Frictions, Net Worth Shocks, and Heterogeneous Impacts

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Outline

Introduction

- The wealth effect is a critical channel through which economic shocks propagate: and Mian, Rao and Sufi (2013); Mian and Sufi (2014) proposed **net worth shock** and the household balance sheet channel

- The presence of financial and nominal frictions can amplify the effects of net worth shocks and impede the recovery process
  - Financial friction: Collateral constraint
  - Nominal friction: Downward Nominal Wage Rigidity (DNWR)

- **This paper**:
  - Develops a tractable two-agent model to illustrate the how the interaction between the two frictions leads to non-linear heterogeneous impacts of net worth shock
  - Builds a novel county-level dataset (*CountyPlus*)
  - Empirically estimates and does inference on the non-linear heterogeneous effects using semi-varying coefficient local projections

Introduction

Related studies:

- Net worth shock and slow recovery: Mian, Rao and Sufi (2013); Mian and Sufi (2014); Bocola and Lorenzoni (2020); Guerrieri, Lorenzoni and Prato (2020); Kaplan, Mitman and Violante (2020a); Kaplan, Mitman and Violante (2020b) ...
- Financial, nominal frictions and their impact: Christiano, Eichenbaum and Trabandt (2015); Schmitt-Grohé and Uribe (2016); Shen and Yang (2018) ...

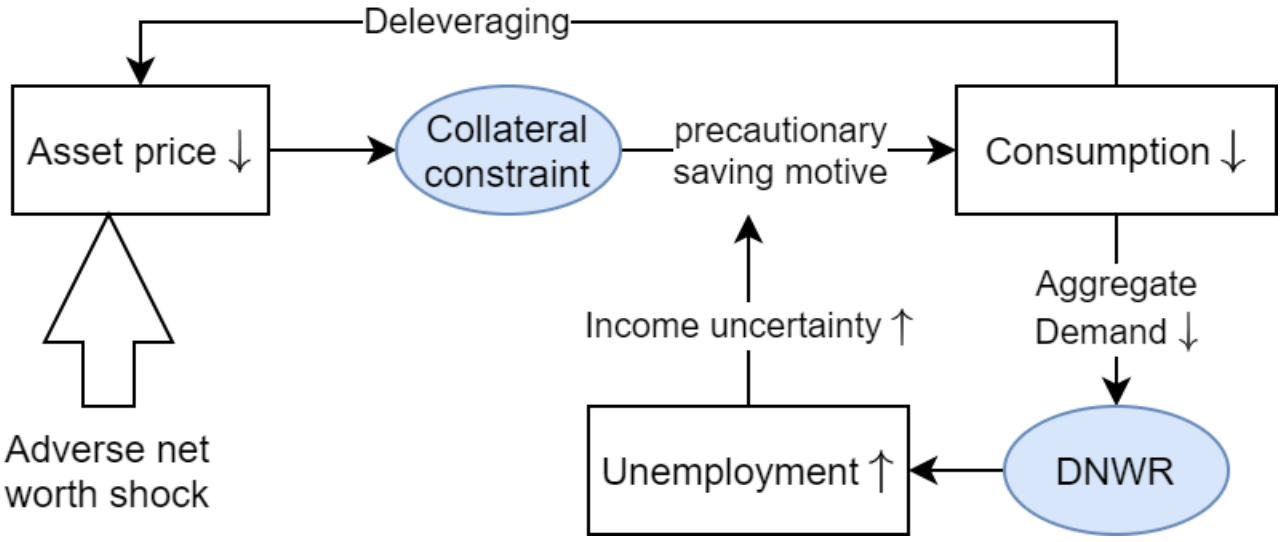
Methodology:

- Local projections (LP) and heterogeneous effect estimation: Jordà (2005); Jordà, Schularick and Taylor (2020); Cloyne, Jordà and Taylor (2023) ...
- Estimation and inference of semi-varying coefficient model: Fan, Zhang and Zhang (2001); Zhang, Lee and Song (2002); Fan and Huang (2005); Hu (2024) ...

Introduction

Key findings:

- Mechanism of friction interaction: adverse net worth shock → higher precautionary savings and deleverage in response to tightened collateral constraints. DNWR → higher income uncertainty. The adjustment process is prolonged, leading to a persistent decline in consumption.
- Found significant heterogeneity in the impact of net worth shocks across counties, with the effect magnitude varying by the degree of local financial and nominal frictions.
- Suggested that the impact of net worth shocks can be greatly amplified when both collateral constraints and DNWR are binding.



Introduction

Key findings:

- Mechanism: adverse net worth shock → higher precautionary savings and deleverage in response to tightened collateral constraints. DNWR → higher income uncertainty. The adjustment process is prolonged, leading to a persistent decline in consumption.
- Found significant heterogeneity in the impact of net worth shocks across counties, with the effect magnitude varying by the degree of local financial and nominal frictions.
- Suggested that the impact of net worth shocks can be non-linearly amplified when both collateral constraints and DNWR are binding.

Main contributions:

- Adds empirical evidence of how financial and nominal frictions affect the impact of net worth shocks.
- Proposes a tractable model to illustrate the amplification mechanism of the frictions.

Outline

A tractable two-agent model

- $t = 0, 1, 2, ...$, economy's state s^t, and aggregate housing productivity shock $u(s^t)$
- Two assets:
  - Housing wealth $h(s^t)$ of price $p(s^t)$
  - State-contingent claims $b(s^{t+1})$ of price $q(s^{t+1}|s^t)$
- Two agents:
  - **Expert**: risk-averse on consumption; produce consumption goods using their housing wealth $h(s^t)$ and household's labor $l(s^t)$; borrow state-contingent claims
  - **Household**: risk-neutral on consumption and risk-averse on housing; constantly supply 1 unit of labor; save in the state-contingent claims
- Two frictions:
  - Collateral constraint: Experts face $b(s^{t+1}) \leq \theta p(s^{t+1}) h(s^t), \forall s^{t+1}$
  - DNWR: $w(s^t) \geq \delta w(s^{t-1})$ and $(1 - l(s^t))(w(s^t) - \delta w(s^{t-1})) = 0$
- The collateral constraint prevents experts from very large amount of borrowing $\Longrightarrow$ **not** complete market

A tractable two-agent model

Expert's problem

$$V^b(s^t) = \max_{c(s^t),\{b(s^{t+1})\},h(s^t),l(s^t)} \log c(s^t) + \beta \mathbb{E} V^b(s^{t+1})$$

$$c(s^t) + p(s^t)h(s^t) = n(s^t) + \sum_{s^{t+1}} q(s^{t+1}|\ s^t) b(s^{t+1}) \qquad \text{(Budget)}$$

$$n(s^t) := p(s^t)h(s^{t-1}) + y(s^t) - b(s^t) \qquad \text{(Net worth)}$$

$$y(s^t) := Y(s^t) - w(s^t)l(s^t) \qquad \text{(Profit)}$$

$$b(s^{t+1}) \leq \theta p(s^{t+1})h(s^t), \forall s^{t+1} \qquad \text{(CC)}$$

where

- $n(s^t) \geq 0$: net worth
- $Y(s^t) := Al^{\alpha}(s^t)[u(s^t)h(s^t)]^{\{1-\alpha\}}$

A tractable two-agent model

Household's problem

$$V^l(s^t) = \max_{c^l(s^t),\{a(s^{t+1})\},h^l(s^t)} c^l(s^t) + \gamma \log h^l(s^t) + \beta \mathbb{E} V^l(s^{t+1})$$

$$c^l + \sum_{s^{t+1}} q(s^{t+1} |\ s^t) a(s^{t+1}) + p(s^t)[h^l(s^t) - h^l(s^{t-1})] = w(s^t) l(s^t) + a(s^t)$$

Housing market

$$h(s^t) + h^l(s^t) = H, H \in \mathbb{R}$$

Bond market

$$a(s^{t+1}) = b(s^{t+1}), \forall s^{t+1}$$

DNWR conditions

$$w(s^t) \geq \delta w(s^{t-1})$$
$$[1 - l(s^t)][w(s^t) - \delta w(s^{t-1})] = 0$$

A tractable two-agent model

Scenario (one-shot deviation)

1. $t = 0$: Unbinding deterministic steady state
2. $t = 1$: u_1 drawn from a distribution over support $(0, \overline{u}]$
3. $t \geq 2$: The realized path of $\{u_t\}$ is always 1

Then,

- Solve the equilibrium of one-shot deviation analytically
- Prove: persistent effects of u_1 shock
- Prove: non-linear heterogeneous impact of u_1

A tractable two-agent model

Proposition (Persistent Effect)

There exist a unique continuation equilibrium that depends on the states

$$(u_1, h_0, b_1(u_1))$$

In the continuation equilibrium, the collateral constraint is binding for a finite number of periods J, with $J = 0$ if $n_1(u_1) \geq \overline{n}_1 := \overline{p}\overline{h}\frac{1-\beta\theta}{\beta}$, where $\overline{p}$ and $\overline{h}$ are jointly determined by

$$(1-\beta)\bar{p} = \frac{\gamma}{H - \bar{h}}$$

$$\bar{p}(1-\beta) = \beta(1-\alpha)\bar{h}^{-\alpha}$$

A tractable two-agent model

Proposition (Non-linear heterogenous effect)

There exist levels of the entrepreneur's financial friction parameter θ and the DNWR parameter δ, such that if

$$\frac{w_0}{n_0} \geq \frac{\alpha}{\delta(1-\alpha)}\left[1+(1-\theta)(1-\alpha)(\frac{p_0 h_0^l}{\gamma}-1)\right]$$

then, in equilibrium, the $t=1$ collateral constraint and DNWR both bind when u_1 is in a non-empty interval $\left[\hat{u}_{\text{lb}}(\theta,\delta), \hat{u}_{\text{up}}(\theta,\delta)\right]$. In this case, the u_1 shock effects:

$$\frac{\partial c_1}{\partial u_1} > 0, \frac{\partial l_1}{\partial u_1} > 0, \frac{\partial p_1}{\partial u_1} > 0 \text{ or } < 0 \text{ or } = 0 \text{ depends}$$

in which these effects are also non-linear functions of θ and δ.

A tractable two-agent model

Comparative statistics

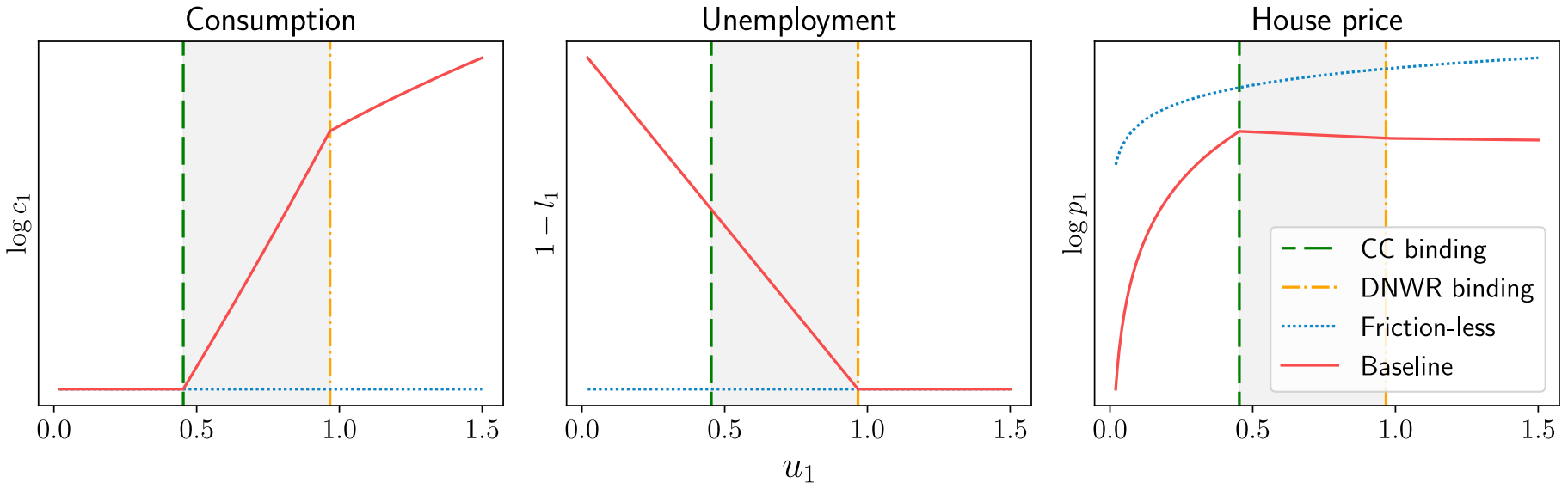


Figure 2: baseline vs. friction-less economy

where:

- Collateral constraint binds when $u_1 \geq$ Green line
- DNWR binds when $u_1 \leq$ Orange line
- Both binds: Grey area

$\Longrightarrow$ Amplification effects

Outline

Data: CountyPlus

- Build a new open-source panel data set *CountyPlus*
  - 03-19 yearly, 3058 US counties
  - Fully replicable: 20+ public available data sources
  - Github: github.com/Clpr/CountyPlus
- Covers: household balance sheet by asset; income and consumption; labor and housing market indicators; friction measures; demographics; ...
- Key variables:
  - Household net worth (wealth)
  - Consumption, unemployment and house price
  - ***DENI***: home mortgage denial due to lack of collateral / total denials
  - ***FWCP***: Fraction of Wage Cuts Prevented
- Net worth shock is identified as:

$$x_{i,t} := \sum_{j \in \{S,B,H\}} s^{j}_{i,t-1} g^{j}_{t-1,t}$$

where i is county, S is equity, B is bond, H is housing wealth; $s^{j}_{i,t-1}$ is lag asset share in the balance sheet; and $g^{j}_{t-1,t}$ is the lag aggregate growth of asset prices.

Definition: net worth Definition: consumption Definition: FWCP

Data: CountyPlus

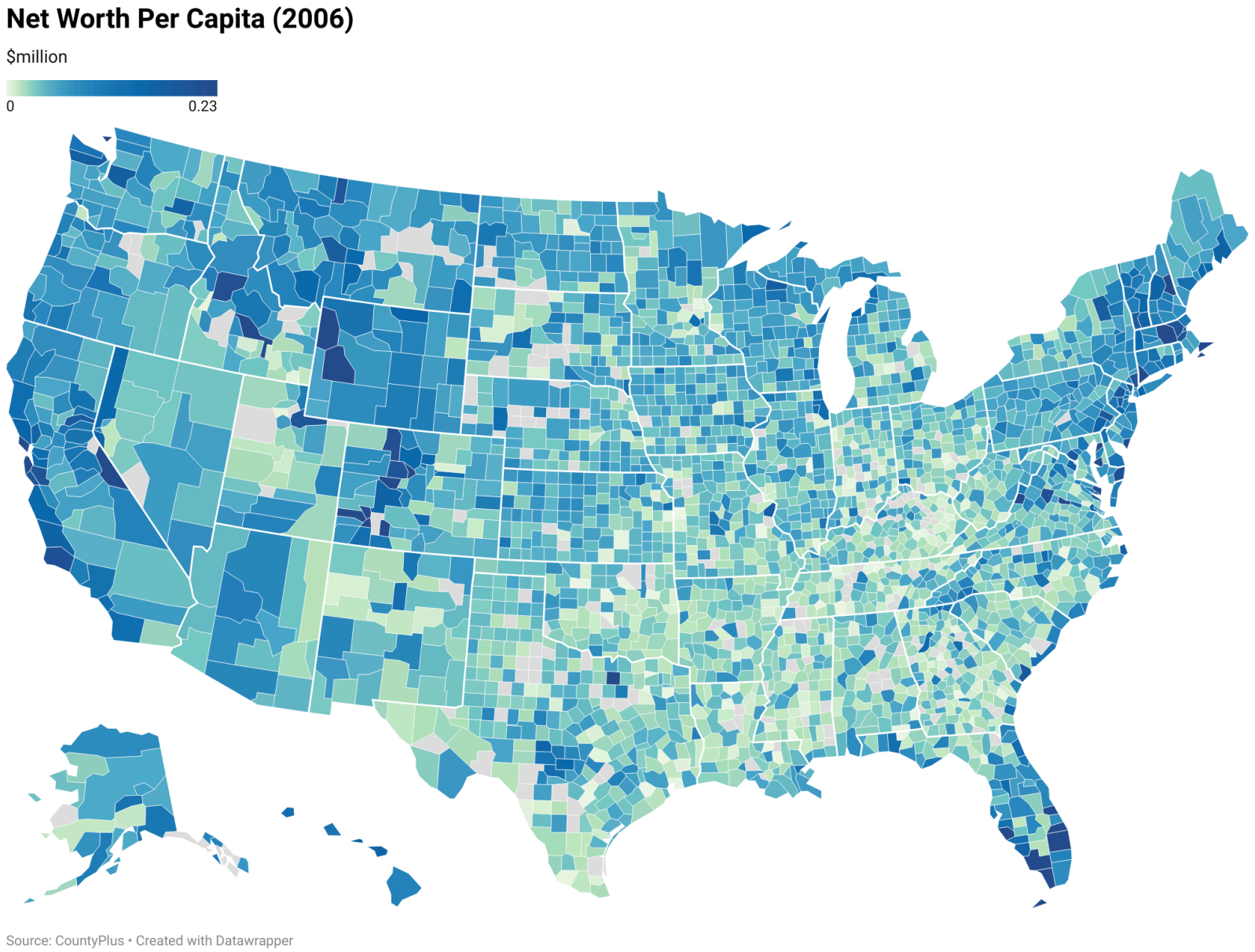


Figure 3: Geographical: Pre-crisis net worth

Data: CountyPlus

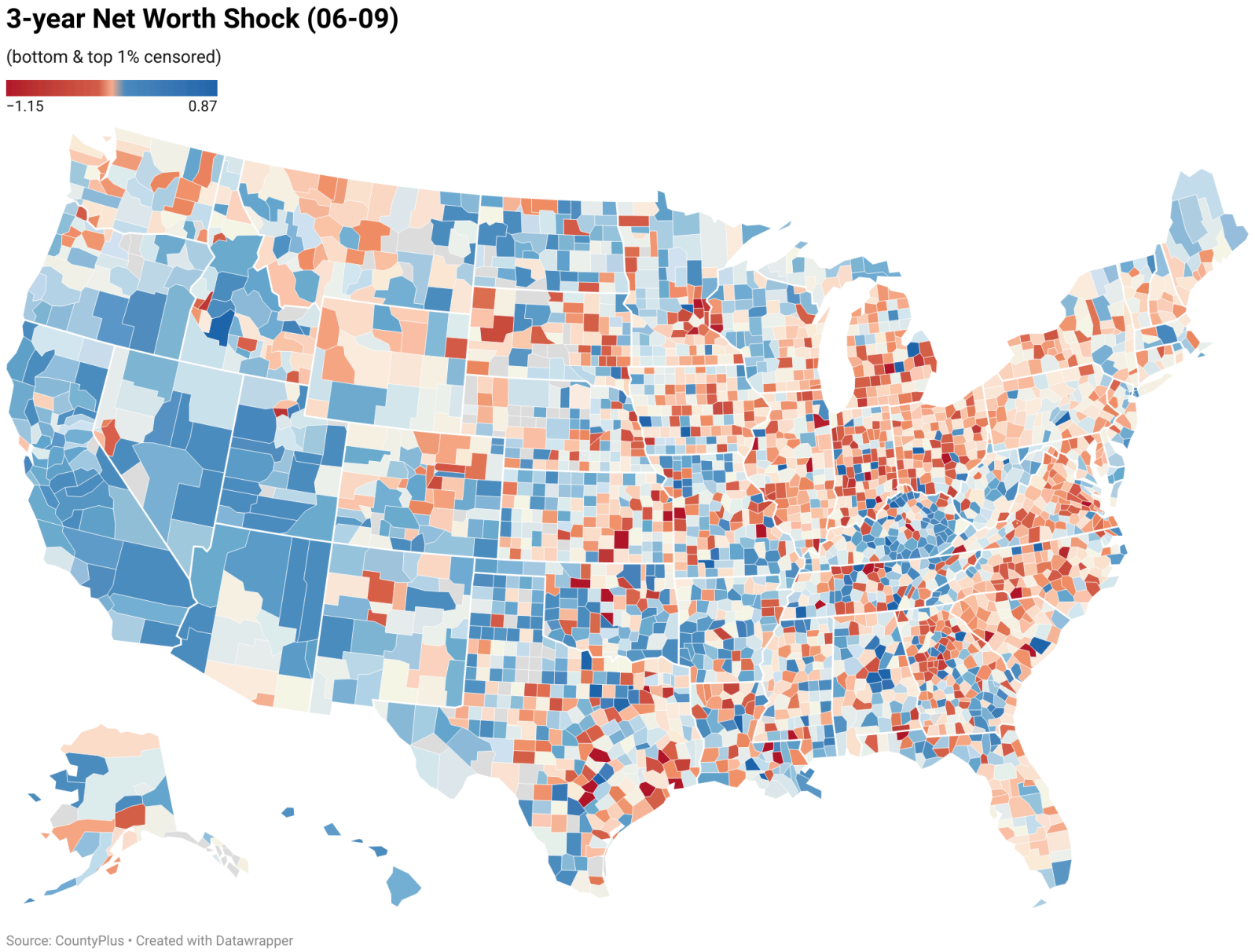


Figure 4: Geographical: Net worth shock during the Great Recession

Data: CountyPlus

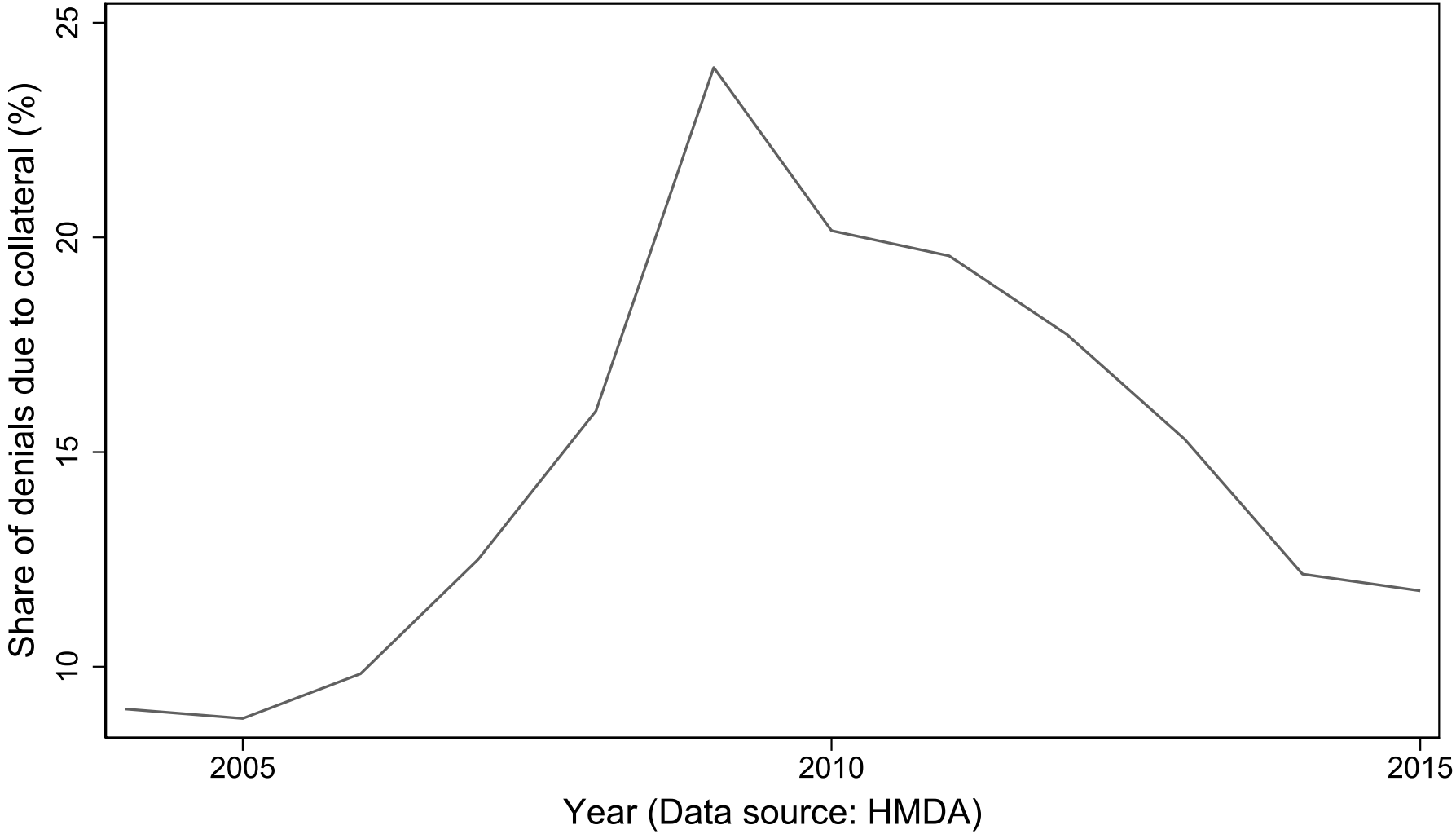


Figure 5: The aggregate extent of collateral constraint

- Larger *DENI*, larger friction

Data: CountyPlus

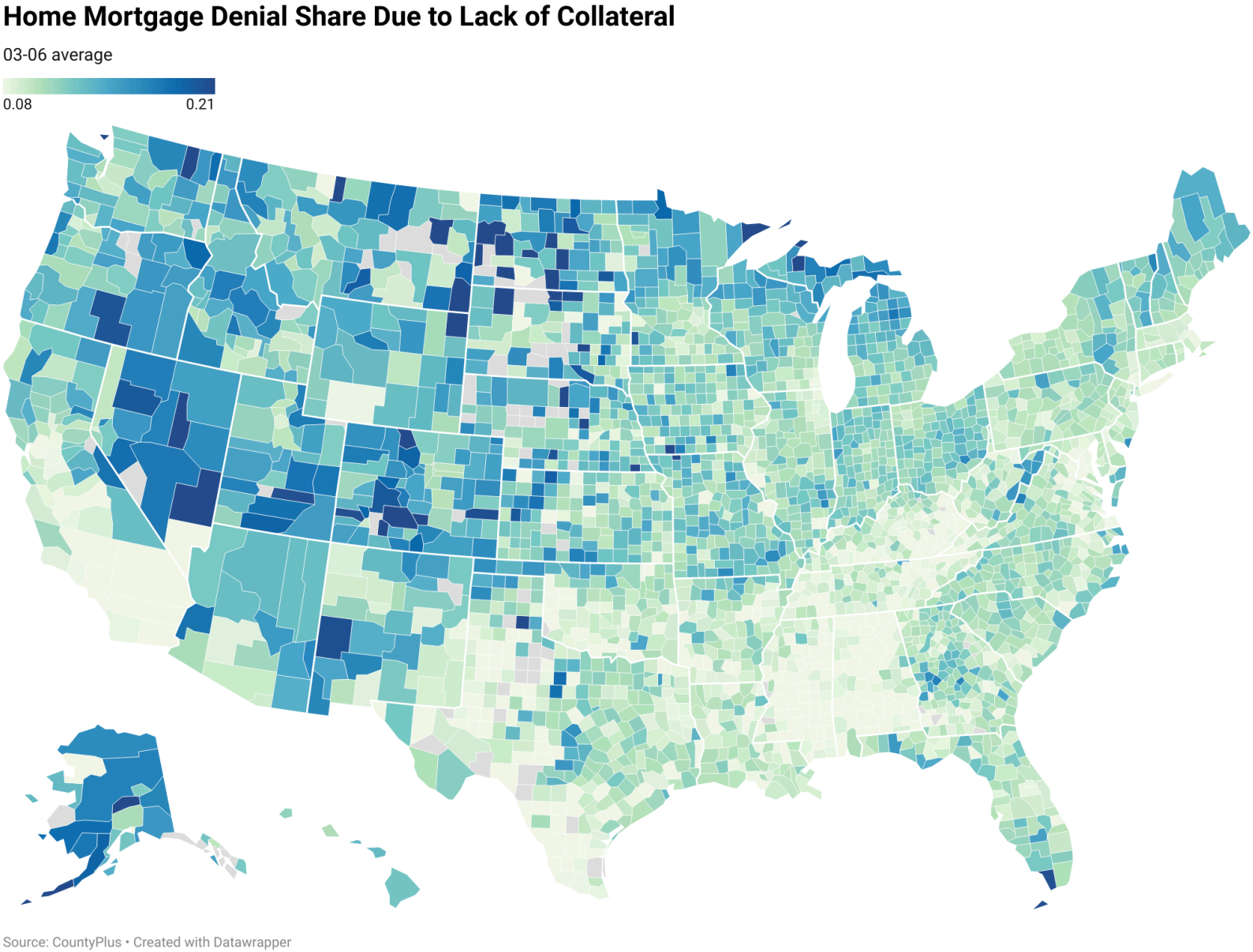


Figure 6: Geographical: Collateral constraint before the crisis

Data: CountyPlus

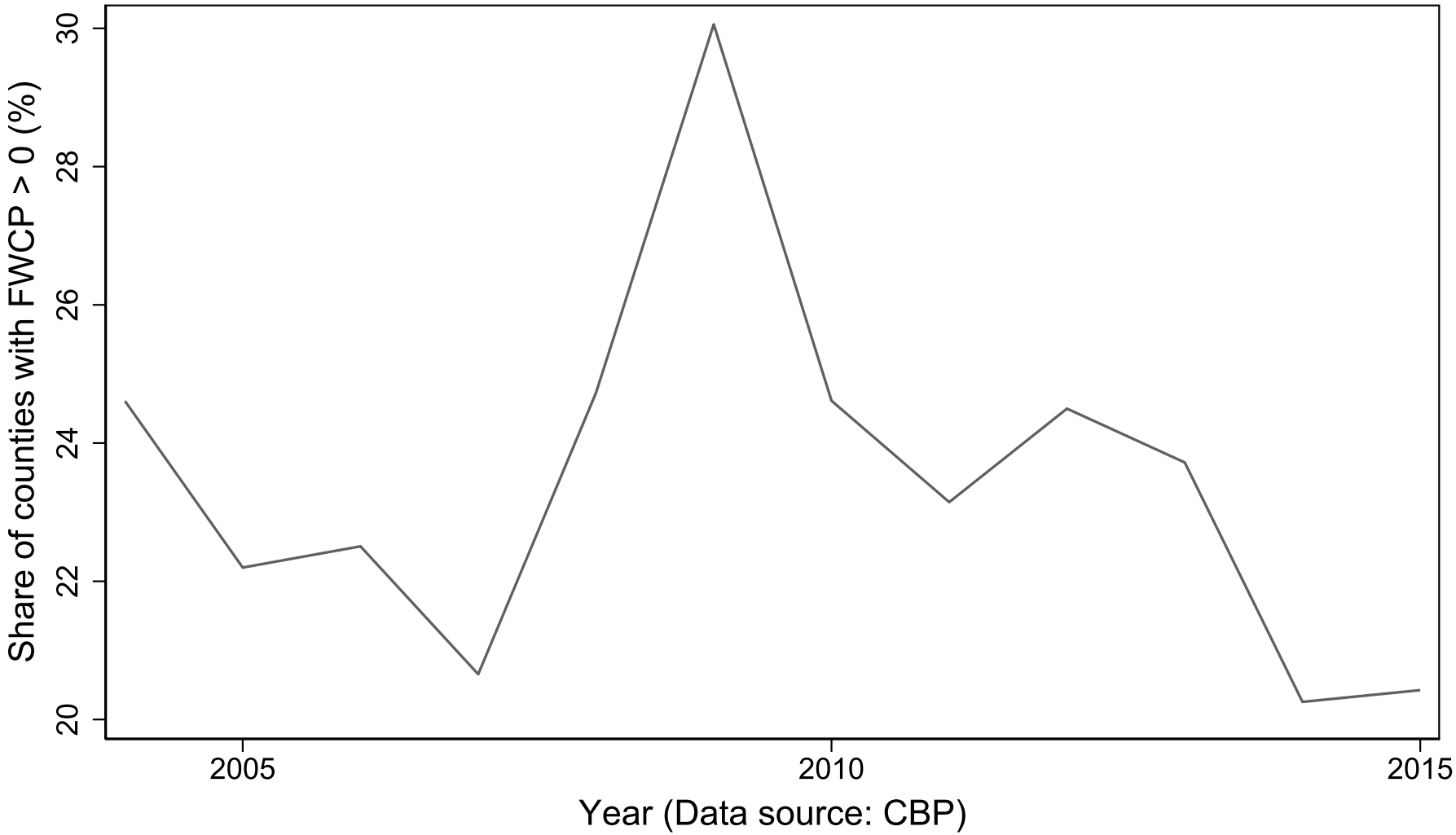


Figure 7: The aggregate extent of DNWR

- Larger *DNWR*, larger friction

Data: CountyPlus

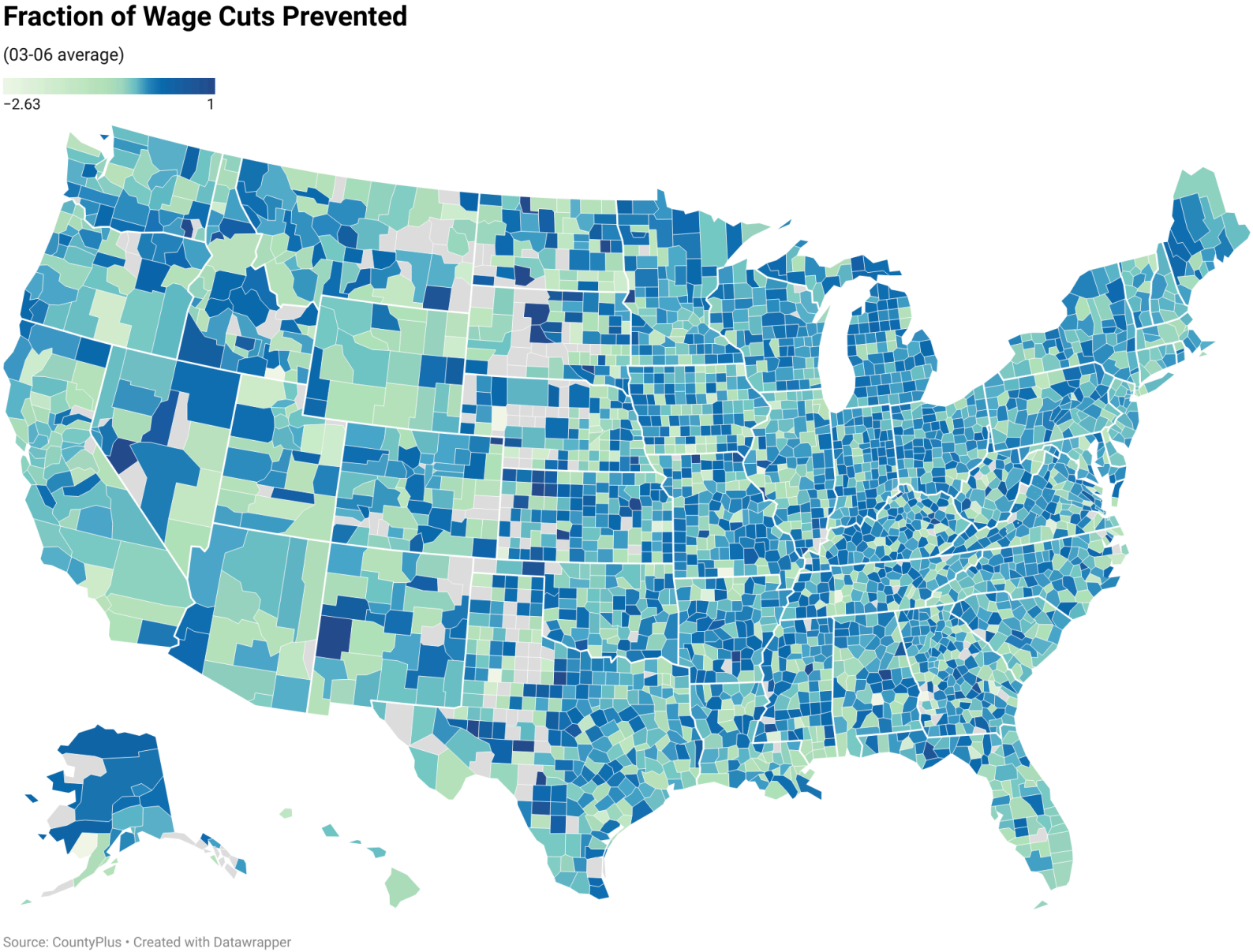


Figure 8: Geographical: DNWR before the crisis

Data: CountyPlus

Compare with the aggregate series:

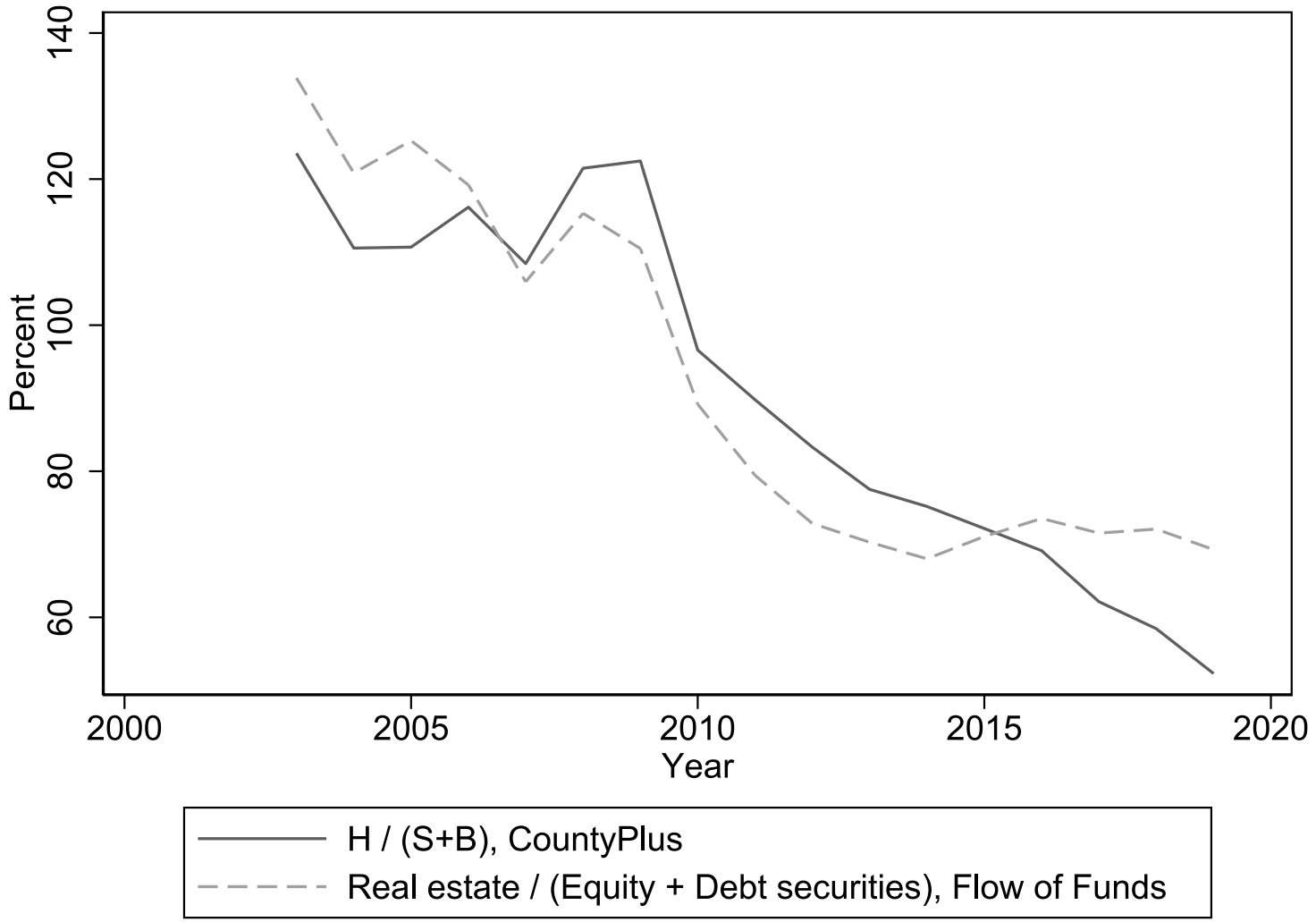


Figure 9: CountyPlus vs. Fed Flow of Funds

Baseline specification

A semi-varying coefficient variant of the linear LP in Cloyne, Jordà and Taylor (2023)

$$y_{i,t+h} = \alpha_h + x_{i,t} \cdot \beta_h(\Delta \mathbf{Z}_{i,t}) + \Delta \mathbf{Z}'_{i,t}\boldsymbol{\delta}_h + g(N_{i,t-1}) + \mathbf{W}_{i,t}\lambda_h + \iota_{i\in s} + \nu_t + \varepsilon_{i,t+h}$$

- where
  - $\Delta \boldsymbol{Z}_{i,t}$: *DENI* and *FWCP* deviation from the county's mean level
  - $\beta_h(\Delta \boldsymbol{Z}_{i,t})$: effects of the net worth shock
  - $h = 0, ..., H$: projection horizons
  - $y_{i,t+h}$: outcomes
  - $g(N_{i,t-1})$: a functional control of lagged net worth
  - $\iota_{i\in s}, \nu_t$: state and year fixed effects

- Sieve estimator of global polynomial approximation:

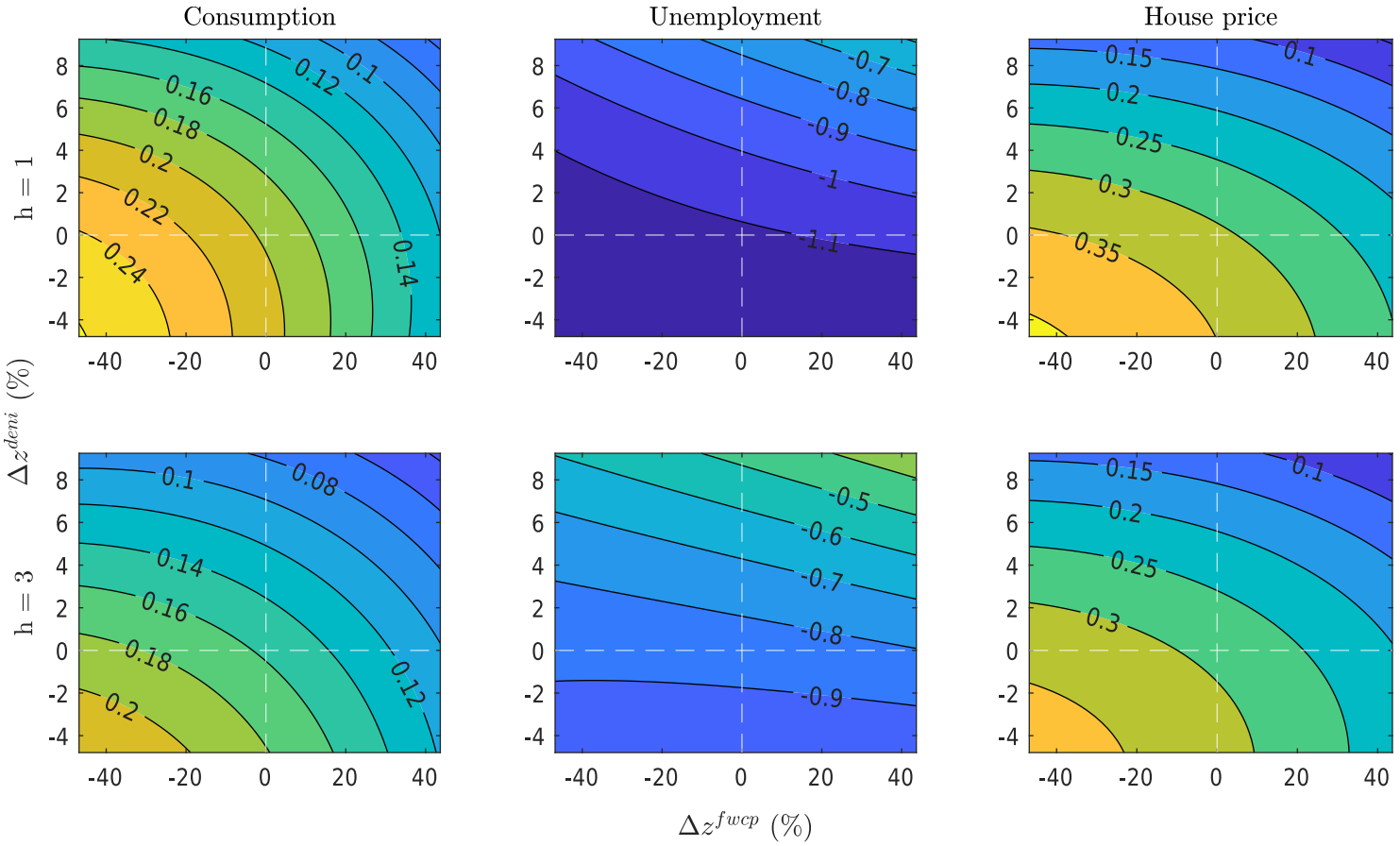
$$\beta_h(\Delta \mathbf{Z}_{i,t}) \approx b_h^0 + b_h^1 \Delta z_{i,t}^{fwcp} + b_h^2 \Delta z_{i,t}^{deni} + b_h^3 \Delta z_{i,t}^{fwcp} \Delta z_{i,t}^{deni} + b_h^4 (\Delta z_{i,t}^{fwcp})^2 + b_h^5 (\Delta z_{i,t}^{deni})^2$$

- Outcomes: Log real consumption per capita; Unemployment rate; Log real house price index

Page: robustness checks Page: Controls

Baseline estimates of $\beta_h(\Delta Z)$

The estimated effect $\beta_h(\Delta \boldsymbol{Z})$ is 2-dimensional functions (+1% shock):



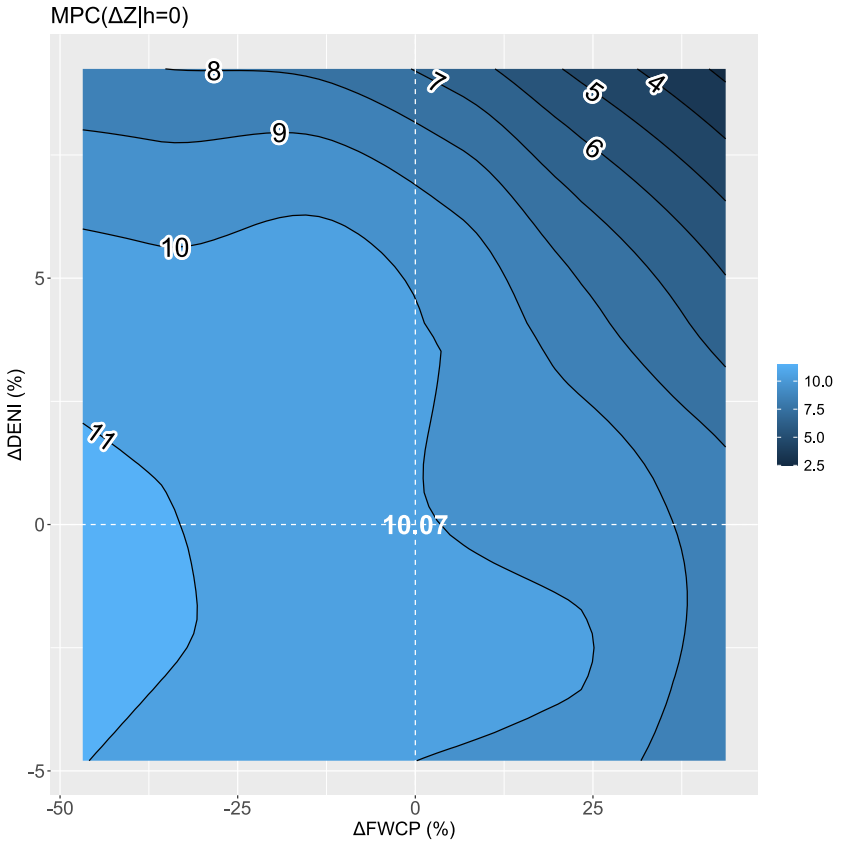
- Contour interval: heterogeneity of the effects
- Contour curvature: interaction & non-linearity

Other horizons

MPC out of wealth

MPC out of wealth reflects the strength of the wealth effect on aggregate demand:

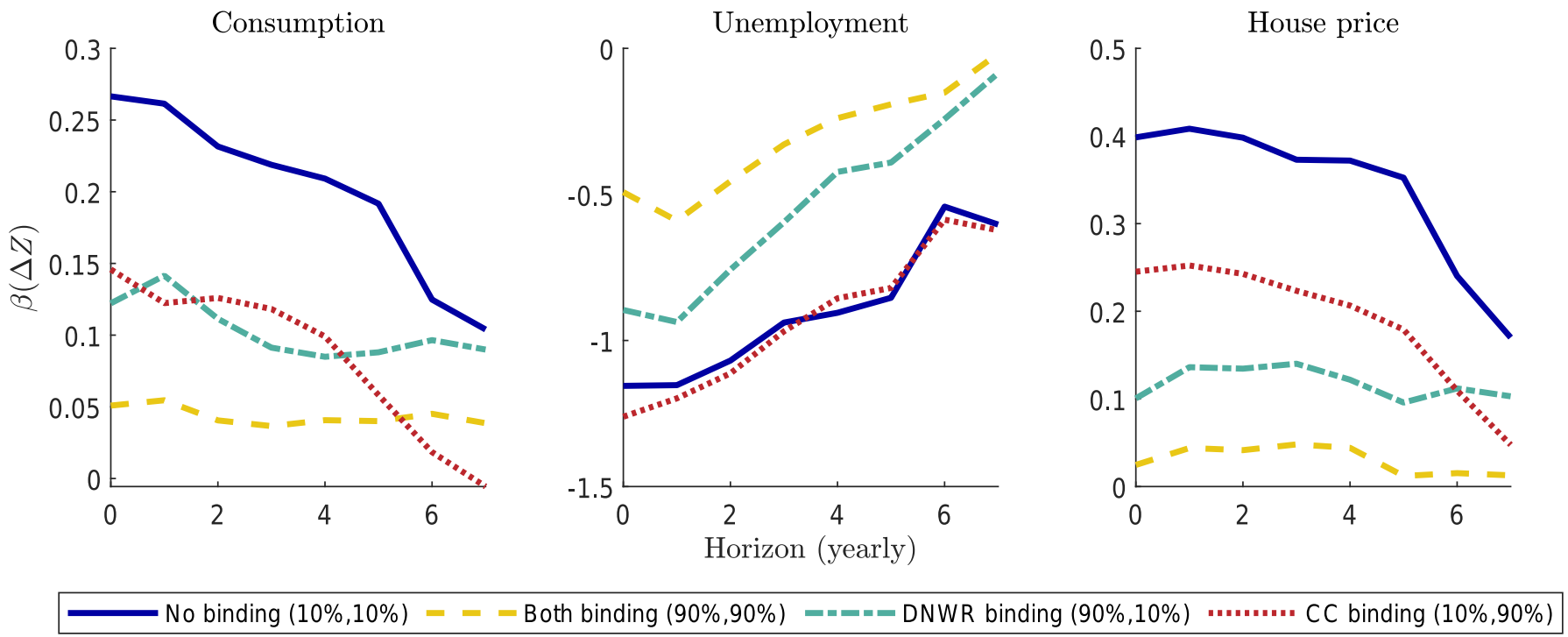
$$\widehat{\text{MPC}}(\Delta Z) = \hat{\beta}_0(\Delta Z) \cdot \frac{\hat{\mathbb{E}}\{c|\Delta Z\}}{\hat{\mathbb{E}}\{n|\Delta Z\}}$$



- Average MPC: 10.07 cents per dollar (literature: 7 out of housing wealth)
- Large range by friction level: $3 \sim 11$ cents per dollar
- Larger friction, larger consumption change (cut) $\Longrightarrow$ amplification

Counterfactual IRF

By scenario of frictions:



- High-friction counties merely response
- Amplification: Large range of the impact: $3 \sim 5$ times difference
- Persistence: ≥ 7 years

Baseline vs. Linear LP

- Baseline specification

$$y_{i,t+h} = \alpha_h + x_{i,t} \cdot \beta_h(\Delta \mathbf{Z}_{i,t}) + \Delta \mathbf{Z}_{(i,t)'} \boldsymbol{\delta}_h + g(N_{i,t-1}) + \mathbf{W}_{i,t} \lambda_h + \iota_{i \in s} + \nu_t + \varepsilon_{i,t+h}$$

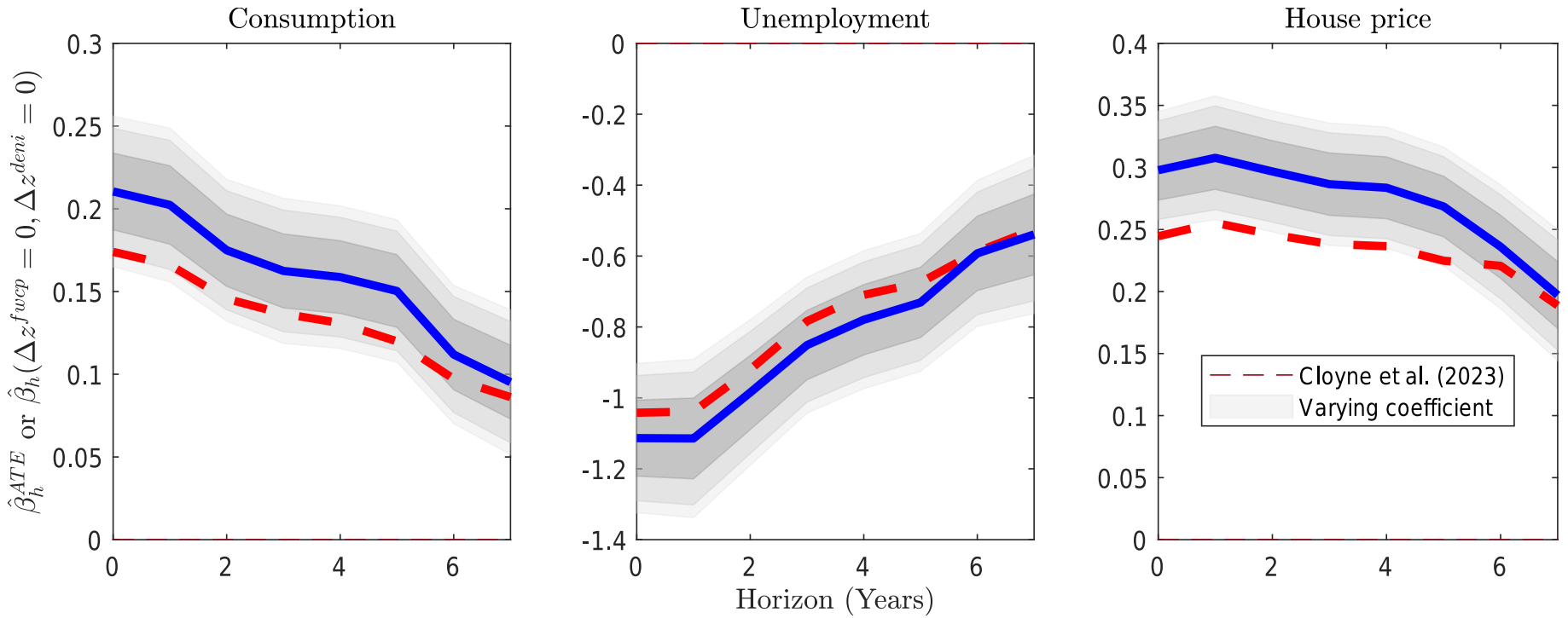
- Linear LP with linear heterogeneous effects Cloyne, Jordà and Taylor (2023)

$$y_{i,t+h} = \alpha_h + x_{i,t}\beta_h + x_{i,t}\Delta \mathbf{Z}'_{i,t} \begin{bmatrix} \gamma_h^{fwcp} \\ \gamma_h^{deni} \end{bmatrix} + \Delta \mathbf{Z}'_{i,t} \boldsymbol{\delta}_h$$
$$+ g(N_{i,t-1}) + \mathbf{W}_{i,t} \lambda_h + \iota_{i \in s} + \nu_t + \varepsilon_{i,t+h}, h = 0, ..., H$$

where γ_h^{fwcp} and γ_h^{deni} are the linear heterogenous effects

Baseline vs. Linear LP

Consistent estimates at the average county:

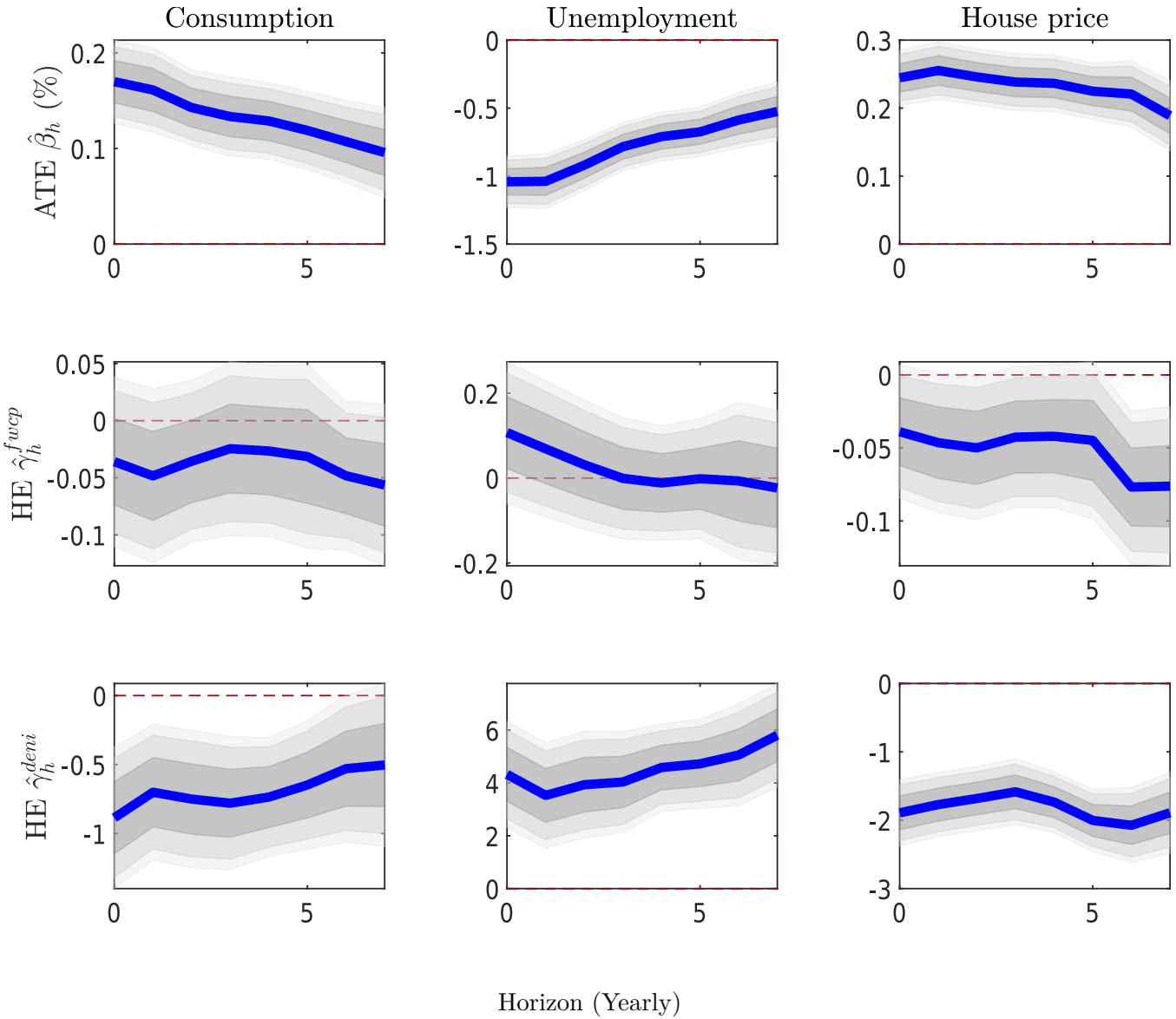


where

- Blue solid line: $\hat{\beta}_h(\Delta \boldsymbol{Z} = 0)$ of the baseline model
- Red dashed line: $\hat{\beta}_h$ of the linear LP model
- CI: 95%, 90%, 1-σ deviation

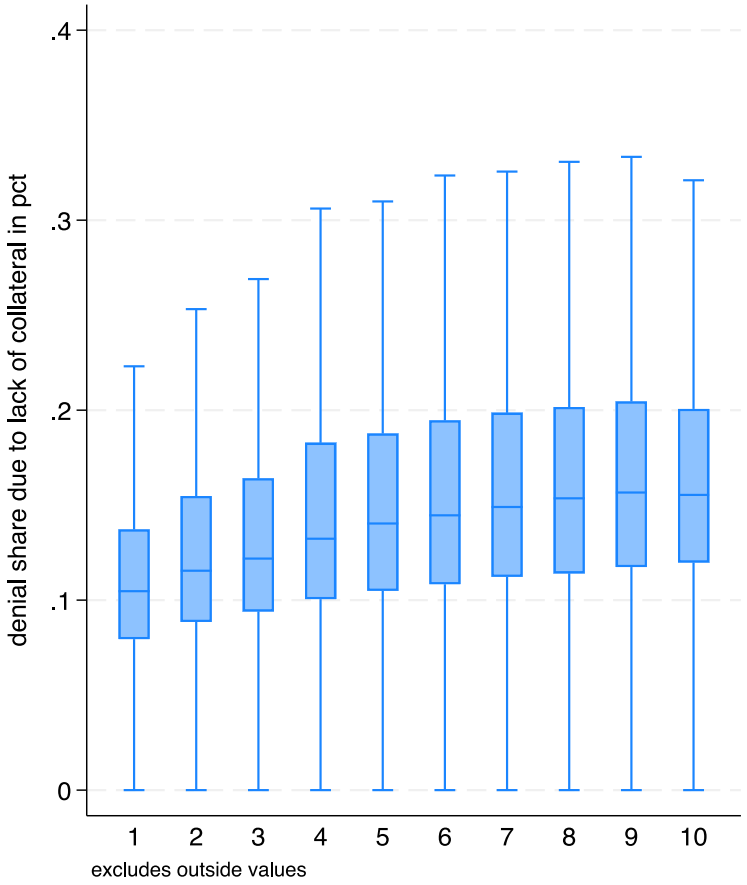
Baseline vs. Linear LP

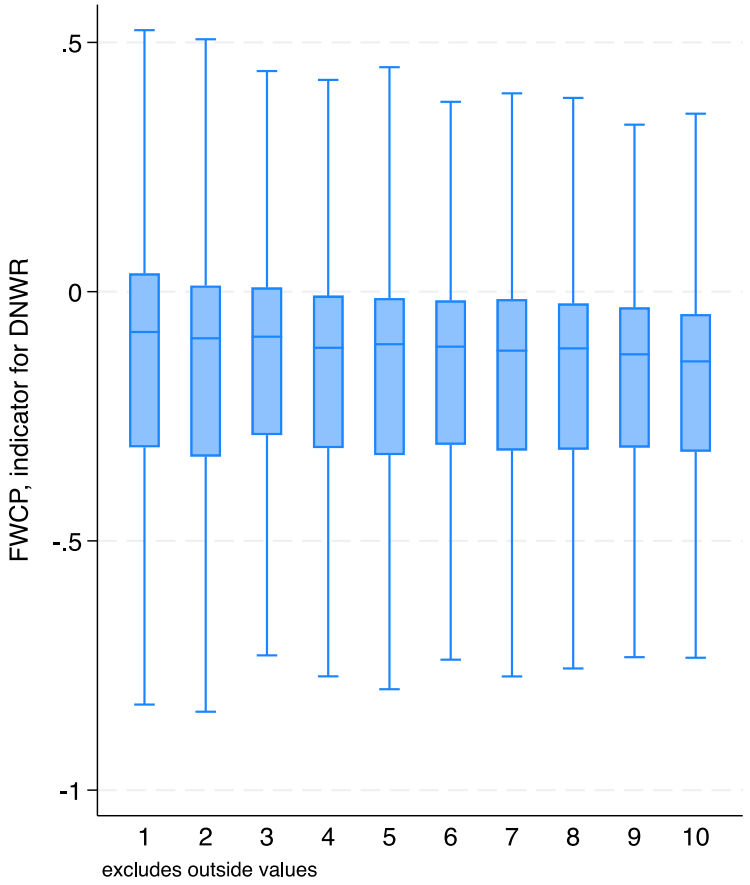
The linear LP misses the heterogeneous effects of DNWR & friction interaction:



Heterogeneity among income groups

Counties with different income levels experiencing varying degree of frictions:

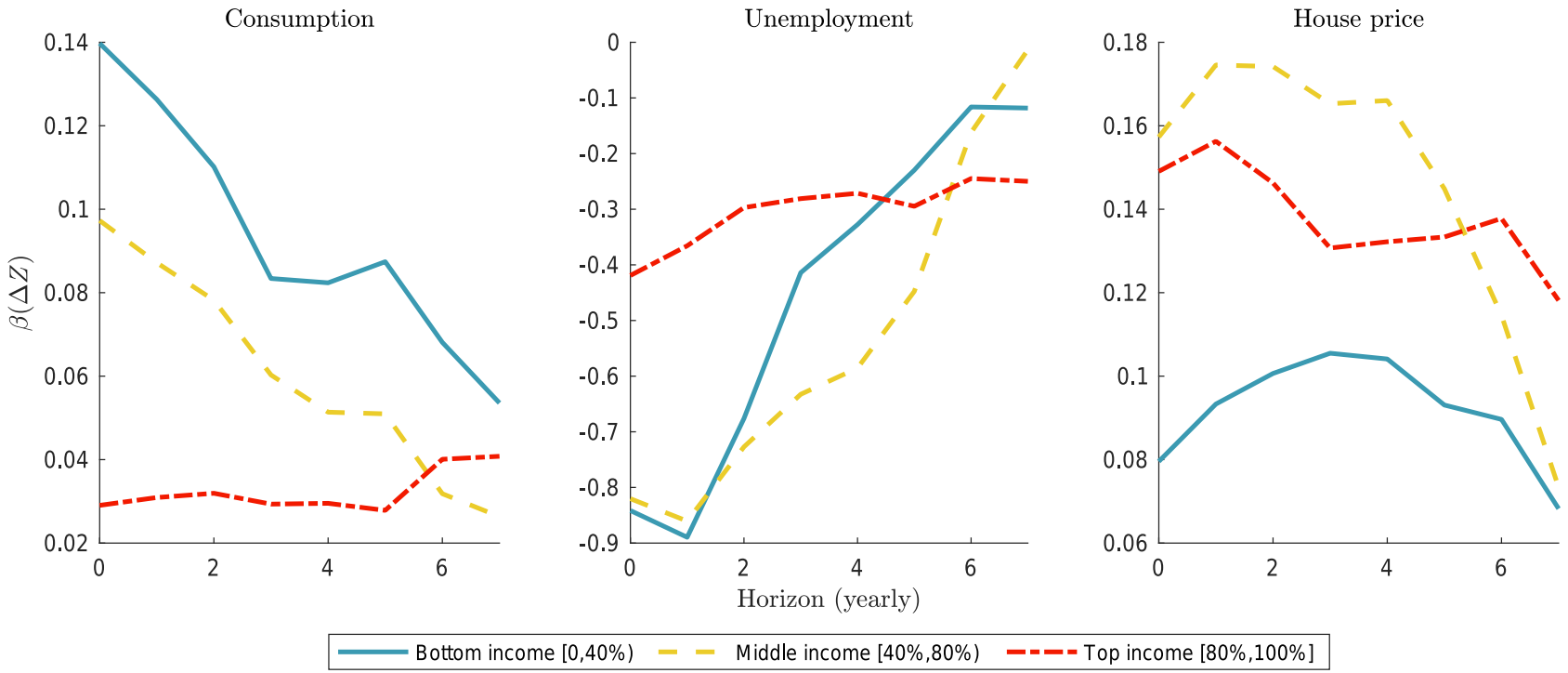




$\Longrightarrow$ Important implications for the transmission of macroeconomic shocks and the design of stabilization policies

Heterogeneity among income groups

Check $\beta(\Delta Z = 0)$:



- Vulnerability against shock:
  - Consumption: Low & Middle
  - Unemployment: Low & Middle
  - House price: Middle & Top
- One-size-fit-all policy may potentially exacerbate existing inequalities
- Policies targeting at different outcomes in difference regions of income

Inference

- F-test: non-linearity of heterogeneous effects and friction interaction

$H_0 : 0 = b_h^3 = b_h^4 = b_h^5$

Horizon	0	1	2	3	4	5	6	7
Consumption	9.680	9.709	9.392	8.086	8.226	11.013	8.152	5.830
	(.000)	(.000)	(.000)	(.001)	(.001)	(.000)	(.000)	(.001)
Unemployment	5.919	3.874	2.551	2.963	3.453	3.292	2.532	1.627
	(.001)	(.009)	(.054)	(.031)	(.016)	(.020)	(.056)	(.181)
House price	24.967	23.961	22.215	21.083	22.661	19.744	14.116	11.973
	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)

Notes: 1. Numbers in the parenthesis are the p-value. 3. $***$: $p < 0.01$, $**$: $p < 0.05$, $*$: $p < 0.1$

- The F-test suggests significant non-linear heterogenous effects and the interaction between collateral constraint and DNWR

Robustness

- **Order selection of the polynomial approximation** Appendix
  - Suggests higher order approximation not introduce new patterns
- **Sensitivity analysis against confounders** Appendix
  - Shows the baseline result is robust against potential confounders
- **Local estimator** Appendix
  - Shows the same patterns of $\beta_h(\Delta \boldsymbol{Z})$
- **Profile-likelihood ratio test** Appendix
  - Rejects H_0 as well
- **Geographical spillover effects of the shock** Appendix
  - Finds statistically significant spillover effects of the shocks on unemployment $\Longrightarrow$ larger non-linearity

Goto: Specification

Conclusion

- **Findings**
  - Economic frictions greatly shape the effect of net worth shocks in which collateral constraints and DNWR and their interaction could explain the US recovery after the Great Recession
  - There are large non-linear heterogenous effects of net worth shocks in the US which bring important policy implications

- **Policy implications**
  - Call for policies advocating for a strong labor market and mitigating financial risks
  - Call for policies based on local economic conditions
  - Country-wise interventions may have uneven effects across the income distribution, potentially worsening existing inequalities

End

Thank you!

Latest version available at SSRN ID: 4915272

Outline

Appendix: Other horizon of the baseline

$\beta_h(\Delta \boldsymbol{Z})$ at horizon $h = 5, 7$

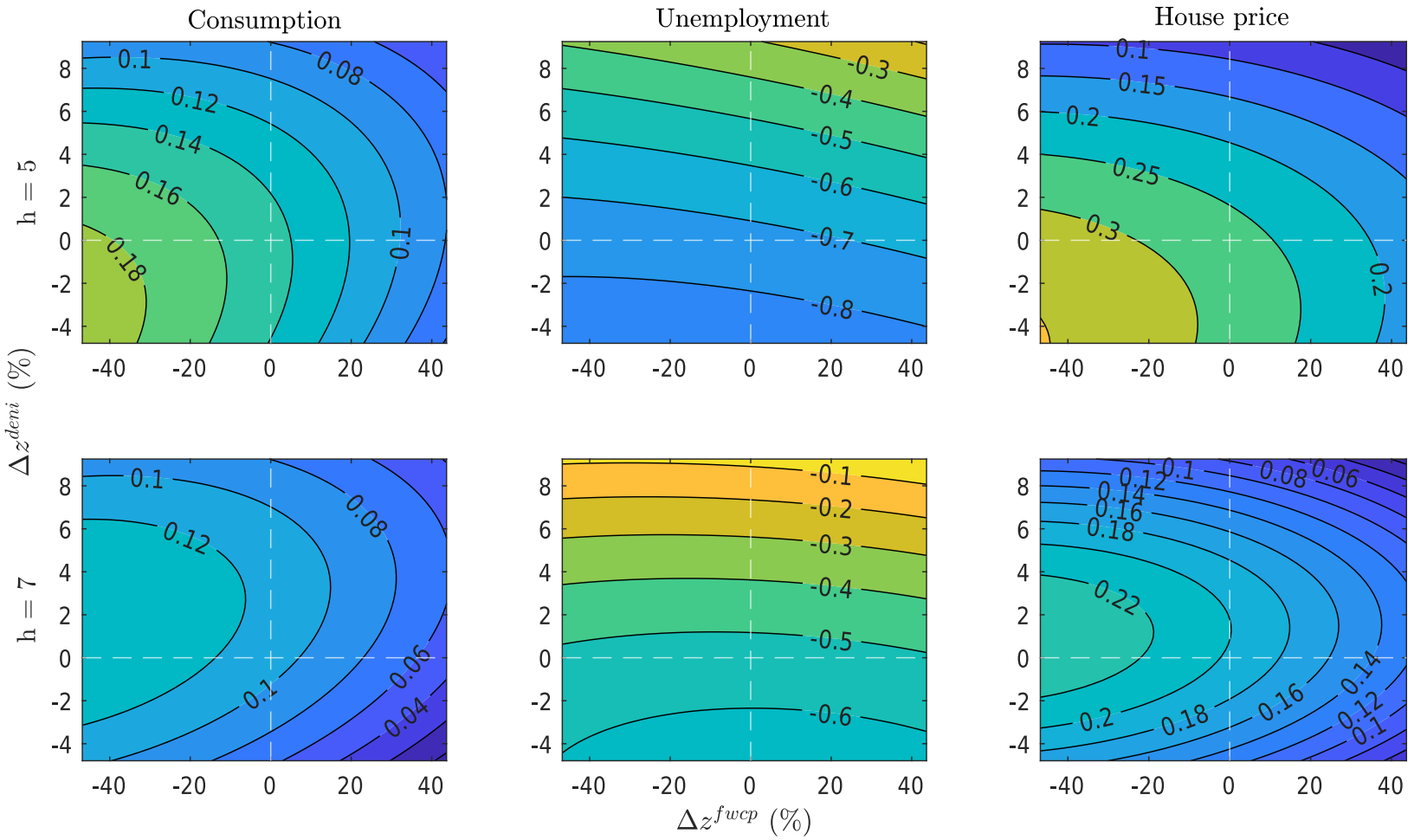


Figure 16: $\beta_h(\Delta \boldsymbol{Z})$

Goto: baseline

Appendix: variable definitions

- Household **net worth** of county i in year t:

$$NW_{it} = S_{it} + B_{it} + H_{it} - D_{it}$$

where S is equity, B is debt security, H is housing wealth, and D is debt

- **Equity** and **Debt security holding**:

$$S_{i,t} = \frac{\text{County dividend income}_{i,t}}{\sum_j \text{County dividend income}_{j,t}} \times \text{National total equity of household}_t$$

$$B_{i,t} = \frac{\text{County interest income}_{i,t}}{\sum_j \text{County interest income}_{j,t}} \times \text{National total debt security of household}_t$$

- Data sources of S and B: Survey of Income (SOI) by IRS, Fed Flow of Funds

Appendix: variable definitions

- **Debt**:

$$D_{i,t} = \text{Household debt-to-income ratio}_{i,t} \times \text{AGI}_{i,t}$$

where i is county index and t is year index, AGI is adjusted gross income.

- **Housing wealth**

$$H_{i,t} = \frac{\text{Total housing units}_{i,t}}{\text{Average housing units per house}} \times \text{Median house value}_{i,2019} \times \frac{\text{HPI}_{i,t}}{\text{HPI}_{i,2019}}$$

where the average housing units per house is 1.8

- Data sources of D and H: SOI; Enhanced Financial Account of Fed Flow of Funds; Census Bureau; American Community Survey (ACS); Federal Housing Finance Agency (FHFA)

Goto: Data

Appendix: variable definitions

- Spirit of Zhou and Carroll (2012): tax data
- Sales tax data from local department of revenues: 27 states, 1700 counties

$$C_{i,t} = \text{PCE}_{s,t} \times \text{Population}_{s,t} \times \frac{\text{Taxable sales}_{i,t}}{\sum_{j \in s} \text{Taxable sales}_{j,t}}$$

- Currently available states (sorted by FIPS code):

1 Alabama, 4 Arizona, 5 Arkansas, 6 California, 8 Colorado, 12 Florida, 17 Illinois, 18 Indiana, 19 Iowa, 22 Louisiana, 27 Minnesota, 29 Missouri, 31 Nebraska, 32 Nevada, 36 New York, 37 North Carolina, 38 North Dakota, 39 Ohio, 42 Pennsylvania, 45 South Carolina, 47 Tennessee, 49 Utah, 50 Vermont, 51 Virginia, 55 Wisconsin, 56 Wyoming.

Appendix: variable definitions

- Some states only report tax revenue $\Longrightarrow$ measurement error due to differential tax rate
- Year t, county i, total J types of goods; True consumption: $C_{j,i,t}$, tax revenue $T_{j,i,t}$, tax rate $\tau_{j,t}$
- True consumption distribution:

$$\tilde{S}_{i,t} := \frac{C_{i,t}}{\sum_{m=1}^{I} C_{m,t}} = \frac{\sum_{j=1}^{J} C_{j,i,t}}{\sum_{m=1}^{I}\sum_{j=1}^{J} C_{j,m,t}}$$

- Estimates:

$$S_{i,t} := \frac{T_{i,t}}{\sum_{m=1}^{I} T_{m,t}} = \frac{\sum_{j=1}^{J} C_{j,i,t}\tau_{j,t}}{\sum_{m=1}^{I}\sum_{j=1}^{J} C_{j,m,t}\tau_{j,t}}$$

- Measurement error:

$$S_{i,t} = \frac{\bar{\tau}_{i,t}\sum_{j=1}^{J} C_{j,i,t}}{\bar{\tau}_{t}\sum_{m=1}^{I}\sum_{j=1}^{J} C_{j,m,t}} = \frac{\bar{\tau}_{i,t}}{\bar{\tau}_{t}}\tilde{S}_{i,t}$$

where:

$$\bar{\tau}_{i,t} = \frac{\sum_{j=1}^{J} C_{j,i,t}\tau_{j,t}}{\sum_{j=1}^{J} C_{j,i,t}} \quad \bar{\tau}_{t} = \frac{\sum_{m=1}^{I}\sum_{j=1}^{J} C_{j,m,t}\tau_{j,t}}{\sum_{m=1}^{I}\sum_{j=1}^{J} C_{j,m,t}}$$

are county & state average tax rates

Appendix: variable definitions

Goto: Data

Appendix: variable definitions

- Methodology of Holden and Wulfsberg (2009)
- **Idea**: true nominal wage distribution vs. constructed notional rigidity-free distribution
- Notional distribution: all county-industry pairs with upper 25% wage growth in a given year
- Fraction of Wage Cuts Prevented:

$$\text{FWCP}_{i,t} = 1 - p_{i,t}/\tilde{p}_{i,t}$$

$$\tilde{p}_{i,t} := \frac{\#\{Z_{i,t} < 0\}}{N_t^{\text{top } 25\%}}$$

$$p_{i,t} := \frac{\#\{\Delta w_{j,i,t} < 0\}}{N_{i,t}}$$

where $Z_{i,t}$ is the rigidity-free wage growth from the notional distribution of county i in year t; $\Delta w_{j,i,t}$ is the true wage growth of industry j

Goto: Data

Appendix: Illustration parameters

Parameter	Definition	Value
β	Utility discounting factor	0.9
α	Labor income share	0.7
δ	Parameter of DNWR	0.99
θ	Collateral constraint as LTV ratio	0.8
A	Technology level	1
$\overline{\nu}$	Steady state LTV ratio	0.79
γ	Housing preference	0.8
H	House supply	30

Goto: comparative statistics

Appendix: Sensitivity analysis

- Framework of Cinelli and Hazlett (2020)

- If there are confounder(s), how strong must it be explaining the residual to:
  - Flip the coefficient sign
  - Overturn the t-tests

- e.g. Policy intervention not captured by fixed effects

- Scalar measures and **contour figures** regarding:
  - $R^2_{D\sim Z,X}$: partial R^2 of confounder(s) Z wrt treatment D
  - $R^2_{Y\sim Z|D,X}$: partial R^2 of confounder(s) Z wrt outcome Y

- Benchmark variable: what if confounder(s) are as strong as an a specific existing regressor?

Goto: Robustness

Appendix: Sensitivity analysis

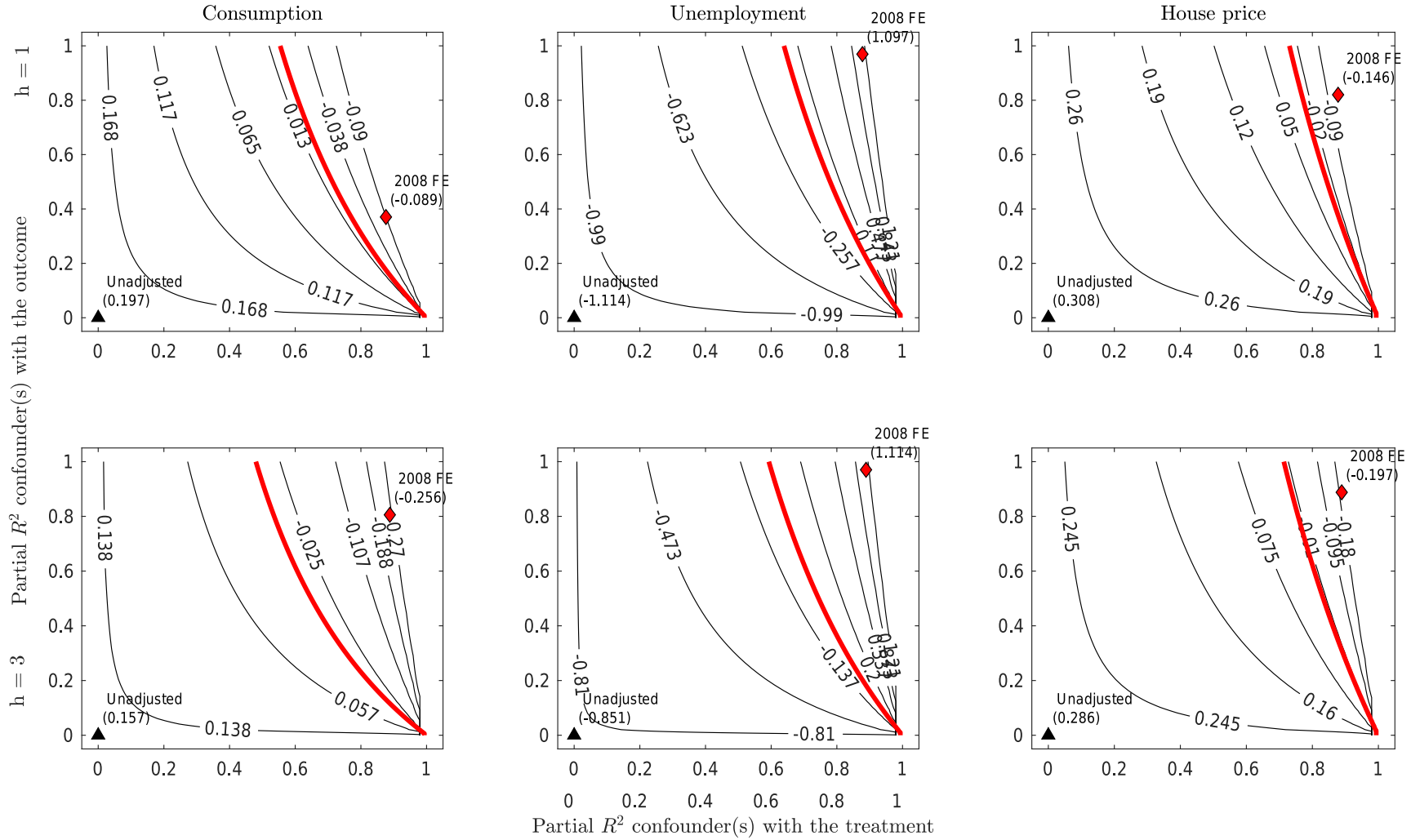


Figure 17: Point estimate of $\beta_h(\Delta \boldsymbol{Z} = 0)$

where the red line marks zero (threshold of sign flip)

- Benchmarking: 2008 year fixed effects

Appendix: Sensitivity analysis

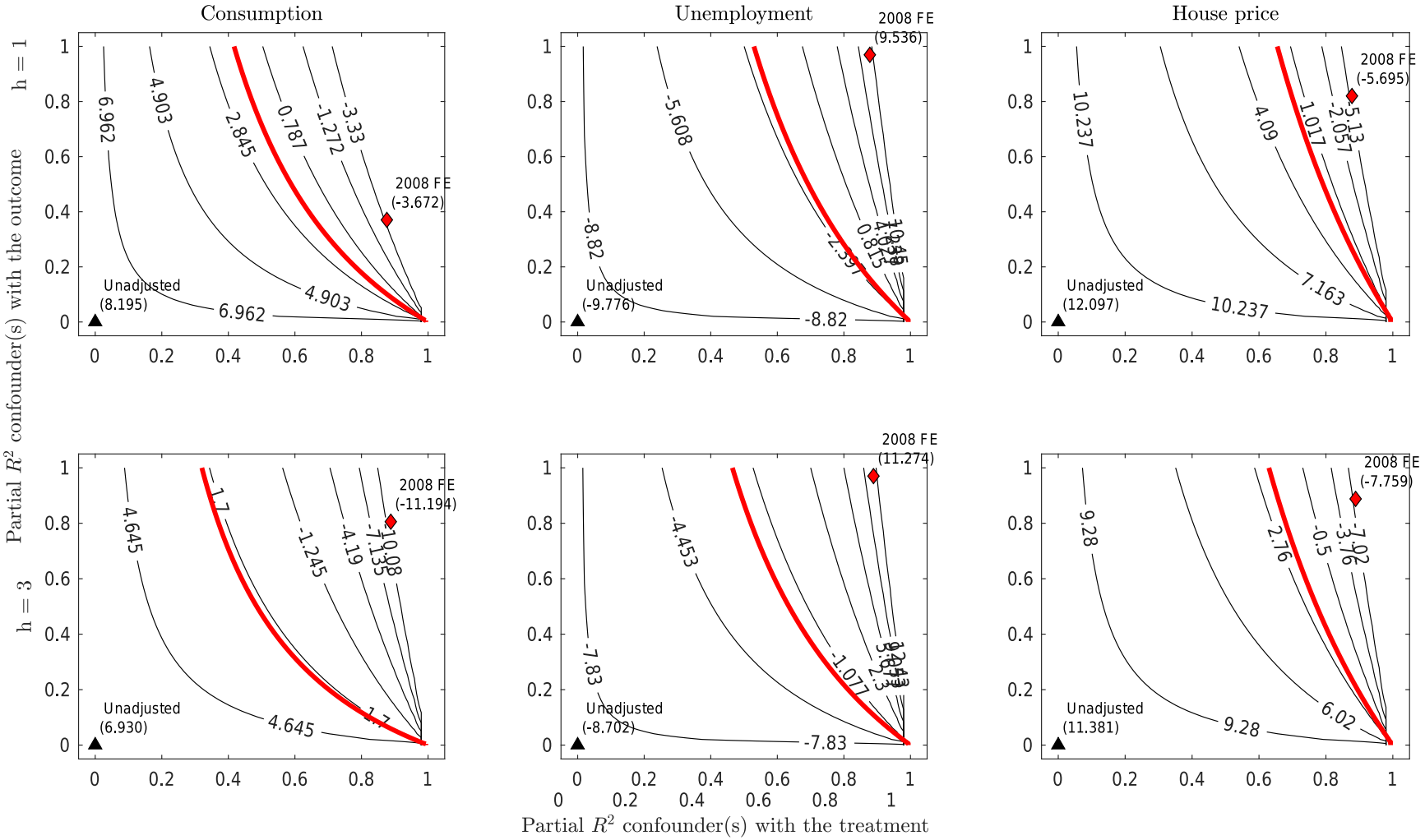


Figure 18: t-statistic of $\beta_h(\Delta \boldsymbol{Z} = 0)$

where the red line marks $\alpha = 5\%$ criteria value of t-test

- Benchmarking: 2008 year fixed effects

Appendix: Order selection

Expanding $\beta_h(\Delta \boldsymbol{Z})$ to the 3rd order:

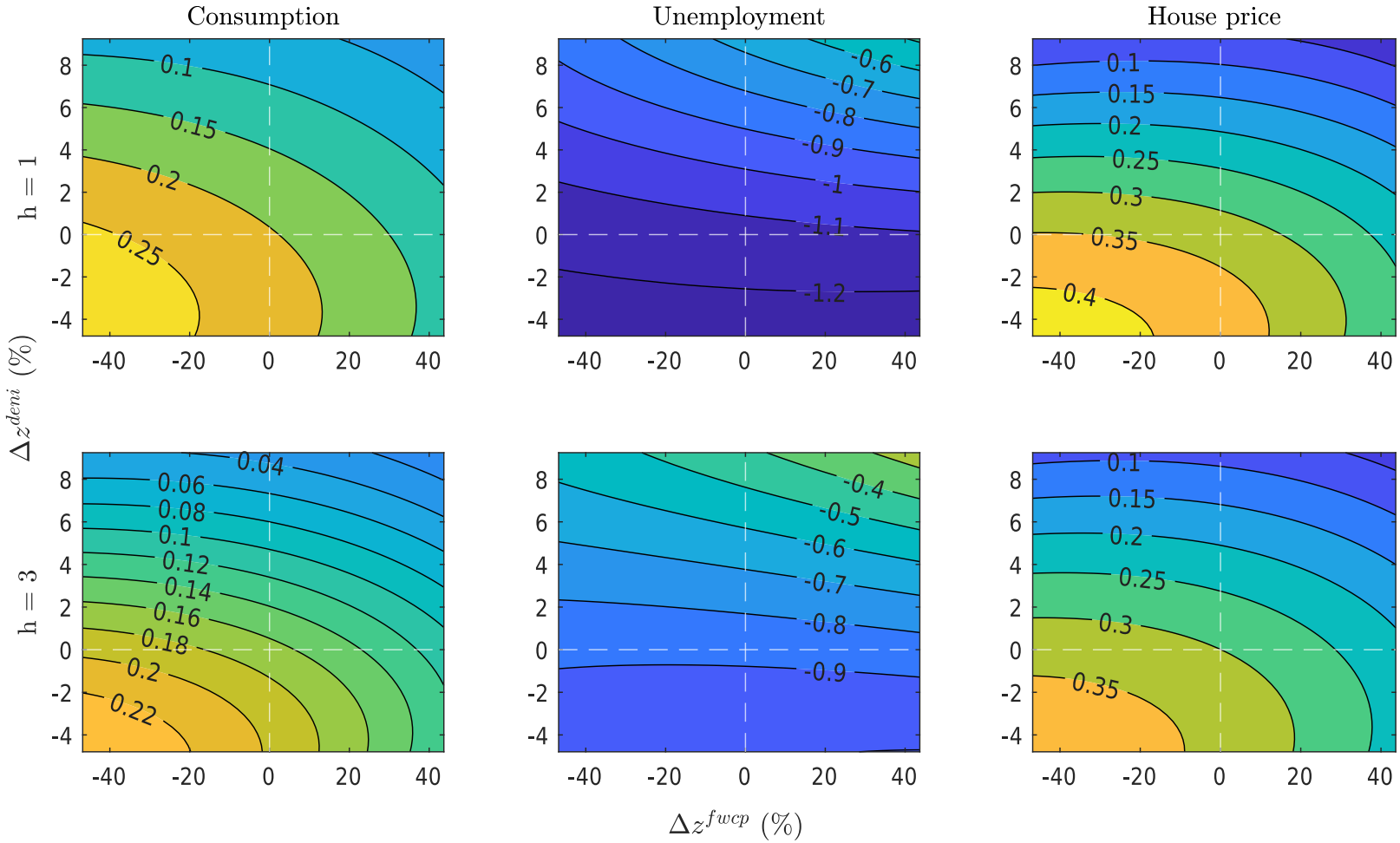


Figure 19: $\beta_h(\Delta \boldsymbol{Z})$

Goto: baseline

Appendix: Local linear estimator

- Global polynomial may mask important local features $\Longrightarrow$ check local estimators
- Use local linear estimator:
  - Gaussian kernel for $\Delta \boldsymbol{Z}$, Normalized Euclidean distance
  - 17×17 quantile knots in percentage range $[10\%, 90\%]^2$ (every 5%)
  - Two-step estimation procedure in Zhang, Lee and Song (2002)
  - Plug-in bandwidth estimator in Yang and Tschernig (1999)

Appendix: Local linear estimator

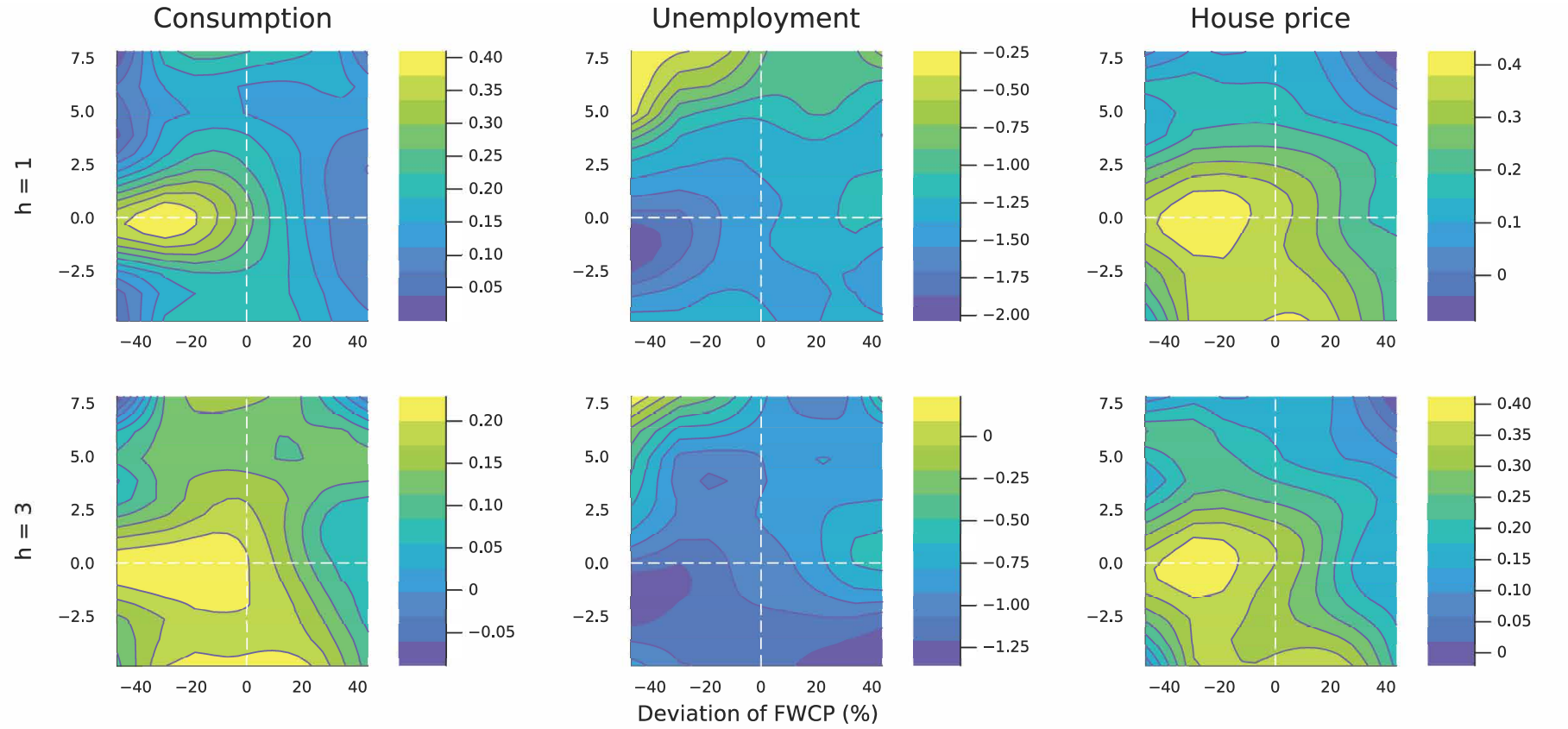


Figure 20: $\beta_h(\Delta \boldsymbol{Z})$

- No significant new features cp. baseline

Goto: robustness

Appendix: Profile-likelihood ratio (PLR) test

- The F-test depends on the parametric assumption of the global polynomial

$\Longrightarrow$ PLR test by Fan and Huang (2005) which test $\beta_h(\Delta \boldsymbol{Z})$ as a whole

- H_0: if the overall treatment effect β_h is dependent on Δz^{fwcp} and Δz^{deni} and the baseline model is correctly specified, then it equals to the estimates from the linear LP model

Goto: Robustness

- Table (next page):

Appendix: Profile-likelihood ratio (PLR) test

Horizon	Consumption	Unemployment	House price
0	3230.96***	328.46***	1596.15***
	(0.1503)	(0.1503)	(0.1503)
1	2921.63***	355.91***	1166.61***
	(0.1504)	(0.1504)	(0.1504)
2	3345.83***	1301.31***	1230.62***
	(0.1504)	(0.1504)	(0.1504)
3	3069.98***	1684.84***	1127.61***
	(0.1504)	(0.1504)	(0.1504)
4	2615.89***	1605.61***	589.91***
	(0.1504)	(0.1504)	(0.1504)
5	2264.8***	1829.66***	770.64***
	(0.1503)	(0.1504)	(0.1504)
6	1886.03***	1837.51***	841.8***
	(0.1503)	(0.1503)	(0.1503)
7	1630.81***	1799.62***	935.84***
	(0.1502)	(0.1502)	(0.1502)

where the number with stars are the generalized likelihood ratio statistic T_0, the number in parenthesis is δ_n the degree of freedom of the asymptotic $\chi^2_{\delta_n}$ distribution, the other asymptotic parameter $r_K \approx 0.51579$ for our Gaussian kernel.

Appendix: Spatial spillover effects

- Neighboring counties may share markets (e.g. labor market of a metropolitan) $\Longrightarrow$ spillover effects of net worth shocks

- Re-estimate the baseline model but:
  - adding a spatial Durbin term: $\eta_h \cdot \boldsymbol{W}\boldsymbol{X_t}$
  - assuming no spillover effects of the outcomes and error

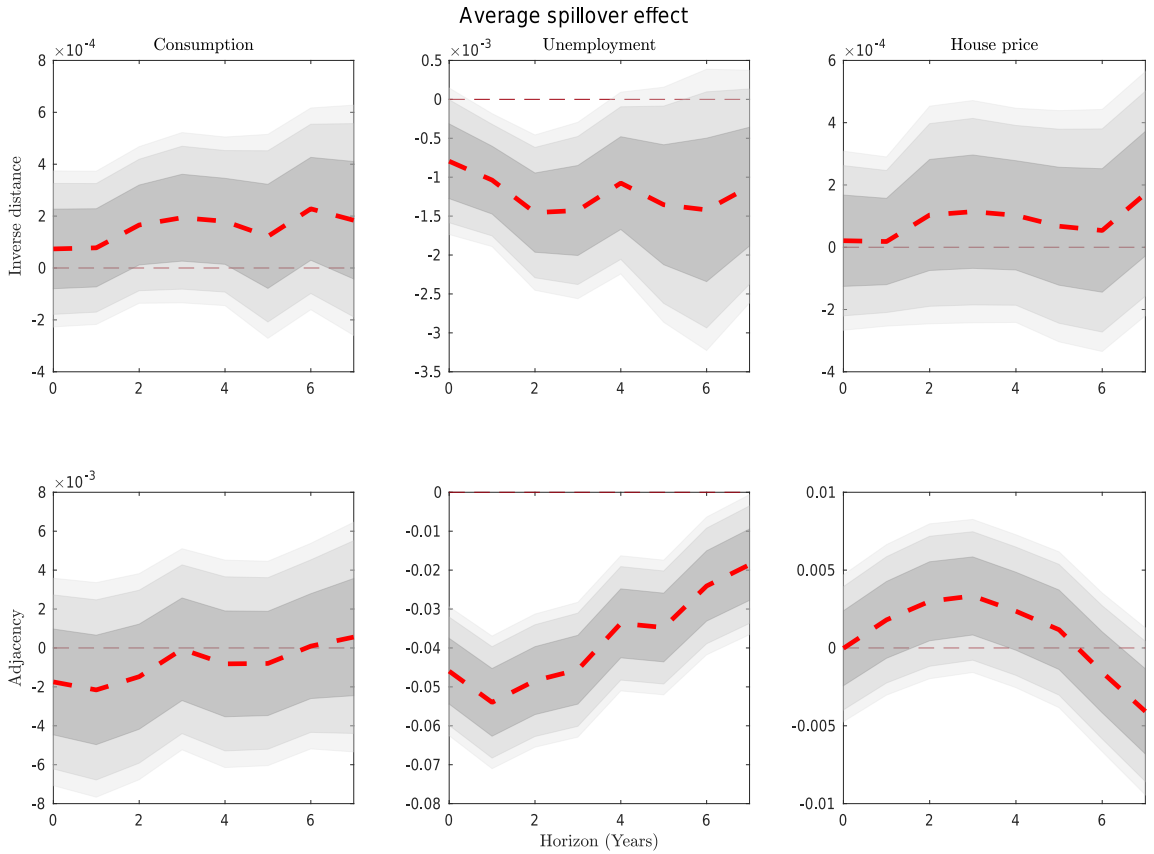
where $\boldsymbol{W}$ is spatial weighted matrix, $\boldsymbol{X}_t$ is stacked net worth shock in year t, and η_h is the coefficient of average spillover effect

- In this special case of Spatial Durbin model, the average indirect/spillover effect defined by LeSage and Pace (2009) degenerates to a number constantly proportional to η_h

- We test two types of spatial weight matrices:
  - Inverse distance weighting
  - 1st-closest neighbor adjacency weighting

Appendix: Spatial spillover effects

Average spillover effect η_h:

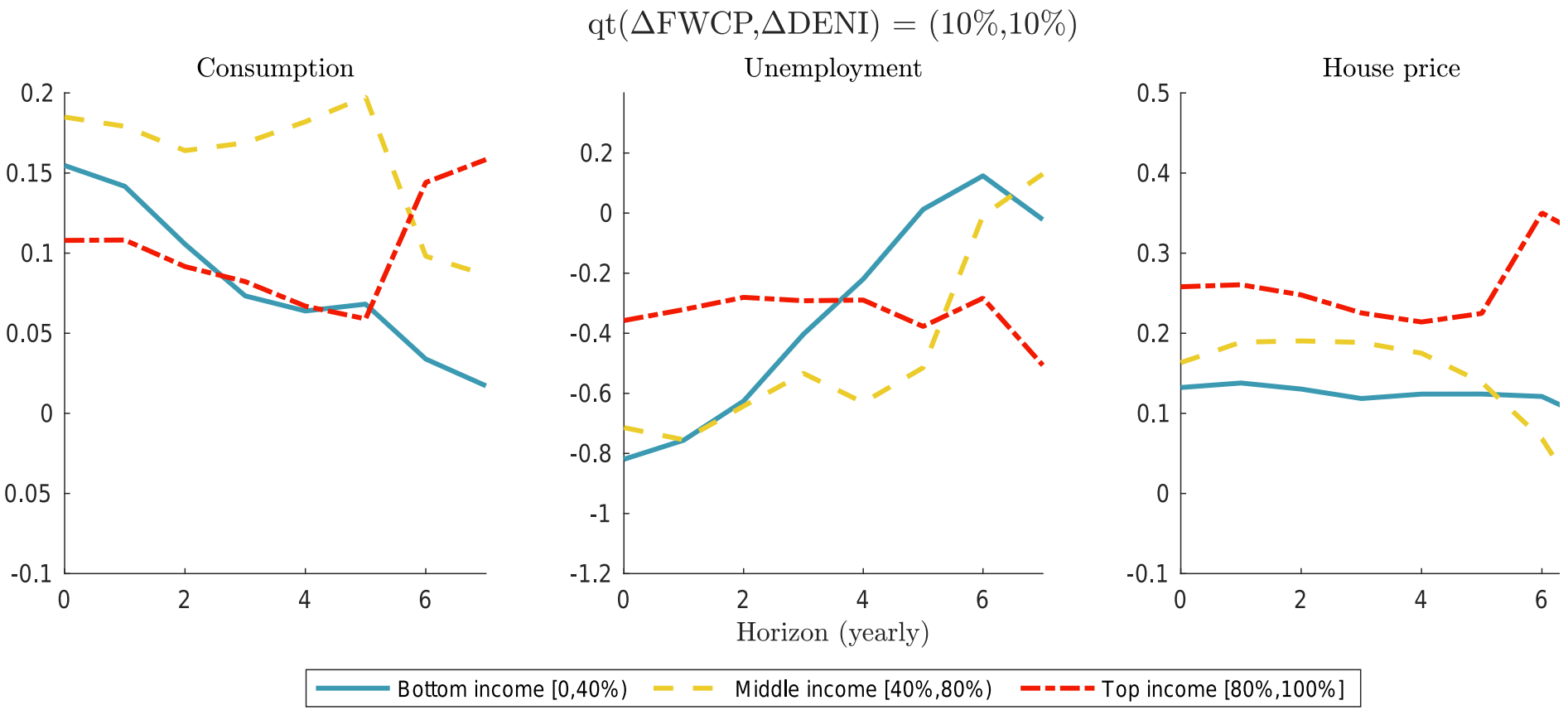


- Significant spillover effect of the shock on local labor markets
- Does not change $\beta_h(\Delta Z)$ in the other ΔZ areas except the "top-right" corner $\Longrightarrow$ even larger non-linearity

Goto: Robustness

Appendix: Counterfactual IRF among income groups

Scenario: Neither binding $(10\%, 10\%)$:



- Similar effect size among income groups

Appendix: Other details in the baseline model

Controls:

- $\boldsymbol{W}_{i,t}$: Similar to Mian, Rao and Sufi (2013)
  - Total housing units
  - Share of housing wealth in household net worth
  - Share of tradable sector employment in total employment
  - Share of construction sector employment in total employment
- $g\big(N_{i,t-1}\big)$: 3rd order polynomial approximation; controlling pre-determined economic conditions

Sample: 2004-2019; 1700 counties with consumption data available

Weights: county population

SE Cluster: state level

Goto: baseline

Appendix: Other details in the baseline model

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