The Foreclosure-House Price Nexus:
A Panel VAR Model for U.S. States, 1981-2009

Supplemental Appendix

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This supplemental appendix presents the tables and figures from our core PVAR regression model using the MBA foreclosure rate (a stock variable) as the measure of foreclosures, instead of the foreclosure start rate (a flow variable) that is used in the body of the paper. Our qualitative results are similar (and some of the main conclusions in our paper are even stronger) using these data.

Note: Figure and table names have been matched to those in the body of the text. Thus, Table A1 corresponds to Table 1 in the text. Figures and tables that would not differ using the foreclosure rate instead of the foreclosure start rate have been omitted.

Table A1 – Panel VAR Regression Results

	Employment	Sales	Permits	Prices	Foreclosures
Employment					
L1	0.457882***	0.201855	0.776741	-0.000941	-1.030743
	(0.052522)	(0.430904)	(0.727672)	(0.043127)	(0.577642)
L2	0.203772***	0.025729	1.315576	0.041054	-0.244007
	(0.032869)	(0.443115)	(0.838033)	(0.042464)	(0.680451)
L3	0.089645***	-2.275960***	-3.539496**	0.022708	-1.065605
	(0.026454)	(0.432505)	(1.128557)	(0.041652)	(0.600509)
L4	-0.145940***	-0.132903	-3.834141***	0.115279**	0.554784
	(0.024176)	(0.419616)	(1.092312)	(0.043992)	(0.632106)
L5	0.131152***	0.788355	1.223148	-0.032501	-0.832345
	(0.024098)	(0.425909)	(0.822912)	(0.045365)	(0.538431)
L6	0.056783**	0.051091	1.097240	-0.086893*	1.304067*
	(0.017850)	(0.388027)	(0.941392)	(0.041621)	(0.596047)
L7	0.012129	0.112194	0.388506	0.132210**	0.707183
	(0.017709)	(0.383872)	(0.805641)	(0.041668)	(0.625848)
L8	-0.155159***	-0.342118	-1.043909	-0.055697	1.453058*
	(0.019063)	(0.385936)	(0.638670)	(0.045386)	(0.596458)
L9	0.091768***	0.771279*	0.445853	0.000849	-1.747600**
	(0.018755)	(0.379112)	(0.696734)	(0.041281)	(0.624246)
L10	0.041490*	-0.797344*	0.365235	-0.097589*	0.573469
	(0.017875)	(0.397383)	(0.696034)	(0.044871)	(0.666006)
L11	0.024920	0.348035	0.236378	0.080951	-1.023068
	(0.015432)	(0.361258)	(0.613072)	(0.046699)	(0.671417)
L12	-0.066459***	0.754364*	0.899688	0.078366	0.530698
	(0.014308)	(0.355045)	(0.554207)	(0.042537)	(0.537517)

Table A1 – Panel VAR Regression Results

		Employment	Sales	Permits	Prices	Foreclosures
Sales						
	L1	0.002093**	-0.209463***	0.217534***	0.004951*	-0.074729*
		(0.000775)	(0.029134)	(0.036770)	(0.002169)	(0.030695)
	L2	0.002028*	-0.049305*	0.152751***	0.009371***	0.020645
		(0.000835)	(0.023962)	(0.038691)	(0.002547)	(0.030163)
	L3	0.000746	-0.084475***	0.107002*	0.006182*	0.024932
		(0.000862)	(0.023238)	(0.042585)	(0.002421)	(0.028644)
	L4	0.002479**	0.073224**	0.089752*	0.003767	0.015414
		(0.000831)	(0.023610)	(0.037027)	(0.002279)	(0.027213)
	L5	0.003237***	0.006487	0.034476	0.006746**	-0.023364
		(0.000816)	(0.021111)	(0.034621)	(0.002220)	(0.028513)
	L6	0.003803***	0.086228***	0.067986	0.006555**	-0.011521
		(0.000772)	(0.021906)	(0.036494)	(0.002248)	(0.029522)
	L7	0.004002***	-0.012415	0.059240	0.008881***	0.029651
		(0.000796)	(0.023961)	(0.043434)	(0.002149)	(0.028799)
	L8	0.002052*	-0.025477	-0.010162	-0.000449	0.003899
		(0.000832)	(0.025160)	(0.037920)	(0.002281)	(0.028064)
	L9	-0.000212	-0.044411*	-0.110030**	0.001181	0.065554*
		(0.000797)	(0.021856)	(0.039458)	(0.002077)	(0.030719)
	L10	-0.001200	0.040780*	-0.087813*	0.001623	0.025782
		(0.000740)	(0.019405)	(0.039577)	(0.002045)	(0.028446)
	L11	-0.000525	0.001522	-0.114672**	0.000190	0.043134
		(0.000698)	(0.018554)	(0.037160)	(0.002111)	(0.027536)
	L12	-0.000653	0.004224	-0.105474***	0.001761	0.006856
		(0.000716)	(0.018288)	(0.029777)	(0.001859)	(0.028990)

Table A1 – Panel VAR Regression Results

	Employment	Sales	Permits	Prices	Foreclosures
Permits					
L1	0.003412***	0.075829***	-0.360408***	0.002659	-0.030458**
	(0.000555)	(0.013713)	(0.051757)	(0.001695)	(0.010581)
L2	0.002445***	0.042704***	-0.168552***	0.003214*	-0.050270***
	(0.000714)	(0.012904)	(0.049550)	(0.001601)	(0.012982)
L3	0.002103***	0.020023	0.013359	0.000268	-0.040527**
	(0.000531)	(0.010866)	(0.082992)	(0.001297)	(0.013637)
L4	0.001546**	-0.030734*	-0.068635	0.000602	-0.035902*
	(0.000531)	(0.012967)	(0.072886)	(0.001708)	(0.015361)
L5	0.002596***	0.008099	0.136102*	0.001538	-0.060971***
	(0.000699)	(0.013921)	(0.053198)	(0.001662)	(0.016146)
L6	0.001947**	0.015039	0.180712**	0.001276	-0.090731***
	(0.000614)	(0.012163)	(0.065427)	(0.001426)	(0.015244)
L7	-0.000190	-0.012842	0.023921	0.000603	-0.056092***
	(0.000546)	(0.012991)	(0.056295)	(0.001628)	(0.016300)
L8	0.000028	-0.009793	-0.010223	0.002627	-0.045326*
	(0.000556)	(0.012474)	(0.061967)	(0.001645)	(0.018827)
L9	0.001635*	0.027560*	0.060340	-0.000293	-0.028052
	(0.000652)	(0.013301)	(0.067283)	(0.001625)	(0.017691)
L10	0.001227*	0.008582	0.191078**	0.000186	-0.027189
	(0.000606)	(0.011710)	(0.060176)	(0.001616)	(0.017664)
L11	0.000480	0.001995	0.208146***	-0.002247	0.006191
	(0.000623)	(0.012096)	(0.050679)	(0.001576)	(0.015781)
L12	-0.000530	-0.011217	0.127562*	0.000617	0.012291
	(0.000575)	(0.012246)	(0.060252)	(0.001434)	(0.016310)

Table A1 – Panel VAR Regression Results

		Employment	Sales	Permits	Prices	Foreclosures
Prices						
	L1	0.014147*	1.219747***	1.645018***	0.348872***	-1.325786***
		(0.006298)	(0.163147)	(0.419131)	(0.023585)	(0.259989)
	L2	0.013143*	0.168398	1.367130*	0.087309***	-0.689599**
		(0.006559)	(0.171935)	(0.552565)	(0.023996)	(0.260767)
	L3	0.022236***	0.146152	-0.177837	0.260901***	-1.423096***
		(0.006556)	(0.163402)	(0.339718)	(0.022544)	(0.245505)
	L4	-0.016480*	-0.164694	-0.593162	0.145160***	0.295837
		(0.006666)	(0.171549)	(0.560589)	(0.021536)	(0.308846)
	L5	-0.028219***	-0.612537**	-1.043950*	0.011166	0.001641
		(0.006956)	(0.189726)	(0.486255)	(0.023441)	(0.303604)
	L6	-0.001410	0.007548	-0.159661	-0.054474**	0.188658
		(0.006794)	(0.187368)	(0.354562)	(0.020326)	(0.322701)
	L7	0.017084*	0.770994***	0.264360	-0.026745	0.163911
		(0.006943)	(0.190244)	(0.434543)	(0.020246)	(0.302881)
	L8	-0.001907	-0.645183***	-0.536218	0.069304***	-0.047965
		(0.006404)	(0.183546)	(0.307931)	(0.019538)	(0.286501)
	L9	0.003027	-0.153063	-0.340950	0.073220***	0.927341**
		(0.006825)	(0.169393)	(0.304833)	(0.019277)	(0.310013)
	L10	0.008560	0.337688*	-0.150332	-0.023405	0.516107
		(0.006004)	(0.170531)	(0.323448)	(0.018113)	(0.290101)
	L11	-0.011874	-0.113832	-0.769697**	-0.040977*	0.240071
		(0.006140)	(0.173426)	(0.266201)	(0.018174)	(0.257897)
	L12	-0.006940	0.110934	-0.200901	0.008250	-0.145952
		(0.005522)	(0.165571)	(0.246162)	(0.016745)	(0.261274)

Table A1 – Panel VAR Regression Results

	Employment	Sales	Permits	Prices	Foreclosures
Foreclosures					
L1	0.000709	0.000865	0.010966	-0.004360 **	0.700875 ***
	(0.000534)	(0.011843)	(0.016404)	(0.001335)	(0.044377)
L2	0.000417	0.036380 *	-0.003397	0.002298	0.228724 ***
	(0.000562)	(0.014295)	(0.016489)	(0.001721)	(0.059930)
L3	-0.000050	-0.019812	-0.044974 *	0.000661	0.081595
	(0.000532)	(0.014548)	(0.017772)	(0.001569)	(0.059847)
L4	-0.001585 **	0.004063	-0.010315	0.001535	0.040177
	(0.000556)	(0.015215)	(0.017123)	(0.001687)	(0.049337)
L5	0.000211	-0.003000	0.016885	0.000519	-0.026631
	(0.000584)	(0.015401)	(0.017454)	(0.001757)	(0.040650)
L6	-0.000622	0.003364	-0.015751	0.001115	-0.041350
	(0.000598)	(0.016676)	(0.018799)	(0.001415)	(0.039758)
L7	-0.000150	0.008610	0.014274	-0.001215	0.037370
	(0.000577)	(0.016766)	(0.017380)	(0.001428)	(0.040653)
L8	0.000712	0.036396	0.056022 **	0.000905	-0.057958
	(0.000645)	(0.019146)	(0.017456)	(0.001388)	(0.053527)
L9	-0.000458	-0.006018	0.002038	0.004135 **	-0.064969
	(0.000671)	(0.015123)	(0.017943)	(0.001573)	(0.040111)
L10	0.000680	-0.004929	-0.023883	-0.000605	0.051911
	(0.000754)	(0.015720)	(0.017756)	(0.001342)	(0.038071)
L11	0.000335	-0.004147	-0.003512	-0.000495	-0.030258
	(0.000763)	(0.014381)	(0.016023)	(0.001514)	(0.037446)
L12	-0.000345	-0.037648 ***	-0.012080	-0.002412 *	0.025879
	(0.000515)	(0.010411)	(0.012591)	(0.001184)	(0.023805)

Notes: Standard errors are presented in parentheses below the regression coefficients.
   *** Coefficient significant at the 0.1% level.
   ** Coefficient significant at the 1% level.
   * Coefficient significant at the 5% level.
   The variables used in the analysis are as follows:
   - **Employment** – Growth rate (log difference) of the quarterly average of seasonally-adjusted monthly total non-farm employment for the state.
   - **Sales** – Growth rate (log difference) of the seasonally-adjusted annual rate of existing home sales for the state in the quarter.
   - **Permits** – Growth rate (log difference) of the quarterly average of the monthly seasonally-adjusted annual rate of single-family residential building permits for the state.
   - **Prices** – Growth rate (log difference) of the quarterly FHFA house price index (all transactions) for the state.
   - **Foreclosures** – Log level of the MBA quarterly foreclosures outstanding as a percent of loans serviced for the state.
   All regression variables were de-meaned using a Helmert transformation, while the actual values of the variables were used as instruments to obtain consistent estimates.

Table A2 – Residuals Correlation Matrix

	Employment	Sales	Permits	Prices	Foreclosures
Employment	1				
Sales	0.0868 (0.0000)	1			
Permits	0.1578 (0.0000)	0.1770 (0.0000)	1		
Prices	-0.0596 (0.0001)	0.0562 (0.0001)	0.0085 (0.5646)	1	
Foreclosures	-0.0407 (0.0060)	-0.0585 (0.0001)	-0.0167 (0.2615)	-0.0374 (0.0117)	1

Notes: All variables are Helmert de-meaned log differences of levels except for foreclosures, which is the (de-meaned) log foreclosure rate (see the notes on Table 1 and the appendix for a complete description of the variables); p-values are reported in parentheses.

Table A3 – Variance Decompositions

	Lag	Employment	Sales	Permits	Prices	Foreclosures
Employment	4	0.9356	0.0152	0.0301	0.0162	0.0029
	8	0.7922	0.1036	0.0692	0.0320	0.0030
	20	0.5830	0.1726	0.1475	0.0757	0.0212
Sales	4	0.0142	0.9481	0.0157	0.0199	0.0022
	8	0.0150	0.9287	0.0227	0.0299	0.0037
	20	0.0180	0.8996	0.0278	0.0345	0.0201
Permits	4	0.0278	0.0319	0.9227	0.0166	0.0010
	8	0.0370	0.0370	0.9048	0.0194	0.0019
	20	0.0389	0.0381	0.8955	0.0229	0.0046
Prices	4	0.0034	0.0288	0.0047	0.9593	0.0038
	8	0.0087	0.0854	0.0150	0.8878	0.0030
	20	0.0089	0.1417	0.0335	0.7070	0.1089
Foreclosures	4	0.0094	0.0120	0.0070	0.0534	0.9182
	8	0.0188	0.0387	0.0408	0.1529	0.7488
	20	0.0158	0.1379	0.1836	0.2801	0.3826

Note: Percent of row variable explained by the column variable at the specified lag.

Table A4 – Orthogonalized Foreclosure and Price "Shocks" since 2007

Group	Obs.	Foreclosure Shocks	Price Shocks
Non-Judicial Foreclosure States	341	0.1868 *** (0.0047)	-0.0003 (0.0006)
Judicial Foreclosure States	220	0.0039 (0.0044)	0.0004 (0.0008)
Combined	561	0.0129 *** (0.0034)	-0.0001 (0.005)
Difference		0.0147 * (0.0064)	-0.0007 (0.0010)

Notes: Cell entries show mean orthogonalized shocks to the variable in question, with standard errors presented in parentheses below.
*** Coefficient significant at the 0.1% level.
** Coefficient significant at the 1% level.
* Coefficient significant at the 5% level.
Orthologanized shocks are calculated as the one-step-ahead forecast errors minus the contemporaneous responses to the shocks to earlier variables in the system according to our Cholesky ordering. Thus, employment shocks are simply the forecast errors, sales shocks are the forecast errors less the contemporaneous response of sales to the observed employment shock, and so forth.
Judicial foreclosure states are identified by Mian, Sufi and Trebbi (2010) as Connecticut, Delaware, Florida, Illinois, Indiana, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Maine, Nebraska, New Jersey, New Mexico, New York, North Dakota, Ohio, Pennsylvania, South Carolina and Vermont.

Table A5 – Variance Decompositions for Various Data Samples

	Lag	Base Model		Full Data		Real HPIs		Purchase-only	
		Prices	For.	Prices	For.	Prices	For.	Prices	For.
Prices	4	0.9593	0.0038	0.9392	0.0110	0.9351	0.0212	0.9030	0.0043
	8	0.8878	0.0030	0.8883	0.0102	0.8913	0.0392	0.8517	0.0045
	20	0.7070	0.1089	0.7313	0.0549	0.8252	0.0395	0.7035	0.0849
Foreclosures	4	0.0534	0.9182	0.0532	0.8988	0.0393	0.9118	0.0597	0.8849
	8	0.1529	0.7488	0.1244	0.7452	0.1059	0.7764	0.1496	0.7089
	20	0.2801	0.3826	0.2059	0.4184	0.1067	0.5597	0.2684	0.3724

Note: Percent of row variable explained by the column variable at the specified lag. The Full Data cells incorporate early observations that were deleted in the base model due to concerns about volatility in the HPI. Real HPIs deflates each state's house price index by the quarterly average of the consumer price index. Finally, the Purchase-only cells use the FHFA purchase-only indices (spliced with the all-transactions indices in the early years as discussed in the text). In each case, prices explain a larger percentage of the variation of foreclosures at 20 lags than foreclosures for prices.

Table A6 – Correlations among U.S. Aggregate System Variables

|	Employment	Sales	Permits	Foreclosures.
FHFA Index	0.3746	0.1006	0.1845	-0.5172
	(0.000)	(0.340)	(0.078)	(0.000)
Case-Shiller Index	0.3784	0.2830	0.5517	-0.3863
	(0.000)	(0.006)	(0.000)	(0.000)

Note: Cells show the pairwise correlations of prices and the other variables in the system for U.S. aggregate values; p-values are shown in parentheses below the correlations. In the top row, prices are measured using the FHFA all-transactions house price index. In the bottom row, prices are measure using the Case-Shiller U.S. national house price index (not seasonally adjusted). The Case-Shiller HPI exhibits larger correlation with existing home sales and building permits, but the correlation with employment is similar across the two measures of home prices. The FHFA index is more strongly correlated with the foreclosure rate than is the Case-Shiller index

Table A7 – Variance Decompositions for Various Orderings

	Lag	Base Model		FHESP		FESPH	
		Prices	For.	Prices	For.	Prices	For.
Prices	4	0.9593	0.0038	0.9673	0.0085	0.9560	0.0085
	8	0.8878	0.0030	0.9000	0.0083	0.8847	0.0083
	24	0.7070	0.1089	0.7330	0.0949	0.7122	0.0949
Foreclosures	4	0.0534	0.9182	0.0413	0.9433	0.0418	0.9433
	8	0.1529	0.7488	0.1338	0.7915	0.1326	0.7915
	24	0.2801	0.3826	0.2747	0.4247	0.2613	0.4247

Note: Percent of row variable explained by the column variable at the specified lag. Ordering FHESP is Foreclosures, House prices, Employment, Sales, and Permits. Ordering FESPH is Foreclosures, Employment, Sales, Permits, and House Prices. In each case, prices explain a larger percentage of the variation of foreclosures at 24 lags than do foreclosures for prices.

Figure A1: Change in Foreclosure Rate vs. FHFA HPI
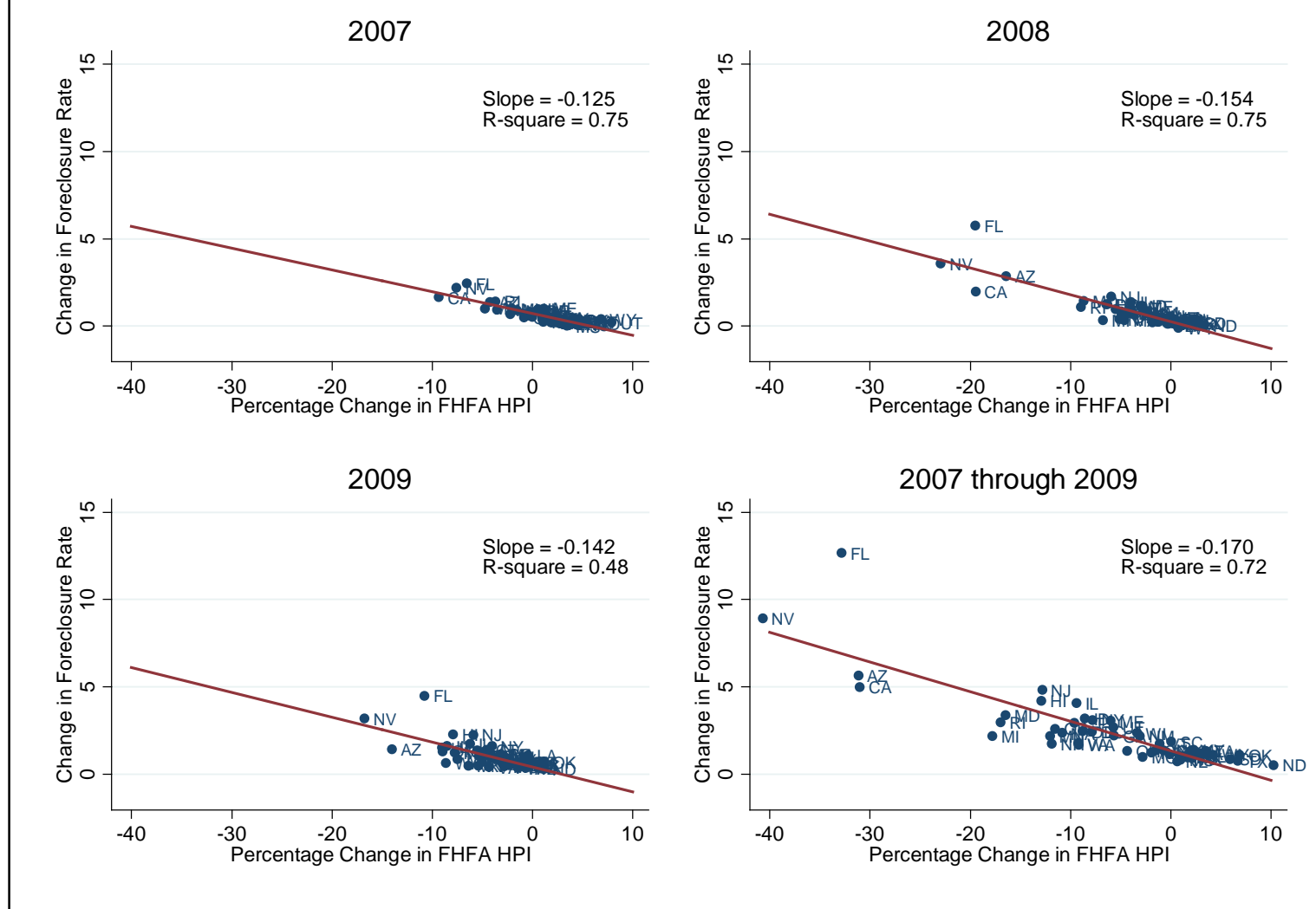
Note: Annual graphs are derived using year-over-year changes based on 4th quarter values. The 3-year graph shows the cumulative changes between 2006Q4 and 2009Q4. The Foreclosure Rate is the percentage of loans serviced that are currently in the foreclosure process. The FHFA HPI is the state-level Federal Housing Finance Agency all-transactions house price index.

Figure A2: Impulse Response Functions
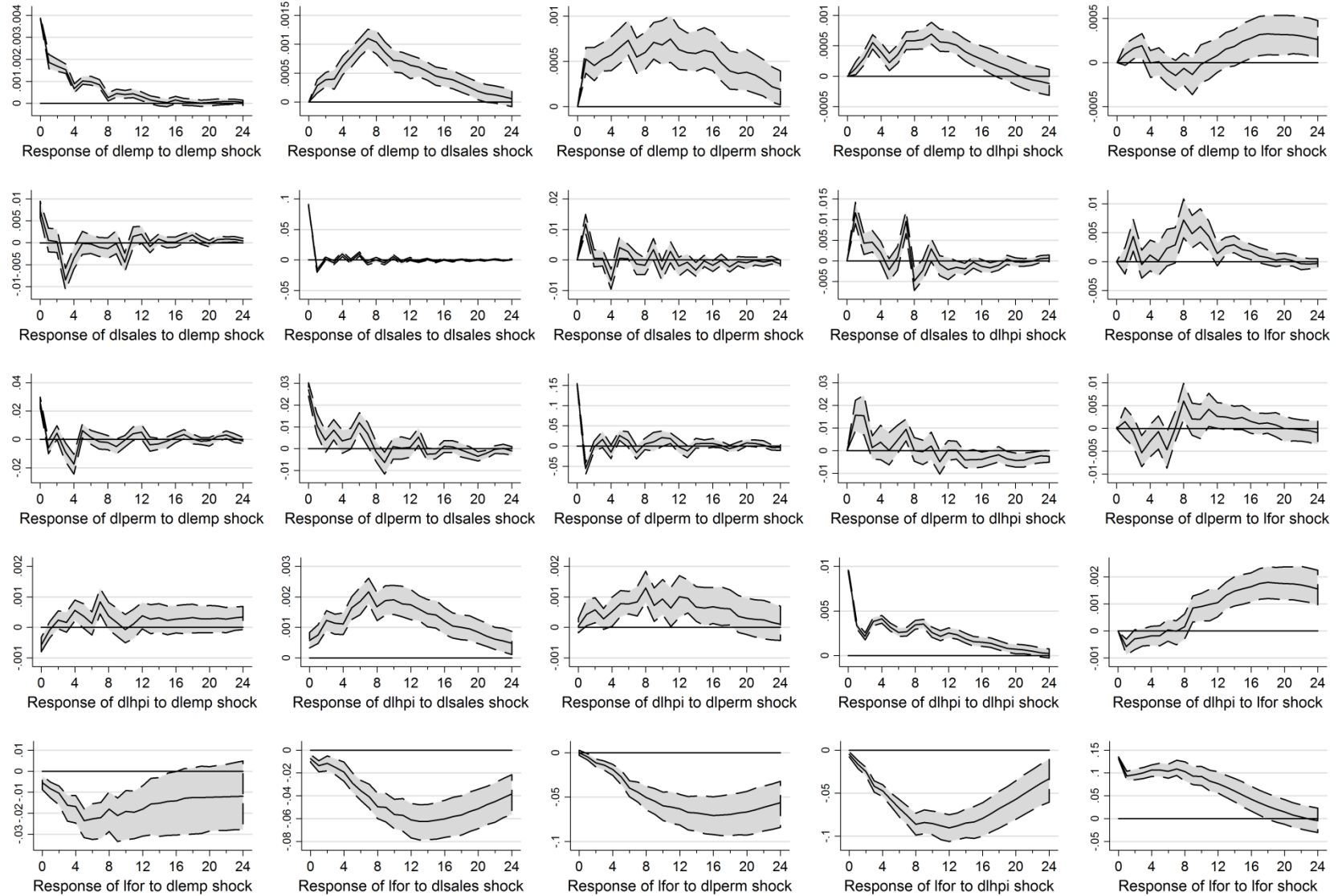
Note: Impulse responses are based on growth rates (difference of logs) of all variables in the system except the foreclosure rate, which is modeled as a log level. The impulse responses are derived using a Cholesky decomposition with the following ordering: employment, sales, permits, prices (HPI), and foreclosure rate.

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Figure A3 - Standardized Impulse Reponses

Legend:
- Response of Foreclosures to Price Shocks
- Response of Prices to Foreclosure Shocks
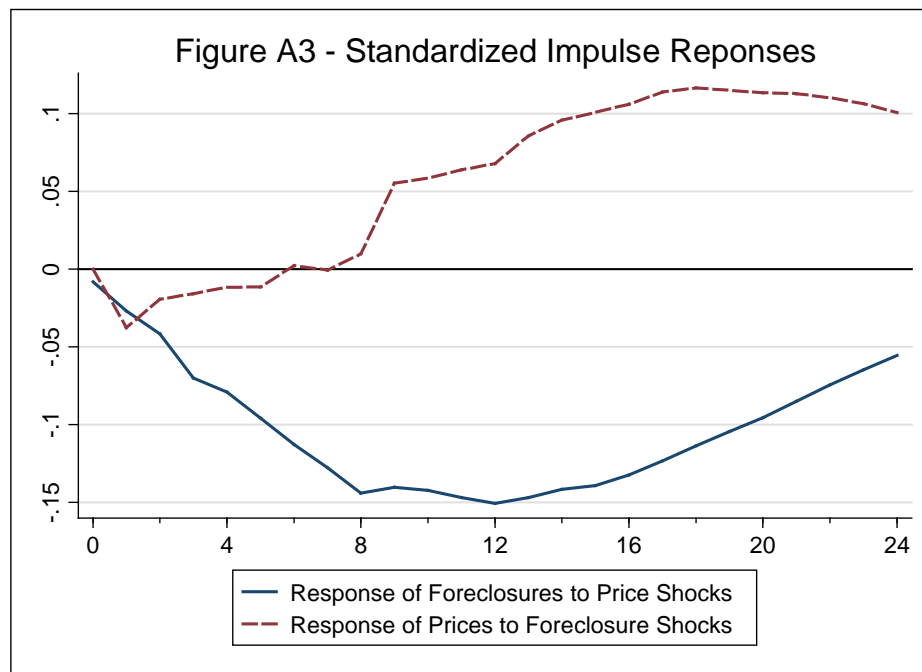
Note: The standardized responses are calculated by dividing the model impulse responses shown in Figure A2 by the sample standard deviations of the response variable.

Figure A4: Crisis Foreclosure Rates vs. Historical Values
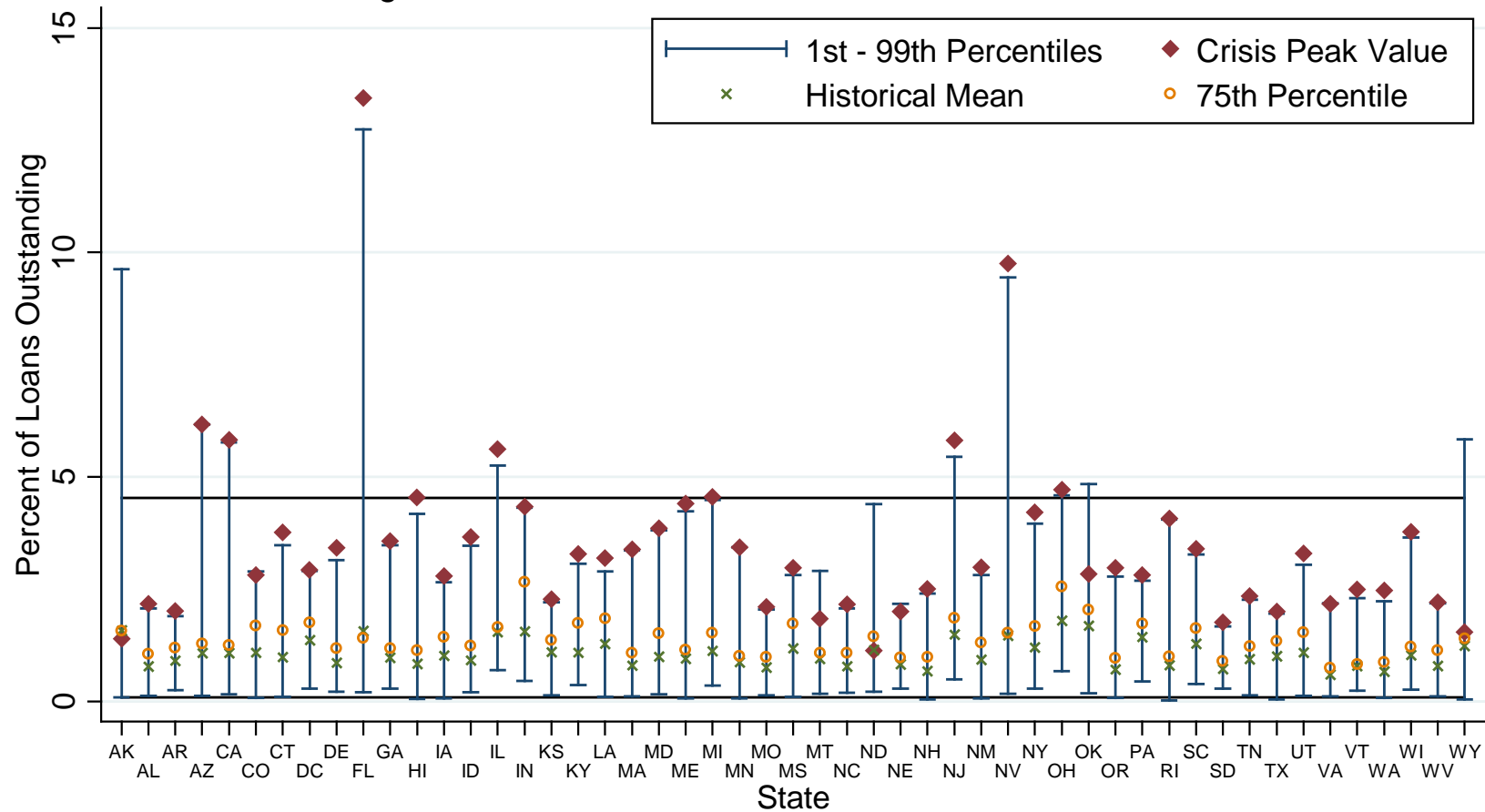
Notes: The bars show the range of historical foreclosure rate values (1st through 99th percentiles) for each state between 1979 and 2009; the historical mean and 75th percentile figures are calculated using this same time frame. The red diamonds show the peak value of the foreclosure start since 2005. The horizontal lines reflect the 1st and 99th percentiles of the foreclosure rate over the entire panel.

Figure A6: IRFs for Various Data Samples
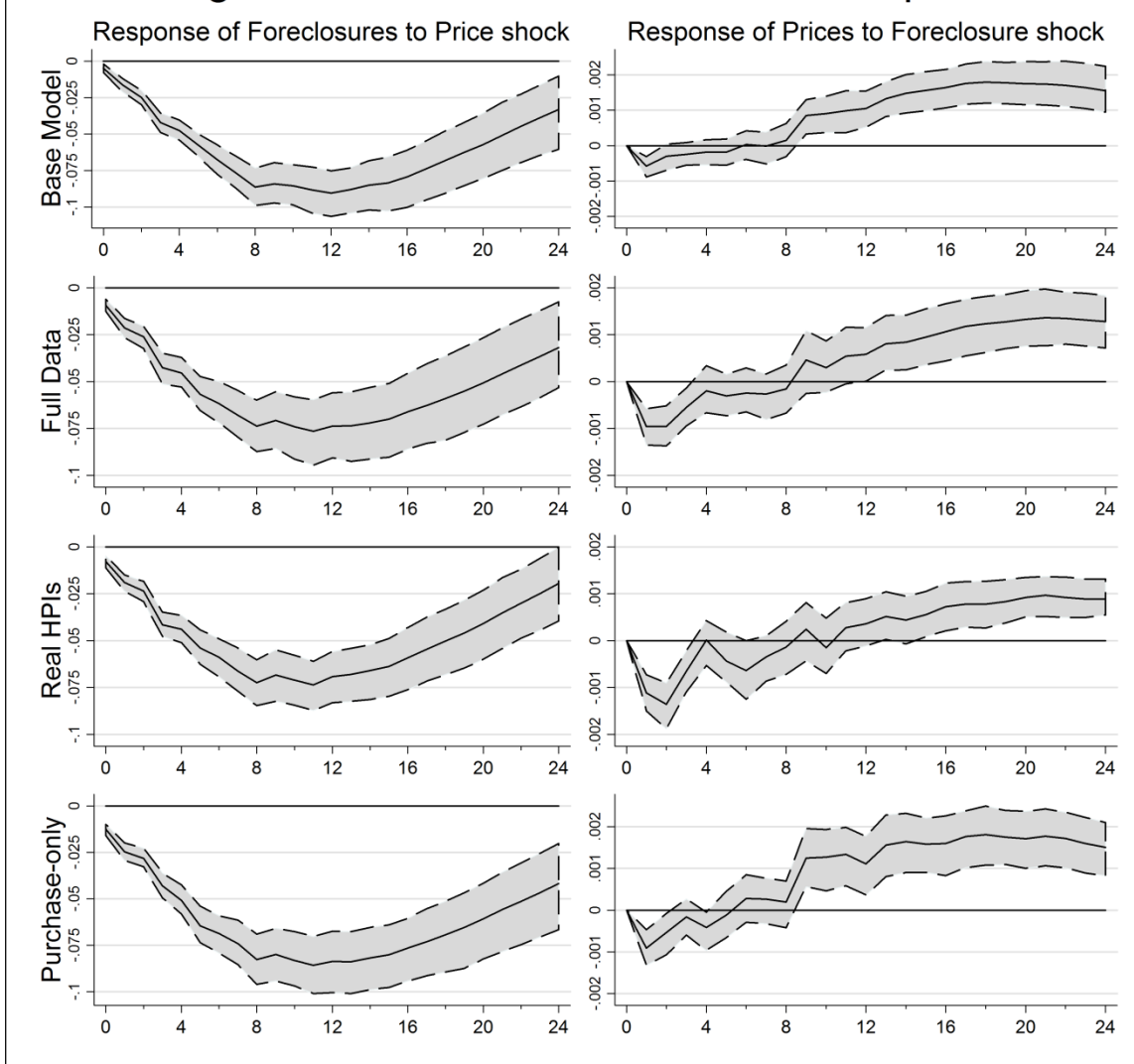
Note: This figure shows the impulse responses functions for prices on the foreclosure rate (left column) and the foreclosure rate on prices (right column) for our base model and four alternatives. The Full Data graphs incorporate early observations that were deleted in the base model due to concerns about volatility in the HPI. Real HPIs deflates each state's house price index by the quarterly average of the consumer price index. Finally, the Purchase-only graphs use the FHFA purchase only indices (spliced with the all-transactions indices in the early years as discussed in the text). The basic relationships between the two variables remain qualitatively unchanged regardless of the sample employed.
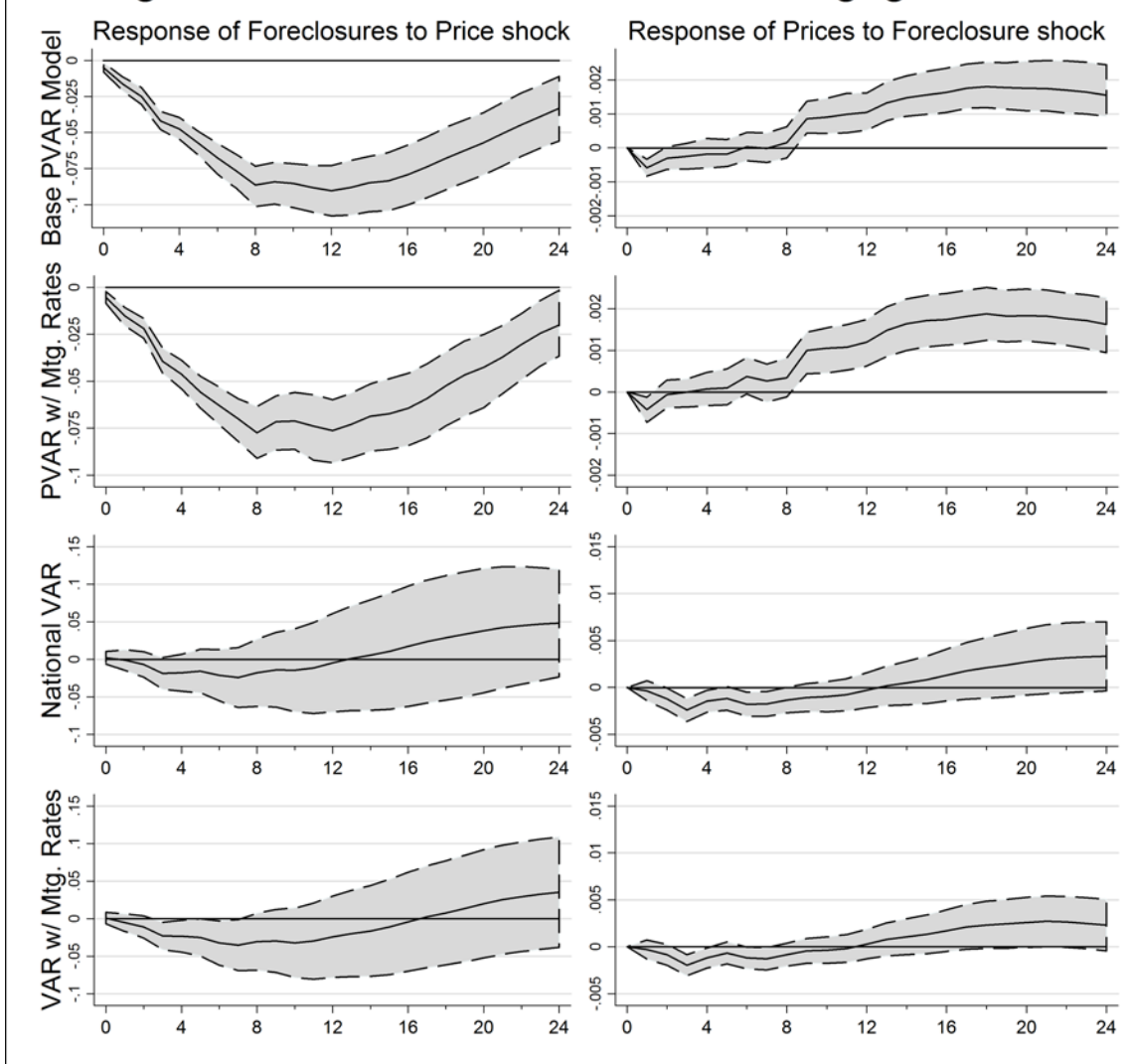
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Figure A8: IRFs for Various Orderings
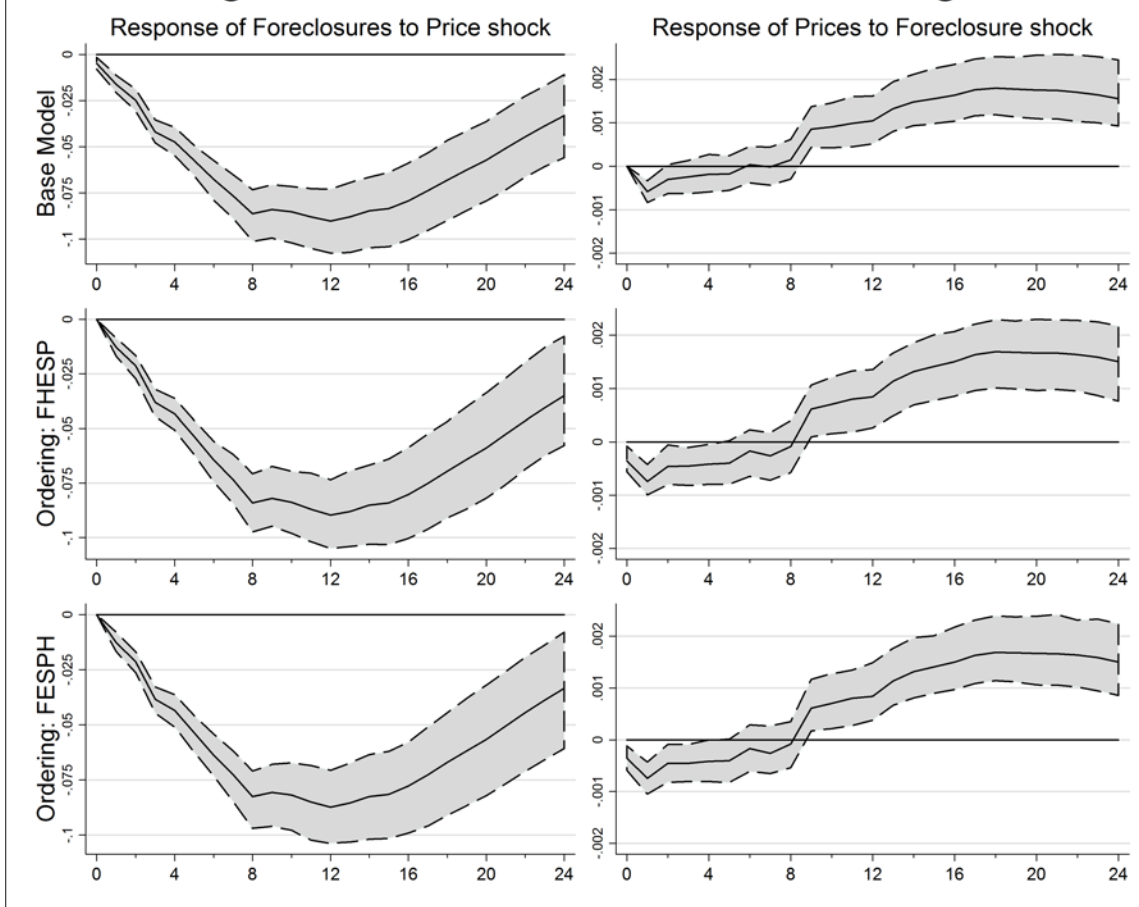
Note: This figure shows the impulse responses of the foreclosure rate to a shock in prices (left column) and of prices to a shock in the foreclosure rate (right column) for our base model and two alternatives orderings. Ordering FHESP is Foreclosures, House prices, Employment, Sales, and Permits. Ordering FESPH is Foreclosures, Employment, Sales, Permits, and House Prices. Shaded regions represent 95 percent confidence intervals. The basic relationships between the two variables are virtually identical under any of the alternative orderings.

Figure A9: IRFs with and Without Mortgage Rates

Note: This figure shows the impulse responses of the foreclosure rate to a shock in prices (left column) and of prices to a shock in the foreclosure rate (right column) for our base PVAR model; our base PVAR model with the 30-year fixed mortgage rate included at the beginning of the ordering; a national VAR using FHFA data and our baseline ordering; and a national VAR using FHF data and our baseline ordering with the regional 30-year mortgage rate included at the beginning of the system. The response of prices to foreclosures is virtually unchanged when mortgage rates are included in the system.