppresses household demand, thus an increase in house prices in ME attracts investments from other regions and the house prices in other regions decrease. The house price shock in region PL also generate impacts on other regions' $\Delta lnHP$, but they are slightly positive and then negative, and zeros are covered by the 68% uncertainty bands for most of the regions. These IRFs show the housing market in PL does not have significant impacts on other regions' housing markets except SW and SE.

4.3 Effectiveness of Monetary Policies

This subsection discusses the effectiveness of monetary policy and their differences across regions over time by conducting two sets of counterfactual analysis. The first set is conditional on unchanged monetary policy with the parameters estimated from the panel VAR-X. The second set is the counterfactual analysis during the financial crisis in 2007-2009 with the actual monetary policy but use before-crisis and after-crisis parameters of monetary policy.

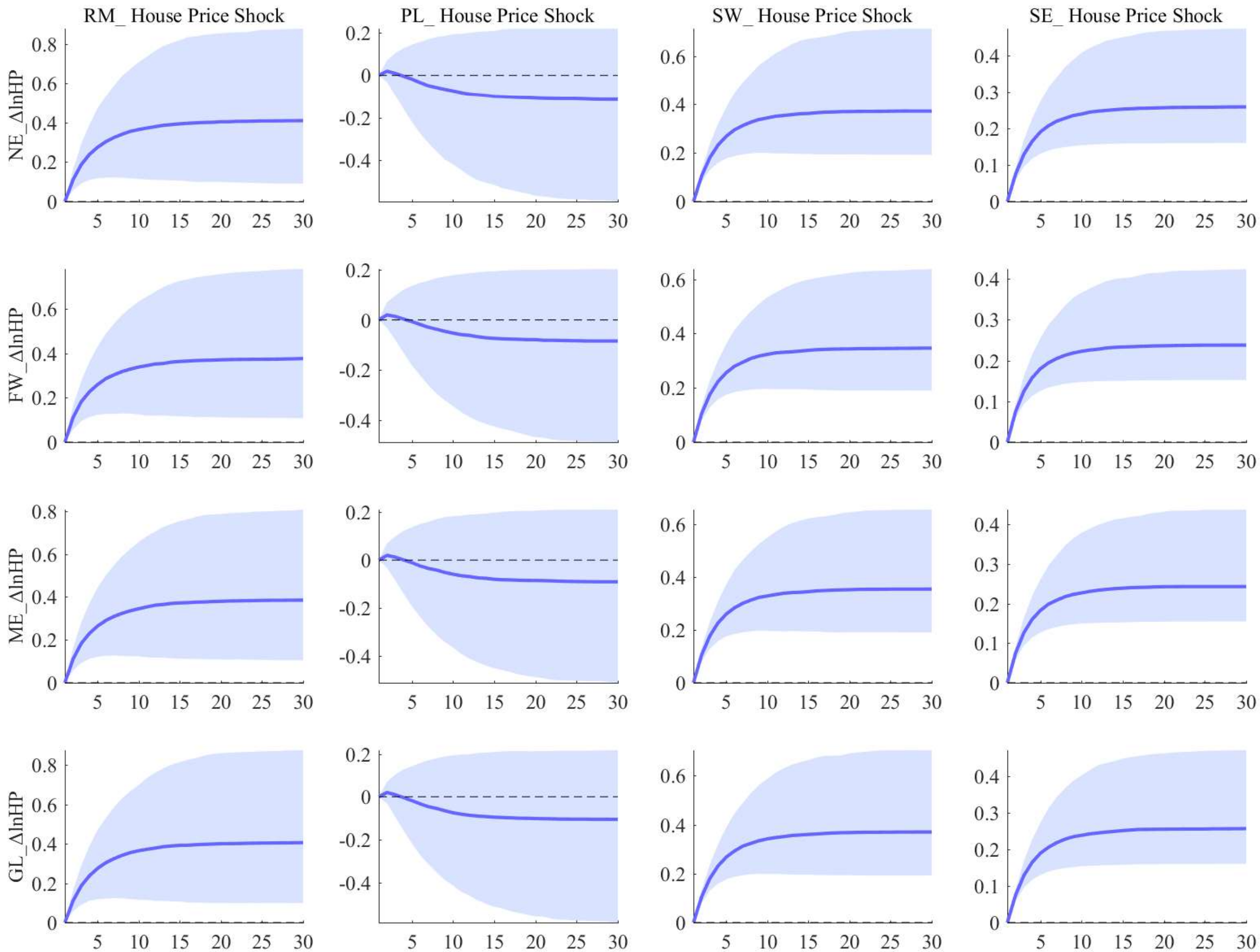
[Material to come.]

Figure 8: IRFs of Noncore Regions' $\Delta lnHP$ to Core Regions' House Price Shocks



Note: This figure displays IRFs of core regions' $\Delta lnHP$ to noncore regions' house price shocks in 24 quarters with 68% uncertainty bands.

Figure 9: IRFs of Core Regions' $\Delta lnHP$ to Noncore Regions' House Price Shocks



Note: This figure displays IRFs of core regions' $\Delta lnHP$ to noncore regions' house price shocks in 24 quarters with 68% uncertainty bands.

5 Conclusion

This paper estimates a TVP-SV panel VAR-X on regional real per capita personal income, real per capita personal consumption, real per capita loan, and real house price growth across eight BEA regions in the U.S.. The target change of federal funds rate is taken as a predetermined monetary policy variable. The estimation of the panel VAR-X gives dynamic responses of regional real income, consumption, loan, and house prices to regional structural income, demand, loan, and house price shocks. I conduct a counterfactual analysis conditional on unchanged monetary policy for studying the effectiveness of monetary policy, and another that is conditional on different coefficients during the financial crisis for comparing the differences in the effectiveness of monetary policy among before-crisis, during crisis, and after-crisis periods. This paper also provides a new regional quarterly data set of real per capita personal income, real per capita personal consumption expenditure, real per capita loan, and real house price growth from 1998Q2 to 2019Q3.

The estimation of the panel VAR-X gives three main results. First, there are within-region transmission of shocks and they are different across regions. Core regions except RM and a noncore region SE have significant within-region transmission of shocks. However, other regions have impeded transmission across real, financial, and housing sectors. Second, there are cross-region transmission of real and financial sector shocks to housing sectors, while not all regions' real and financial sector shocks can be directly transmitted to other regions' housing sectors. Third, the house price spillovers across regions exist broadly. All regions' house prices respond positively to other regions house price shocks. Only the house price shocks from ME and PL do not generate significantly positive dynamic responses of house prices in other regions.

This paper suggests the following directions for future works. First, it will be interesting to incorporate more monetary policy tools to examine the differences of their impacts on regional housing markets. Second, tools other than counterfactual analysis can be used in evaluating the effectiveness of monetary policy. I hope this paper stimulates this research.

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