The Aggregate Implications of Regional Business Cycles

Martin Beraja
University of Chicago

Erik Hurst
University of Chicago

Juan Ospina
University of Chicago

Fall 2017
This Paper

- Can we use cross-sectional information to learn about the type of aggregate shocks hitting an economy?

- Region economies differ from their aggregate counterparts in two key respects:
  - Local response to a given shock may differ from the aggregate response to the same shock (General Equilibrium effects).
  - The shocks that drive cross region variation may not be the same shocks that drive aggregate variation (some shocks may not have a regional component).
This Paper

- During the Great Recession: Cross-state patterns different than the US aggregates.

- Why?
  - Shocks were different?
  - Elasticities were different?

- Can we learn anything about aggregates from regional data?

- Yes!
  - Regional data + Theory $\rightarrow$ discipline shocks driving aggregates
Why is This Important

- Many papers are estimating “elasticities” using cross-region data.
  - Assume these regional elasticities are the same as the corresponding aggregate elasticities.

- Examples include:
  - Mian and Sufi
  - Autor, Dorn, and Hanson
  - Charles, Hurst and Notowidigdo
  - 1,000 others

- Conclude certain channels and shocks matter (or don’t) in the aggregate.
  - Not so straight-forward to make that link.
What This Paper Is About?

1. Make price and wage indices at the state level (use scanner data)

2. Explore the cross-sectional patterns of prices and wages during the Great Recession.

3. Explore why the cross-region correlations are so different than the aggregate correlations.
   o. Different shocks driving the variation in the aggregate vs. the cross-region variation?
   o. General equilibrium effects make aggregate response to a given shock different than the regional response to a given shock?

4. Develop a procedure that uses the cross-region data and aggregate data jointly to uncover both the regional and aggregate shocks.

5. Apply that procedure to the Great Recession within the U.S.
Some Take Aways…

1. Estimate that wages are fairly flexible at the local level (using cross-region variation). (Both real and nominal)

2. Stands in stark contrast to the apparent wage “stickiness” at the aggregate level (in recent years).

3. Hard to get “demand shocks” (discount rate shocks) as the sole driver of aggregate employment during the recession given the estimated amount of wage stickiness using regional variation.

4. Need a combination of “demand” and “supply” shocks to explain the aggregate behavior – with “supply” shocks doing most of the work post 2010.

5. However, we estimate that regional business cycles during this period were primarily driven by “demand” shocks.
Part 1:
Regional and Aggregate Business Cycles
Data Part 1: Nominal Wage Data

- Use data from the 2000 Census and 01-12 American Community Surveys and (separately) the CPS.

- Measure prime age (25-54) **male** hourly wage (earnings divided by hours). Exclude self employed, those in military, and those with zero earnings.

- Examine patterns for unadjusted and “adjusted” wages.

- To adjust wages, create demographic cells based on age and education. Hold cell weights fixed at some initial year level. Track changes in wages within each cell.

- Deflate local wages by local price indices (made with scanner data).

- Deflate aggregate wages by aggregate CPI.
Data Part 2: *Nielsen’s Retail Scanner Database*

- Data from first week of January 2006 through last week of December 2012.
- Data at level of UPC*store*week. Includes number of units sold and average price per unit during week.
- Each store can be matched to a specific location (county, MSA, state) and to a specific chain.
- ~75 billion unique observations (UPC*store*week)!
- In 2011, ~36,000 participating stores and 86 participating chains (97 percent of sales come from grocery, drug, and mass merchandising stores).
- In 2011, $236 billion dollars worth of sales (~30 percent of food expenditures and ~2 percent of total expenditures).
- Large geographic coverage: Data from about 86% of U.S. counties.
Comparing Scanner Price Index to BLS Food CPI

<table>
<thead>
<tr>
<th>Month-Year</th>
<th>Retail Scanner Price Index</th>
<th>BLS Chained Food/Beverage CPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr-06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul-06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct-06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan-07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr-07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul-07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct-07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan-08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr-08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul-08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct-08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan-09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr-09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul-09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct-09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan-11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr-11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul-11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct-11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan-12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr-12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul-12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct-12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan-13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr-13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul-13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct-13</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Comparing Scanner Price Index to BLS Food CPI, NYC Metro

Price Index (Normalized Jan 2006 = 1.00)
Comparing Scanner Price Index to BLS Food CPI, Chicago Metro

Price Index (Normalized Jan 2006 = 1.00)

Month-Year

Jan-06 Apr-06 Jul-06 Oct-06 Jan-07 Apr-07 Jul-07 Oct-07 Jan-08 Apr-08 Jul-08 Oct-08 Jan-09 Apr-09 Jul-09 Oct-09 Jan-10 Apr-10 Jul-10 Oct-10 Jan-11 Apr-11 Jul-11 Oct-11 Jan-12 Apr-12 Jul-12 Oct-12

- Red: Retail Scanner Price Index
- Black: BLS Local Food/Beverage CPI
Retail Price Variation vs. Total Price Variation

- Assume that local retail prices ($P^r$) and the prices of a local composite good ($P$) are a function of both tradable ($P^T$) and non-tradable ($P^{NT}$) prices:

\[
P^r_{k,t} = (P^T_t)^\alpha (P^{NT}_{k,t})^{1-\alpha}
\]

\[
P_{k,t} = (P^T_t)^\beta (P^{NT}_{k,t})^{1-\beta}
\]

- Therefore, the local price growth of the composite good across two regions (k and k') can be expressed as:

\[
\Delta \log P_{k,t} - \Delta \log P_{k',t} = \frac{1-\beta}{1-\alpha} (\Delta \log P^r_{k,t} - \Delta \log P^r_{k',t})
\]

- Need an adjustment factor to scale retail price variation by: \(\frac{1-\beta}{1-\alpha}\)

- Share of tradables in groceries ($\alpha$) relative to tradable share in composite local consumption good ($\beta$). Use estimate of 1.4 (using BLS MSA level data).
1 pp decline in employment growth corresponds to about a 0.72 pp difference in nominal wage growth (s.e. = 0.14).
1 pp decline in employment growth corresponds to about a 0.61 pp difference in nominal wage growth (s.e. = 0.17).
## Estimated Cross-State Elasticity wrt Emp. 2007-2010

<table>
<thead>
<tr>
<th>Variable</th>
<th>Log Wage (Nominal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Wage</td>
<td>0.72 (0.14)</td>
</tr>
<tr>
<td>Real Wage, Scaling = 1.4</td>
<td>0.61 (0.17)</td>
</tr>
<tr>
<td>Real Wage, Scaling = 1.0</td>
<td>0.64 (0.16)</td>
</tr>
<tr>
<td>Real Wage, Scaling = 2.0</td>
<td>0.57 (0.21)</td>
</tr>
</tbody>
</table>
The Evolution of **Aggregate** Nominal Wages, Composition Adjusted
The Evolution of **Aggregate** Real Wages, Composition Adjusted
## Aggregate Summary

<table>
<thead>
<tr>
<th>Variable</th>
<th>CPS Data</th>
<th>ACS Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A: Nominal Wages</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual Wage Growth, 2007-2010</td>
<td>1.0 percent</td>
<td>0.8 percent</td>
</tr>
<tr>
<td>Nominal Wage Elasticity, 2007-2010</td>
<td>-0.13</td>
<td>-0.10</td>
</tr>
<tr>
<td><strong>Panel B: De-Trended Real Wages</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual Wage Growth, 2007-2010</td>
<td>-3.7 percent</td>
<td>-3.9 percent</td>
</tr>
<tr>
<td>Predicted Wage Growth, 2007-2010</td>
<td>-1.4 percent</td>
<td>-1.0 percent</td>
</tr>
<tr>
<td>Deviation form Predicted Growth, 2007-2010</td>
<td>-2.4 percent</td>
<td>-2.9 percent</td>
</tr>
<tr>
<td>Real Wage Elasticity, 2007-2010</td>
<td>0.31</td>
<td>0.38</td>
</tr>
</tbody>
</table>
First Take Away: Some Facts

- Wages (both real and nominal) respond much more to changes in real activity at the local level as opposed to the national level. How sticky are wages?

- Nominal wages look “sticky” at aggregate level. Yet, move sharply in response to local shocks.

- Real wage elasticity twice as large at local level.

- Implication? Some role for aggregate labor supply shocks?
Part 2:
A Model Economy
Purpose

1. Highlight differences in aggregate v. regional shock elasticities

2. Calibrate the model and quantify these elasticities

3. Show theoretical response of prices, wages and employment to shocks

4. Specify a structural wage setting equation

5. (3) and (4) will be used to identify the underlying shocks in our VAR procedure (will serve as our identifying restrictions)
A Model of a Monetary Union

- Economy composed of islands
- Agents: households, firms and a monetary authority
- 2 sectors: final good and intermediates
- One asset: one-period nominal bond
A Model of a Monetary Union

- Final/consumption good is non-tradable $\rightarrow$ price dispersion across islands.

- Intermediates are tradable $\rightarrow$ law of one price holds

- Labor mobility across sectors, but not islands $\rightarrow$ wage dispersion across islands

- Monetary Authority: nominal interest rate rule $\rightarrow$ same for all islands
4 types of shocks

- A monetary policy shock (shifter of Euler equation)
- A discount rate shock (shifter of Euler equation)
- Productivity/mark up shock (shifter of labor demand)
- A leisure shock (shifter of marginal rate of substitution)

Note 1: Cannot separately identify monetary policy shock from discount rate shock given our procedure. We will have one combined shock floating around the model.

Note 2: Shocks (aside from monetary shock) will have both an aggregate and island specific component.
Firms in each island

- Intermediate goods $x$ production (tradable)

$$\max_{N_k^x} Q e^{z_k} (N_k^x)^\theta - W_k N_k^x$$

- Final goods $y$ production (non-tradable)

$$\max_{N_k^y, X_k} P_k e^{z_k} (N_k^y)^\alpha (X_k)^\beta - W_k N_k^y - Q X_k$$

- $z_k^x, z_k^y$ are exogenous processes for productivity (mark-up)
Households in each island

- Preferences represented by:

\[ E_0 \sum_{t=0}^{\infty} e^{-\rho_{kt} - \delta_{kt}} \left( C_{kt} - e^{\varepsilon_{kt}} \frac{\phi}{1 + \phi} N_{kt}^{\frac{1+\phi}{\phi}} \right)^{1-\sigma} \]

- Sequential Budget Constraint

\[ P_{kt} C_{kt} + B_{k,t+1} \leq W_{kt} N_{kt} + B_{kt} (1 + i_t) + \Pi_{kt} \]

- \( \delta_{kt}, \varepsilon_{kt} \) are exogenous processes affecting the discount factor and the MRS between labor and consumption.
Key Constraint: Wage Setting Rule

- Sticky Nominal Wages:

\[ W_{kt} = (MRS)^{\lambda} (W_{k,t-1})^{1-\lambda} \]

\[ W_{kt} = \left( P_{kt} e^{\varepsilon_{kt}} (N_{kt})^{1/\phi} \right)^{\lambda} (W_{k,t-1})^{1-\lambda} \]


- Robustness (in model estimation): Move away from GHHH preferences.

- Robustness (in model estimation): Allow for forward looking behavior.
Shocks

- **Nominal interest rate rule:** \( i_t = \varphi_p E_t(\pi_{t+1}) + \varphi_y (y_t - y^*_t) + \mu_t \)

- **Define:** \( \gamma_{kt} \equiv \delta_{kt} - \delta_{kt-1} + \mu_t \)

- **The exogenous processes take the following form:**

\[
\begin{align*}
\varepsilon_{kt} &= \rho_{\varepsilon} \varepsilon_{kt-1} + u_t^\varepsilon + v_{kt}^\varepsilon \\
z_{kt}^y &= \rho_{z} z_{kt-1}^y + u_t^y + v_{kt}^y \\
z_{kt}^x &= \rho_{z} z_{kt-1}^x + u_t^x + v_{kt}^x \\
\gamma_{kt} &= \rho_{\gamma} \gamma_{kt-1} + u_t^\gamma + v_{kt}^\gamma
\end{align*}
\]

- **With** \( \sum_k \frac{1}{N} v_{kt}^\varepsilon = \sum_k \frac{1}{N} v_{kt}^x = \sum_k \frac{1}{N} v_{kt}^y = \sum_k \frac{1}{N} v_{kt}^\gamma = 0 \)

- **At the aggregate level,** \( u_t^z \equiv u_t^\gamma + \beta u_t^x \)
Equilibrium

- A collection of prices \{P_{kt}, W_{kt}, Q_t\} and quantities \{C_{kt}, N_{kt}, B_{kt}, N_{kt}^x, N_{kt}^y, X_{kt}\} for each \(k\) and \(t\)

- for given exogenous shock processes \{z_{kt}^x, z_{kt}^y, \varepsilon_{kt}, \delta_{kt}\} and an interest rate rule for \(i_t\)

- Market Clearing:
  \[
  C_{kt} = e^{z_{kt}^y} (N_{kt}^y)\alpha (X_{kt})\beta
  \]
  \[
  N_{kt} = N_{kt}^x + N_{kt}^y
  \]
  \[
  \sum_k X_{kt} = \sum_k e^{z_{kt}^x} (N_{kt}^x)\theta
  \]
  \[
  \sum_k B_{kt} = 0
  \]
Equilibrium characterization

- Log-linearize the model around zero inflation SS.

- **Notation:** lowercase letters are in logs. Variables without subscript $k$ are aggregates.

- **Claim 1:** Log-linearized economy aggregates

- **Claim 2:**
  - Island economies in log-deviation from aggregates are stationary.
  - Behave like independent small open economies.

- Can write: $c_{kt} = c_t + \tilde{c}_{kt}$

- Study aggregate and local economies separately.
Summary

➢ Four aggregate shocks:
  “Discount rate” shock (a component of \( \gamma \))
  “Interest rate” shock (a component of \( \gamma \))
  “Productivity” shock (\( z \) – combining tradable/nontradable)
  “Leisure” shock (\( \varepsilon \))

➢ Two general equilibrium forces:
  Tradable demand
  Interest rate rule

➢ Why different patterns in the time series vs. cross-section? Different shocks or general equilibrium effects?
Part 3:
Aggregate v. Regional Elasticities
Aggregate and Local Elasticities

- Aggregate employment elasticity to a discount rate shock:

$$\frac{dn_0}{d\gamma_0} = \frac{(1 - \lambda)}{(1 - \alpha + \frac{\lambda}{\phi})(\varphi_p - 1) + (\varphi_y \alpha - (\varphi_p - 1)(1 - \alpha)) \frac{1-\lambda}{\rho_\gamma}}$$

- Local employment elasticity to a discount rate shock

$$\frac{d\tilde{n}_0}{d\tilde{\gamma}_0} = \frac{(1 - \lambda + \lambda \beta)}{\left(1 - \alpha + \frac{\lambda}{\phi} + \left(\frac{\sigma(1-\lambda(\alpha-\frac{1}{\phi}))}{1-\frac{\alpha \phi}{1+\phi}} - (1 + \frac{\lambda}{\phi}) \beta\right) \left(\frac{1+r}{\rho_\gamma} - 1\right)\right)}$$

- Local elasticity to a $\gamma$ shock is larger than aggregate elasticity due to monetary rule.

- Local elasticity to a $\gamma$ shock is usually smaller than aggregate elasticity due to trade.
# Calibration

## Table 4: Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>0.62</td>
<td>Aggregate labor share in the non-tradable sector in 2006</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.55</td>
<td>Aggregate labor share in the tradable sector in 2006</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.16</td>
<td>Aggregate labor share in 2006, $\alpha + \theta \beta = 0.61$</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>2</td>
<td>Intertemporal elasticity of substitution</td>
</tr>
<tr>
<td>$\phi$</td>
<td>2</td>
<td>Frisch elasticity. Own estimate.</td>
</tr>
<tr>
<td>$\theta_p$</td>
<td>1.5</td>
<td>Taylor Rule from Galí (2011)</td>
</tr>
<tr>
<td>$\theta_y$</td>
<td>0.5</td>
<td>Taylor Rule from Galí (2011)</td>
</tr>
<tr>
<td>$\Phi_0$</td>
<td>0.01</td>
<td>Trade balance-output ratio volatility = 2 from Mendoza (1991).</td>
</tr>
<tr>
<td>$R$</td>
<td>0.03</td>
<td>Real interest rate</td>
</tr>
<tr>
<td>$X$</td>
<td>0.17</td>
<td>Median tradable output share in the US 2006.</td>
</tr>
<tr>
<td>$\rho_\gamma$</td>
<td>0.9</td>
<td>Persistence of discount rate shock</td>
</tr>
<tr>
<td>$\rho_z$</td>
<td>0.9</td>
<td>Persistence of productivity shock.</td>
</tr>
<tr>
<td>$\rho_\varepsilon$</td>
<td>0.9</td>
<td>Persistence of leisure shock</td>
</tr>
</tbody>
</table>
Estimates of Employment Elasticities

<table>
<thead>
<tr>
<th>$\rho_g$</th>
<th>0.9</th>
<th>0.9</th>
<th>0.9</th>
<th>0.6</th>
<th>0.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.16</td>
<td>0</td>
<td>0.16</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>$\vartheta_p$</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.31</td>
<td>1.5</td>
</tr>
<tr>
<td>$\vartheta_y$</td>
<td>0.5</td>
<td>0.5</td>
<td>0</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>($\lambda, \phi$)</td>
<td>(0.7,2)</td>
<td>(0.7,1)</td>
<td>(0.5,2)</td>
<td>(0.7,2)</td>
<td>(0.7,2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Aggregate</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\gamma$</td>
<td>0.77</td>
<td>0.53</td>
<td>1.29</td>
<td>0.74</td>
<td>1.11</td>
<td>1.76</td>
</tr>
<tr>
<td>$z$</td>
<td>0.29</td>
<td>0.20</td>
<td>-0.35</td>
<td>0.28</td>
<td>-0.24</td>
<td>-1.07</td>
<td>0.29</td>
</tr>
<tr>
<td>$\epsilon$</td>
<td>-0.65</td>
<td>-0.51</td>
<td>-0.28</td>
<td>-0.69</td>
<td>-0.26</td>
<td>0.41</td>
<td>-0.65</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Regional</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\gamma$</td>
<td>1.76</td>
<td>1.26</td>
<td>2.95</td>
<td>2.85</td>
<td>1.76</td>
<td>1.76</td>
</tr>
<tr>
<td>$z^y$</td>
<td>0.44</td>
<td>0.38</td>
<td>-0.18</td>
<td>0.10</td>
<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
</tr>
<tr>
<td>$z^x$</td>
<td>0.08</td>
<td>-0.06</td>
<td>0.23</td>
<td>0.05</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>$\epsilon$</td>
<td>-0.64</td>
<td>-0.52</td>
<td>-0.16</td>
<td>-0.43</td>
<td>-0.64</td>
<td>-0.64</td>
<td>-0.64</td>
</tr>
</tbody>
</table>

- Local employment elasticities 2-3 times greater than aggregate employment elasticities under base parameters.
- Tradable production makes differences smaller.
- Interest rate rule makes differences larger.
Second Take Away: Aggregate v. Local Elasticities

- Standard calibrations suggest that local elasticities of demand shocks are 2-3 times larger than aggregate elasticities.

- Papers like Mian-Sufi that emphasize “demand” shocks and use local variation to estimate “demand elasticities” will likely overstate their importance at the aggregate level.

- Can use our estimates to provide a ball park scaling factor for papers estimating local employment elasticities to various shocks (in different environments).
Aggregate v. Regional Impact Elasticities

<table>
<thead>
<tr>
<th></th>
<th>$\pi^p$</th>
<th>$\pi^w$</th>
<th>$w^r$</th>
<th>$n$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aggregate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma$</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>$z$</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>$\epsilon$</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td><strong>Regional</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma$</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>$z^y$</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>$z^x$</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>$\epsilon$</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>
Part 4:
Estimating Aggregate Shocks During
Great Recession Using Regional Variation
Estimating Local Shocks

➢ Use Above Model

- Business cycle accounting
- Explored this.....most aggregate variation in “labor wedge” – does not isolate fundamental shock driving economy.

➢ Estimate Using a Larger Class of Models

- VAR
- Take a stance on one part of model: wage setting equation.
- Semi-structural approach allows VAR to be identified with no further assumptions.
- Benefit – can be agnostic to may other parts of underlying model.
- Cost – relies on specification of wage setting equation.
Estimating Aggregate and Local Shocks

- Aggregate VAR (∞) Representation of above model:

  \[(I - \rho(L)) \begin{bmatrix} \pi_t \\ \pi_t^w \\ n_t \end{bmatrix} = \Lambda \begin{bmatrix} u_t^e \\ u_t^z \\ u_t^\gamma \end{bmatrix}\]

- Nests a large class of models (included one discussed above)

- Impose one additional constraint on above more general class of models

  \[\pi_t^w = \lambda(\pi_t + \epsilon_t - \epsilon_{t-1} + \frac{1}{\phi}(n_t - n_{t-1}) + (1 - \lambda)\pi_{t-1}^w \text{ Agg Wage Setting Equation}\]

- Reason: The above structural equation imposes several linear constraints that the reduced form errors must satisfy.
Identification Assumptions

- Wage Setting Equation (gives two restrictions):

\[
\begin{bmatrix}
\lambda & -1 & \frac{\lambda}{\phi} \\
\end{bmatrix}
\Lambda
\begin{bmatrix}
u_i^e \\
u_i^z \\
u_i^\gamma
\end{bmatrix}
+ \lambda \sigma_\varepsilon u_i^e = 0
\]

\[
\left(\begin{bmatrix}
\lambda & -1 & \frac{\lambda}{\phi} \\
0 & 1-\lambda & 0
\end{bmatrix} \rho_1 + \begin{bmatrix}
0 & 1-\lambda & 0
\end{bmatrix}\right)\Lambda
\begin{bmatrix}
 u_{t-1}^e \\
u_{t-1}^z \\
u_{t-1}^\gamma
\end{bmatrix}
+ \lambda (\rho_\varepsilon - 1) \sigma_\varepsilon u_{t-1}^e = 0
\]

- Impact elasticities have the “right” sign:

\[\Lambda_{n_\gamma} \Lambda_{\pi \rho_\gamma} > 0 \text{ and } \Lambda_{n_\gamma} \Lambda_{w_\gamma} < 0\]

- Standard orthogonalization: \[\Lambda \Lambda' = V\]
Identifying The Aggregate Shocks

\[
\begin{bmatrix}
\lambda & -1 & \frac{\lambda}{\phi}
\end{bmatrix}
\Lambda
\begin{bmatrix}
0 & 0 \\
1 & 0 \\
0 & 1
\end{bmatrix}
= [0 
0]
\]

\[
\left(\begin{bmatrix}
\lambda & -1 & \frac{\lambda}{\phi}
\end{bmatrix}\rho_1 + \begin{bmatrix}
0 & 1 - \lambda & 0
\end{bmatrix}\right)
\Lambda
\begin{bmatrix}
0 \\
\psi \\
1 - \psi
\end{bmatrix}
= 0
\]

\[\Lambda\Lambda' = V\]
Third Take Away: Semi-Structural Estimation

- Can use theory to help identify VARs

- In our regional system, knowing the aggregate wage setting equation (as specified) is sufficient to identify the VAR with minimal additional assumptions (i.e., no ordering of shocks, long run restrictions, etc.)

- Useful if regional variation can be used to estimate parameters of wage setting equation.

- In that sense, regional variation can help inform aggregate shocks.
Part 5:
Using Regional Data to Estimate Structural Parameters of Wage Setting Equation
Using Regional Data To Parameterize Structural Equations

- Having regional data allows two advantages:
  - Under certain conditions, the regional data can be used to estimate parameters of the aggregate structural equations.
  - Necessary for estimating the regional shock.

- Consider the regional labor supply curve:

\[
\pi_{kt}^w = \lambda (\pi_{kt} + \frac{1}{\phi} (n_{kt} - n_{kt-1}) + (1 - \lambda)\pi_{k,t-1}^w + \lambda (u_t^e - (1 - \rho_\epsilon)\varepsilon_{t-1}) + \lambda \nu_{kt}^e
\]

- If \( \nu_{kt}^e = 0 \) (or \( \text{cov}(\nu_{kt}^e, (n_{kt} - n_{kt-1}) = \text{cov}(\nu_{kt}^e, \pi_{kt}) = 0 \) ) or isolate variation orthogonal \( \nu_{kt}^e \):
  - Regional data can be used to estimate \( \lambda \) and \( \phi \)
Using Regional Data To Parameterize Structural Equations

➢ Consider the regional labor supply curve:

\[ \pi_{kt}^w = \lambda (\pi_{kt} + \frac{1}{\phi} (n_{kt} - n_{kt-1}) + (1 - \lambda) \pi_{k,t-1}^w + \lambda (u_t^e - (1 - \rho_e) \epsilon_{t-1}) + \lambda \nu_{kt}^e \]

➢ An application to the Great Recession:

o Argue that \( \nu_{kt}^e = 0 \) (or at least \( \text{cov}(\nu_{kt}^e, n_{kt} - n_{kt-1}) = \text{cov}(\nu_{kt}^e, \pi_{kt}) = 0 \)) is a good assumption during this time period.

o Discuss how we use regional data to get estimates of \( \lambda \) and \( \phi \)
  - Measurement error
  - Migration

o Isolate variation orthogonal to \( \nu_{kt}^e \).
  - House price variation (pre-2010)
Estimating Equation

$$\pi_{kt}^{w} = b_0 + b_1 \pi_{kt} + b_2 (n_{kt} - n_{kt-1}) + b_3 \pi_{kt-1}^{w} + \Psi D_t + \Gamma X_k + e_{kt}$$

- Compute **growth rates** of key variables
- We pool data from 2007-2010 (4 periods) – include time fixed effects.
- Also focus on 2007-2008 (2 periods) – include time fixed effects
- Estimate via 2SLS because of measurement error in wages and prices (split samples).
- Restrict coefficients on prices and lagged wages to sum to 1
- Use housing price growth as an instrument in some specifications
- Estimates of $\lambda$ are consistently about 0.7. Estimates of $\phi$ range from 1 to 2.2 (similar to other macro elasticities).
### Table 1: Estimated Parameters

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>λ</td>
<td>0.69 (0.13)</td>
<td>0.69 (0.13)</td>
<td>0.75 (0.17)</td>
<td>0.73 (0.17)</td>
</tr>
<tr>
<td></td>
<td>0.73 (0.13)</td>
<td>0.73 (0.17)</td>
<td>0.77 (0.13)</td>
<td>0.79 (0.18)</td>
</tr>
<tr>
<td>λ/ϕ</td>
<td>0.31 (0.08)</td>
<td>0.32 (0.08)</td>
<td>0.31 (0.07)</td>
<td>0.39 (0.09)</td>
</tr>
<tr>
<td></td>
<td>0.39 (0.07)</td>
<td>0.39 (0.10)</td>
<td>0.76 (0.17)</td>
<td>0.99 (0.25)</td>
</tr>
<tr>
<td>Implied φ</td>
<td>2.2</td>
<td>2.2</td>
<td>2.4</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.9</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.8</td>
</tr>
<tr>
<td>Year Fixed Effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Industry Controls</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Scaling Factor of Prices</td>
<td>1.4</td>
<td>1.4</td>
<td>1.0</td>
<td>1.4</td>
</tr>
</tbody>
</table>

**Estimated λ (local level):** 0.69-0.79

**Estimated φ (local level):** 1.0-2.4

**Estimated λ (aggregate):** 0.40-0.50 (specification not shown)
Part 6:
Results – Estimating Aggregate Shocks During the Great Recession
VAR Estimates: Employment Decomposition

The more flexible are wages, the less important are product demand ($\gamma$) shocks relative to productivity/markup ($z$) shocks (for fluctuations in $n$).

The more elastic is labor supply, the less important are leisure ($\varepsilon$) shocks relative to the sum of product demand and productivity/markup shocks.

<table>
<thead>
<tr>
<th>$\lambda$</th>
<th>2008 to 2009</th>
<th>$\phi$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td>0.1</td>
<td>$\gamma$</td>
<td>103</td>
</tr>
<tr>
<td></td>
<td>$z$</td>
<td>-3</td>
</tr>
<tr>
<td>0.3</td>
<td>$\gamma$</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>$z$</td>
<td>2</td>
</tr>
<tr>
<td>0.5</td>
<td>$\gamma$</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>$z$</td>
<td>6</td>
</tr>
<tr>
<td>0.7</td>
<td>$\gamma$</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>$z$</td>
<td>3</td>
</tr>
<tr>
<td>0.9</td>
<td>$\gamma$</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>$z$</td>
<td>-1</td>
</tr>
</tbody>
</table>
VAR Estimates: Employment Decomposition

The more flexible are wages, the less important are product demand ($\gamma$) shocks relative to productivity/markup ($z$) shocks (for fluctuations in $n$).

The more elastic is labor supply, the less important are leisure ($\varepsilon$) shocks relative to the sum of product demand and productivity/markup shocks.

<table>
<thead>
<tr>
<th>$\lambda$</th>
<th>$\gamma$</th>
<th>2008 to 2012</th>
<th>$\phi$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td>0.1</td>
<td>$\gamma$</td>
<td>40</td>
<td>-34</td>
</tr>
<tr>
<td></td>
<td>$z$</td>
<td>47</td>
<td>126</td>
</tr>
<tr>
<td>0.3</td>
<td>$\gamma$</td>
<td>-13</td>
<td>-25</td>
</tr>
<tr>
<td></td>
<td>$z$</td>
<td>98</td>
<td>123</td>
</tr>
<tr>
<td>0.5</td>
<td>$\gamma$</td>
<td>-1</td>
<td>-13</td>
</tr>
<tr>
<td></td>
<td>$z$</td>
<td>94</td>
<td>123</td>
</tr>
<tr>
<td>0.7</td>
<td>$\gamma$</td>
<td>47</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>$z$</td>
<td>53</td>
<td>72</td>
</tr>
<tr>
<td>0.9</td>
<td>$\gamma$</td>
<td>45</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>$z$</td>
<td>58</td>
<td>79</td>
</tr>
</tbody>
</table>
Counterfactual: Employment Decomposition
Counterfactual: Price Decomposition
Counterfactual: Nominal Wage Decomposition
Shock Decomposition

Leisure Shock

Discount rate Shock

Productivity / Markup Shock
Part 7: Robustness
Robustness I: Income effect

- Suppose the wage setting equation was:

\[ w_{kt} = \hat{\lambda}(p_{kt} + \left(\frac{1}{\phi} + \omega\right)n_{kt} + \omega c_{kt}) + (1 - \hat{\lambda})w_{kt-1} + \hat{\lambda}\epsilon_{kt} \]

- If we use aggregate consumption implied by the model \( c_t = w_t - p_t + n_t \):

\[ w_t = \lambda(p_t + \frac{1}{\phi}n_t) + (1 - \lambda)w_{t-1} + \lambda\epsilon_t \]

where \( \lambda = \frac{\hat{\lambda}(1-\omega)}{1-\hat{\lambda}\omega} \) and \( \frac{1}{\phi} = \frac{1+2\omega}{1-\omega} \).

- Re-estimate using new BLS state-level consumption expenditures.

- We get \( \lambda = 0.67 \) and \( \phi = 1.92 \).
Robustness II: Forward looking wage setting

- Suppose the wage setting equation was:
  \[ w_{kt} = \lambda(p_{kt} + \frac{1}{\phi}n_{kt}) + (1 - \lambda)w_{kt-1} + \lambda\kappa E_t[w_{kt+1} - w_{kt}] + e_t \]

- Consider the case where:
  - Local wages are AR(1) with persistence \( \rho_w \).
  - Aggregate expected wage inflation is zero.

- Then,
  \[ w_t = \lambda(p_t + \frac{1}{\phi}n_t) + (1 - \lambda)w_{t-1} + e_t \]

\[ \tilde{w}_{kt} = \frac{\lambda}{1 + \lambda\kappa(1 - \tilde{\rho}_w)}(\tilde{p}_{kt} + \frac{1}{\phi}\tilde{n}_{kt}) + \frac{1 - \lambda}{1 + \lambda\kappa(1 - \tilde{\rho}_w)} \tilde{w}_{kt-1} + e_{kt} \]

- So \( \lambda = \frac{1 - \beta_w}{1 + \beta_w \kappa(1 - \tilde{\rho}_w)} \) and our estimator is upward biased.

- For the true \( \lambda \) to be below 0.3 we would need \( \kappa(1 - \tilde{\rho}_w) > 4 \) when our estimator is \( \beta_w = 0.3 \).
### What Drives Regional Variation During Great Recession?

<table>
<thead>
<tr>
<th>$(\lambda, \phi)$</th>
<th>$\tilde{\omega}$</th>
<th>$\tilde{p}$</th>
<th>$\tilde{n}^y$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$(0.7, 2)$</td>
<td>$\zeta^\gamma$</td>
<td>24</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>$\zeta^z^y$</td>
<td>17</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>$\zeta^z^x$</td>
<td>60</td>
<td>20</td>
</tr>
<tr>
<td>$(0.5, 1)$</td>
<td>$\zeta^\gamma$</td>
<td>19</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>$\zeta^z^y$</td>
<td>14</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>$\zeta^z^x$</td>
<td>67</td>
<td>19</td>
</tr>
</tbody>
</table>
Conclusions

- **Two methodological contributions:**
  - Creating local wage and price indices
  - A procedure that uses regional information to identify aggregate shocks

- **Results:**
  - Contrasting aggregate and regional patterns during US Great Recession
  - The wage flexibility at the state level limits how much demand (discount rate) shocks could have driven aggregate fluctuations given aggregate wage dynamics.
  - During the 2007-2012 period, “productivity/mark up” drive much of the employment and price variation. “Leisure” shocks are needed to explain wage dynamics.
  - Caution when extrapolating results from regional variation to the aggregate!
Extra Slides
Scanner Price Index vs. BLS Total CPI

Appendix Figure A3
Scanner Data Price Index vs. BLS CPI All
(January 2006 Normalized to 1)
Inflation and Unemployment:
High vs. Low Unemployment Change States

Retail Price Difference (Low vs. High)

Unemployment Rate Difference (Low vs. High)
Net Migration Rates During Recession

- Small variation across states.
- Consistent with Yagan (2014)