The Interstate Multiplier

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Motivation

- On fiscal policy research, macroeconomists have paid more attention to military spending and less attention to investment in infrastructure.

- Problematic because theory predicts that different government spending categories may have very different effects on output.

- In Baxter & King (1993) the long-run multiplier for:
  - Permanent & unproductive spending is 1.2.
  - Permanent & productive spending is between 1.5-13.0.

$$Y_t = (AH_t^{\theta})K_t^{\alpha}N_t^{1-\alpha}$$

Estimates of the Spending Multiplier

- Multiplier estimates based on military spending are usually between 0.6-0.8.
- Far less evidence for government investment:
  - Pereira (2000): 2.0 for spending on highways and streets.
  - Iletzki et al. (2013): 1.5-1.6 for public-investment.
  - Leduc & Wilson (2013): 6.6-18.1 for highway spending.
  - Bohem (2018): Near 0.0 for temporary government investment shocks.
- New trade literature highlights benefits from transportation infrastructure (Donaldson, 2018).

Other Estimates

What this paper does

I focus on spending in highways

1. Estimate the **relative** multiplier from the **Interstate Highway System (IHS)** construction.
   - Relative multiplier of 1.70.

2. Estimate spillovers across states from the IHS construction.
   - High multicollinearity $\rightarrow$ hard to uncover spillovers precisely.
   - Preliminary results $\rightarrow$ aggregate multiplier of at least 1.70.

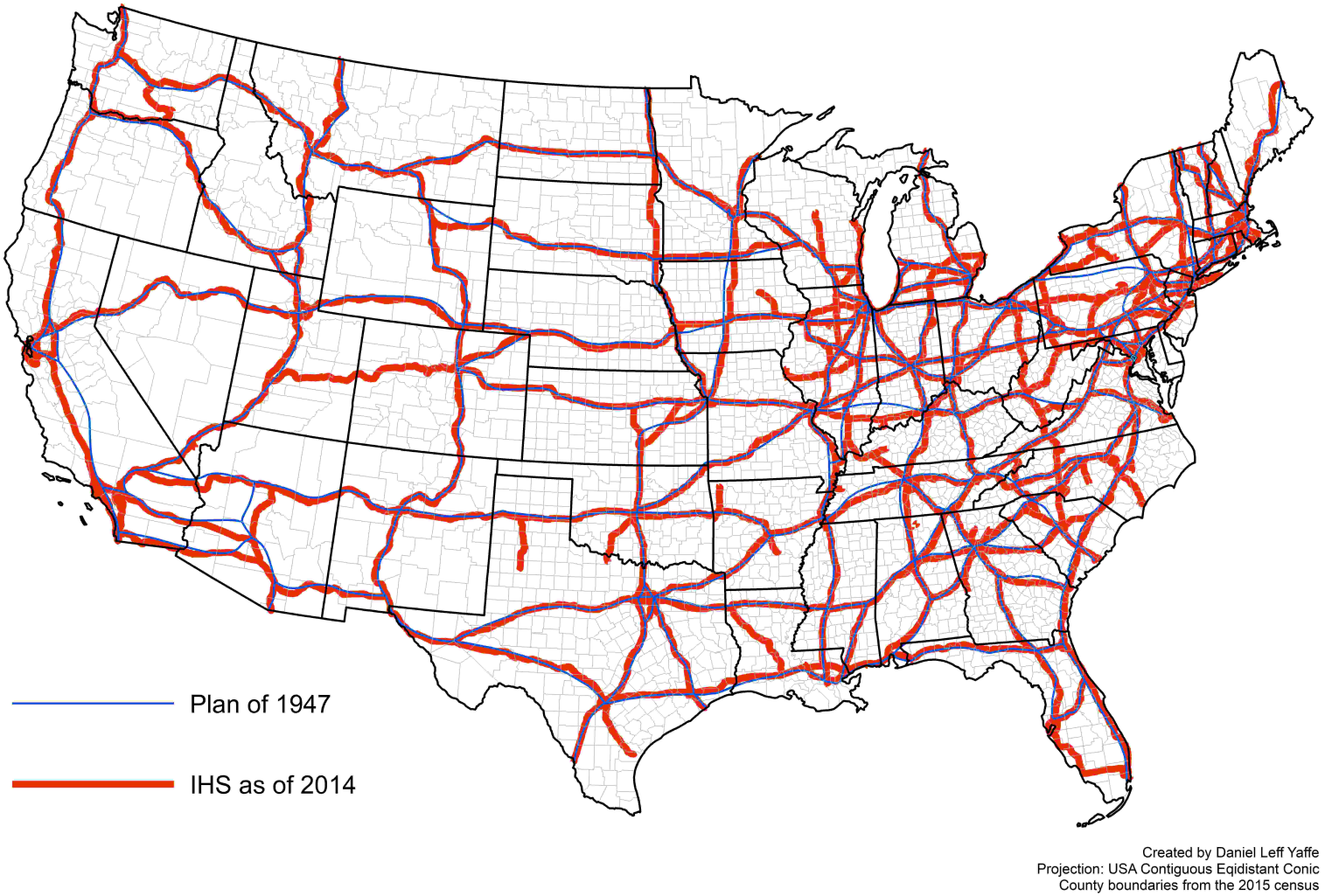
1. The IHS
2. Identification Challenges
3. Empirical Results
4. Aggregate Multiplier
5. Conclusions

About the IHS

"There shall be designated within the continental United States a National System of Interstate Highways not exceeding forty thousand miles in total extent so located as **to connect by routes as direct as practicable, the principal metropolitan areas, cities, and industrial centers**, to serve the **national defense**, and to connect at suitable border points with routes of continental importance in the Dominion of Canada and the Republic of Mexico"

Federal Aid Highway Act of 1944

Figure 1: Plan of 1947 vs. Today



The IHS

- The Act of 1956 created the Highway Trust Fund to pay for the system.
- The federal government raised money (mainly with a gas tax), and then apportioned it to the states.
- Each year, states were assigned funds out of the federal budget according to their **Apportionment Factors (AF)**.
  - Until 1959 the AF were calculated by assigning weights on: population (66.7%), area (16.7%), and rural mileage (16.7%).
  - Starting in 1960 weights were based on relative costs of completing the system.

Why focus on the IHS?

- With only 1% of the nation's road mileage, the IHS accounts for 25% of all distance traveled.
- Intuitively, a second IHS would not be as productive as the first (Fernald, 1999).
- The federal government covered 90 cents for every dollar devoted to the interstate construction.

The Big Identification Challenges

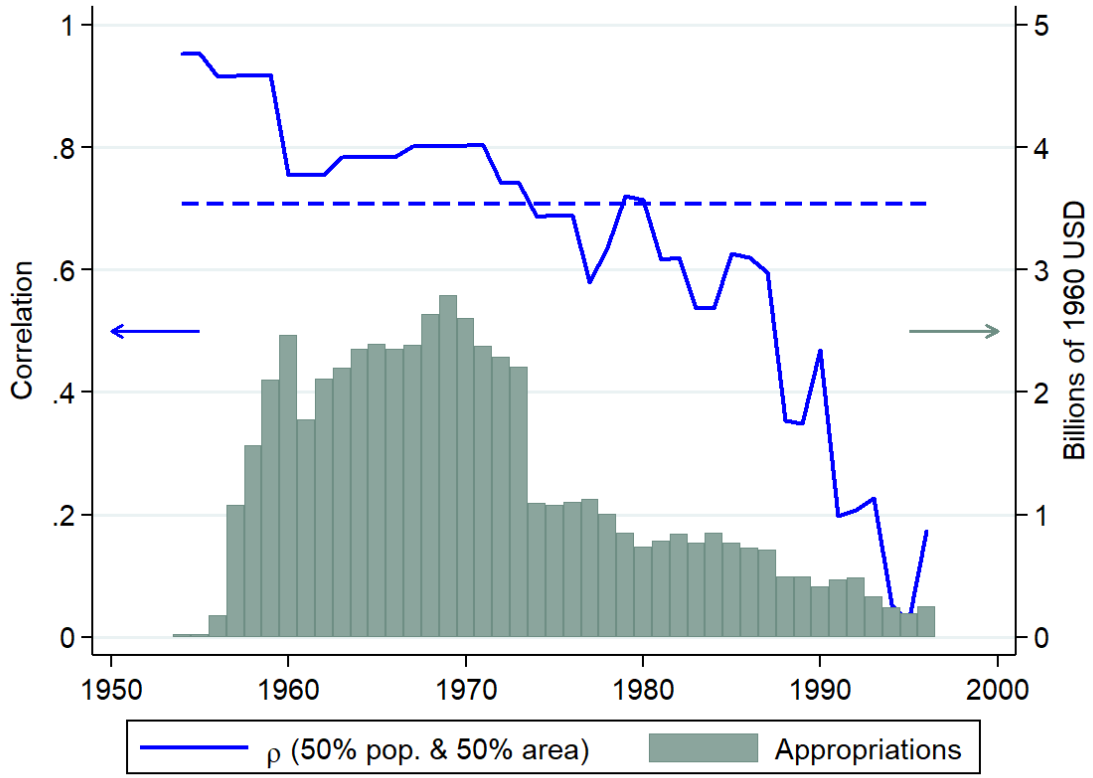
- **Endogeneity** $\rightarrow$ G is not allocated randomly.
  $G_t = f(E_{t-1}[Y_{t+s}], \cdots)$
- **Anticipation** $\rightarrow$ News about G may directly affect Y.
- **Spending Crowd-In** $\rightarrow$ IHS spending affects other types of spending.

Endogeneity

- Population of 1947 and area shares are correlated with the observed AF (σ_{it}). Average $\rho = 0.7$.

$$s_i = 0.5 \left(\frac{Pop_{i,1947}}{\sum_i Pop_{i,1947}} \right) + 0.5 \left(\frac{Area_i}{\sum_i Area_i} \right)$$

Figure 2: Apportionment Factor Correlations & IHS Appropriations



Endogeneity

Consider the system:

$$y_{i,t} = \mu g_{i,t} + \alpha_i^y + r_{it} + \varepsilon_{i,t}^y \tag{1}$$

$$g_{i,t} = \pi \underbrace{\left(s_i \sum_i g_{i,t} \right)}_{z_{it}} + (1-\pi)\theta\, \mathbb{E}_{t-1}\left[y_{i,t} \right] + \alpha_i^g + \varepsilon_{i,t}^g \tag{2}$$

- r_{it} can be seen by policy-makers, but not by the econometrician.
- s_i combines the share of 1947 population and area.

$$s_i = p \underbrace{\left(\frac{Pop_{i,1947}}{\sum_i Pop_{i,1947}} \right)}_{s_i^{(P)}} + (1-p) \underbrace{\left(\frac{Area_i}{\sum_i Area_i} \right)}_{s_i^{(A)}}$$

- FE estimator is biased for μ since $corr(g_{i,t}, r_{i,t}) \neq 0$.

Endogeneity

- FE-IV can consistently estimate μ with the following instrument:

$$z_{i,t} = s_i \sum_i g_{i,t}$$

- If s_i is not known use 2 instruments instead:

$$z_{i,t}^{(P)} = \underbrace{s_i^{(P)}}_{\left(\frac{Pop_{i,1947}}{\sum_i Pop_{i,1947}}\right)} \sum_i g_{i,t} \quad \& \quad z_{i,t}^{(A)} = \underbrace{s_i^{(A)}}_{\left(\frac{Area_i}{\sum_i Area_i}\right)} \sum_i g_{i,t}$$

- Using 2 instruments, one can back out the weights assigned to population and area (50% to each in my baseline).

Anticipation

TITLE I—FEDERAL-AID HIGHWAY ACT OF 1956 Public Law 627

JUNE 29, 1956

SEC. 108. NATIONAL SYSTEM OF INTERSTATE AND DEFENSE HIGHWAYS.

... additional sum of $1,000,000,000 for the fiscal year ending June 30, 1957, which sum shall be in addition to the authorization heretofore made for that year, the additional sum of $1,700,000,000 for the fiscal year ending June 30, 1958, the additional sum of $2,000,000,000 for the fiscal year ending June 30, 1959, the additional sum of $2,200,000,000 for the fiscal year ending June 30, 1960, the additional sum of $2,200,000,000 for the fiscal year ending June 30, 1961, the additional sum of $2,200,000,000 for the fiscal year ending June 30, 1962, the additional sum of $2,200,000,000 for the fiscal year ending June 30, 1963, the additional sum of $2,200,000,000 for the fiscal year ending June 30, 1964, the additional sum of $2,200,000,000 for the fiscal year ending June 30, 1965, the additional sum of $2,200,000,000 for the fiscal year ending June 30, 1966, the additional sum of $2,200,000,000 for the fiscal year ending June 30, 1967, the additional sum of $1,500,000,000 for the fiscal year ending June 30, 1968, and the additional sum of $1,025,000,000 for the fiscal year ending June 30, 1969.

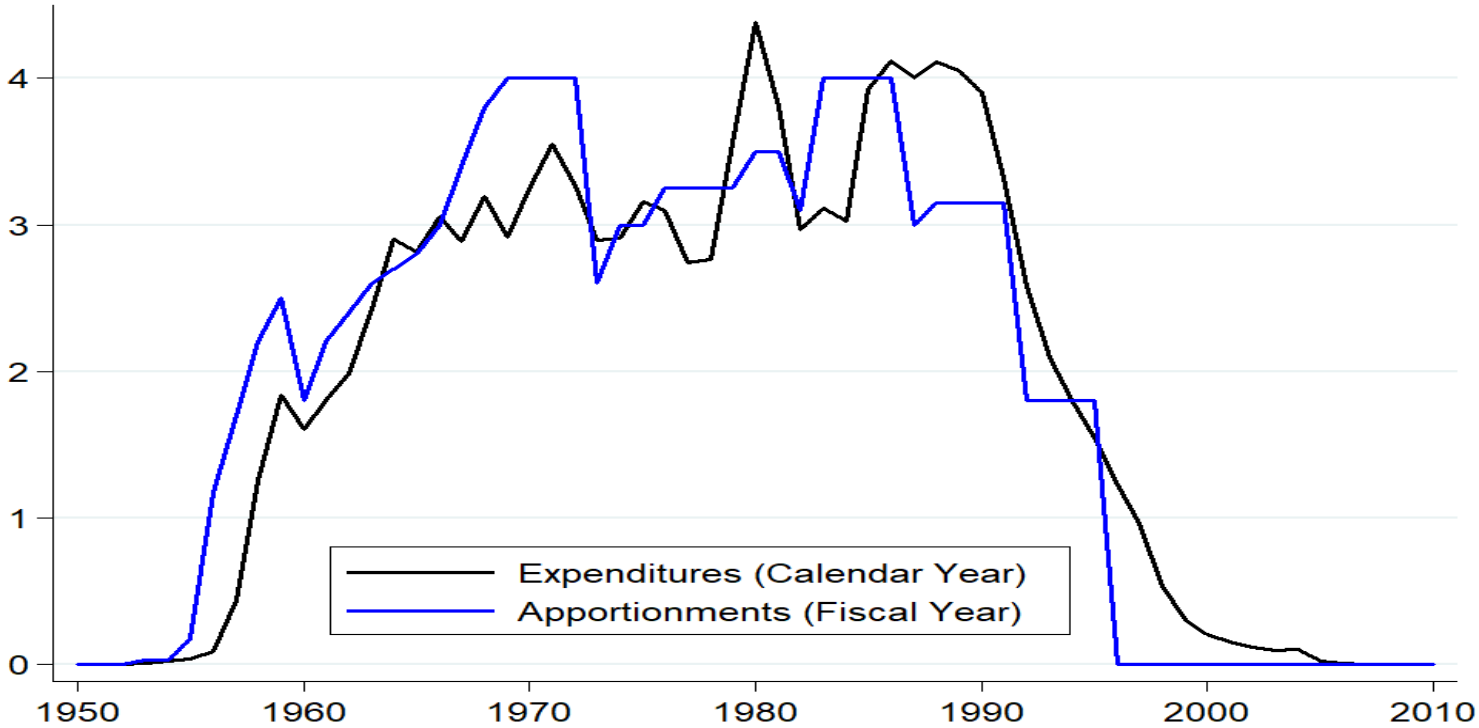
Anticipation

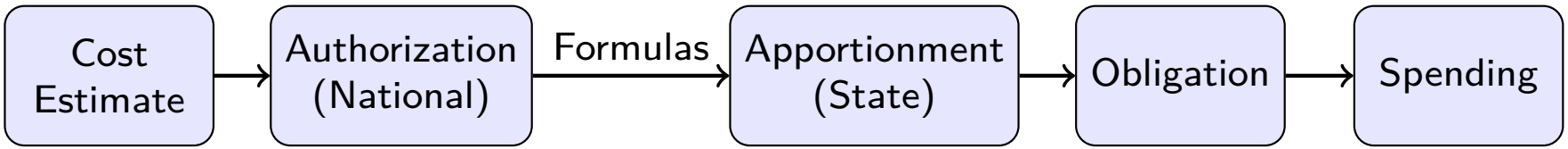
- The creation of the IHS can be decomposed into several news-shocks.

- **News-shock definition**: each time additional funds were assigned or the final year was pushed forward (20 occasions):
  - In 1956 the plan was to provide funds for interstate construction until 1969.
  - However, the final year kept being pushed until it reached 1996.
  - Construction cost 2.2 times its initial cost-estimate (in real terms).

- A news-shock contains changes in both the Q of highways (quantity, or quality) and the P of highways (price). I only use variation in Q.

Figure 3: Federal Government Funds to Construct the IHS
(Billions of Nominal USD)





Anticipation

- We may define a shock at the state-level as:

$$\phi_{i,t} = \frac{\mathbb{E}_t[PDV_{i,t}] - \mathbb{E}_{t-1}[PDV_{i,t}]}{Y_{i,t-1}}$$

where

- $PDV_{i,t} = \sum_{\tau=0}^{\infty} \beta_t^{\tau} \underbrace{\sigma_{i,t+\tau} A_{t+\tau}}_{\approx G_{i,t+\tau}}$
- A_t are national authorizations + state matching funds.
- $\sigma_{i,t}$ are the (endogenous) AFs ($\sum_i \sigma_{i,t} = 1$).

Anticipation

- Consider the following specification for $H \in \{0, \ldots, 60\}$:

$$\sum_{h=0}^{H} y_{i,t+h} = \mu_H \sum_{h=0}^{H} g_{i,t+h} + \boldsymbol{\psi_H x_{i,t}} + \varepsilon_{i,t}^{(H)} \tag{3}$$

$$[y_{i,t+h}, g_{i,t+h}] \equiv \left[\frac{Y_{i,t+h} - Y_{i,t-1}}{Y_{i,t-1}}, \frac{G_{i,t+h} - G_{i,t-1}}{Y_{i,t-1}} \right]$$

- To estimate μ_H instrument $\sum_{h=0}^{H} g_{i,t+h}$ with $\phi_{i,t}$. (Local IV Projection)
- The multiplier μ_H is affected by anticipation for low $H \rightarrow$ focus on high H (15 years).

Control Variables

Summary of Solutions to Identification Challenges

- Use anticipation framework, but substitute $\sigma_{i,t}$ with $s_i^{(P)}$ and $s_i^{(A)}$ and obtain 2 instruments:
  1. $PDV_{i,t}^{(P)} = \sum_{\tau=0}^{\infty} \beta_t^{\tau} s_i^{(P)} A_{t+\tau} \rightarrow \phi_{i,t}^{(P)}$
  2. $PDV_{i,t}^{(A)} = \sum_{\tau=0}^{\infty} \beta_t^{\tau} s_i^{(A)} A_{t+\tau} \rightarrow \phi_{i,t}^{(A)}$

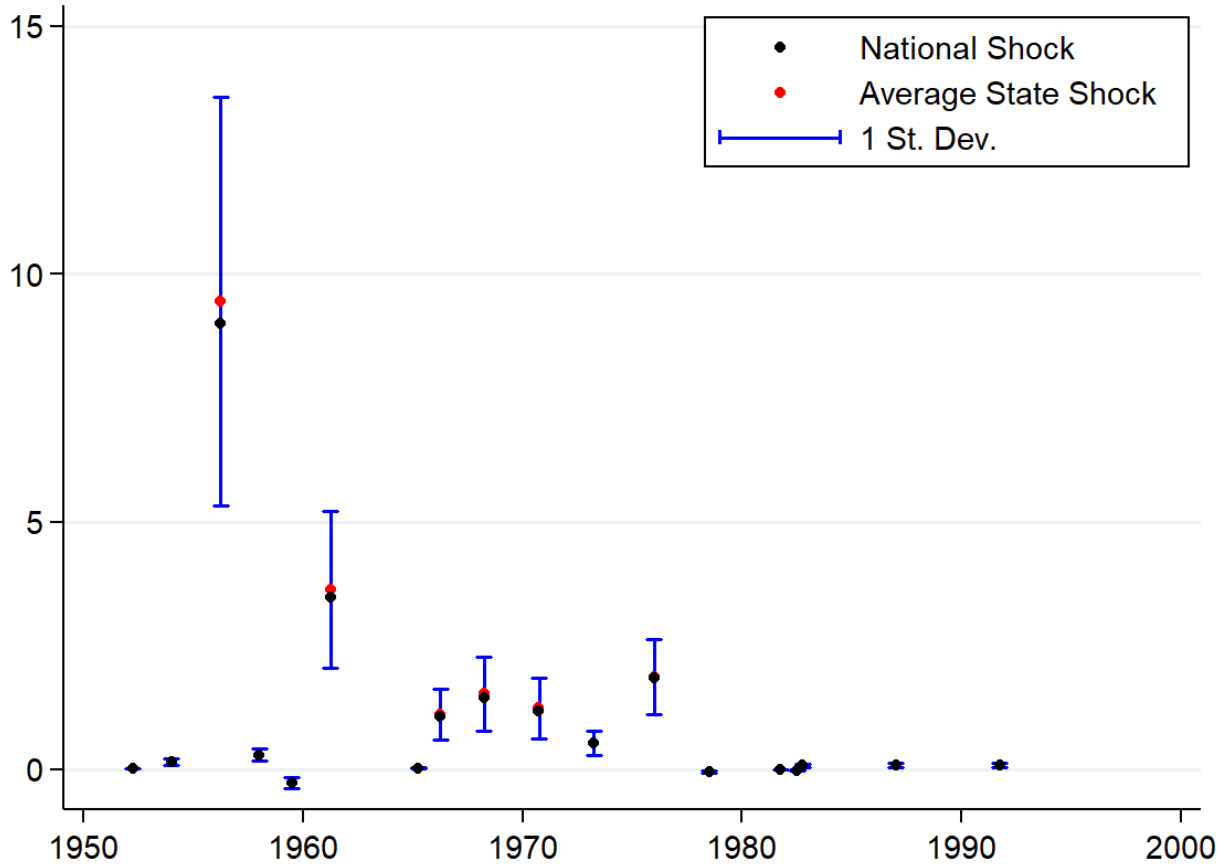
- **Spending Crowd-In** IHS spending may crowd-in other types of G $\rightarrow$ use a broader spending measure.

$$\text{Measures of } G_{it} = \begin{cases} \text{IHS Spending} \\ \text{All State Spending} \\ \text{All Local \& State Spending} \end{cases}$$

Spending Measures

Average News-Shock

Figure 4: $\phi^*_{i,t} = 0.5\phi^{(P)}_{i,t} + 0.5\phi^{(A)}_{i,t}$
(as fraction of annualized lagged GDP (%))



1956 Shock

Empirical Results

- 48 contiguous states.
- Quarterly data: 1948:Q1 - 2009:Q4.

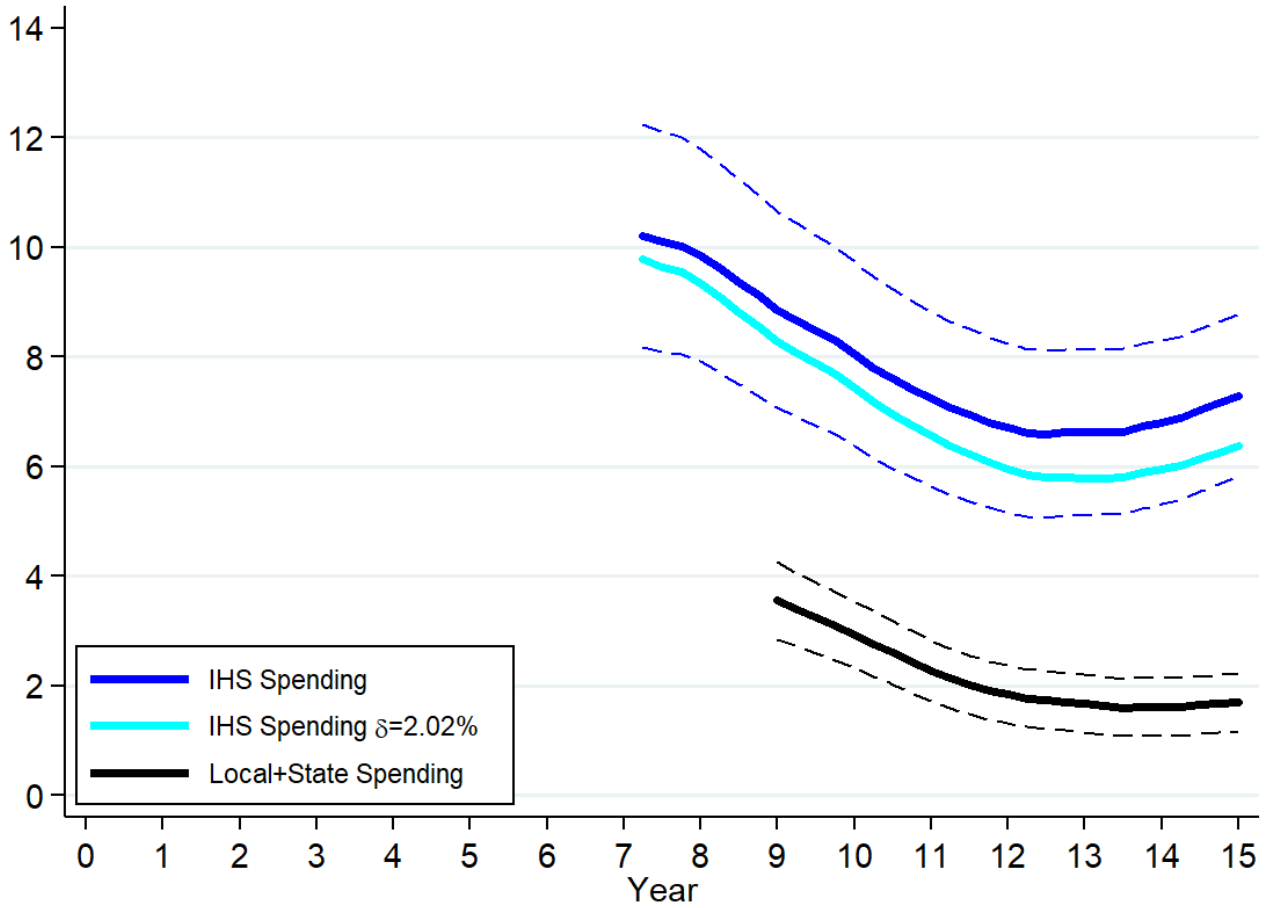
Cumulative Multiplier at a 15-year horizon

Table 1: **IV-GMM estimates of the 15-year multiplier**

Spending Measure		Without Weights	With Weights
IHS	$\hat{\mu}$	10.52^{***}	7.30^{***}
	$\hat{se}(\hat{\mu})$	(1.15)	(0.89)
	Hansen's J	{0.16}	{0.85}
	R^2	[0.59]	[0.68]
State	$\hat{\mu}$	6.76^{***}	2.52^{***}
	$\hat{se}(\hat{\mu})$	(0.58)	(0.56)
	Hansen's J	{0.08}	{0.49}
	R^2	[0.58]	[0.72]
Local + State	$\hat{\mu}$	4.20^{***}	1.70^{***}
	$\hat{se}(\hat{\mu})$	(0.39)	(0.32)
	Hansen's J	{0.83}	{0.89}
	R^2	[0.66]	[0.74]

Notes: Robust SEs in parentheses, Hansen's J overidentification test P-Value in braces, R^2 in brackets. SEs are robust with respect to heteroskedasticity and autocorrelation. Each estimate is based on a regression with a sample size of 7,776 observations.

Figure 5: Multiplier at Different Horizons (IV-GMM)



Instrument Relevance IV-GMM and IV-2SLS

Reduced Form and First Stage

- Informative to look at the reduced form and first stage:
- β_y from the **Reduced Form:**

$$\sum_{h=0}^{H} y_{i,t+h} \text{ on } \phi^*_{i,t}$$

- β_g from the **First Stage:**

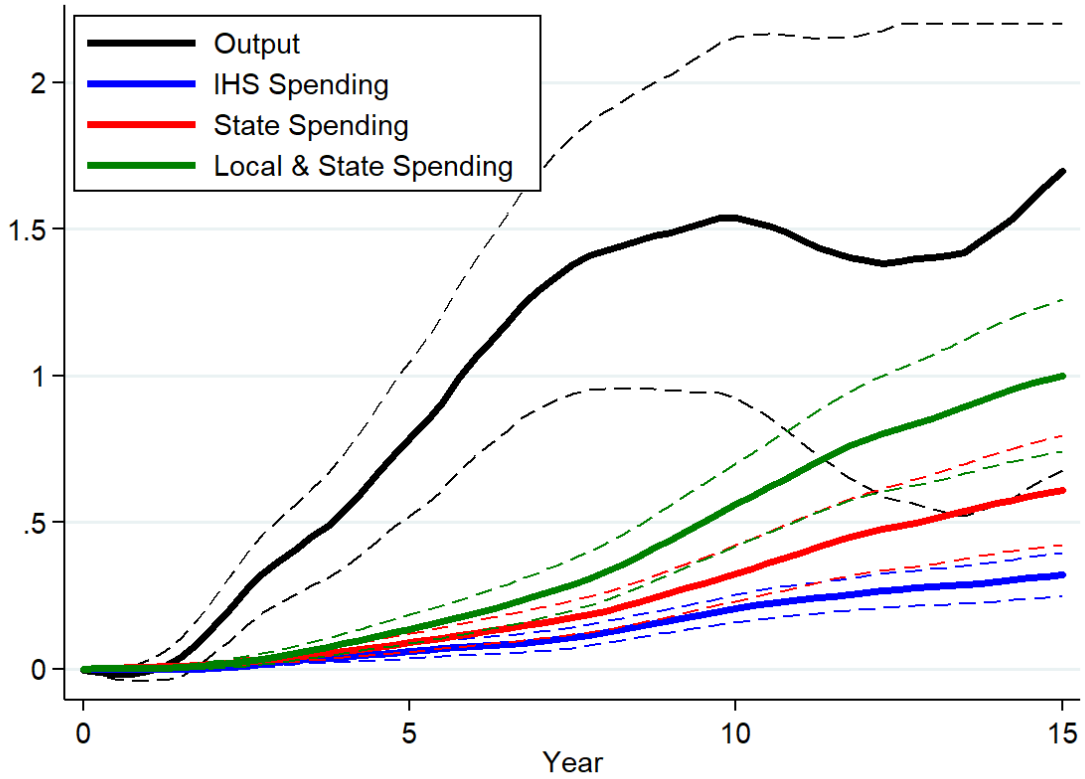
$$\sum_{h=0}^{H} g_{i,t+h} \text{ on } \phi^*_{i,t}$$

- β_{IV} **:**

$$\hat{\beta}_{IV} = \frac{\hat{\beta}_y}{\hat{\beta}_g}$$

Integral of IRFs for Y and G

Figure 6: Integral of IRFs for Y and G



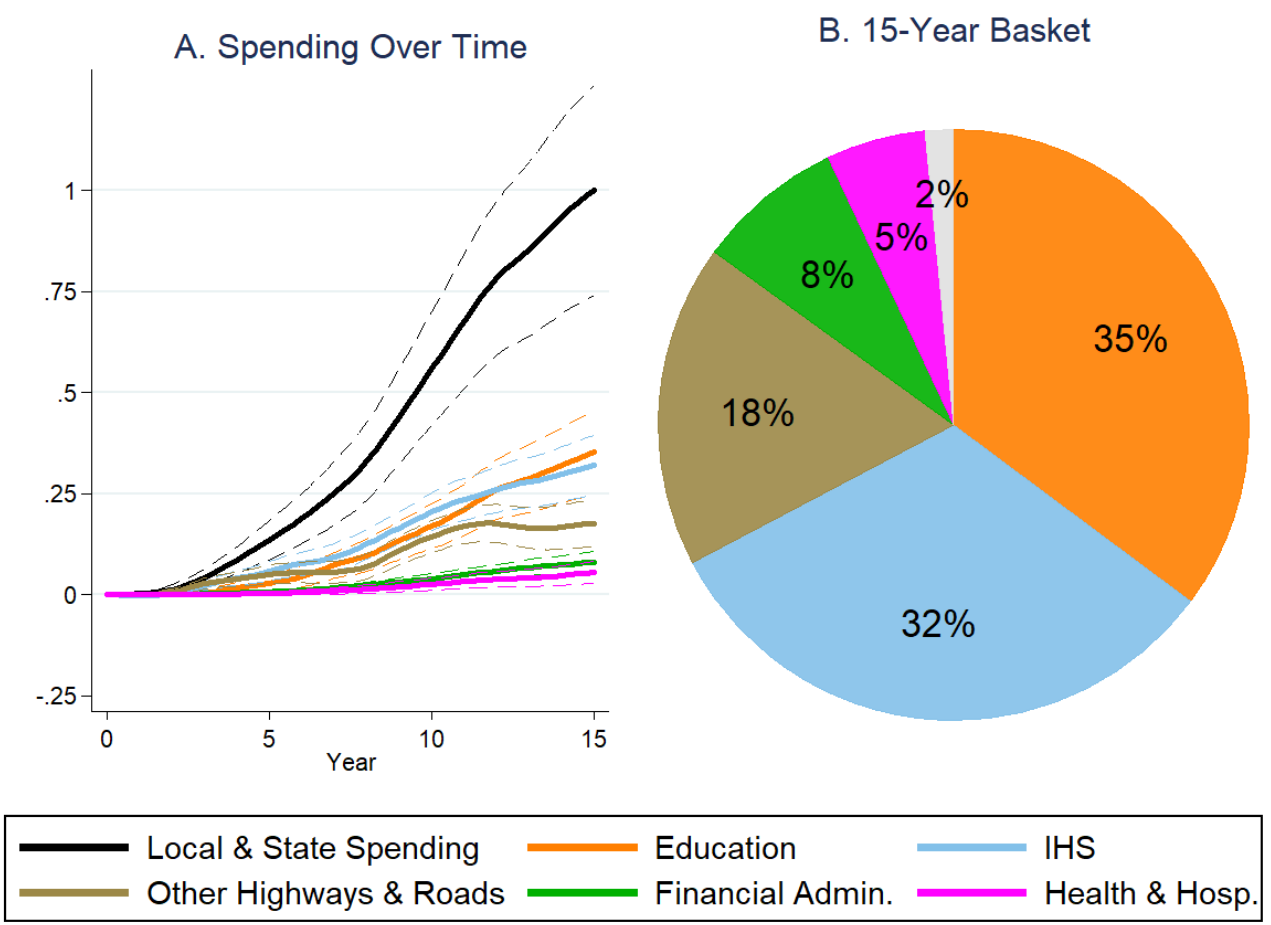
For each USD devoted to IHS construction: (1) states spend \$0.90 more, (b) local governments spend \$1.20 more.

Effect on Population Growth

Spending Crowd-In

- What spending components are driving local+state to increase more than IHS spending?
- Let $w_{i,t}$ denote the spending category of interest.
- To study the effect of the news-shock on $w_{i,t}$, I include it as an endogenous variable in my baseline specification (one category at a time).
- New first stage: look at the coefficient on the news-shock when $\sum_{h=0}^{H} w_{i,t+h}$ is the dependent variable.

Figure 7: The Identified Spending Basket



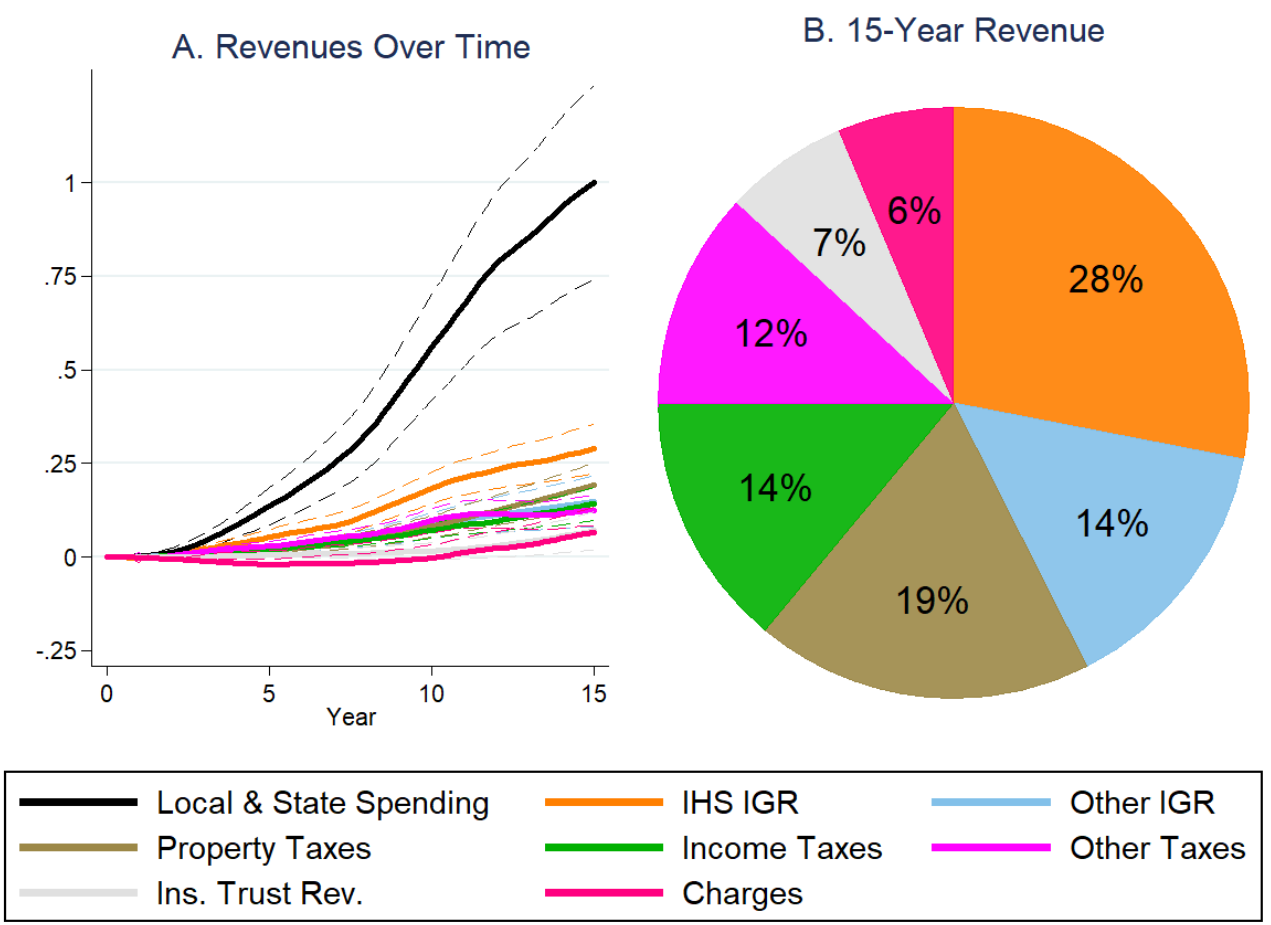
- 5 categories add to 98 cents.

Other Expenditures

State & Local Income

- How is the local & state spending financed?
- Let $w_{i,t}$ denote the income category of interest.
- New first stage: look at the coefficient on the news-shock when $\sum_{h=0}^{H} w_{i,t+h}$ is the dependent variable.

Figure 8: How the Spending is Financed



- 7 categories add to 103 cents.

Other Revenues

More Results

1. Testing Anticipation CLICK
2. Outliers Analysis CLICK

About the Aggregate Multiplier

About the Aggregate Multiplier

- Dupor & Guerrero (2017) show how to estimate aggregate multipliers using state-level data.

$$\mu^A = \mu^R + \text{Spillovers}$$

- The idea is to capture spillovers from spending at other states.

- Their results suggest that relative multipliers can be good estimates of aggregate multipliers if:
  - Spillover impacts are confined to nearby areas.
  - Or multiple spillover effects cancel out in the aggregate.

Spillovers

- In the case of the IHS, neighboring states are the most likely to receive spillovers.
- Let N_i be the set of states that share a border with i.
- Augment system:
  1. New endogenous variable: $\gamma_{i,t+h}$ adds up spending within neighbors.
  2. New instruments: $\lambda_{i,t}^{(A)}$ & $\lambda_{i,t}^{(P)}$ add up the shocks within neighbors (for both area and population).

Table 2: **15-year multiplier with spillovers terms**

	(1)	(2)	(3)
Own G	1.70***	3.32***	2.07***
	(0.32)	(0.49)	(0.41)
Neigh. G		-0.44	
		(0.30)	
All other G			-.01
			(.01)
Total Multiplier	1.70***	2.87***	2.06***
	(0.32)	(0.45)	(0.40)
Kleibergen-Paap F	10.09	1.57	3.89
N	7776	7776	7776

Conclusions

Conclusions

- **Estimate of the relative multiplier of 1.70.**
  - Infrastructure spending can be very productive.
  - Externally valid to similar contexts.
- **Future research should be cautious with**:
  - Crowd-in effects from spending.
  - Multiplier estimates at short horizons when using news-shocks.
- **Preliminary evidence on the aggregate multiplier.**
  - Relative multiplier as a lower bound for the aggregate multiplier.
  - Next steps: need more theory and evidence on this.

Appendix

Table 3: **Local Multipliers Estimated by the Literature**

Authors	**Shock**	**Estimate**
Nakamura & Steinsson (2014)	Military Buildups	1.5
Acconcia et al. (2014)	Political Corruption Law in Italy	1.5
Serrato & Wingender (2010)	Population Estimates	1.9
Shoag (2010)	State Pension Fund Returns	2.1
Leduc & Wilson (2013)	New Highways	6.6

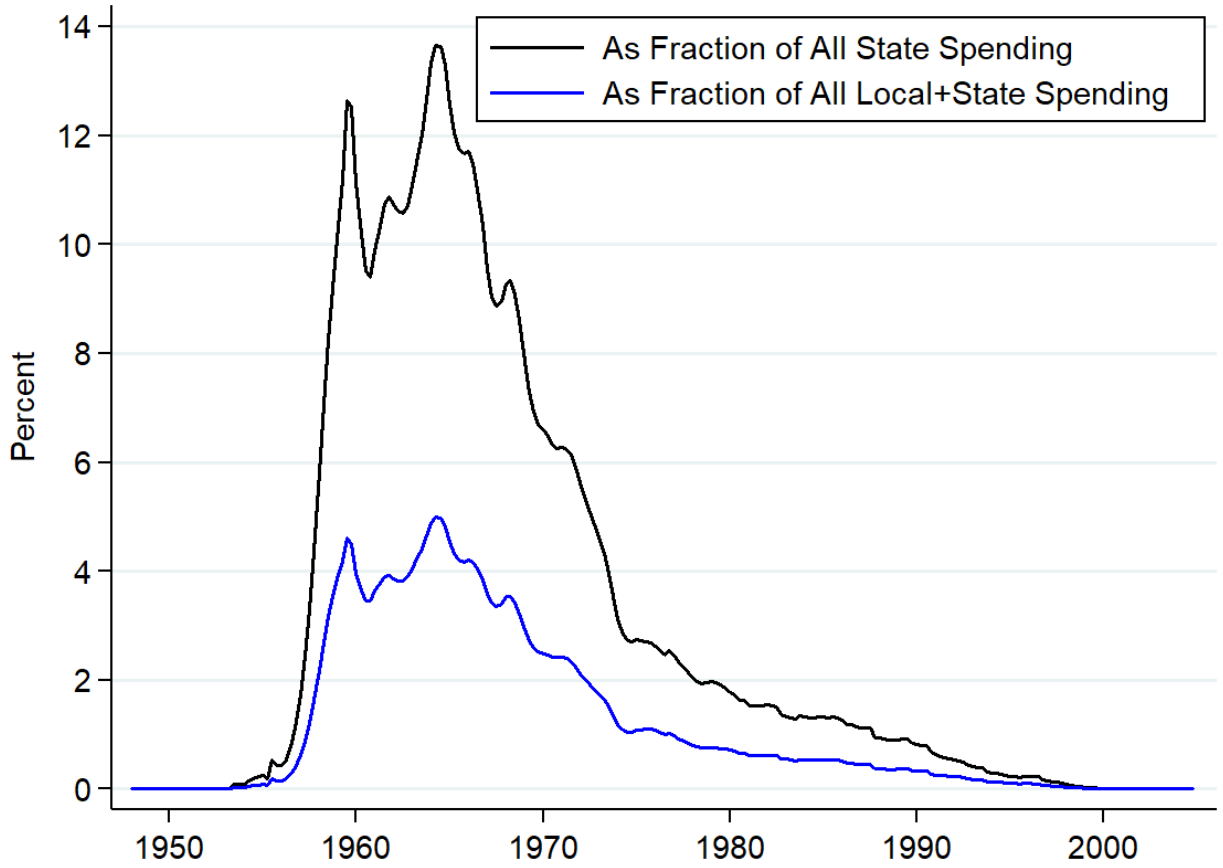
Motivation

Control Variables

- State fixed effects.
- Time fixed effects.
- Lags of y and g.
- 5-year changes of y and g.
- Y_{t-1}, G_{t-1}, and P_{t-1}.
- Lags on population growth.
- 5-year population growth.

Specification

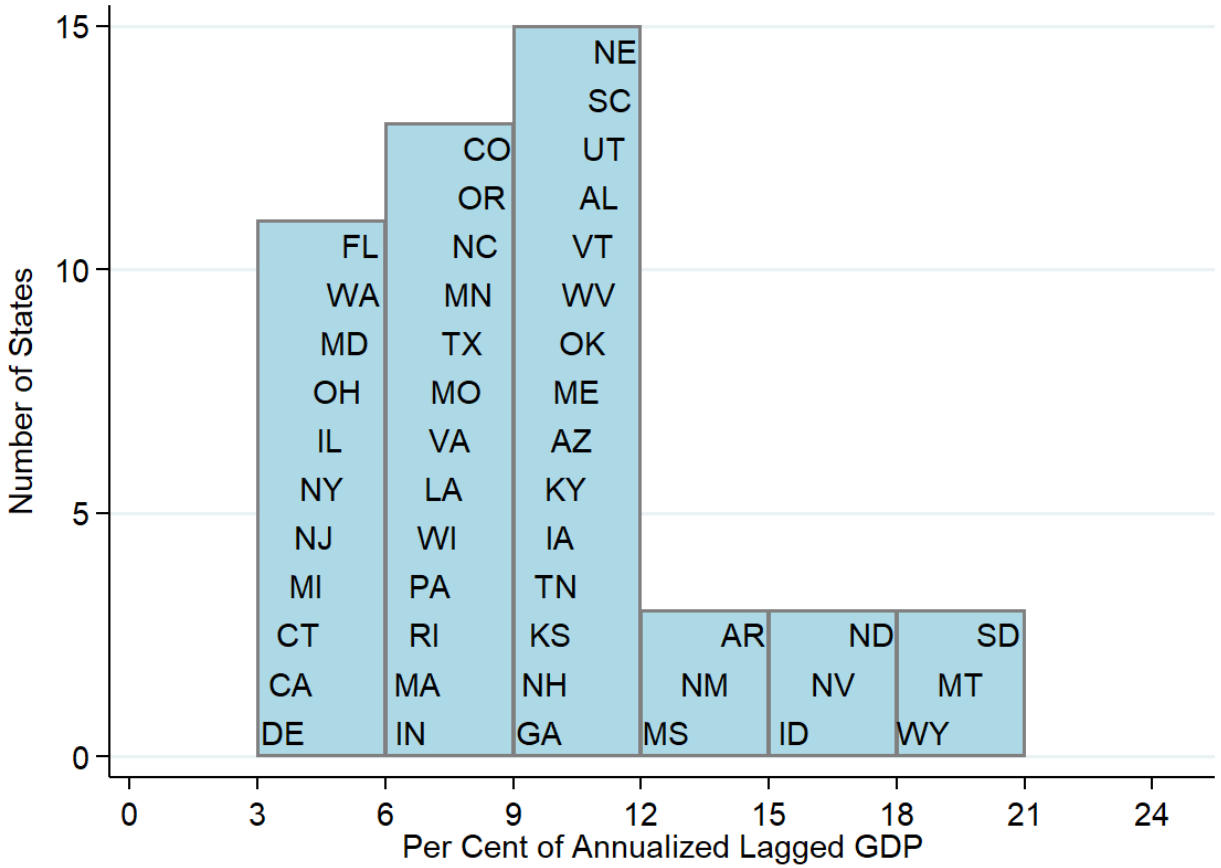
Figure 9: IHS Spending (%)



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$Z_{i,1956,60}$: the shock of 1956

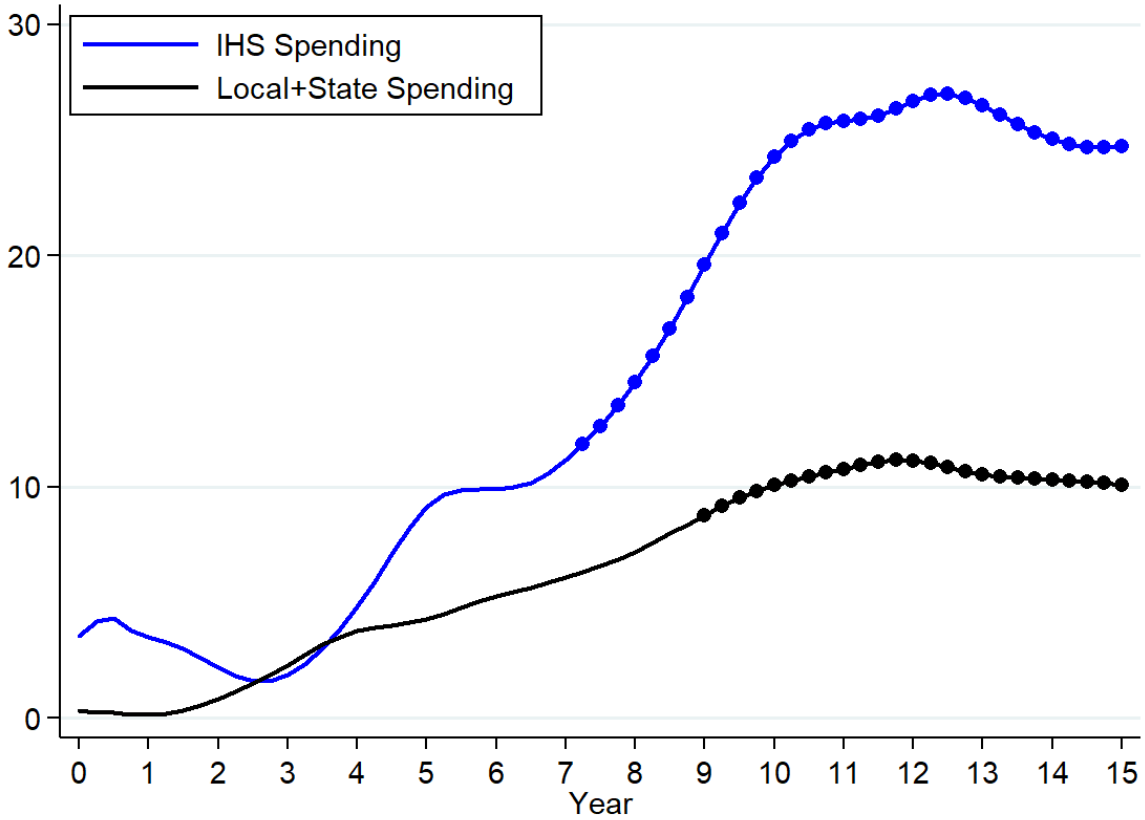
Figure 10: $Z_{i,1956,60}$ (the shock of 1956)



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Instrument Relevance: First stage F-statistic

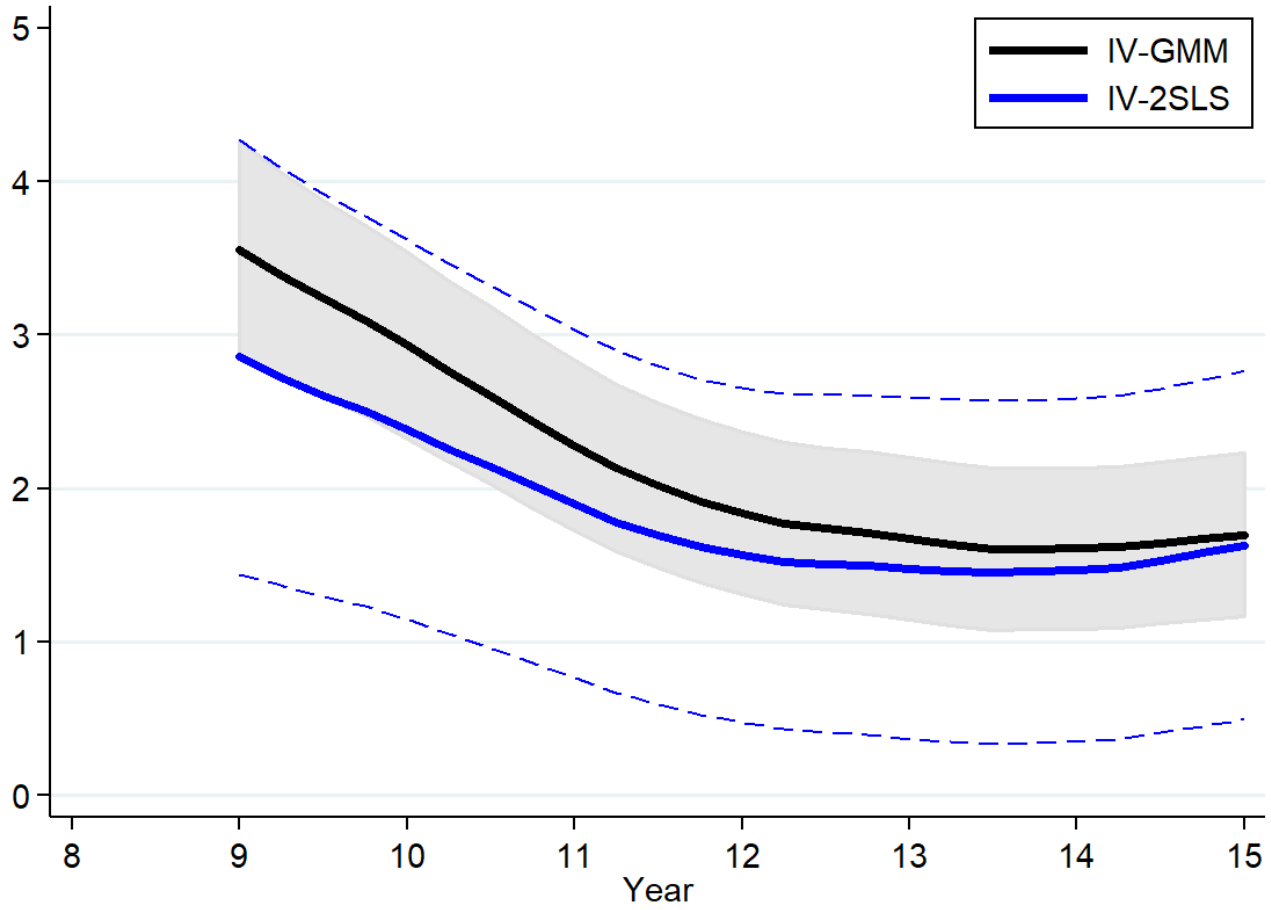
Figure 11: First stage F-statistic



Dots denote horizons where weak instruments are rejected using the the Montiel-Olea & Pflueger (2013) test.

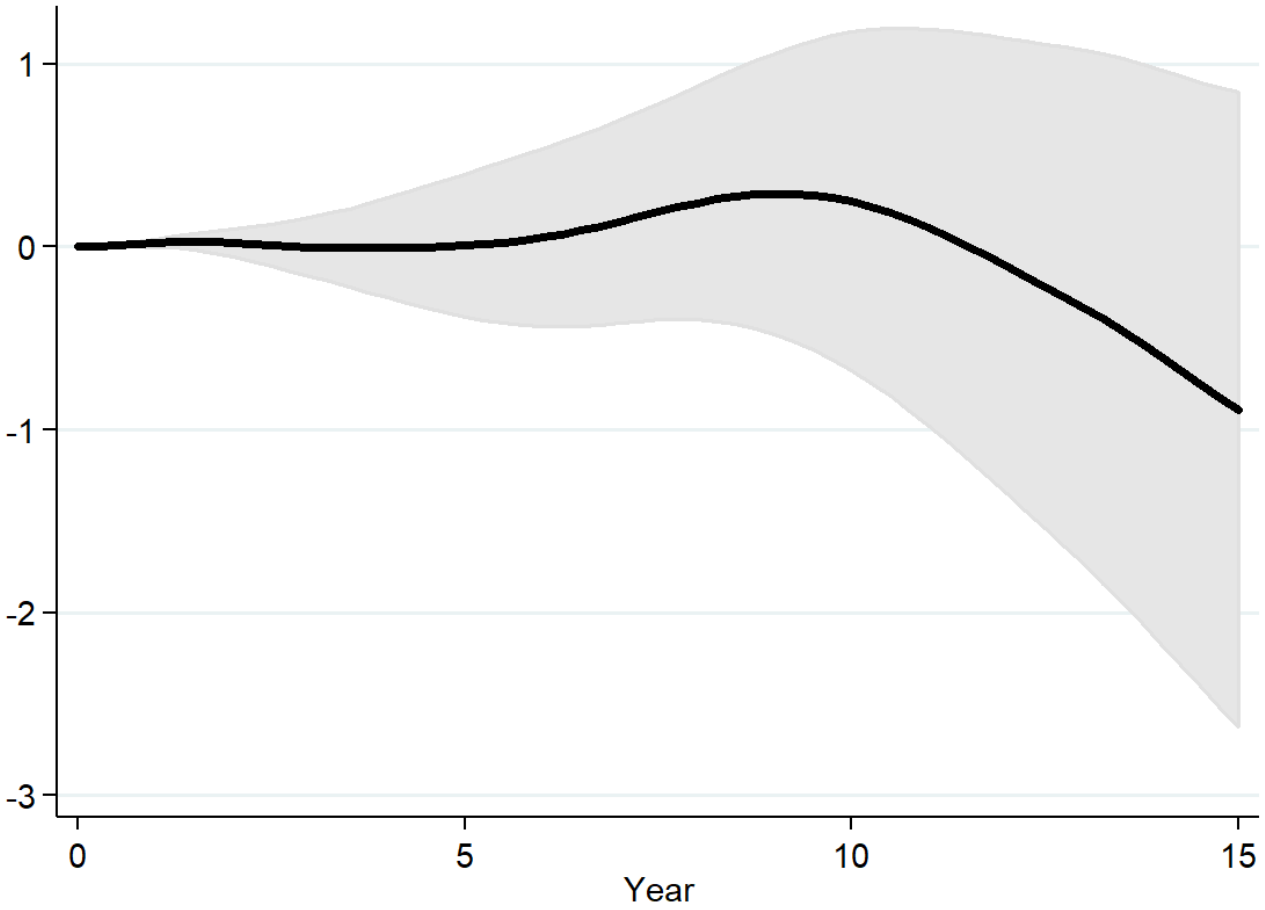
Dynamic Multiplier

Figure 12: Multiplier at Different Horizons



Dynamic Multiplier

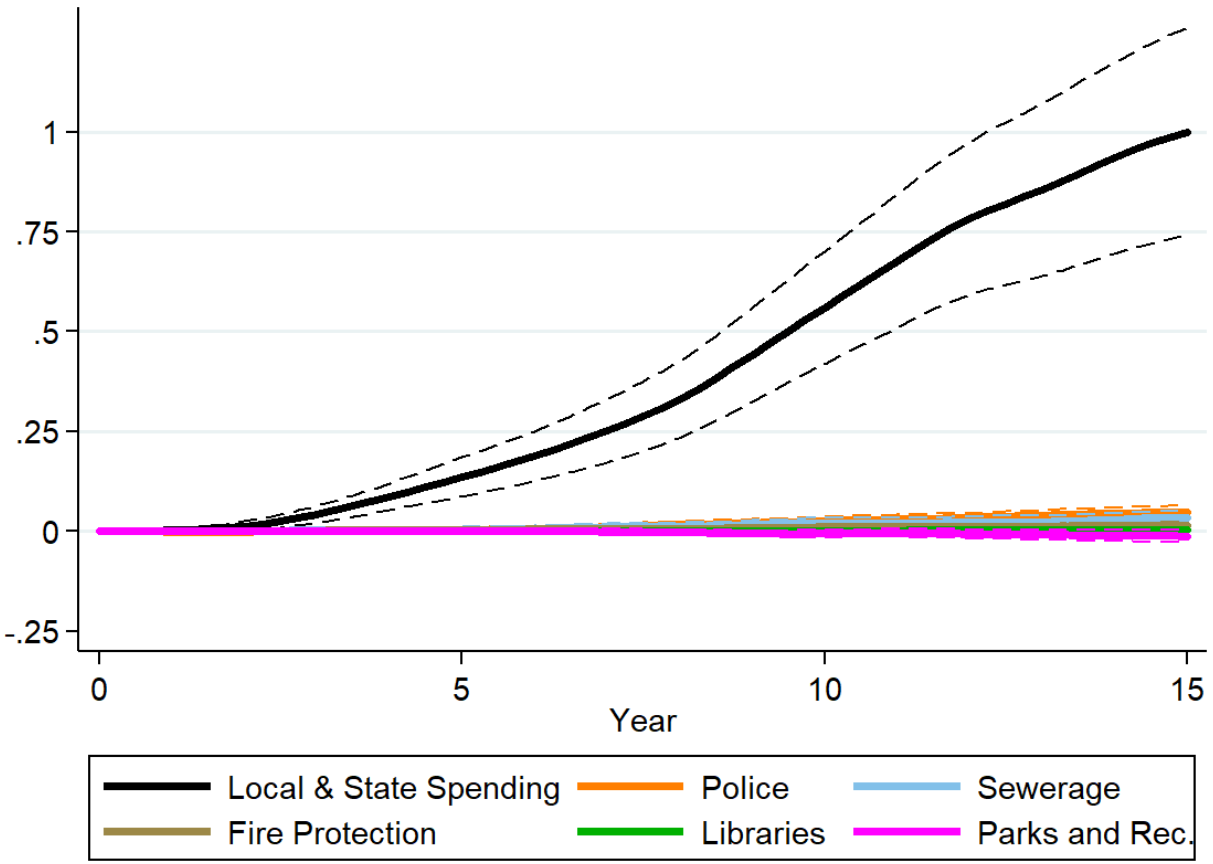
Figure 13: Effect on Population Growth



Cumulative IRFs

Other Spending Categories

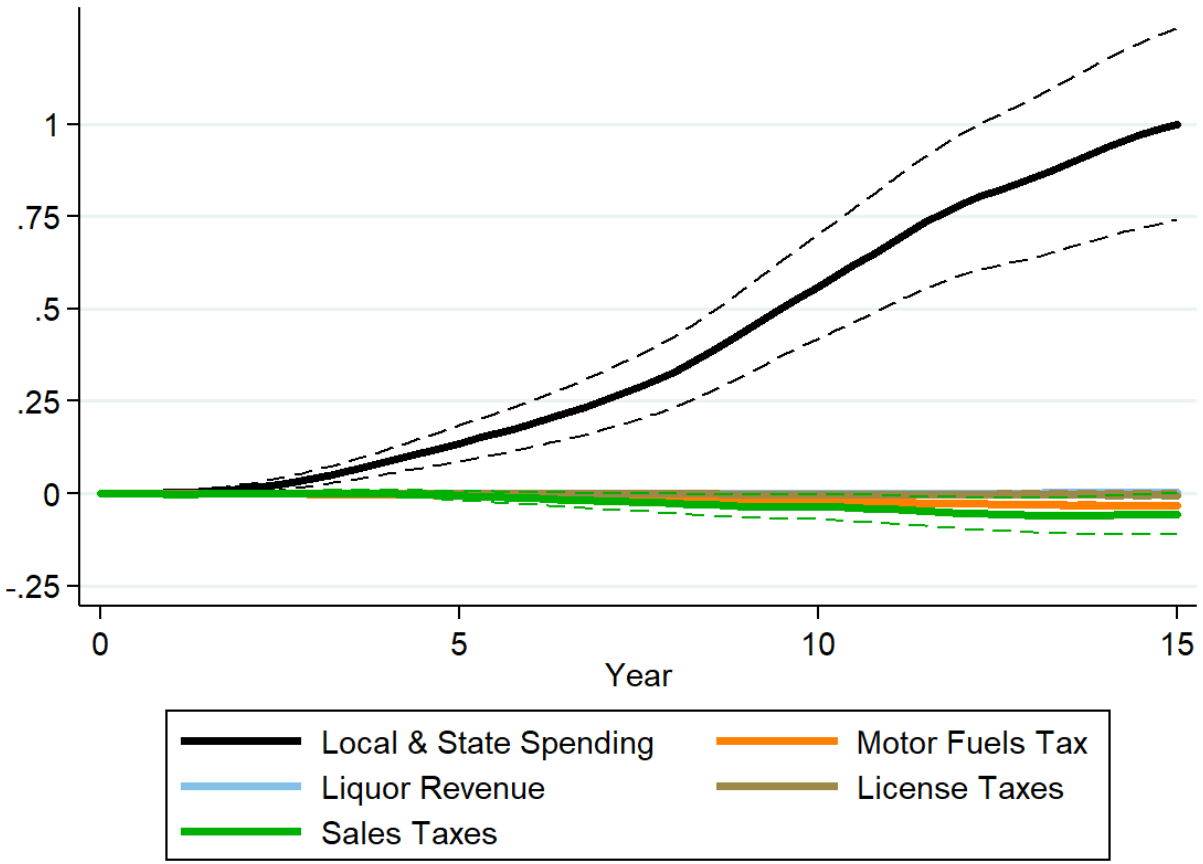
Figure 14: More Spending Categories



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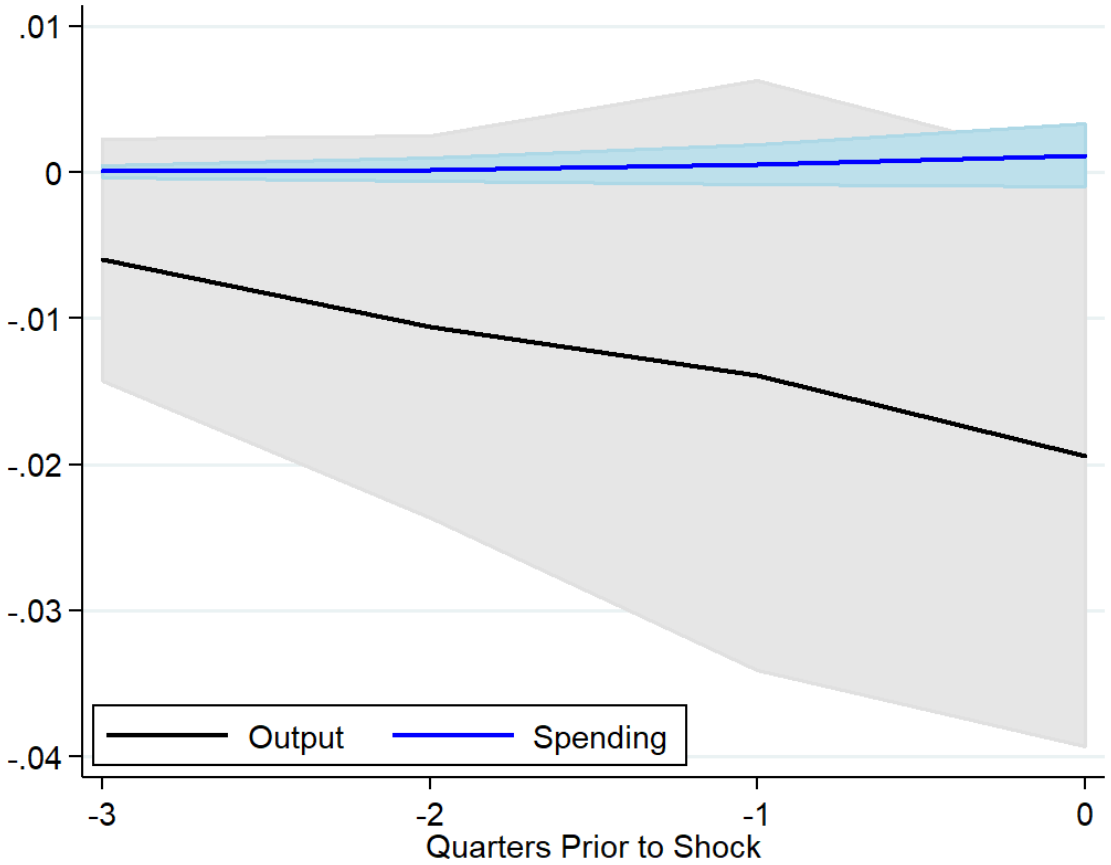
Other Income Categories

Figure 15: More Income Categories



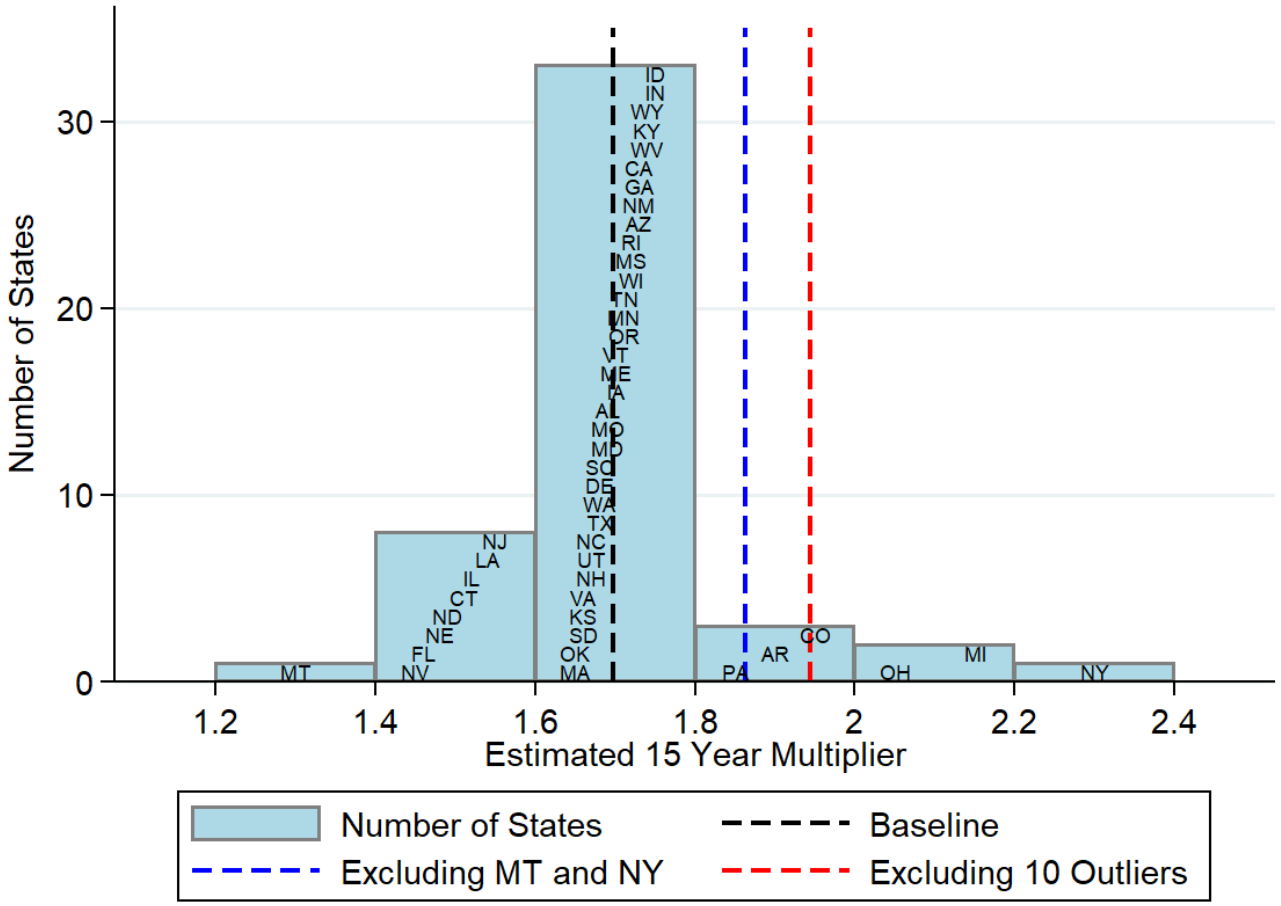
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Figure 16: IRFs Testing Shock Anticipation



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Figure 17: Outlier Analysis



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