The Aggregate Implications of Regional Business Cycles

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Chicago Fed, October 2014
This Paper

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

- We develop a methodology to do this. Application is to the Great Recession.

  - Use regional business cycle variation in the US to inform about the drivers of aggregate business cycles.

- Caveat: Work is preliminary (and evolving). Particularly the end. Feedback is very welcome!
Figure 1: Aggregate Inflation vs. Aggregate Unemployment
Quarterly Data: 2000Q1 - 2013Q4

( Beraja, Chicago Fed, Oct 2014 )
Figure 2: Real and Nominal Log Wages from the CPS, Adjusted for Changing Labor Force Composition
“If you believe that we’ve spent the past six years suffering from a huge overhang of excess supply, that inadequate demand is the whole story - as Yellen does, I do, and so should you - you do have one slightly awkward question to answer:

While inflation has been subdued, why hasn’t it turned into deflation? If labor is in huge excess supply, why are average wages still rising, albeit slowly?”

Paul Krugman (“Yellen, Wages, and Intellectual Honesty”, NYT, 8/25/2014)

- Lack of wage and price declines pointed out by many in the literature (Hall (2011), Ball and Mazumder (2011)).

What We Do

1. Make price indices at the state level using scanner data.
   - We think this is novel in its own right.
   - Discuss how variation in retail prices across regions can inform about variation in non-tradeable prices.

2. Explore the cross-sectional patterns of prices and wages during the Great Recession.
   - We think this is novel in its own right. Patterns very different than the aggregate.
   - Strong negative relationship between prices and unemployment in cross section of states.
   - Strong negative relationship between nominal wage growth and unemployment in cross section of states.
What We Do

3. Illustrate our methodology with an application to the Great Recession.

- Write down a model of a monetary union with multiple shocks.
- **Shocks include:**
  - A demand shock (proxy for household borrowing constraints)
  - A supply shock (proxy for real productivity or firm borrowing costs)
  - A leisure shock (proxy for Casey Mulligan stories)
- Impose a key identification assumption: one of the shocks is only aggregate.
  - Show that a combination of regional data and aggregate time series data can be used to infer all the shocks in the aggregate.
4. Findings

- Today: assume the leisure shock is aggregate.

- We find that both the demand and supply shocks significantly contributed to the decline in employment early in the recession.

- However, the supply shock is behind the slow recovery in employment thereafter.

- One put downward pressure on prices and wages, the other put upward pressure on prices...

- A leisure shock is needed to put upward pressure on wages. Employment effect is small relative to the other shocks.
Fits in Many Literatures

- Using scanner data to look at local price movements.
- A resurgence in using regional variation to learn about aggregate mechanisms.
- Understand the economy during the recent recession.
- Identification of aggregate shocks.
Part 1:
Making Local Price Indices
Data: *Nielsen’s Retail Scanner Database*

- Data from first week of January 2006 through last week of December 2011.
- 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, ≈36000 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 percent of U.S. counties.

( Beraja, Chicago Fed, Oct 2014 )
A Scanner Price Index (2 Step procedure like BLS)

- **Some notation:**
  - \( j \) = product category (1,000 or so; granulated sugar, powdered sugar, etc.)
  - \( i \) = UPC code (1,000,000 or so) * store (40,000 or so)
  - \( t \) = time (monthly)
  - \( y \) = base year
  - \( k \) = location (U.S. state)

- \( \bar{q} \) = quantity (average quantity from prior year)
- \( p \) = price

\[
P_{j,y,k,t}^L = P_{j,y,k,t-1}^L \frac{\sum_{i \in j} p_{i,k,t} \bar{q}_{i,k,t-1}}{\sum_{i \in j} p_{i,k,t-1} \bar{q}_{i,k,t-1}} \quad \text{(Step 1)}
\]
A Scanner Price Index

- **Some notation:**
  \[ S_{j,k,t} = \text{the share of expenditures of category } j \text{ in location } k \text{ at time } t \]

- **Our Scanner Price Index \((P_{k,t})\) in location \(k\) at time \(t\)**

\[
\frac{P_{k,t}}{P_{k,t-1}} = \prod_{j=1}^{N} \left( \frac{P_{j,y,k,t}^L}{P_{j,y,k,t-1}^L} \right)^{\frac{S_{j,k,t} + S_{j,k,t-1}}{2}} \tag{Step 2}
\]

- **Note:** the price index controls for “store effects” (it captures store switching behavior by households)

- **It is a chained price index across years.**
Figure 3
Scanner Data Price Index vs. BLS Food CPI
(January 2006 Normalized to 1)

Scanner Price Index (Solid Line)
BLS Food Index (Dashed Line)
Part 2a:

Is there a relationship between local economic activity and local price inflation?
Each observation is a U.S. State

Both changes from 2007 to 2010.

3 pp difference in $\Delta$ unemp rate implies about 1.5 pp difference in inflation rate.
What Can Retail Price Variation Tell Us About Local Price Variation?

- Assume that retail prices \( P^r \) and local prices \( P \) are a function of both tradeable and nontradeable components such that:

\[
P^r_{k,t} = \left(P^T_t\right)^\alpha (P^N_{k,t})^{1-\alpha} \\
P_{k,t} = \left(P^T_t\right)^\beta (P^N_{k,t})^{1-\beta}
\]

- Therefore, the local price growth across two regions \((k\text{ and } k')\) can be expressed as:

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

- Estimates suggest that local distribution costs are about 30 percent of gross revenues for the grocery industry \(\Rightarrow 1 - \alpha = 0.3\)

- What about \(1 - \beta\)?
Figure 8
Differential Scanner Price Level Index and Unemployment Rate between High and Low Unemployment Change States

Non-Tradable Price Level Difference

Price Level Difference (Low vs. High)

Unemployment Rate Diff (Low vs. High)

Correlation: -0.93
Part 2b:

Is there a relationship between local economic activity and local nominal wage growth?

( Beraja, Chicago Fed, Oct 2014 )
Wage Data

- Use data from the 2000 Census and 01-12 American Community Surveys.

- Measure hourly wage (earnings divided by hours) for those workers working at least 30 hours per week.

- Examine patterns for unadjusted and “adjusted” wages.

- To adjust wages, we regress log wage rate on age dummies (6 groups), education dummies (5 groups), citizenship dummies (3 groups), a black dummy, and usual hours worked dummies (4 groups).
  - Do this separately for each year.
  - Take residuals from regression add constant back and average by state.

- Regional patterns for adjusted and unadjusted wages are very similar. Show results for adjusted wages today.
Figure 9
Change in State Unemployment vs. Nominal Wage Change

$\beta = 1.23 \ (0.21)$
Figure 12:
Nominal Wage Index (2000 = 100): High and Low Unemployment States

( Beraja, Chicago Fed, Oct 2014 )
Part 3:
Using Regional Information to Identify Aggregate Shocks
How would you use cross-sectional information to learn about aggregate driving forces?

1. Show cross-sectional patterns that are indicative of a certain mechanism.
2. Write down a model with the proposed mechanism.

How would you infer aggregate shocks?

1. VARs with some identification scheme: Ordering, sign-restrictions, etc.
A New Methodology

- We propose: incorporate cross-sectional information to an aggregate VAR.

- Under some assumptions, it gives extra moment conditions that allow for identification of structural shocks.

- To fix ideas:
  1. Start with a model economy where the required assumptions hold.
  2. Illustrate the type of shocks that can be identified.

- The model is that of a monetary union (like the US?).

- The application is of independent interest: driving forces behind the Great Recession.
A Model of a Monetary Union

- Economy composed of islands.

- Agents: households, firms and monetary authority.

- 2 sectors: final good and intermediates.

- One asset: nominal bond.
Model (cont.)

- Final/consumption good is non-tradable.

- Intermediates are tradable.

- Labor mobility across sectors, but not islands.

- Monetary Authority: nominal interest rate rule.
Firms

- Intermediates $x$ production:

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

- Final goods $y$ production:

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

- $z_k^x, z_k^y$ are exogenous processes for productivity.
Households

- Preferences represented by:

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

- Sequential budget constraint:

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

- Sticky nominal wages:

\[ W_{kt} = \left( P_{kt} e^{\epsilon_{kt} \left( N_{kt} \right)^{\frac{1}{\phi}}} \right)^\lambda \left( W_{kt-1} \right)^{1-\lambda} \]

- \( \delta_{kt} \) and \( \epsilon_{kt} \) are exogenous processes affecting the discount factor and the MRS between labor and consumption.
Equilibrium

Given exogenous processes and an interest rate rule $i_t$.

Market clearing:

$$C_{kt} = e^{z^y_{kt}} (N^y_{kt})^\alpha X^\beta_{kt}$$

$$N_{kt} = N^y_{kt} + N^x_{kt}$$

$$\sum_k X_{kt} = \sum_k e^{z^x_{kt}} (N^x_{kt})^\theta$$

$$\sum_k B_{kt} = 0$$
Aggregation

- Log-linearize the model around symmetric, zero inflation SS.
- Notation: lowercase letters are log-growth rates. Variables without subscript $k$ are aggregates.
- Assume: $i_{t+1} = \varphi_p p_t + \varphi_n n_t + \mu_{t+1}$

Lemma

The behavior of $p_t, w_t, n_t$ in the log-linearized economy is identical to that of a representative economy with only a final goods sector with labor share in production $\alpha + \theta \beta$ and only 3 exogenous processes $\{z_t, e_t, \gamma_t\}$ where $z_t = z_t^y + \beta z_t^\delta$ and $\gamma_t = \delta_t - \delta_{t-1} + \mu_t$. 

( Beraja, Chicago Fed, Oct 2014 )
Shocks

- The exogenous processes take the following form:

\[ \epsilon_{kt} = \rho \epsilon_{kt-1} + u_t^\epsilon + v_{kt}^\epsilon \]

- With \( \sum_k v_{kt}^\epsilon = 0 \)

- Same specification for \( z' \)'s and \( \gamma \).

- We will call \( u_t^z \), \( u_t^\gamma \) and \( u_t^\epsilon \) the aggregate supply, demand and leisure shocks.

- Analogously, \( v_{kt}^y \), \( v_{kt}^x \), \( v_{kt}^\gamma \), \( v_{kt}^\epsilon \) are the regional shocks.
Aggregate structural relations

- Aggregate system:

\[
\begin{align*}
\dot{w}_t &= \lambda(p_t + \epsilon_t - \epsilon_{t-1} + \frac{1}{\phi} n_t) + (1 - \lambda)\dot{w}_{t-1} \\
\dot{w}_t &= p_t - (1 - (\alpha + \theta \beta)) n_t + z_t - z_{t-1} \\
0 &= \mathbb{E}_t(mu_{t+1} - p_{t+1} + \gamma_{t+1}) + \varphi_p p_t + \varphi_n n_t
\end{align*}
\]

Labor supply
Labor demand
Euler

- Recursive solution:

\[
\begin{bmatrix}
\dot{p}_t \\
\dot{w}_t \\
\dot{n}_t
\end{bmatrix} = \tilde{\rho} \begin{bmatrix}
\dot{p}_{t-1} \\
\dot{w}_{t-1} \\
\dot{n}_{t-1}
\end{bmatrix} + B \begin{bmatrix}
\epsilon_{t-1} \\
\gamma_{t-1}
\end{bmatrix} + \Lambda \begin{bmatrix}
u_t^\epsilon \\
u_t^z \\
u_t^\gamma
\end{bmatrix}
\]

( Beraja, Chicago Fed, Oct 2014 )
Regional structural relations

- For given $p_t, q_t, n_t,$
  - Labor supply
    \[ w_{kt} = \lambda (p_{kt} + \epsilon_{kt} - \epsilon_{kt-1} + \frac{1}{\phi} n_{kt}) + (1 - \lambda) w_{kt-1} \]
  - Labor demands
    \[ w_{kt} = p_{kt} - (1 - (\alpha + \theta \beta)) n_{kt}^y - \beta (1 - \theta) (n_{kt}^x - n_{kt}^y) + z_{kt} - z_{kt-1} \]
    \[ w_{kt} = z_{kt}^x - z_{kt-1}^x + q_t - (1 - \theta) n_{kt}^x \]
  - Euler
    \[ 0 = \mathbb{E}_t (mu_{kt+1} + \varphi_p p_t + \varphi_n n_t + \gamma_{kt+1}) \]

(Beraja, Chicago Fed, Oct 2014) 34 / 53
The Procedure in the Model Economy
Mapping the cross-section to the aggregate

- **Assumption 1**: at least one of the regional shocks is zero.
- **Assumption 2**: at least one of the cross-sectional structural relations,
  - Has no aggregate variables in it.
  - Only the shock from Assumption 1 shows up.
- We have two of such equations in the model.

**Purely aggregate leisure shock:**

\[ w_{kt} = \lambda (p_{kt} + \frac{1}{\phi} n_{kt}) + (1 - \lambda) w_{kt-1} + \lambda (u_{t}^{e} - (1 - \rho_{e}) \epsilon_{t-1}) \]

**Purely aggregate supply shock:**

\[ w_{kt} = p_{kt} - (1 - (\alpha + \theta \beta)) n_{kt}^{y} - \beta (1 - \theta) (n_{kt}^{x} - n_{kt}^{y}) + u_{t}^{z} - (1 - \rho_{y}) z_{t-1} \]
Econometric model

- **Today**: the leisure shock is aggregate.

- **Model**: Reduced form VAR + cross-sectional equation

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

\[
w_{kt} = \lambda(p_{kt} + \frac{1}{\phi}n_{kt}) + (1 - \lambda)w_{kt-1} + \lambda e_{kt}
\]

where \( e_{kt} \equiv u_t^e + v_{kt}^e - (1 - \rho_\epsilon)\epsilon_{kt-1} \)

- **Note**: If you can write other models in this form, then the procedure can be applied.
Assumptions

1. **Identification:** \( \nu_{k_t}^e = 0 \) for all \( k, t \)

2. **Orthogonality:** for all \( j, t \)

\[
\begin{align*}
\mathbb{E}(u_t^e) &= \mathbb{E}(u_t^z) = \mathbb{E}(u_t^\gamma) = 0 \\
\mathbb{E}(u_t^e u_{t-j}^e) &= \mathbb{E}(u_t^z u_{t-j}^z) = \mathbb{E}(u_t^\gamma u_{t-j}^\gamma) = 0 \\
\Sigma &= \text{Var} \begin{bmatrix} u_t^e \\ u_t^z \\ u_t^\gamma \end{bmatrix} = I_{3.3}
\end{align*}
\]
Step 1: Cross-sectional estimation

- Using regional data, estimate

\[ w_{kt} = \lambda(p_{kt} + \frac{1}{\phi} n_{kt}) + (1 - \lambda)w_{kt-1} + \lambda e_t \]

- We use pooled data from 2007-2011 with time fixed effects.
- Estimate via 2SLS because of measurement error in wages and prices.
- Also, restrict coefficients in prices and lagged wages to sum up to 1.
- Find:

\[ \hat{\lambda} = 0.66 \quad (0.111) \]
\[ \frac{\hat{\lambda}}{\hat{\phi}} = 0.27 \quad (0.088) \]
Step 2: Construct aggregate instrument

- Using the estimated coefficients, construct

\[ \hat{s}_t = \frac{1}{\hat{\lambda}}(w_t - \hat{\lambda}(\rho_t + \frac{1}{\hat{\phi}}n_t) + (1 - \hat{\lambda})w_{t-1}) \]

- This is an estimate of \( e_t \). Demean it to obtain the instrument \( s_t \).

- Under Assumptions 1 and 2:

\[
\mathbb{E} \begin{bmatrix} s_t u_t^\epsilon \\ s_t u_t^z \\ s_t u_t^\gamma \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}
\]
Step 3: $\Lambda$ and structural shocks

- Estimate the reduced form VAR and obtain the reduced form errors $U$.
- Obtain estimates of $\Sigma$ and the moments vector $\tilde{E} \equiv E(sU)$.
- Normalize the variance of the shocks to 1: $E = \frac{\tilde{E}}{\sqrt{\tilde{E}'\Sigma^{-1}\tilde{E}}}$
- Solve for $\Lambda$:

$$
\Sigma = \Lambda \Lambda' \quad \text{Standard orthogonalization conditions}
$$

$$
\begin{bmatrix}
1 \\
0 \\
0 \\
\end{bmatrix}
\Lambda =
E \quad \text{New moment conditions}
$$

- Obtain the structural shocks $u = \Lambda^{-1}U$
Which shock?

- The procedure constructs an instrument that is the “right” linear combination of variables in the VAR.
  - The one that is orthogonal to $u_t^z$ and $u_t^\gamma$, but correlated with $u_t^\epsilon$.
- From here we can identify the impulse vector corresponding to $u_t^\epsilon$ (a column vector in $\Lambda$).
- However, while each remaining column corresponds to the impulse vector of either $u_t^z$ or $u_t^\gamma$, we cannot say which one is which.
- We are gonna use the theoretical co-movement to label the columns.
- This is in the spirit of the sign-restriction literature (Uhlig (2005)).
Part 4: Aggregate Shocks in the Great Recession
Impulse Response to 2008 Demand Shock

( Beraja, Chicago Fed, Oct 2014 )
Impulse Response to 2008 Leisure Shock

(Beraja, Chicago Fed, Oct 2014)
Counterfactual Price Response

Data
Only Supply
Only Demand
Only Leisure

(Beraja, Chicago Fed, Oct 2014)
Counterfactual Wage Response

Data
Only Supply
Only Demand
Only Leisure

(Beraja, Chicago Fed, Oct 2014)
What patterns in the cross-section are behind this particular decomposition?

The labor supply elasticity $\phi$ affects the relative importance of the leisure vs. the demand+supply shocks combined.

We estimate the elasticity off the cross-section $\hat{\phi} = 2.4$

- Micro-estimates: 0 to 0.5 and Macro-estimates: 2 to 4

Suppose we set $\phi = 0.5$ and construct $s_t$. The leisure shock accounts for most of the employment decline in the Great Recession.

Intuition 1 (theory): big movements in employment can be rationalized without the need of big leisure shocks given the relatively small movements in real wages.

Intuition 2 (data): $s_t$ is more correlated with employment. Then, the element in the $u^\epsilon_t$ impulse vector corresponding to $n_t$ is larger.
The degree of wage flexibility $\lambda$ affects the relative importance of supply vs. demand shocks (within the remaining unexplained part by the leisure shock).

Suppose we set $\lambda = 1$ and construct $s_t$. The supply shock accounts for most of the employment decline.

Intuition 1 (theory): When $\lambda$ is large, demand shocks don’t matter much in the theoretical model.

Intuition 2 (data): $s_t$ becomes more correlated with inflation. The leisure shock generates deflation. We need a larger supply shock to account for the observed inflation, and hence, a smaller demand shock to account for the employment decline.
Conclusions

▶ Two methodological contributions

▶ Creating local price indices using scanner data for the US.

▶ Developing a methodology that combines cross-sectional and aggregate data. Under some assumptions, regional information can be used to identify aggregate shocks.

▶ Results

▶ Large variation in prices and wages across regions during the 2007-2010 period in the U.S. Stands in stark contrast with the aggregate data.

▶ Suggests that more than just “demand” shocks hit the U.S. economy during this period.

▶ More work to be done...

( Beraja, Chicago Fed, Oct 2014 )
Extra Slides
Appendix Figure A3
Scanner Data Price Index vs. BLS CPI All
(January 2006 Normalized to 1)
Other Local Price Indices?

- There are not many...
- **BLS puts out 27 metro area price indices.**
- 3 monthly (Chicago, LA, and New York)
- 11 bi-monthly (Boston, Cleveland, Dallas, Detroit, Houston, Miami, Phili, San Fran, Seattle and Washington)
- 13 semi-annually (Anchorage, Cincinnati, Denver, Honolulu, Kansas City, Milwaukee, Minneapolis, Phoenix, Pittsburg, Portland, St. Louis, San Diego, Tampa)
- Segment the 27 metro areas into high and low unemployment MSAs (2007-2010)
Figure 10a
Differential Metro Non Durable Less Food and Unemployment Rate between High and Low Unemployment Change MSAs
Figure 10c
Differential Metro All Goods CPI and Unemployment Rate between High and Low Unemployment Change MSAs

-3.0
-2.0
-1.0
All Price Level Difference
Unemployment Difference
0.0
1.0
2.0
3.0 4.0


All Price Level Difference
Unemployment Difference