Economics 742 Lecture 7: Aggregation II: Aggregation in the Cross Section and Time Series

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Aggregation II

1. Aggregation in the Cross Section Framework and Challenges
   - 1.1 Measuring Spillovers (OVB)
     - Carvalho, Nirei, Saito, and Tahbaz-Salehi (2021)
     - See also appendix slides on Stumpner (2019)
   - 1.2 Bounding/Measuring Local GE Effects
     - Mian and Sufi (2014)
     - Huber (2018)
     - Guren, McKay, Nakamura, and Steinsson (2020)
2. Some New Attempts at Aggregation
   - 2.1 Herreño (2023)
   - 2.2 Wolf (2023)
3. Beraja, Hurst, and Ospina (2019)[1]
4. Hazell, Herreño, Nakamura, and Steinsson (2022)

[1] These notes build on slides by Erik Hurst, which are gratefully acknowledged.

Micro vs. Macro

- Theme: agg "macro" effect potentially very diff from "micro."
- Example: Chodorow-Reich (2014) bank shocks.
  - Imagine all firms producing for consumer with CES utility.
  - As $\sigma \to 0$ (Leonteif) consumers do not substitute away from firms with shocks, micro shock to firms has aggregate effect.
  - As $\sigma \to \infty$ consumers substitute freely towards goods produced by firms without shocks, no aggregate effect.
- Idea goes back to Houthakker (1955).
  - Each firm Leontief.
  - Cobb-Douglas aggregate production fn if distribution of input required to produce unit of output is Pareto.
- Aggregation is the Achilles heel of "micro to macro."

Aggregation: Framework

- Population of firms, households, or regions indexed by i.
  - Exogenous shock S_i.
  - Outcome Y_i.
- Canonical regional/household/firm variation regression:

$$Y_i = \beta_0 + \beta_1 S_i + \varepsilon_i$$

  - Sometimes interactions to account for heterogeneity.
- "Partial Equilibrium" aggregate effect everyone reports:

$$Agg = \int_0^1 \beta_1 S_i di$$

Aggregation: Framework

- Distinguish between two problems with *Agg*:

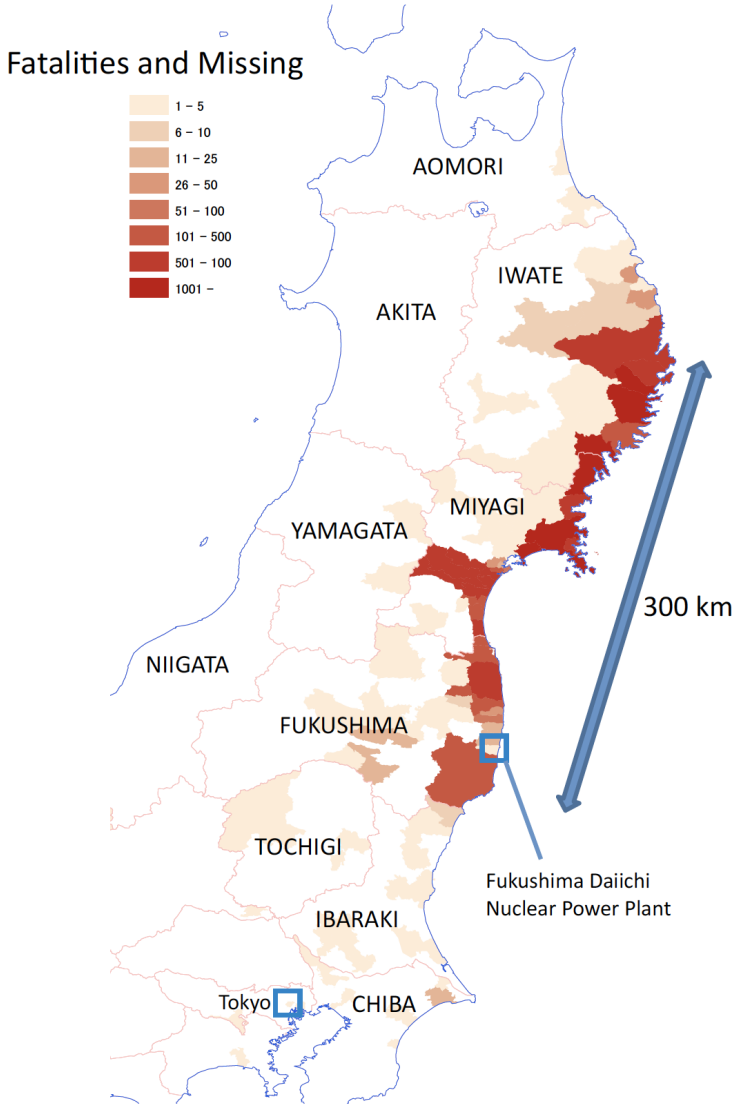
1. "Spillovers": Shock is mismeasured because there are *potentially-observable direct links* between *i*s with different shocks that are unaccounted for.
   - Example: Firm A, which has shock, is supplier to firm B, which does not. Firm B is thus not the "right" control group as gets passed-through portion of firm A's shock. OVB problem.
   - Example: Neighboring regions, or regions connected by trade.

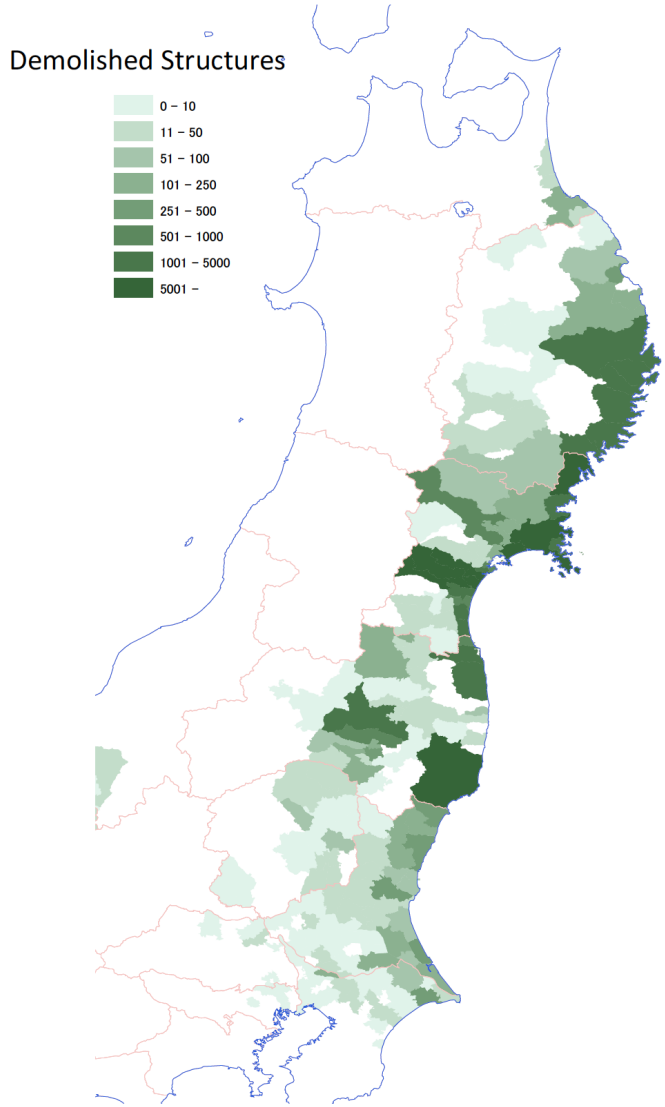
2. "GE Effects": Response to shock leads to r*esponses by i*s *that are not directly linked through the price mechanism*.
   - Example: Firms that are hit with shock cut labor demand, pushing wages down and stimulating demand at other firms.
   - β_0 contains GE effects but also other macro shocks unrelated to identified shock, and we cannot distinguish the two.

Carvalho et al. (2021): Firm Level Production Networks

- Do input-output networks lead to large aggregate effects of a concentrated shock due to spillovers?
  - Look at Japanese earthquake.
  - Output falls dramatically in tsunami zone.
  - Does this shock propagate outside Tsunami zone? How important is this propagation to overall impact on economy?
- To answer, unique Japanese data.
  - Credit bureau collects 24 suppliers and 24 customers for each firm as credit "references."
    - No measure of "strength" just binary.
  - Use this to reconstruct rich IO network at firm level.

Carvalho et al. (2021): Extent of Earthquake





Carvalho et al. (2021): Network as Omitted Variable

- Let $Down_i$ and Up_i be dummy variables for minimum number of degrees of removal downstream and upstream from a firm in tsunami zone.
- Regression without network info:

$$\begin{aligned} Y &= \alpha + \beta Downstream_0 + \varepsilon \\ Agg_0 &= \beta \times N_{Downstream_0} \end{aligned}$$

- Regression with network info:

$$Y = \alpha + \sum_{i=1}^{5} \beta_{Down,i} Down_i + \sum_{i=1}^{5} \beta_{Up,i} Up_i + \gamma X_i + \varepsilon$$

  - Also include prefecture and industry dummies.
- Identifying assumption:
  - Conditional on observables, presence of IO linkages is uncorrelated with unobservables.
  - Also requires parallel trends (placebo test).

Carvalho et al. (2021): Main Results

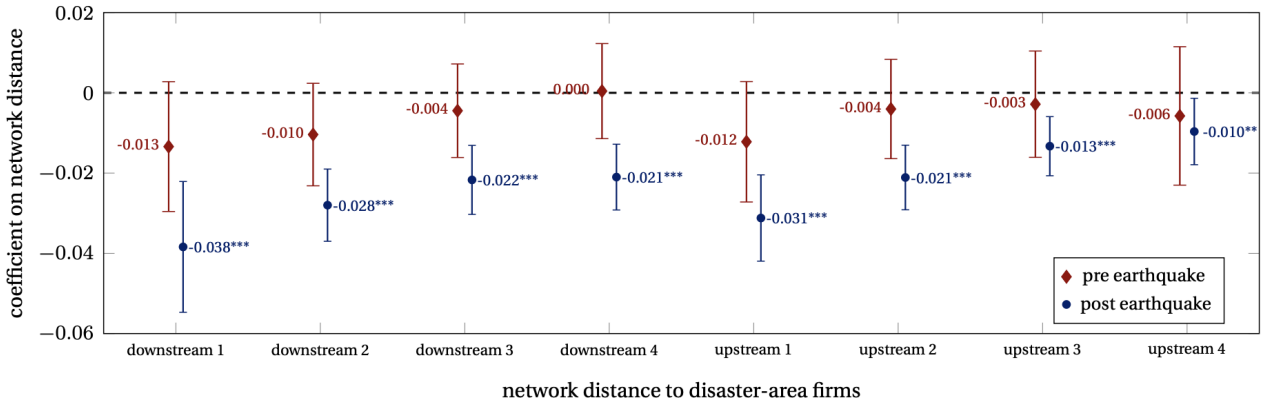


Figure 5. Propagation of the Shock over the Production Network: Baseline Specification

- Disaster resulted in 3.8pp decline in sales growth rate of firms with disaster-hit suppliers, 3.1pp decline for firms with disaster-hit customers.
- Propagates through network: disaster-stricken firms' customers' customers experience 2.8pp decline, suppliers' suppliers experience 2.1pp decline.

Carvalho et al. (2021): Firms By Number of Linkages to Affected Firms

Carvalho et al. (2021): Aggregation

- GE model of production networks (will not cover in full).
  - Propagation depends on network and elasticities of substitution.
  - Use micro-data to figure out agg effect of earthquake.
  - Earthquake caused 0.47pp decline in real GDP growth (was 0.6% annually prior).
- Counterfactual: Identical economy except no input-output linkages between firms inside and outside disaster area.
  - 0.21pp decline in GDP growth
  - Network accounts for hover half of aggregate impact!

Estimating GE Effects

- GE effects are harder because not OVB problem, so cannot solve with more data. Approaches include:

1. Use model to split β_0 into GE effect and other shocks.
   - Very model-dependent (see Chodorow-Reich web appendix).
2. Structural estimation with reduced form moments (e.g. Catherine et al. (2021) for GE effects of collateral constriants).
3. Use untreated units in treated areas to bound *local* GE effects.
   - Mian and Sufi (2014): Look at tradable employment in areas with high vs. low deleveraging.
   - Huber (2018): Look at degree of local treatment.
   - Mian, Sufi, and Sarto (2022): Compare within-MSA estimates (e.g. across banks, only PE) with cross-MSA estimates (includes "fenced in" regional GE effects).
   - Guren, McKay, Nakamura, Steinsson (2020): Use fiscal multipliers to approximate local GE effects.
4. Time series methods like Granular IV.

Simple Framework

- Assume mass of monopolistic competitors facing:
  - A demand curve $c_{j,t} = \xi_{j,t} \left(\frac{p_{j,t}}{P_j} \right)^{-\sigma} C_t$
  - Production function $y_{j,t} = a_{j,t} l_{j,t}^{1-\gamma}$
  - Markets clear so $c_{j,t} = y_t$.
  - This describes a large class of models.
- Try to be agnostic as to the rest of the model. Instead, use the effect of a shock on prices and quantities to figure out the aggregate effect (because GE effects work through prices).
- Combining and taking log differences gives

$$\begin{aligned} d \log L_{j,t} &= \frac{1}{1-\gamma} d \log C_t - \frac{\sigma}{1-\gamma} \left(d \log P_{j,t} - d \log P_t \right) \\ &\quad - \frac{1}{1-\gamma} d \log A_{j,t} \end{aligned}$$

Simple Framework

$$d \log L_{j,t} = \frac{1}{1-\gamma} d \log C_t - \frac{\sigma}{1-\gamma} (d \log P_{j,t} - d \log P_t) - \frac{1}{1-\gamma} d \log A_{j,t}$$

- Assume we have an exogenous productivity shock s_j. Run:

$$\Delta \log L_j = \beta_0 + \beta_1 s_j + \varepsilon$$

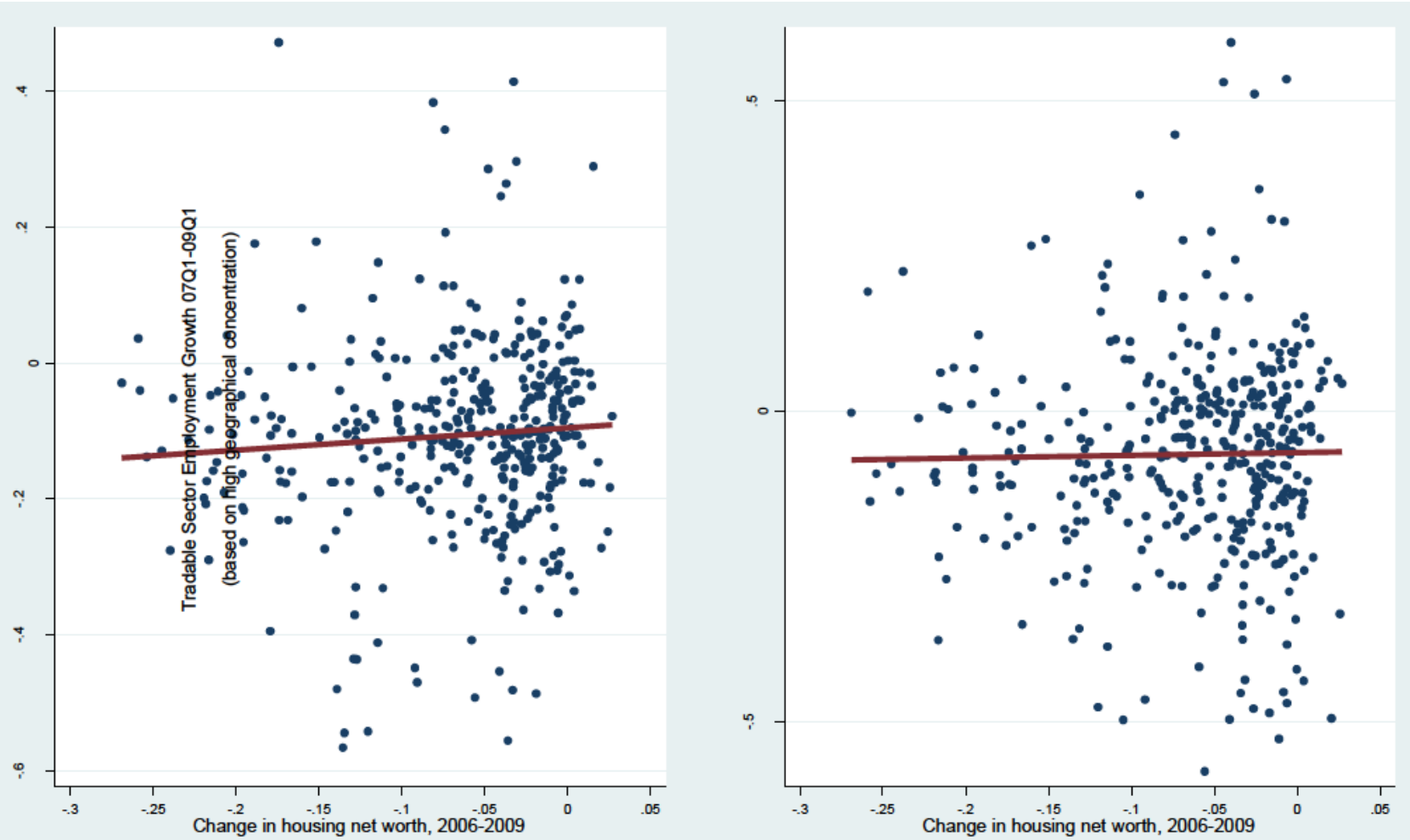
  and get $\beta_1 = \frac{-1}{1-\gamma}$.
- With relative price data, can regress shock on relative prices and from that back out $d \log P_{j,t}$ term.
- The $d \log C_t$ and $d \log P_t$ terms are pesky: these are the *aggregate price reallocation effect* and the *aggregate demand* effect, and we cannot say anything about either in this model.
  - Need a full structural model to recover these effects.
  - Results very model dependent.
- Now: Research on local GE effects – any j, t term.
- Next: More on aggregates.

Mian and Sufi (2014): Deleveraging and Unemployment

- Recall: Mian and Sufi (2014) show large declines in non-tradeable employment in areas with a deleveraging shock.
- Second part of paper looks at GE effects at *local level*
  - E.g. Non-tradable shock could push down wages, reallocating labor towards tradable.
  - Cannot look at nation-wide responses that offset shock, e.g. interest rate response.

1. Stark and simple model of adjustment mechanisms (I skip)
2. Use tradable industry response to get at GE effects

Mian and Sufi (2014): Tradables



Mian and Sufi (2014): Tradables

	Employment growth, tradable industries, 2007-2009				Employment growth, 2007-2009 (county-4digitIndustry level)		
Tradable definition used:	Global Trade	Geographical Concentration	Global Trade	Geographical Concentration			
Change in Housing Net Worth, 2006-2009	0.018	-0.085	0.064	-0.063	0.221**	0.157***	-
	(0.099)	(0.063)	(0.098)	(0.074)	(0.062)	(0.065)	
Industry Geographical Herfindahl Index					-3.864**	-	-
					(0.600)		
ΔHNW * (Geographical Herfindahl)					-13.592**	-11.22**	-11.24**
					(3.089)	(2.22)	(2.19)
Constant	-0.114**	-0.091**	-0.286	0.542	-0.067**	-	-
	(0.012)	(0.012)	(0.950)	(1.144)	(0.011)		
2-digit 2006 employment share controls?			Yes	Yes			
4-digit Industry Fixed Effects						Yes	Yes
County Fixed Effects							Yes
N	944	944	944	944	180,756	180,756	180,756
R^2	0.000	0.002	0.079	0.064	0.006	0.134	0.17

Mian and Sufi (2014): Wages and Migration

	(1) Total wage growth, 2007 to 2009, CBP	(2) Average Hourly wage growth, 2007 to 2009, ACS	(3) Population growth, 2007-2009	(4) Labor force growth, 2007-2009
Change in Housing Net Worth, 2006-2009	0.061	0.054	0.019	-0.0094
	(0.041)	(0.039)	(0.021)	(0.020)
Constant	0.031**	0.037**	0.021**	0.0136
	(0.007)	(0.003)	(0.004)	(0.004)
Specification				
Sample				
N	944	943	939	944
R^2	0.012	0.018	0.009	0.001

- Wages notoriously difficult to measure; take with grain of salt.
- But evidence of rigidities and limited GE effects.
- Mian and Sufi then extrapolate to other sectors, combining their estimates with Stumpner (2019) and Mian-Sufi-Rao (2013). Aggregation explains 55% of employment decline.

Measuring Local GE Effects: Huber (2018)

- Huber (2018) takes this one step further.
  - Rather than just looking at non-treated areas, instrument for degree of local treatment.
  - Recover GE effect in more robust way.
- Huber's instrument: Comerszbank's locations determined by post WW II location of HQ, which was dictated by allies.
  - Worry that proximity to 3 major cities correlated with observables and unobservables.
    - Instruments with minimum of three distances, controlling for distance to each.
    - Shows that controls eliminate correlation with observables.
- Finds substantial spillover effects.
  - 1 SD (6pp) greater CB dependence $\Rightarrow$ 1% lower emp growth.
  - Indirect accounts for 2/3-3/4 of total local effect.
  - Concentrated in non-tradeables and high-innovation firms $\Rightarrow$ likely agglomeration and agg demand.
  - Cannot be household debt because German mortgage system insulated from any one bank's health.

Guren et al. (2020): Another Use for Local Multipliers

- Guren et al. (2020) measure housing wealth effect at city level, want to interpret results with PE model.
  - But house prices are not exogenous from perspective of a city like they are from perspective of a household.
  - Because of local GE effects, which amplify city response.
- Idea: Use local multiplier to measure local GE effects, recover true PE (useful for model calibration) from regional estimates.
  - Additional \$1 on local economy through gov't spending or household spending in response to house prices are equivalent.
  - Find that $\beta \simeq LFM \times \beta_{PE}$ where β PE is PE effect of house prices on consumption, β is empirical estimate with local GE.
  - To get pure PE effect purged of local GE amplification, divide by local multiplier estimates (1.5).

Bounding GE Effects: Evaluation

- Idea of looking at non-treated is important first step.
  - A lot depends on horizon (rigidities dissipate over time).
  - Also potentially unobserved *direct* effects so hard to tell spillovers from GE effects.
- Mian, Sufi, and Sarto (2022) try to get at this by comparing within-MSA (PE) to across MSA (includes some GE effects, e.g. through local asset prices).
  - Focus is on Kiyotaki-Moore like "credit multipliers" that work through asset prices.
- Big problem: Only gets at *local* GE effects, and the aggregate effect we care about contains the *global* GE effects as well, which could be large.

New Attempts to Study Aggregate Effects

- Want to quickly discuss two new attempts (2020 JMPs) to study aggregate effects that take very different approaches:

1. Herreño (2023): Bank shock aggregation using semi-structural model and reduced-form elasticities.

2. Wolf (2023): Using fiscal spending responses for aggregation in a class of models.

- Think about what you do and do not like about these approaches, which I will cover briefly.
    - Related literature: Beraja (2023) and McKay and Wolf (2023). More about doing policy counterfactuals in a robust way than aggregating micro estimates, but similar ideas.

Herreño (2023): Bank Shocks

- What does evidence of bank shocks on firms imply about the aggregate output effects of a cut in aggregate bank lending?
- Problem: Shocks to banks and firms lead to substitution; affect other banks and firms, leading to dampening.
- Approach: Flexible GE model with three key features:
  1. Relationship lending: multi-bank firms and bank market power.
  2. Flexible substitution between banks; other sources of financing.
  3. Labor market with upward-sloping firm-specific supply curve.
- Modeling innovation: Continuum of tasks with discrete choice model for financing each one as in Eaton-Kortum. Parameters determine substitution.
- Key determinants is extent of frictions:
  1. That limit finding other sources of finance (bank or other)
  2. Frictions in labor and goods markets nested in slope of firm's labor supply curve.

Herreño (2023): Bank Shocks

- Cross-sectional regressions directly map to and discipline model.
- Key Parameters:
  1. Elasticity with which firms substitute funding from one bank with others.
  2. Elasticity with which firms avoid bank credit altogether.
- Moments:
  1. Effect of idiosyncratic bank shock on firm credit.
  2. Effect of idiosyncratic bank shock on firm employment.
- Findings: Significant frictions limit GE dampening.
  - 1% drop in agg lending $\Rightarrow$ 0.2% drop in agg output.
  - Ignoring labor market frictions $\Rightarrow$ 3$\times$ smaller
  - PE aggregation not much larger than GE, but without frictions 5$\times$ smaller.
- At core a sophisitcated way of using a model to aggregate.

Wolf (2023): Fiscal and Demand Shock Equivalence

- Idea: "Demand Equivalence" similar to GMNS, Auclert-Rognlie-Straub:
  - In class of macro models, shocks to private consumption demand elicit same GE responses as changes in gov't spending.
  - Why? Differentiate resource constraint $Y = C + I + G + NX$.
  - Two shocks perturb market clearing conditions by same amount, so by chain rule GE adjustment must be same.
- Implies two step semi-structural method:
  1. Use cross-sectional approaches to recover PE IRF of shock on consumption demand.
  2. Add in GE by adding impulse response of consumption to same sized change in government spending.
     - Use existing toolkit for fiscal shocks.
- Method generally implies small GE effects due to fiscal multipliers close to one.

Wolf (2023): What Is The Class of Models?

- Linearized models with three assumptions:

1. Households and government consume same final good.
   - Usually assume, but not true; argues price changes of gov't relative to private basket small.
   - To me, this is most heroic assumption; particularly relative to local multiplier for same idea (e.g. GMNS).
2. Households and government borrow and lend at same rate.
3. Labor supply responds the same $\Rightarrow$ no wealth effects (GHH).
   - Not true, but argues error is small.

- Applies to study tax rebates as example.
- New idea here: Try to find similar variation to GE effects from another estimable shock.
  - McKay and Wolf (2023) do similar thing with news shocks.
  - Drawback: Need to estimate that shock well.

"The Aggregate Implications of Regional Business Cycles"

- Question: What can we learn from regional variation about the type of aggregate shocks driving business cycles?
  - In particular, many papers estimate elasticities in cross-regional data. Do these aggregate?
- Beraja, Hurst, and Ospina (2019) combine regional data with currency union model.[2]
  - Use model to disentangle shock elasticities from shock realizations.
  - Are able to say something about shocks driving aggregates *using regional moments*.

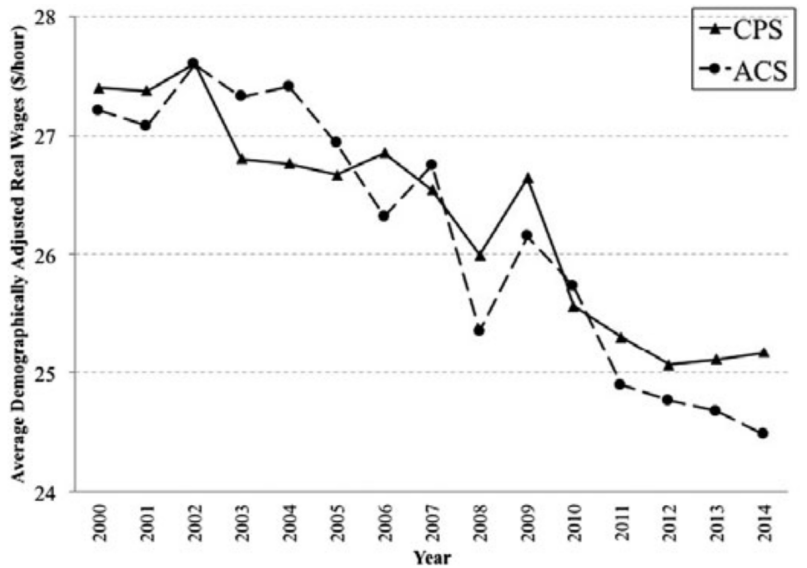
[2] These slides are in part based on slides by Martin Beraja.

5 Parts to Beraja et al. (2019) Paper

1. Create state-level price and wage indices. (I will skip)
2. Cross-sectional facts on prices and wages in Great Recession.
   - Wages are flexible at local level, in contrast to aggregate.
3. Theory to explain differences between cross-sectional correlations and aggregate time-series correlations (skip, see appendix slides).
   - GE Effects: Local response different from aggregate response.
   - Shocks may be different as some shocks may not be regional.
4. Use regional data to provide restrictions on structural NKWPC and use them to estimate aggregate DSGE model.
5. Shock Decomposition for Great Recession:
   - Throws cold water on primacy of "demand shocks."
   - Intuition: Wages too flexible for demand shocks to be persistent enough to explain post-2010. Need supply shocks.
   - But demand shocks explain almost all of regional variation.

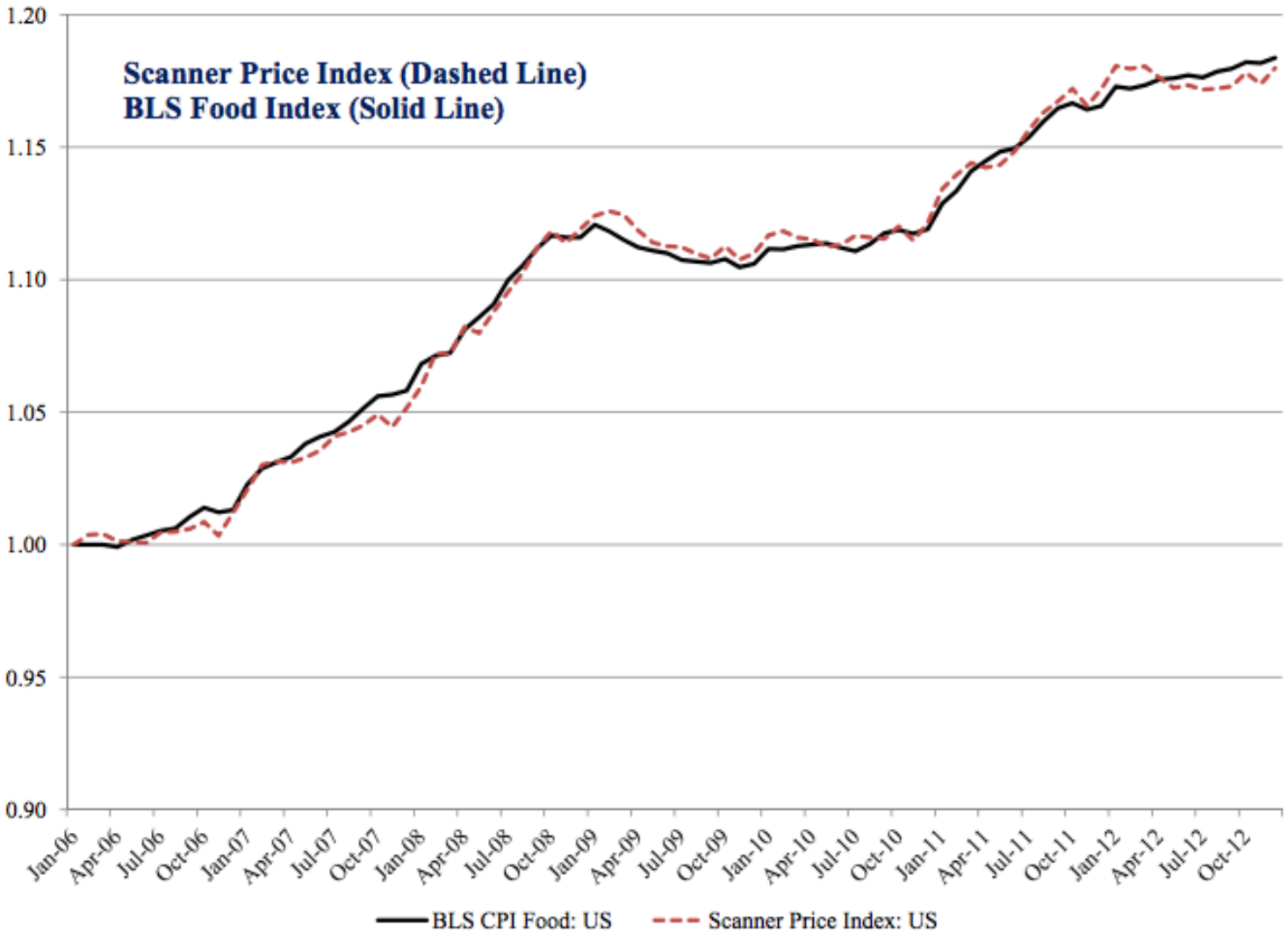
Aggregate Wages in Great Recession

Panel A: Nominal Wages

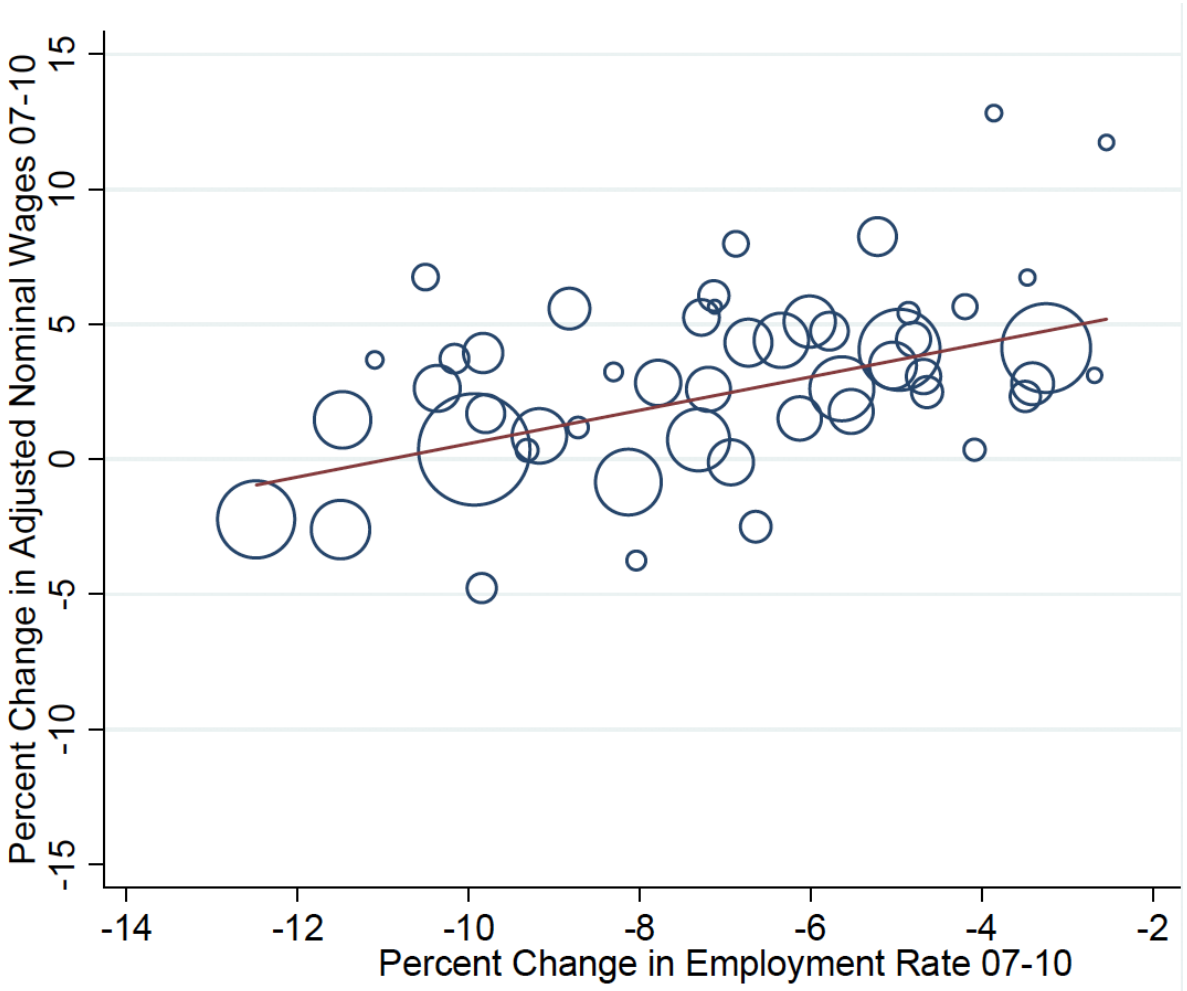


Panel B: Real Wages

Aggregate Prices in Great Recession

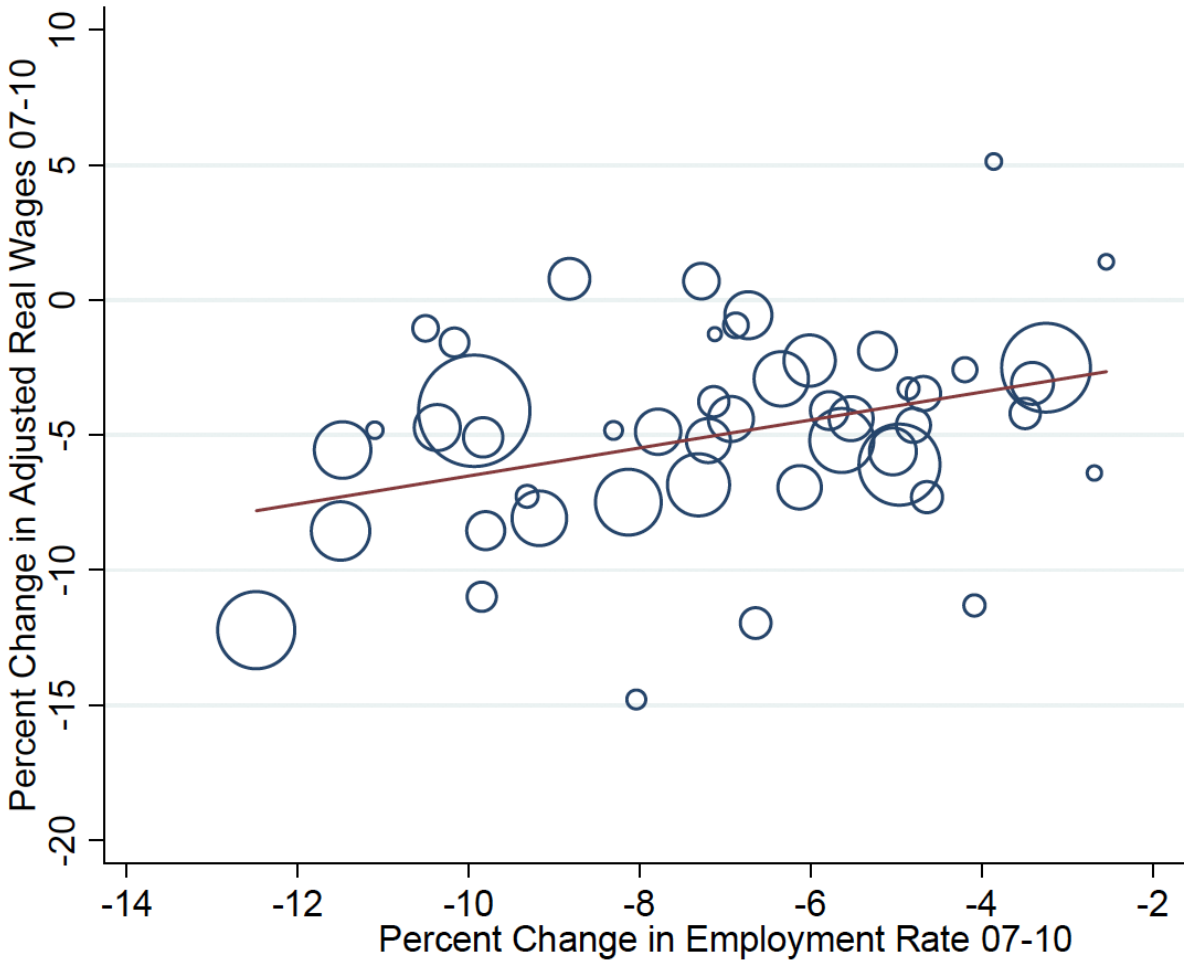


Nominal Wage Growth vs. Employment Growth, 07-10



- 1 pp emp growth $\Rightarrow$ 0.72 pp nominal wage growth.

Real Wage Growth vs. Employment Growth, 07-10



- 1 pp emp growth $\Rightarrow$ 0.64 pp real wage growth.

Comparison With Mian and Sufi (2014)

- Comparison with Mian and Sufi (2014) is stark.
- Some important differences:
  1. Mian and Sufi look at 2007 to 2009, whereas Beraja et al. look at 2007-2010.
     - The extra year matters, as the big event was in 2008 and Beraja et al. do find some short-run stickiness.
  2. Mian and Sufi use county-level data, Beraja et al. use state
     - Less measurement error for states $\Rightarrow$ less biased towards zero.
  3. Data
     - Mian and Sufi construct hourly wages from ACS. Unclear how.
     - Beraja et al. also use ACS for males highly attached to labor force. Divide labor income by weeks $\times$ ave hours per week. Finally, residualize on observables.
     - Concern for both: "division bias."
- Most papers find some wage response.

Currency Union Model: Setup

- Many islands: identical prefs and tech, diff shocks.
- Agents: households, firms, and monetary authority
- Two sectors: Region-specific final good and traded intermediates
- One asset: One-period nominal bond.
- Sticky prices and wages (Calvo)
- 7 shocks, each with an island-specific and aggregate component.
- Modern NK DSGE bells and whistles: Habits, investment adj. costs, etc.

Estimation

- Iterative procedure with aggregate and regional data.

1. Fix β, ν, ι_w, and h. Estimate κ_w from regional NKWPC using regional data only.
   - Have to instrument due to expectations, endogenous regressors.
   - To deal with expectations, GMM using lagged variables outside equations.
   - To deal with endogenous regressors, use current and lagged house prices.
2. Estimate aggregate model with aggregate data as in medium-scale NK literature, but restricting κ_w.
3. Obtain new β, ν, ι_w, and h. Iterate until convergence.

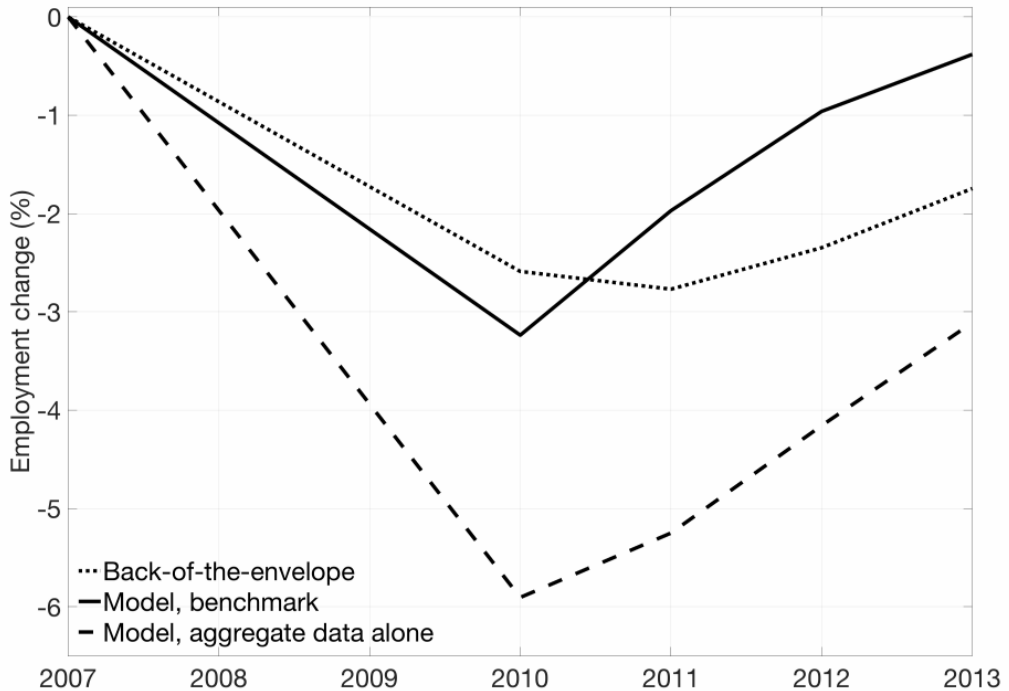
What Does Regional Data Add?

Table 7: Predicted $\frac{dlog(w^{agg})}{dlog(n^{agg})}$ during the Great Recession in Response to Various Shocks

	Shocks		
	b	b and μ	b, μ, and φ
Benchmark	0.97	0.83	0.31
Aggregate data alone	0.41	0.41	0.25

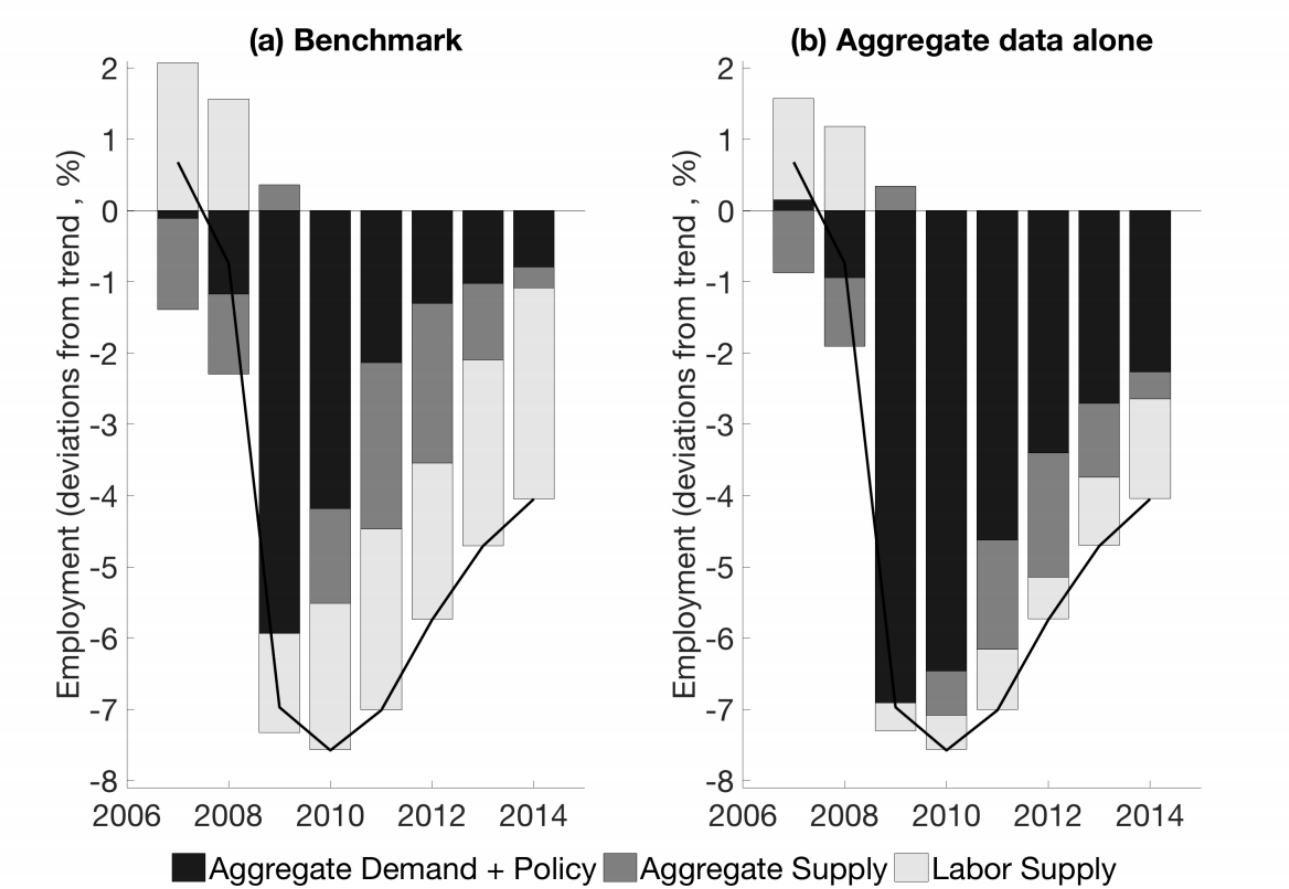
- Much more flexible wages!
- Aggregate wages stickier because of labor supply shocks hitting aggregate economy.

Employment Response to 2007-2010 Household Demand Shocks



- Back of Envelope: Extrapolating like Mian-Sufi.
  - Good in short run when demand shocks dominate, bad in medium run because wages adjust.

Employment Shock Decomposition



- Aggregate leisure / wage markup shock seems important.
- Motivates studying labor wedge.

Take Aways and Thoughts

- Paper provides a lot of food for thought.
  - Fact about wages adjusting quickly in cross section is stark and important.
  - Big question: What is the "phantom cost-push shock" and "phantom labor wedge shock"? Why did it happen?
- Really like idea that regional data can help think about aggregate with theory.
  - Lots more to do here.

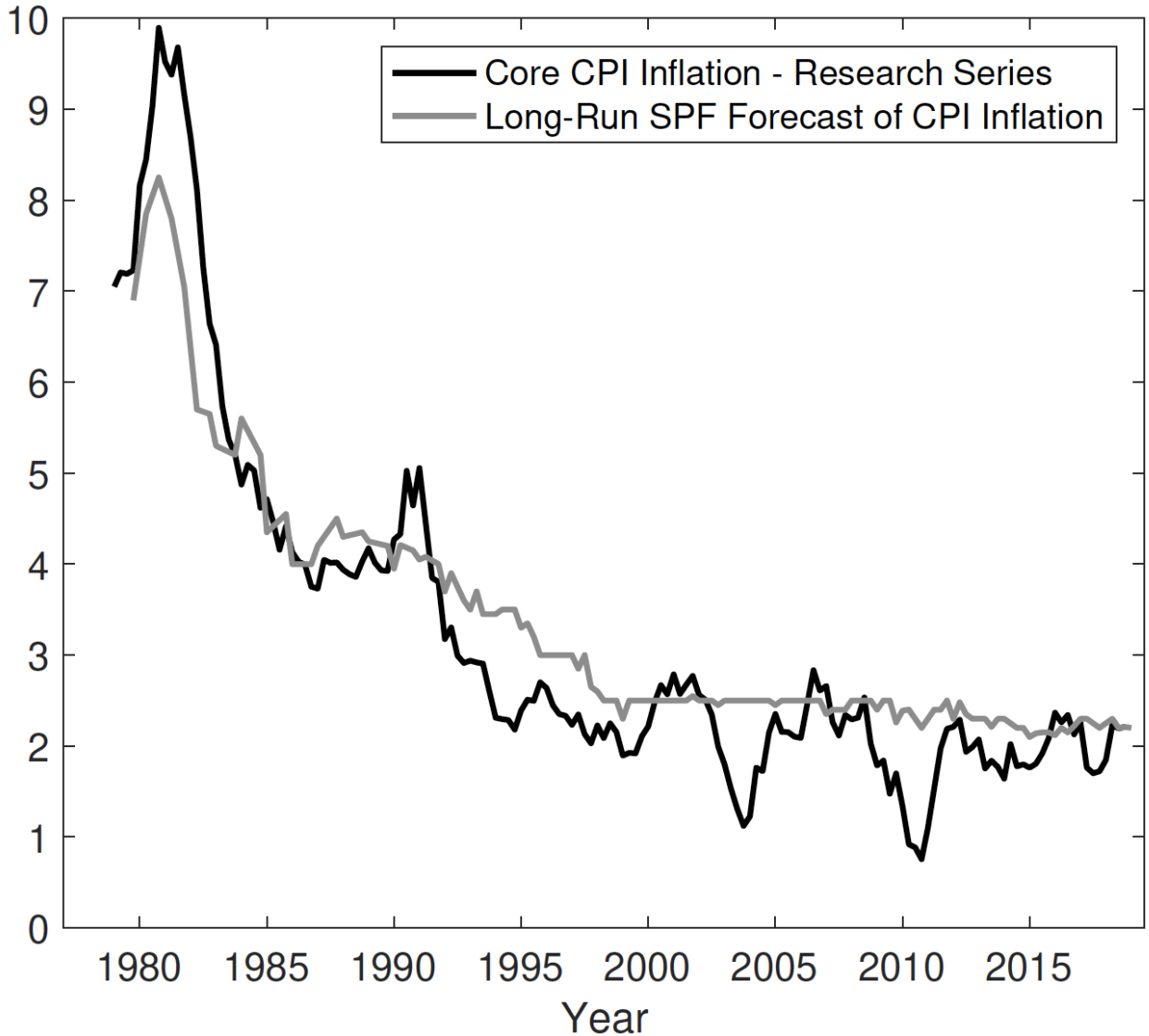
Hazell et al.: Regional Data on the Phillips Curve

- What is slope of Phillips Curve? Has it changed over time?
- Conventional wisdom: Steep and yes.
  - Volcker disinflation: Unemp $\uparrow$, $\pi\downarrow \Rightarrow$ steep slope.
  - With adaptive expectations, get PC flattens from 0.67 1960-1983 to 0.03 2000-2019
  - Leads to "missing deflation" in GR and "missing reinflation" in late 2010s.
- Alternative view: Volcker disinflation was all decline in inflation expectations. Phillips curve is flat and has always been and inflation was anchored 2000-2019.
  - Assuming inflation follows AR(1),

$$\pi_t = -\psi \tilde{u}_t + E_t \pi_{t+\infty} + \omega_t$$

  - Long-run inflation expectations enter with coefficient of 1.
  - Problem: Inflation expectations covary with output gap, hard to control for them so PC sensitive to methodology.

Hazell et al.: Inflation Tracks Expectations



Hazell et al.: Regional Data on the Phillips Curve

- Paper has four parts:

1. Currency union model to show how regional data helps (skip)
   - Intuition: Changes in long-term monetary regime are common across currency union and absorbed into time FE in panel specification.
   - Use non-tradeable inflation, which gives same coefficient as aggregate PC
2. New Data: State-level panel from BLS microdata 1978-2018
3. Empirical Estimates:
   - PC is flat and was flat in 1980s.
   - 1pp $\uparrow$ unemp $\Rightarrow$0.34 pp $\downarrow$ in inflation. Implies small fraction of 1980s changes accounted for by unemp.
   - Long-run expectations account for most of fall in inflation.
   - Because PC stable, no "missing disinflation" or "missing reinflation"

- Only scratching surface - more in paper.

Hazell et al.: Time Effects Lead to Stable PC

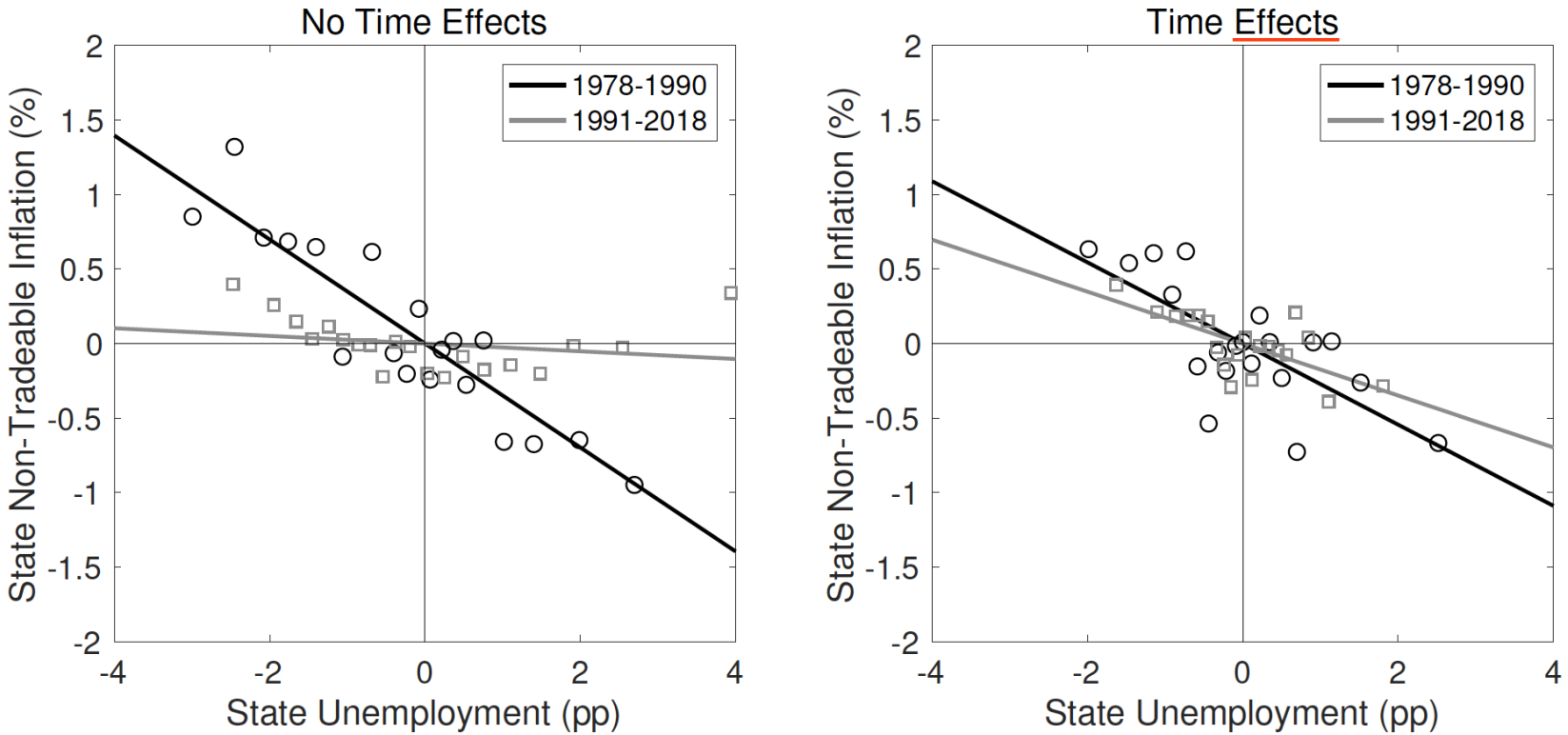


Figure 5: Scatterplots—Non-Tradeable Inflation and Unemployment

- Half as flat in recent years, rather than 1/25th

Hazell et al.: Flat PC ⇒No Missing Disinflation

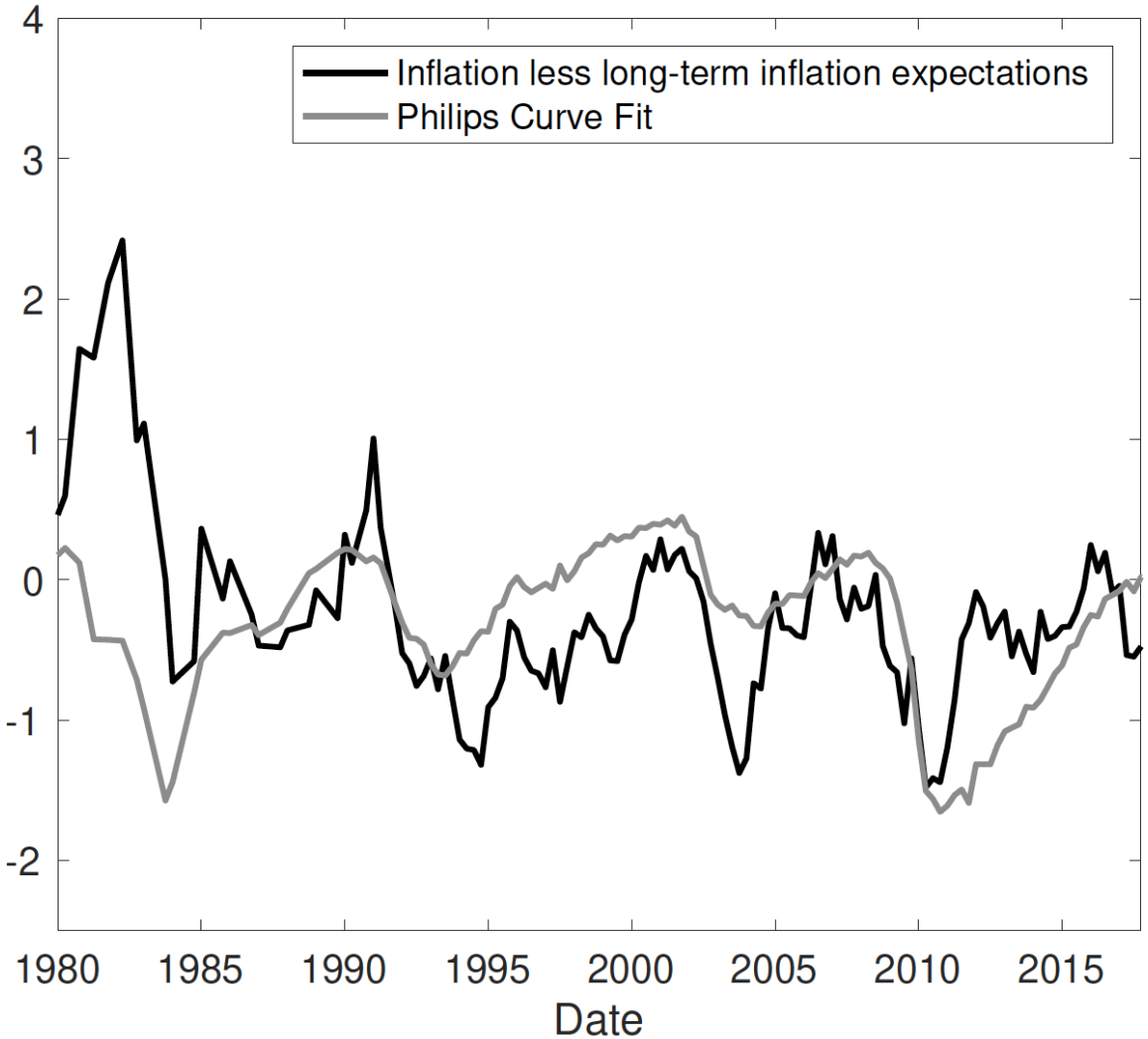


Figure 6: Aggregate Phillips Curve

Hazell et al.: Evaluation

- Shows how regional data and theory can help solve issues.
- Theme: Taking out time fixed effects neutralizes potential confounders.
  - Here, allows you to identify aggregate slope assuming you work with non-tradeables!
  - In long run, where you are in business cycle today does not matter $\Rightarrow$ $E_t \pi_{t+\infty}$ is same across regions as in long run.
- Nice paper with cool data and important results for policy!
  - Implication for today: Inflation expectations are what matters.

EXTRA APPENDIX SLIDES

1. Stumpner (2019)
2. A bit more on Beraja, Hurst, and Ospina (2019)

Stumpner (2019): Trade and Spread of Great Recession

- How did local shocks due to consumer deleveraging (Mian and Sufi) diffuse through the economy?
- Regression:

$$y_{s,i} = \xi_s + \psi_i + \beta TDS_{is} + \varepsilon_{is}$$

  - The trade demand shock is defined as

$$TDS_{is} = \sum_{n=1}^{N} \frac{X_{ins}}{Y_{is}} Lev_n$$

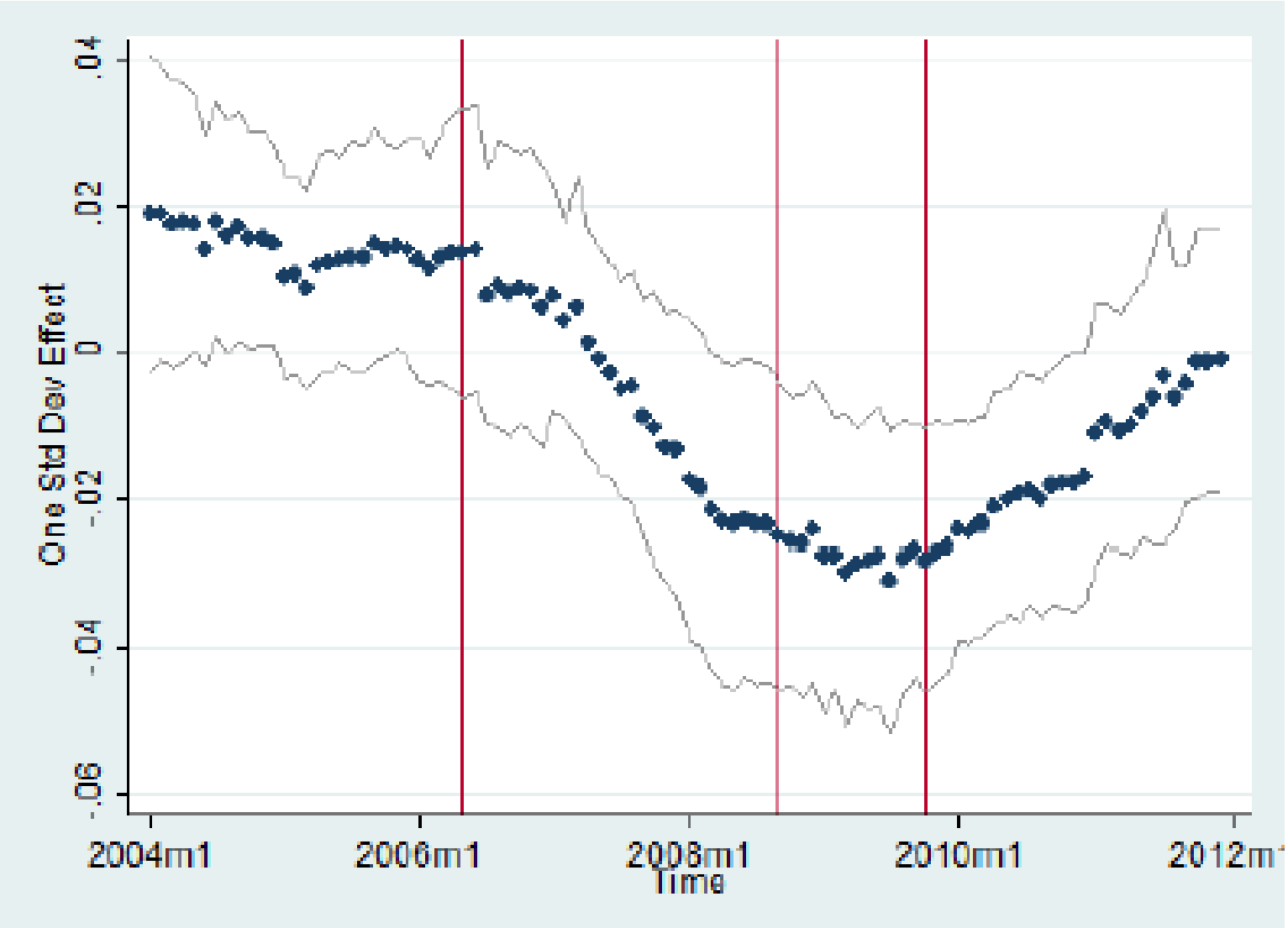
    - X_{ins}: purchases by state s of industry i goods produced in state n, constructed from Commodities Flow Survey data.
    - Lev is the Mian-Sufi deleveraging shock in state n.
- Identification Assumption: Industries that trade relatively more with high-leverage states are not relatively more affected by unobserved shocks.

Stumpner (2019): Trade and Spread of Great Recession

	(1)	(2)	(3)	(4)	(5)	(6)
	Employment 2007-09		Earnings 2007-09		Av. Wage 2007-09	
TDS	-0.090***	-0.095***	-0.115***	-0.135***	-0.025	-0.040***
	(0.027)	(0.017)	(0.032)	(0.023)	(0.021)	(0.014)
Observations	1,519	1,519	1,519	1,519	1,519	1,519
R-squared	0.402	0.568	0.428	0.548	0.232	0.280
Industry FE	✓	✓	✓	✓	✓	✓
State FE	✓	✓	✓	✓	✓	✓
Specification	OLS	WLS	OLS	WLS	OLS	WLS

- Rules out credit supply.
- Calibrated model: trade applied to M-S shock accounts for 1/3 of spread of Great Recession to low-leverage states.

Stumpner (2019): Trade and Spread of Great Recession



BHO: Equilibrium

- Log-linearize around zero inflation steady state.
- Claim 1: Log-linearized economy aggregates.
- Claim 2: Island economies in log deviation form aggregates are stationary and behave like small open economies.
  - Can study aggregate and local economies separately.
  - Can write $c_{kt} = c_t + \tilde{c}_{kt}$.
- Let $\tilde{x_{k,t}}$ represent log deviations form aggregates and $\hat{x}_t$ represent log deviations from BGP.

BHO: Aggregate vs. Regional NKPC

- Regional NKWPC is:

$$\tilde{\pi}^{w}_{k,t} = \beta E_t\left\{\tilde{\pi}^{w}_{k,t+1}\right\} + \kappa_\omega \nu \tilde{n}_{k,t} - \kappa_w \tilde{w}_{k,t} + \iota_w\left(\tilde{\pi}_{k,t-1} - \beta\tilde{\pi}_{k,t}\right) + \frac{\kappa_w}{1-h}\left(\tilde{c}_{k,t} - h\tilde{c}_{k,t-1}\right) + \tilde{\varphi}_{k,t}$$

  - Slope

$$\kappa_w = \frac{\left(1-\beta\xi_w\right)\left(1-\xi_w\right)}{\xi_w}\frac{\lambda_w - 1}{\lambda_w\left(1+\nu\right)-1}$$

    where $1-\xi_w$ is fraction of wages reset every period, λ_w is wage markup based on differentiated labor, and ν is Frisch elasticity.

- Aggregate KNWPC is:

$$\hat{\pi}^{w}_{t} = \beta E_t\left[\hat{\pi}^{w}_{t+1}\right] + \kappa_w \nu \hat{n}_t - \kappa_w \hat{w}_t + \iota_w\left(\hat{\pi}_{t-1} - \beta\hat{\pi}_t\right) + \frac{\kappa_w}{1-h}\left(\hat{c}_t - h\hat{c}_{t-1}\right) + \hat{\varphi}_t$$

- Insight: cross-regional parameters same as aggregate!

BHO: Aggregate vs. Regional Responses

- In simplified model, analytically examine impact to discount factor shock at local and national level.
- Differences reminiscent of Nakamura and Steinsson (2014) from last class:
  - Monetary Policy: φ_y coefficient in Taylor rule in agg not local.
  - Openness:
    - α: Can substitute labor for intermediates in production of final goods by "trading" with rest of economy.
    - $\frac{1}{\beta}$: Can transfer resources inter-temporally.