

# Non-linear Heterogeneous Impact of Net Worth Shocks

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September, 2024

# Outline

**Introduction**

A tractable two-agent Model

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# 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); Greg Kaplan, Kurt Mitman and Giovanni L. Violante (2020); Greg Kaplan, Kurt Mitman and Giovanni L. Violante (2020) ...
- Financial, nominal frictions and their impact: Christiano, Eichenbaum and Trabandt (2015); Schmitt-Grohé and Uribe (2016); Shen and Yang (2018) ...

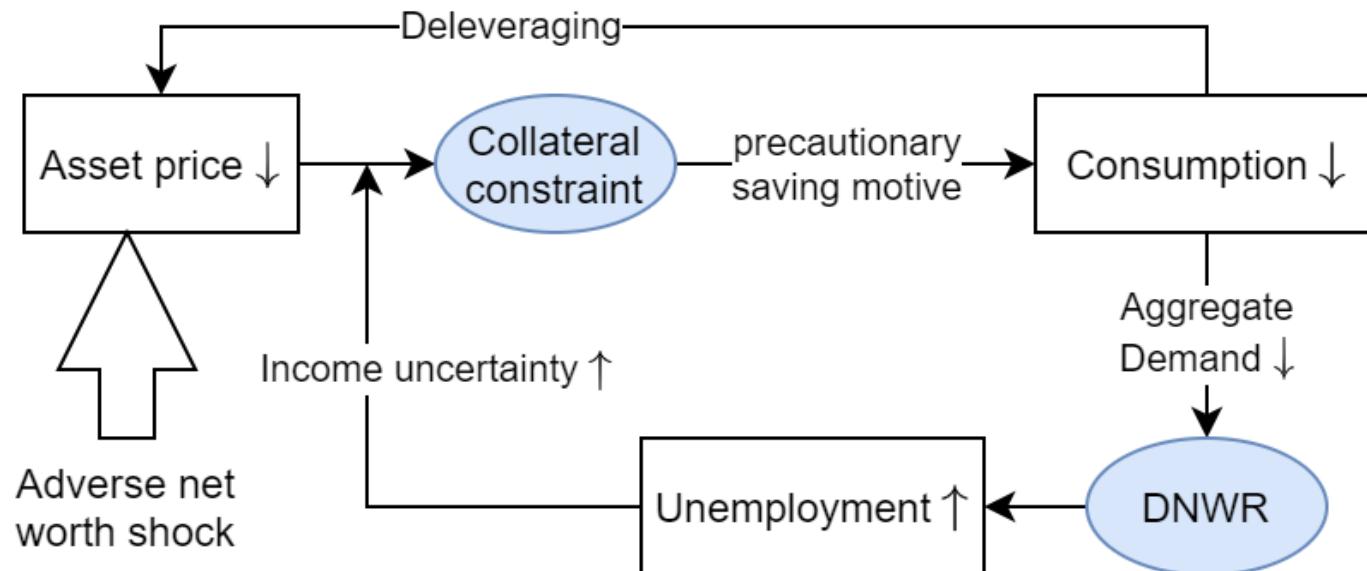
## Methodology:

- 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: 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.



# 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.

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# A tractable two-agent model

- $t = 0, 1, 2, \dots$ , 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  
 $\implies$  **not** complete market

# A tractable two-agent model

## Expert's problem

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

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

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

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

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

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  $(0, \bar{u}]$
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  $n_1(u_1) \geq \bar{n}_1 := \bar{p}\bar{h}^{\frac{1-\beta\theta}{\beta}}$ , where  $\bar{p}$  and  $\bar{h}$  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  $\theta$  and the DNWR parameter  $\delta$ , such that if*

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

*then, in equilibrium, the  $t = 1$  collateral constraint and DNWR both bind when  $u_1$  is in a non-empty interval  $[\hat{u}_{lb}(\theta, \delta), \hat{u}_{up}(\theta, \delta)]$ . 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  $\theta$  and  $\delta$ .*

# A tractable two-agent model

## Comparative statistics

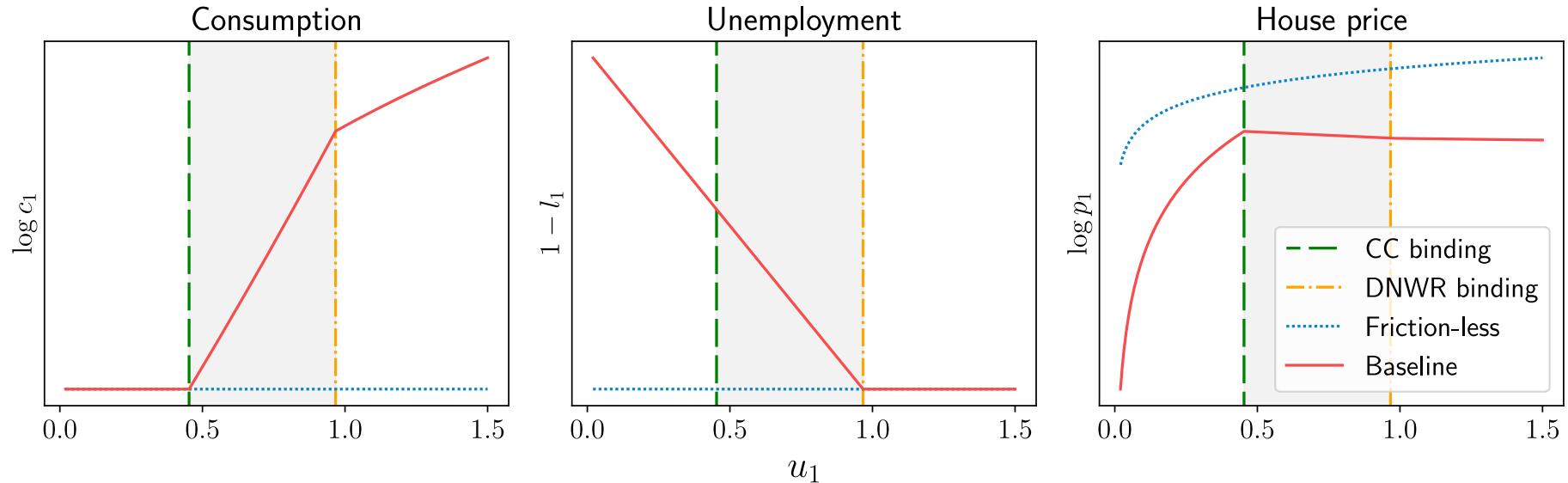


Figure 2: baseline vs. friction-less economy

where:

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

$\implies$  Amplification effects

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# 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](https://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:

$$x_{i,t} := \sum_{j \in \{S, B, H\}} s_{i,t-1}^j g_{t-1,t}^j$$

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

[Definition: net worth](#)

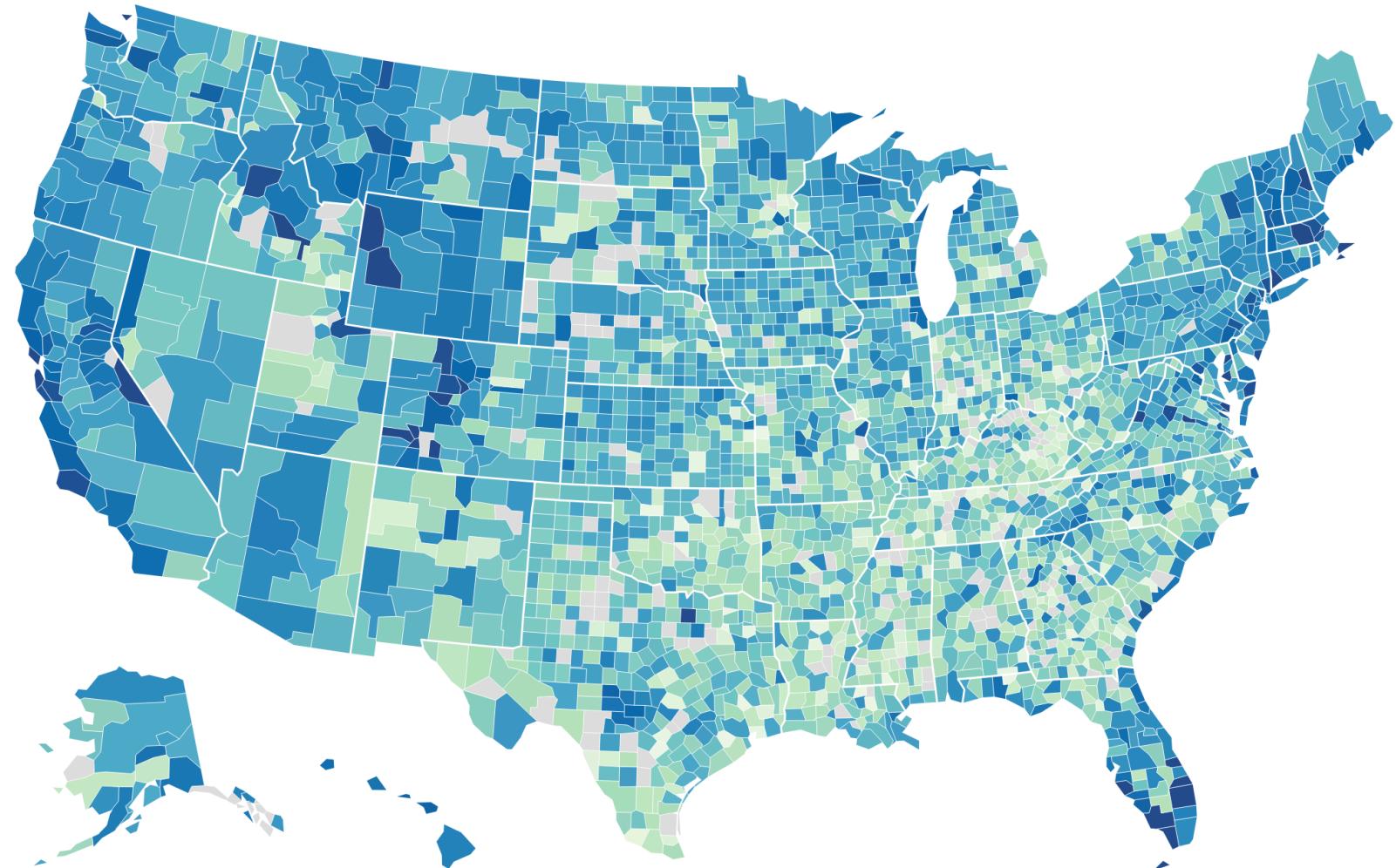
[Definition: consumption](#)

[Definition: FWCP](#)

# Data: CountyPlus

## Net Worth Per Capita (2006)

\$million



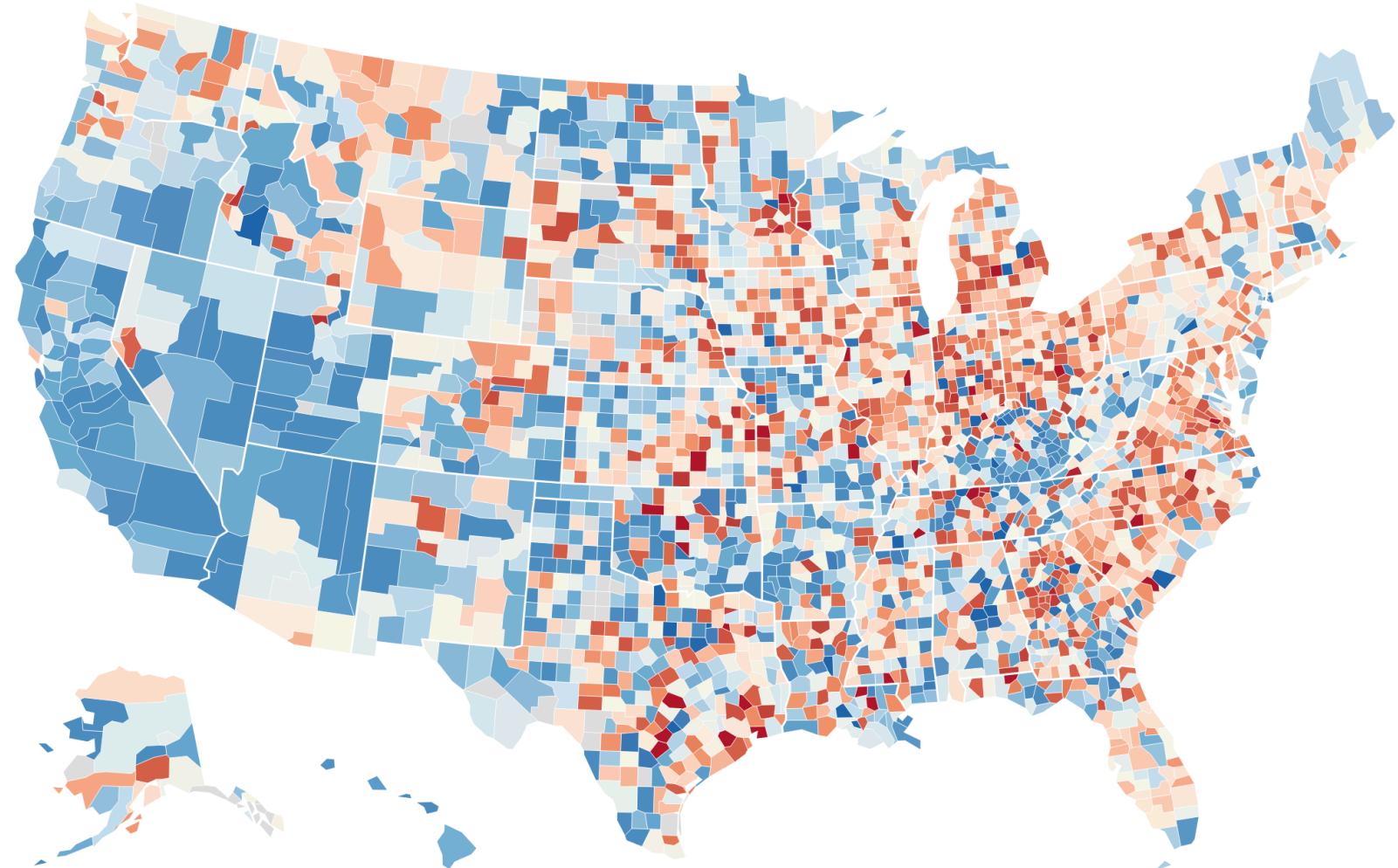
Source: CountyPlus • Created with Datawrapper

Figure 3: Geographical: Pre-crisis net worth

# Data: CountyPlus

## 3-year Net Worth Shock (06-09)

(bottom & top 1% censored)



Source: CountyPlus • Created with Datawrapper

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

# Data: CountyPlus

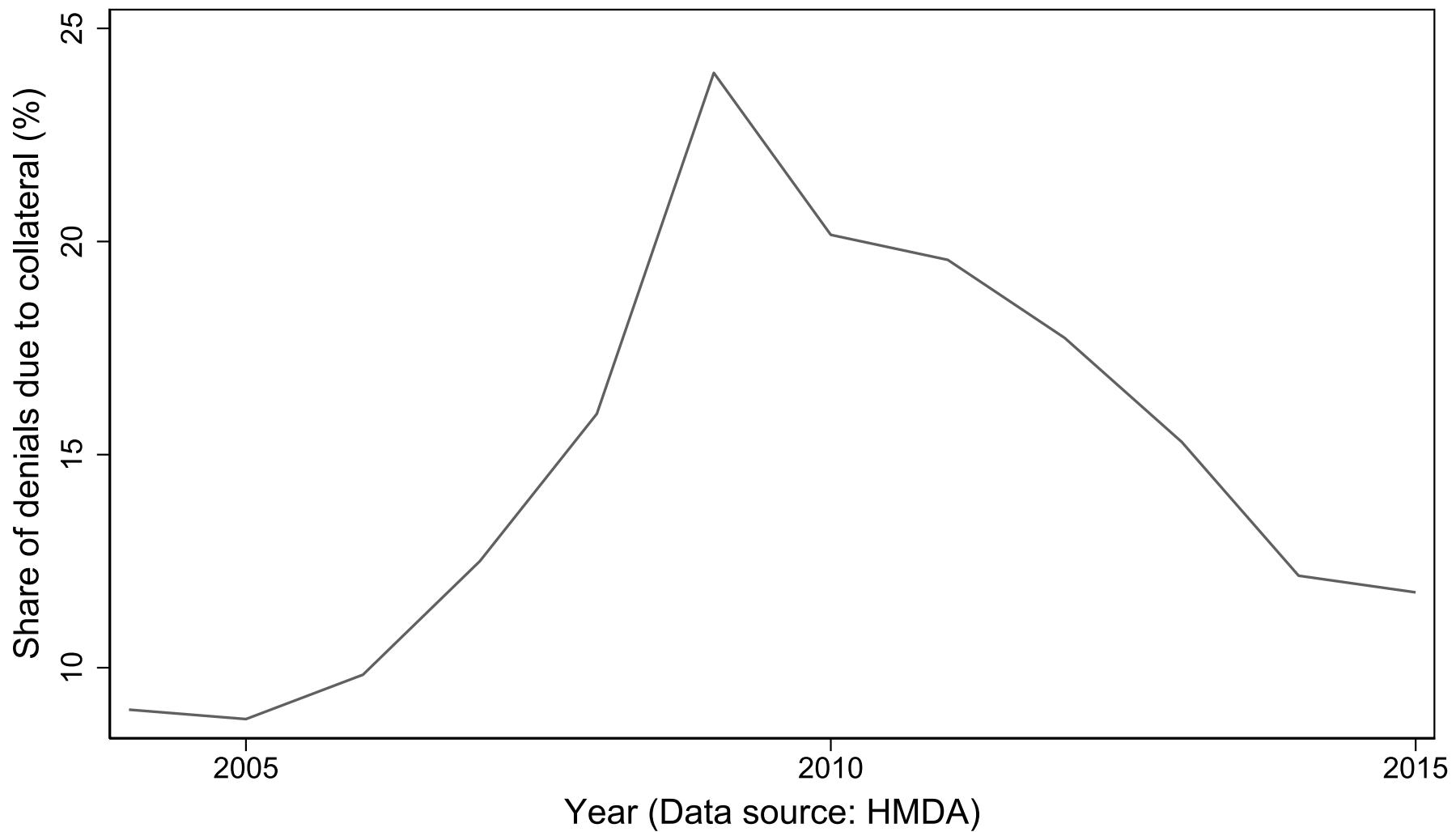


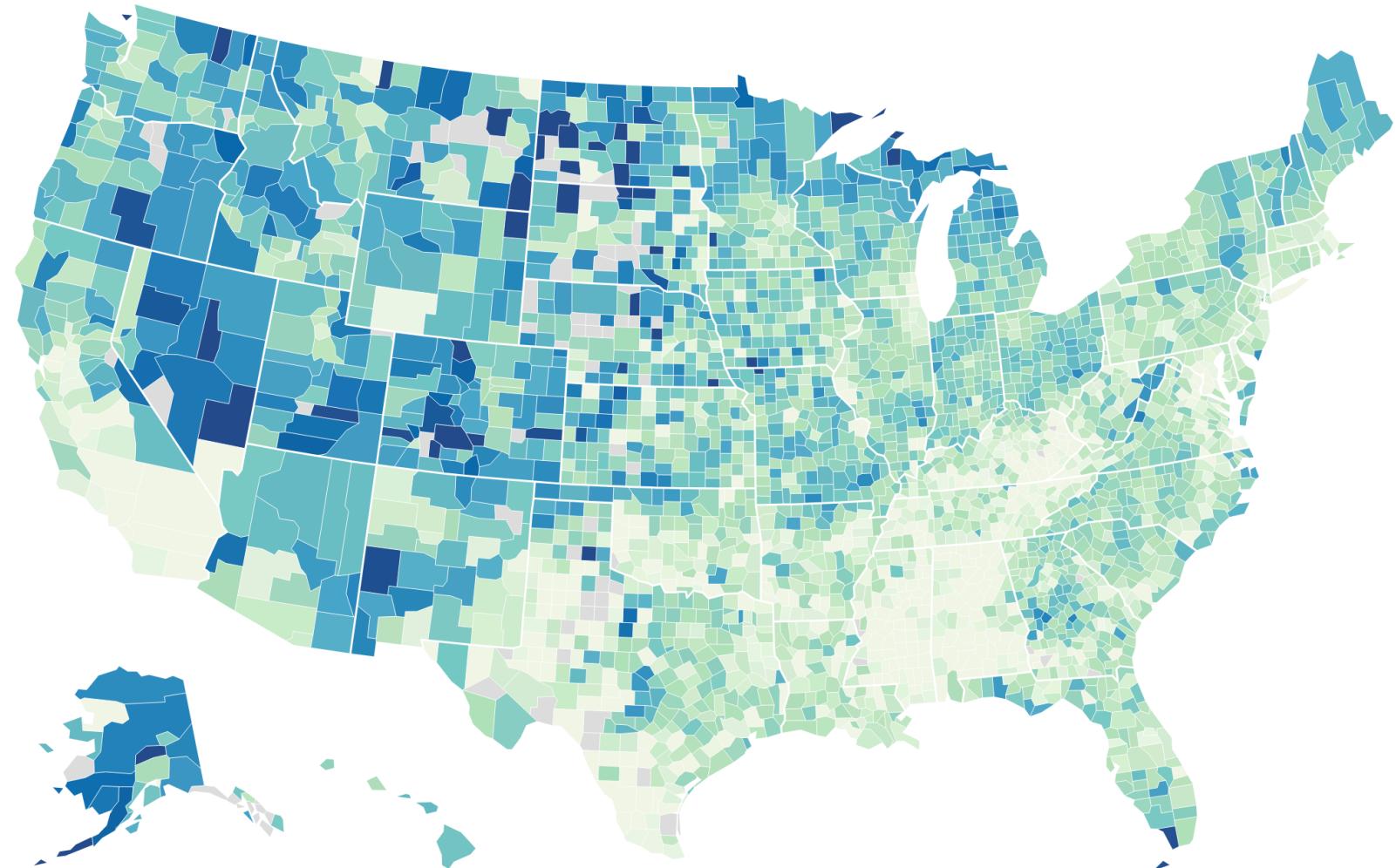
Figure 5: The aggregate extent of collateral constraint

- Larger  $DENI$ , larger friction

# Data: CountyPlus

## Home Mortgage Denial Share Due to Lack of Collateral

03-06 average



Source: CountyPlus • Created with Datawrapper

Figure 6: Geographical: Collateral constraint before the crisis

# Data: CountyPlus

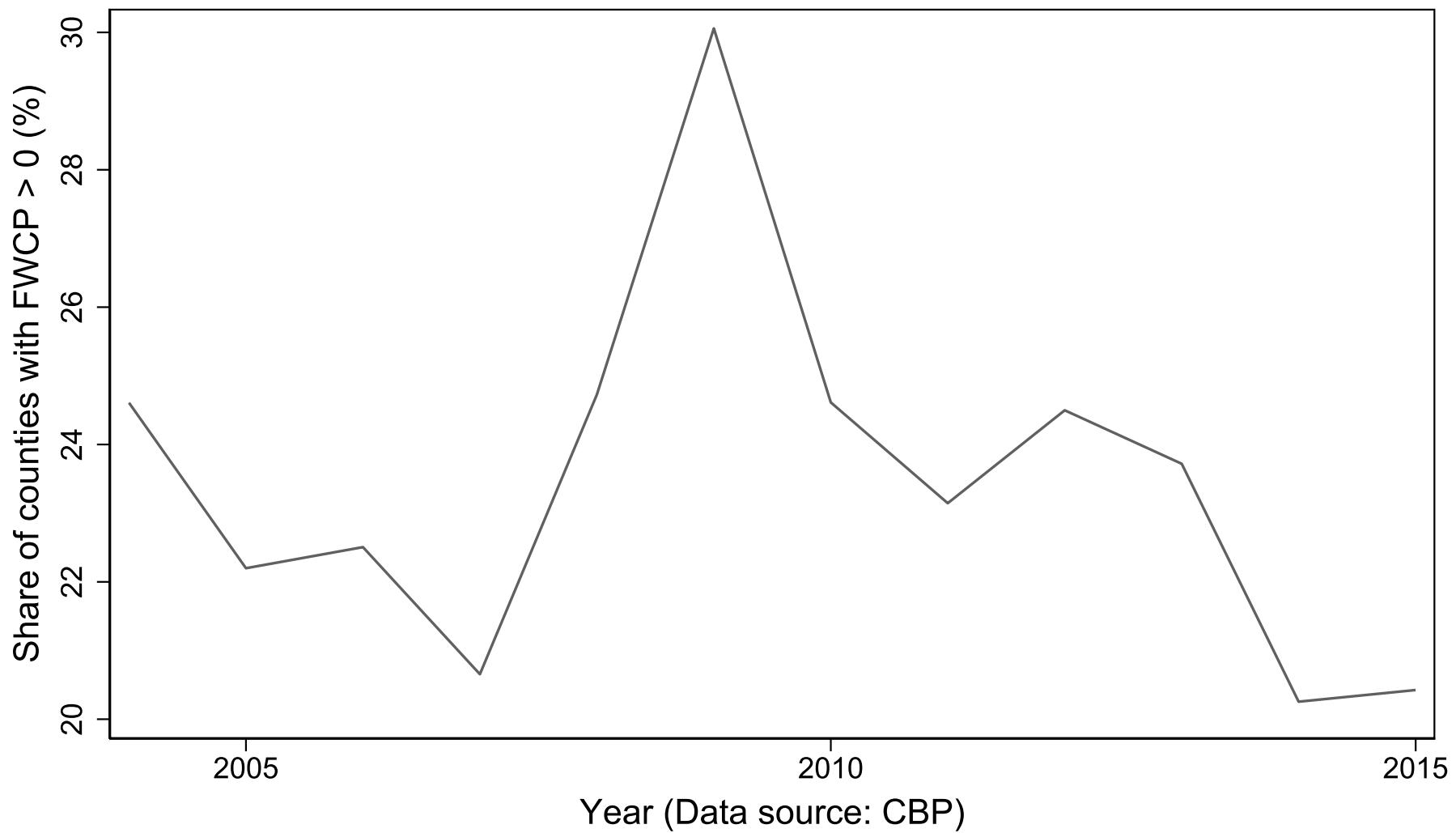


Figure 7: The aggregate extent of DNWR

- Larger *DNWR*, larger friction

# Data: CountyPlus

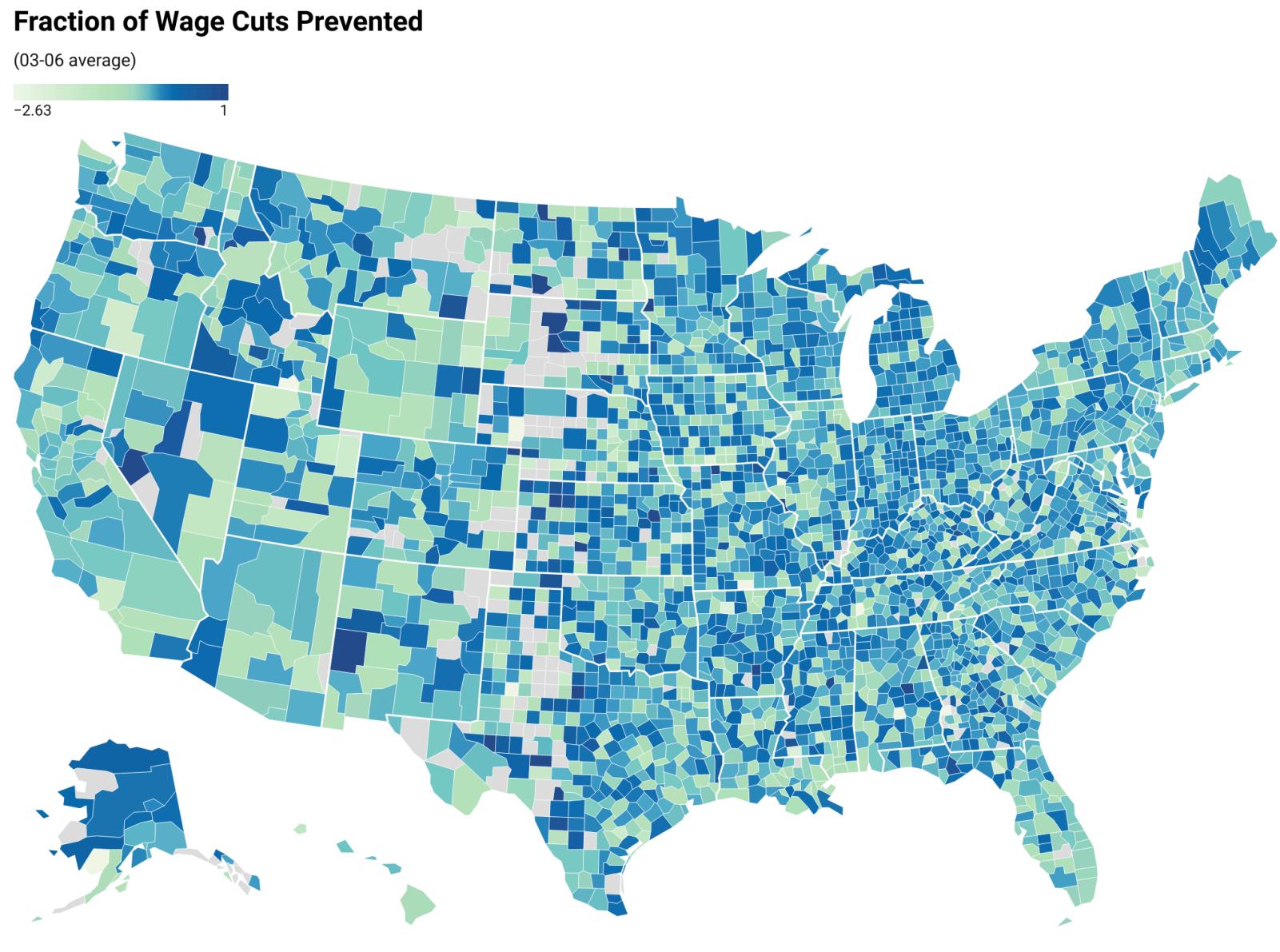


Figure 8: Geographical: DNWR before the crisis

# Data: CountyPlus

Compare with the aggregate series:

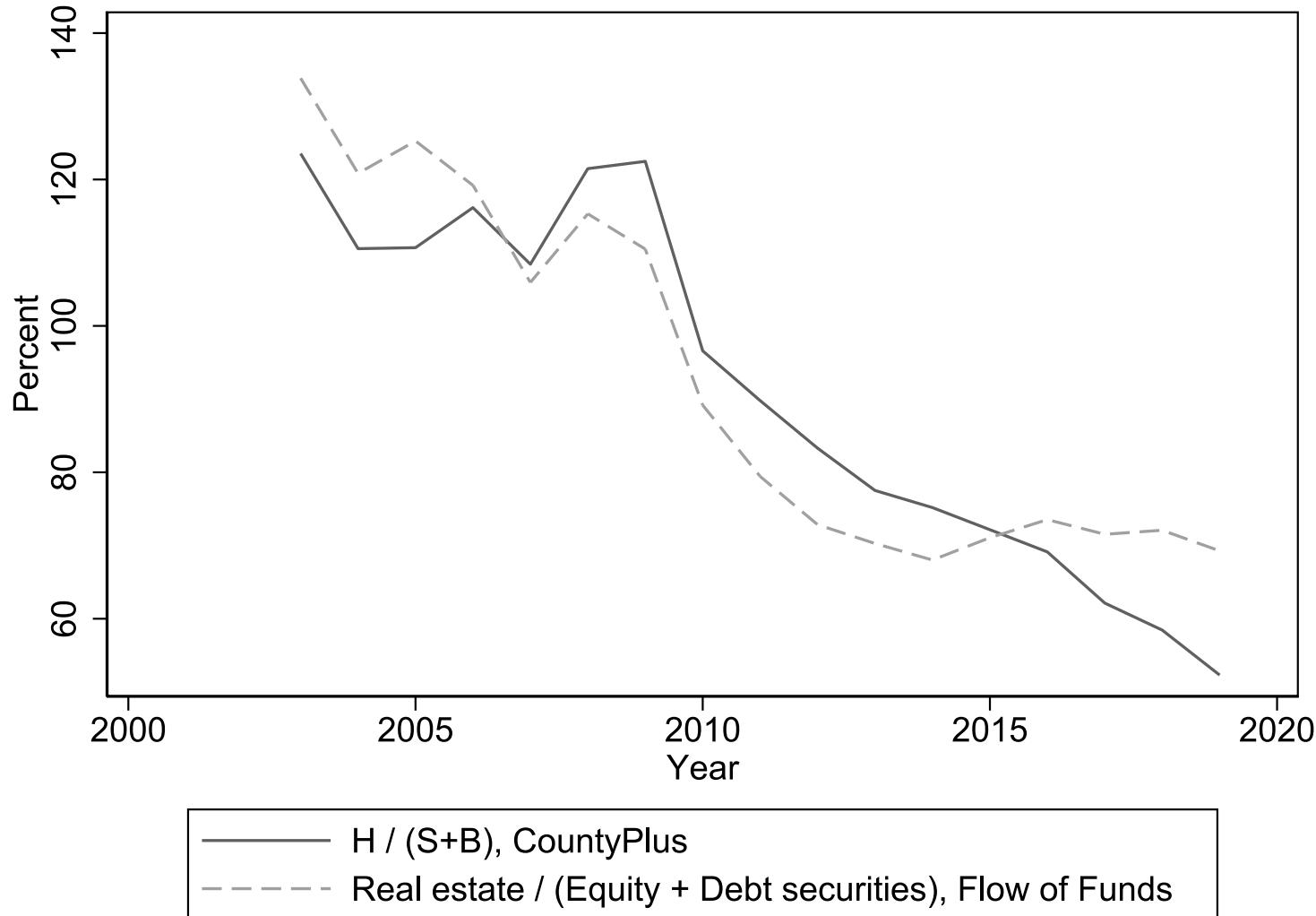


Figure 9: CountyPlus vs. Fed Flow of Funds

# Baseline specification

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

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

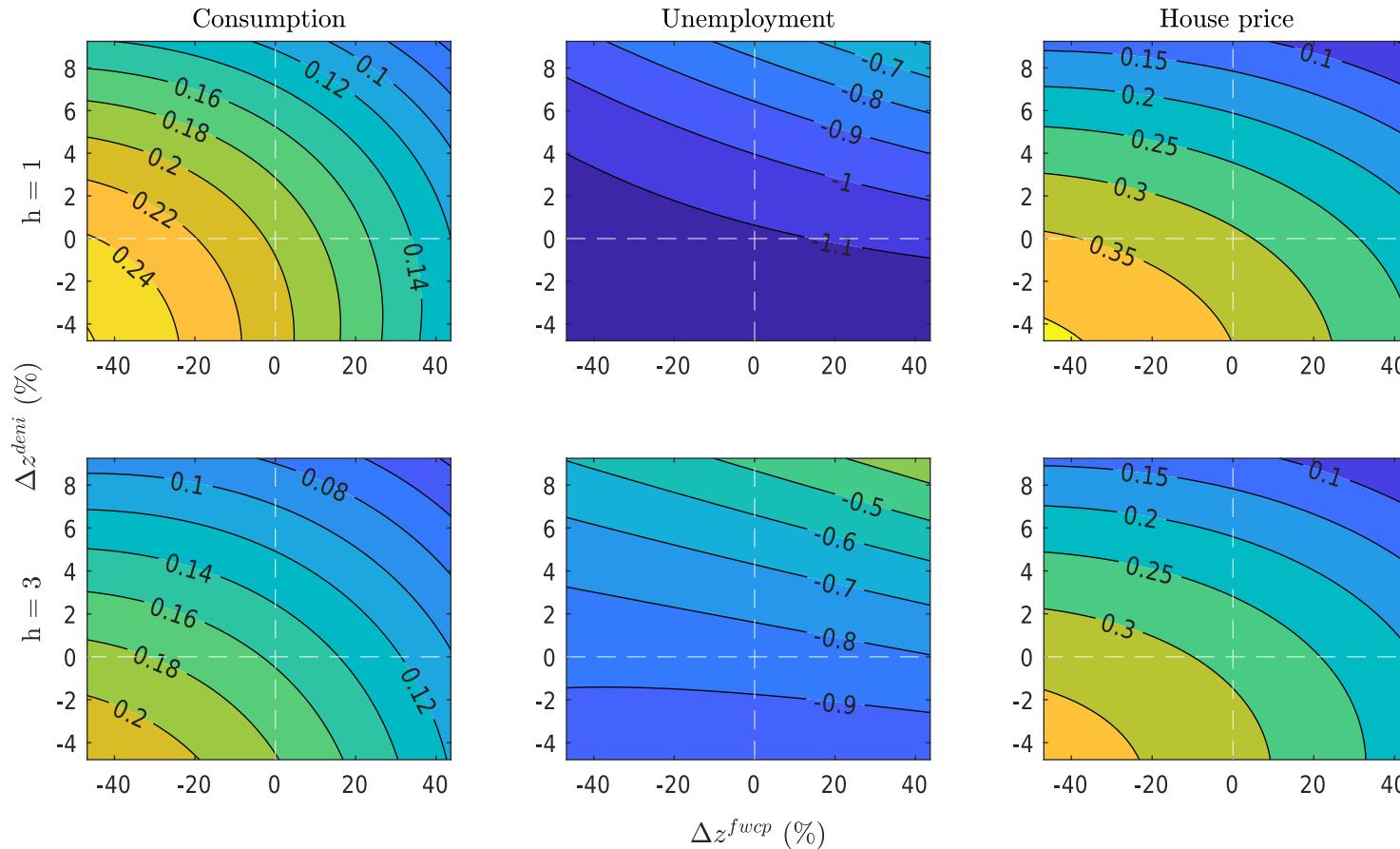
- where
  - $\Delta \mathbf{Z}_{i,t}$ : *DENI* and *FWCP* deviation from the county's mean level
  - $\beta_h(\Delta \mathbf{Z}_{i,t})$ : effects of the net worth shock
  - $h = 0, \dots, H$ : projection horizons
  - $y_{i,t+h}$ : outcomes
  - $g(N_{i,t-1})$ : a functional control of lagged net worth
  - $\iota_{i \in s}, \nu_t$ : 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  $\beta_h(\Delta Z)$  is 2-dimensional functions (+1% shock):

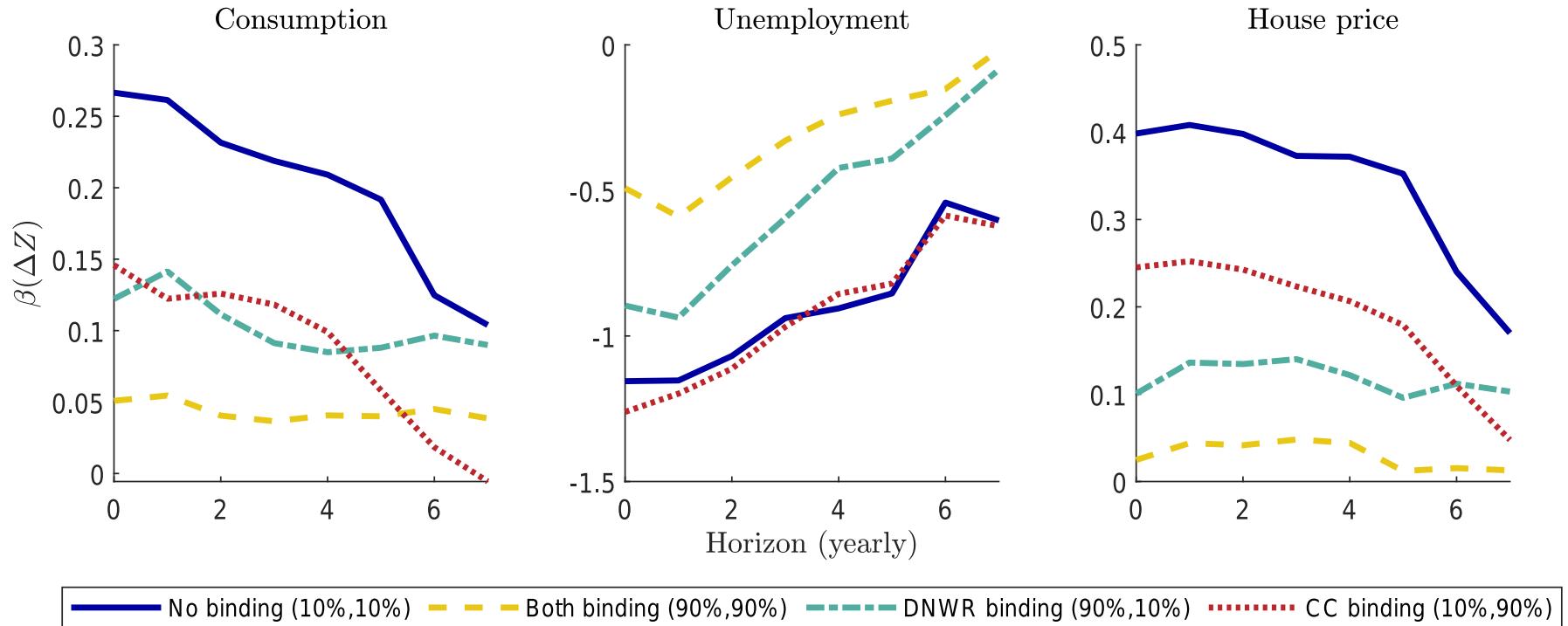


- Contour interval: heterogeneity of the effects
- Contour curvature: interaction & non-linearity

Other horizons

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

Counterfactual IRF by scenario:



- Numbers in parenthesis are quantiles of  $\Delta Z$  distribution: number ↘, bindingness ↘

# Baseline vs. Linear LP

- Baseline specification

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

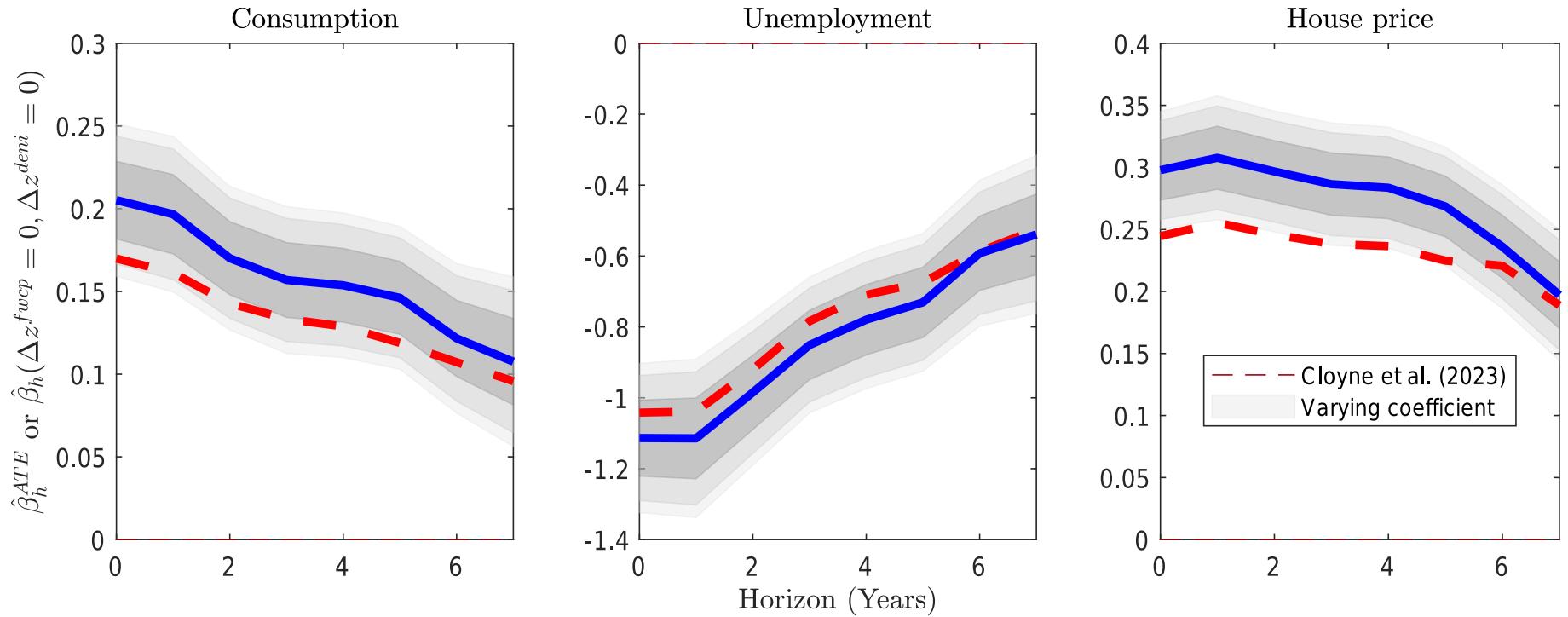
- Linear LP with linear heterogeneous effects Cloyne, Jordà and Taylor (2023)

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

where  $\gamma_h^{\text{fwcp}}$  and  $\gamma_h^{\text{deni}}$  are the linear heterogeneous effects

# Baseline vs. Linear LP

Consistent estimates at the average county:

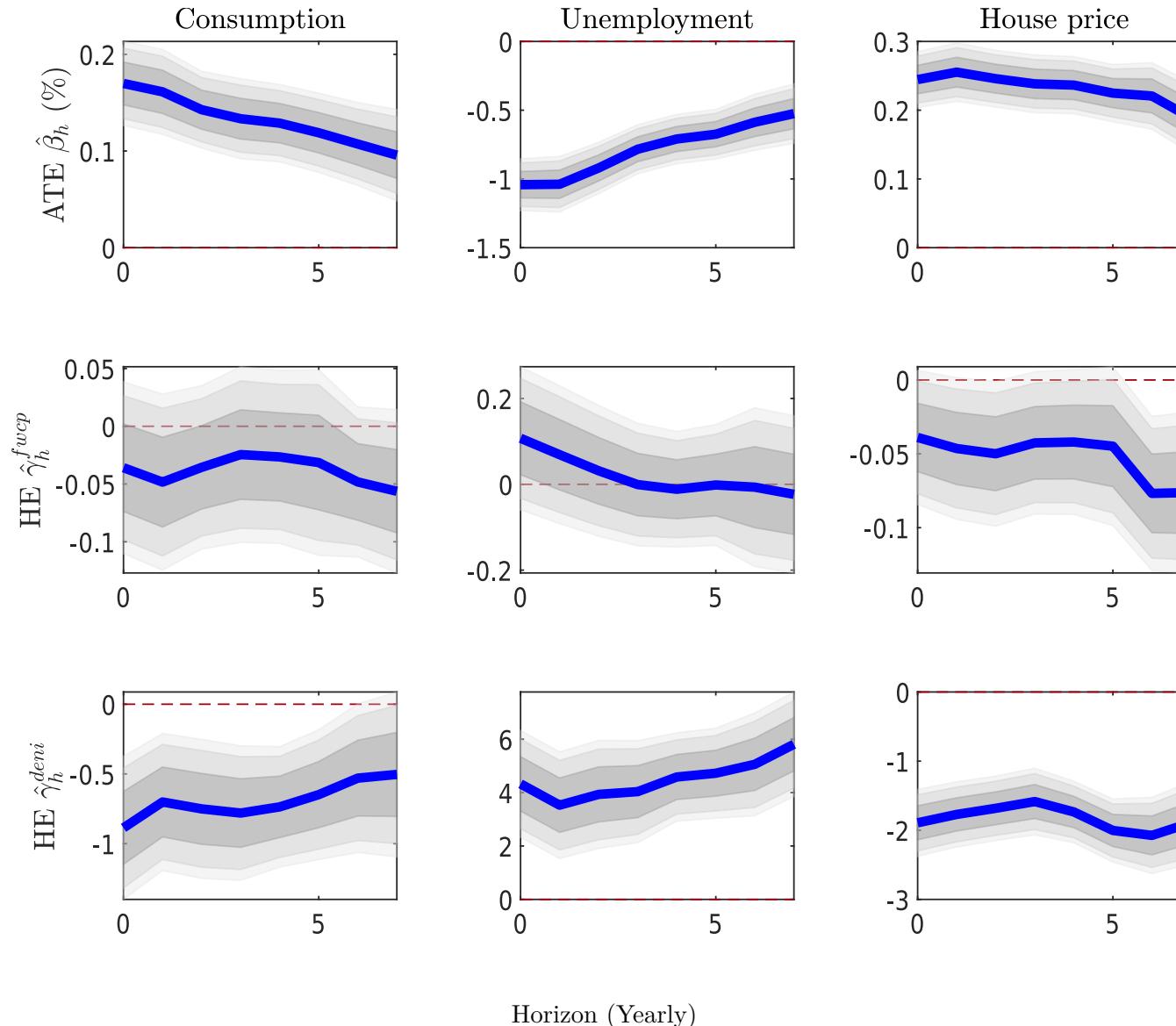


where

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

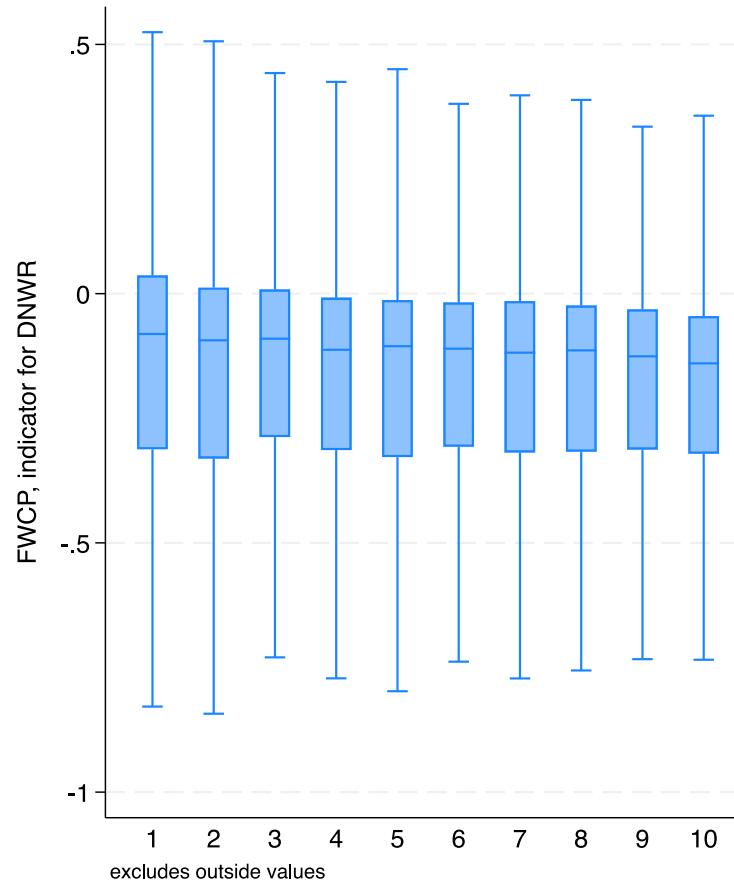
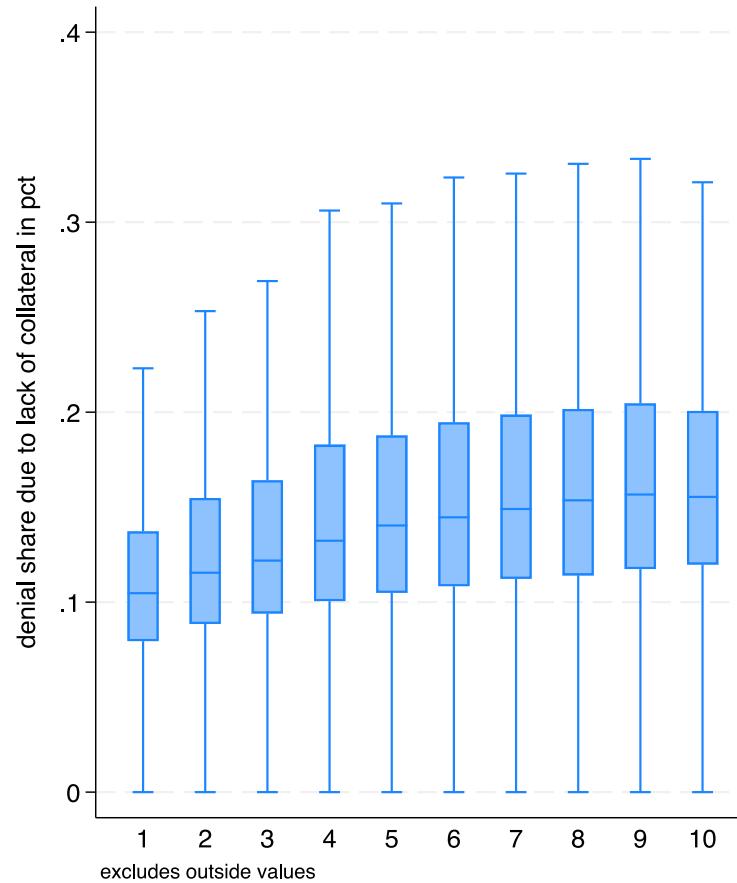
# Baseline vs. Linear LP

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:



⇒ Important implications for the transmission of macroeconomic shocks and the design of stabilization policies

# Heterogeneity among income groups

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



- 2006 cross-sectional distribution of county real median household income
- Vulnerability against shock:
  - Consumption: Low
  - Unemployment: Low & Middle
  - House price: Middle & Top

# 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	8.403*** (.000)	8.641*** (.000)	6.127*** (.000)	5.289*** (.001)	5.627*** (.001)	7.282*** (.000)	5.286*** (.001)	4.002*** (.008)
Unemployment	5.919*** (.001)	3.874*** (.009)	2.551* (.054)	2.963** (.031)	3.453** (.016)	3.292** (.020)	2.532* (.056)	1.627 (.181)
House price	24.967*** (.000)	23.961*** (.000)	22.215*** (.000)	21.083*** (.000)	22.661*** (.000)	19.744*** (.000)	14.116*** (.000)	11.973*** (.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 heterogeneous 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  $\beta_h(\Delta Z)$
  
- **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  $\Rightarrow$  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 heterogeneous 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

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# Appendix: Other horizon of the baseline

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

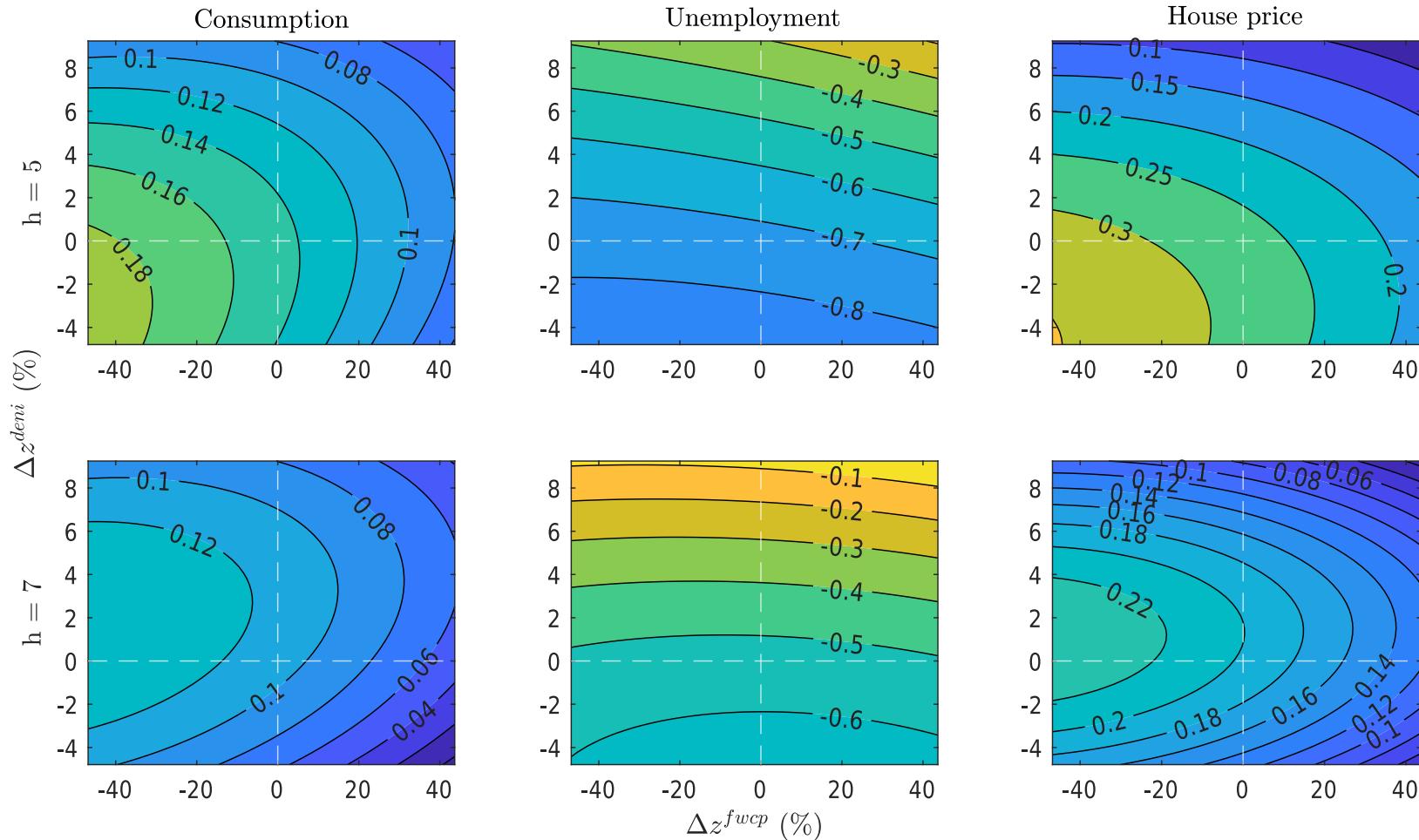


Figure 15:  $\beta_h(\Delta Z)$

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  $\Rightarrow$  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

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
$\beta$	Utility discounting factor	0.9
$\alpha$	Labor income share	0.7
$\delta$	Parameter of DNWR	0.99
$\theta$	Collateral constraint as LTV ratio	0.8
$A$	Technology level	1
$\bar{\nu}$	Steady state LTV ratio	0.79
$\gamma$	Housing preference	0.8
$H$	House supply	30

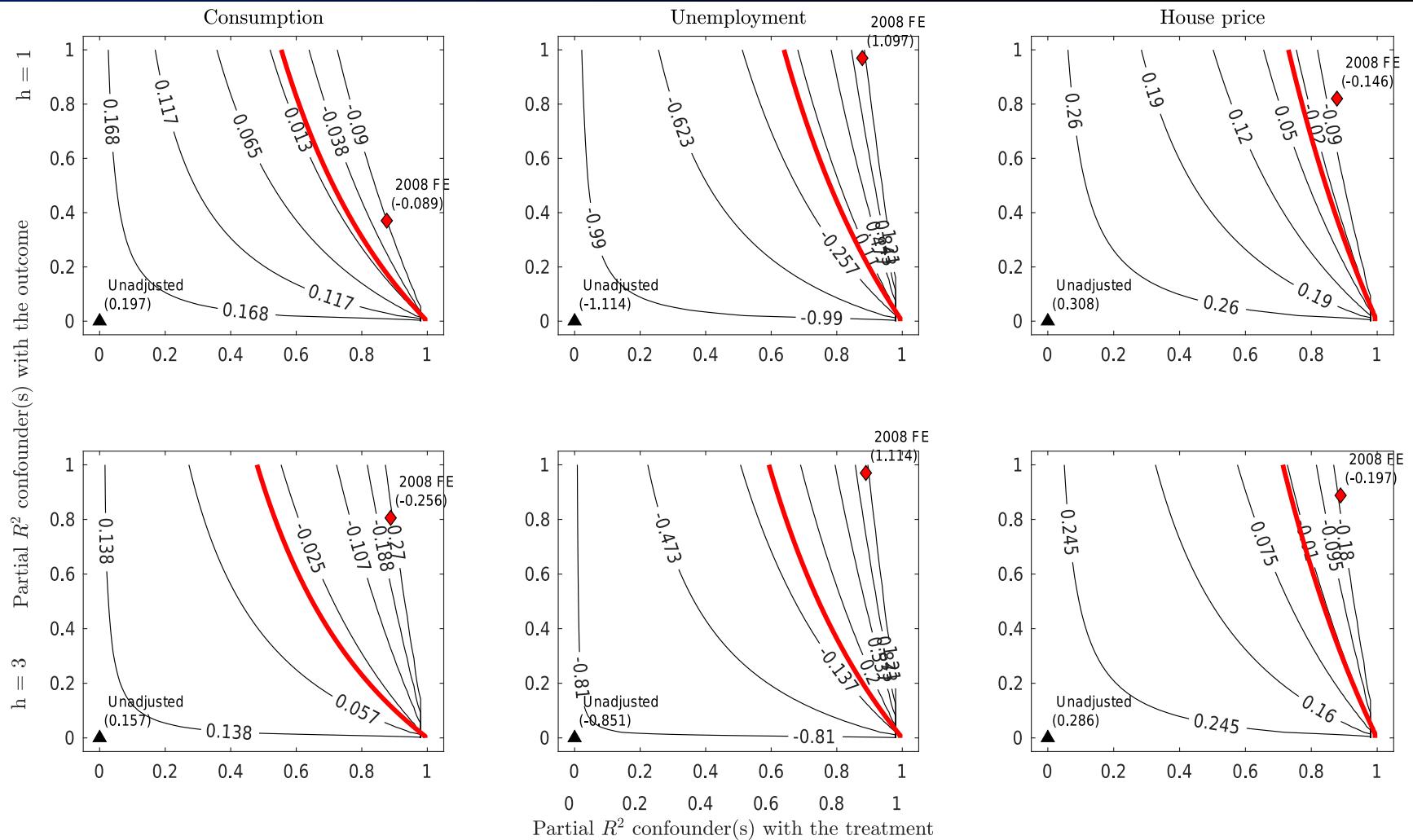
Goto: comparative statistics

# 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

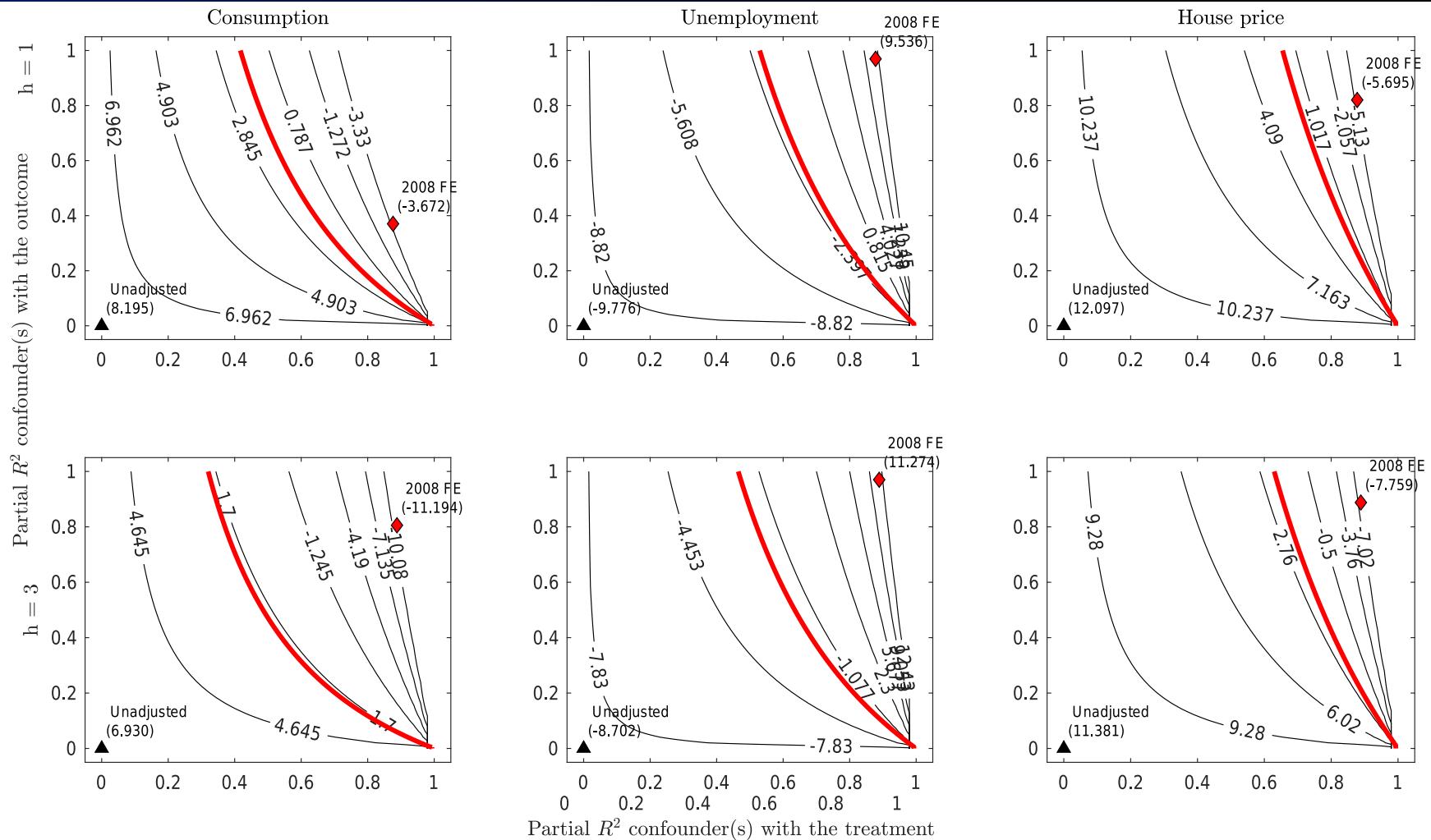
# Appendix: Sensitivity analysis

Figure 16: Point estimate of  $\beta_h(\Delta Z = 0)$ 

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

- Benchmarking: 2008 year fixed effects

# Appendix: Sensitivity analysis

Figure 17:  $t$ -statistic of  $\beta_h(\Delta Z = 0)$ 

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

- Benchmarking: 2008 year fixed effects

# Appendix: Order selection

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

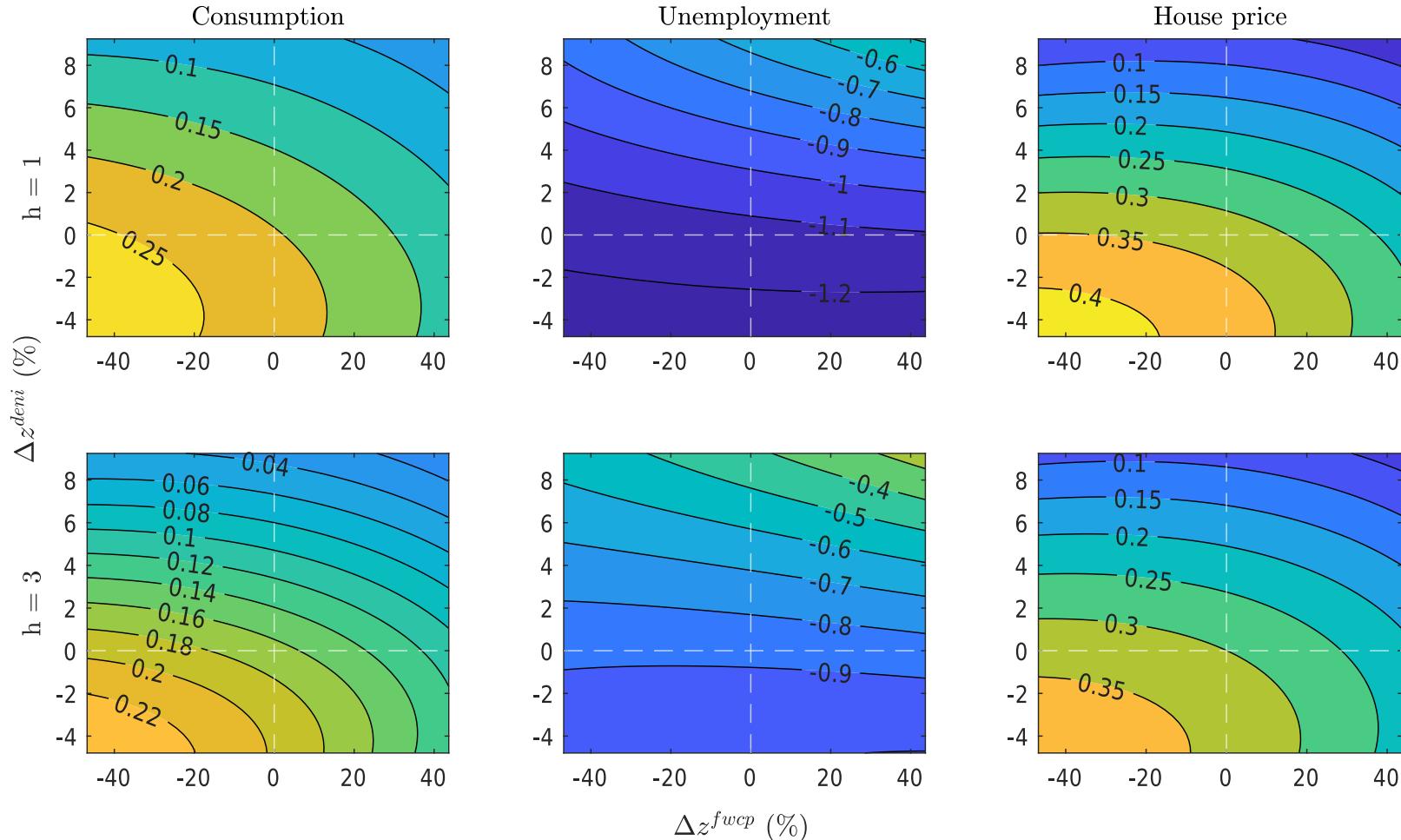


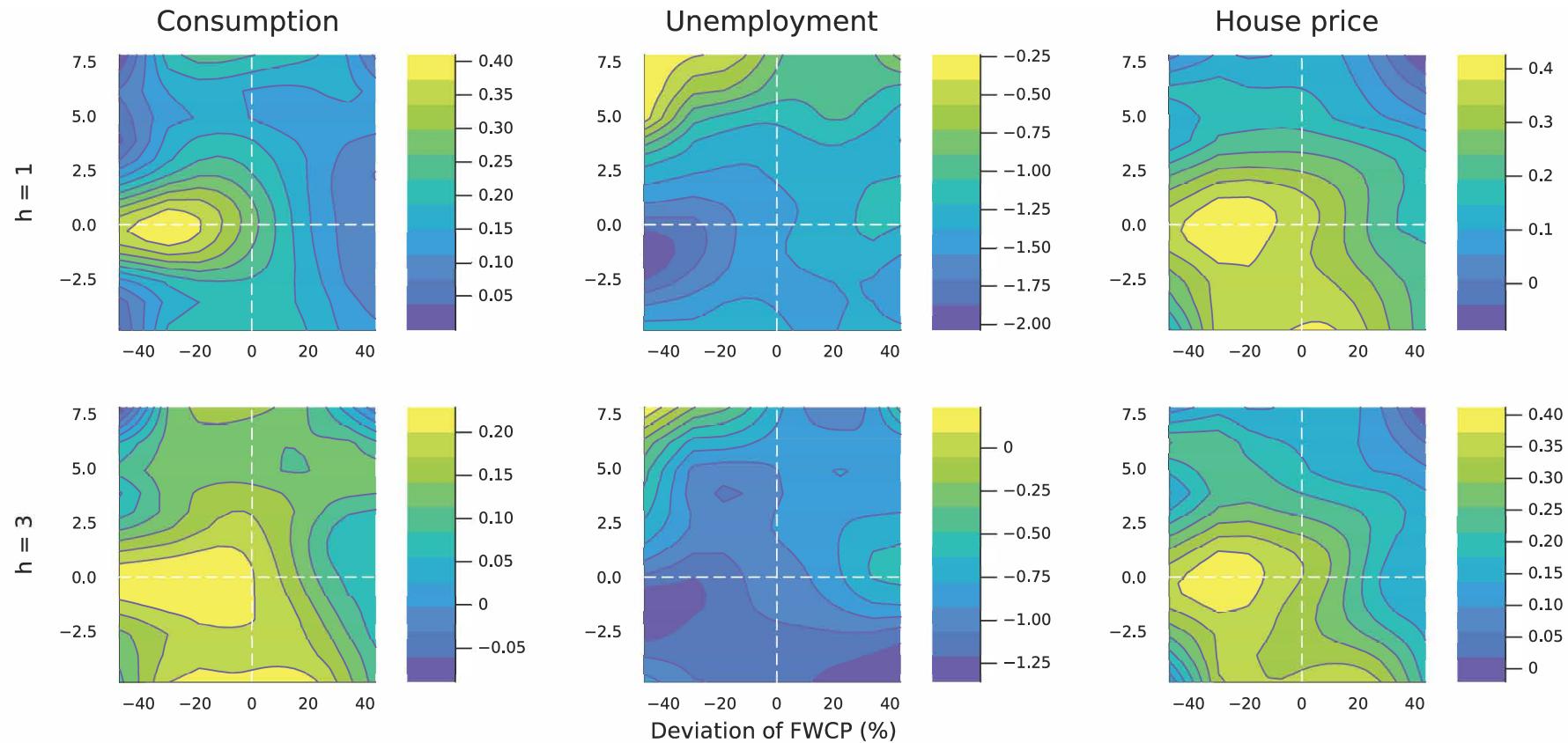
Figure 18:  $\beta_h(\Delta Z)$

Goto: baseline

# Appendix: Local linear estimator

- Global polynomial may mask important local features  $\implies$  check local estimators
- Use local linear estimator:
  - Gaussian kernel for  $\Delta Z$ , Normalized Euclidean distance
  - $17 \times 17$  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 19:  $\beta_h(\Delta Z)$ 

- 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  
⇒ PLR test by [Fan and Huang \(2005\)](#) which test  $\beta_h(\Delta Z)$  as a whole
- $H_0$ : if the overall treatment effect  $\beta_h$  is dependent on  $\Delta z^{\text{fwcp}}$  and  $\Delta z^{\text{deni}}$  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*** (0.1503)	328.46*** (0.1503)	1596.15*** (0.1503)
1	2921.63*** (0.1504)	355.91*** (0.1504)	1166.61*** (0.1504)
2	3345.83*** (0.1504)	1301.31*** (0.1504)	1230.62*** (0.1504)
3	3069.98*** (0.1504)	1684.84*** (0.1504)	1127.61*** (0.1504)
4	2615.89*** (0.1504)	1605.61*** (0.1504)	589.91*** (0.1504)
5	2264.8*** (0.1503)	1829.66*** (0.1504)	770.64*** (0.1504)
6	1886.03*** (0.1503)	1837.51*** (0.1503)	841.8*** (0.1503)
7	1630.81*** (0.1502)	1799.62*** (0.1502)	935.84*** (0.1502)

where the number with stars are the generalized likelihood ratio statistic  $T_0$ , the number in parenthesis is  $\delta_n$  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

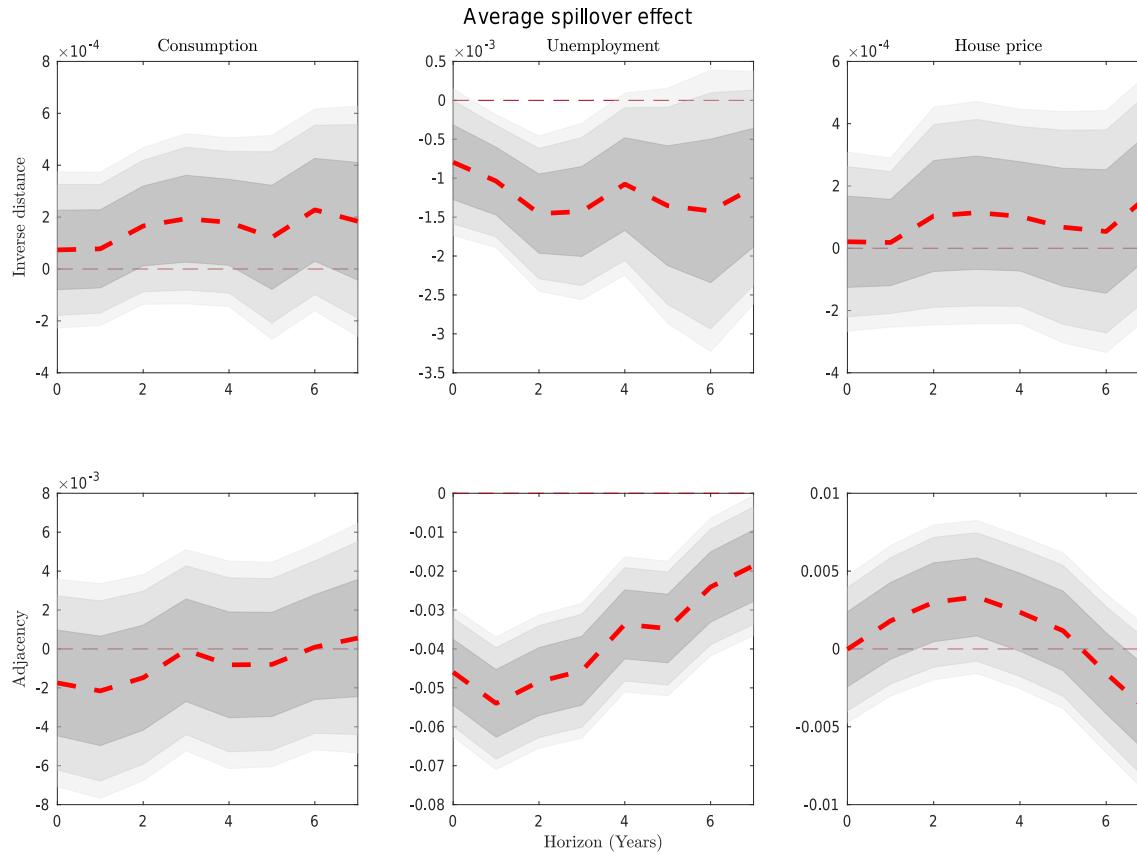
- Neighboring counties may share markets (e.g. labor market of a metropolitan)  $\Rightarrow$  spillover effects of net worth shocks
- Re-estimate the baseline model but:
  - adding a spatial Durbin term:  $\eta_h \cdot \mathbf{W} \mathbf{X}_t$
  - assuming no spillover effects of the outcomes and error

where  $\mathbf{W}$  is spatial weighted matrix,  $\mathbf{X}_t$  is stacked net worth shock in year  $t$ , and  $\eta_h$  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  $\eta_h$
- We test two types of spatial weight matrices:
  - Inverse distance weighting
  - 1st-closest neighbor adjacency weighting

# Appendix: Spatial spillover effects

Average spillover effect  $\eta_h$ :

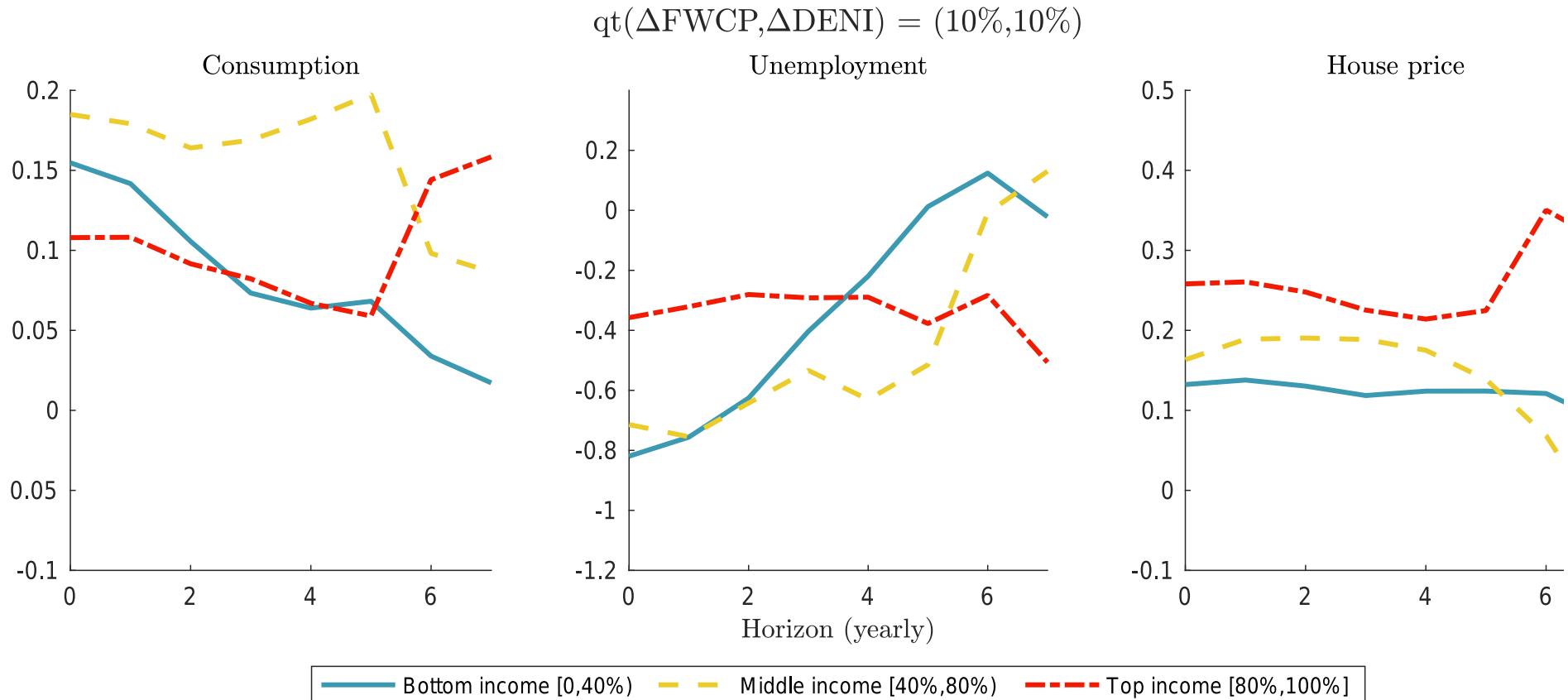


- Significant spillover effect of the shock on local labor markets
- Does not change  $\beta_h(\Delta Z)$  in the other  $\Delta Z$  areas except the “top-right” corner  $\Rightarrow$  even larger non-linearity

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:

- $W_{i,t}$ : 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
- $g(N_{i,t-1})$ : 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

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