# The Interstate Multiplier

Daniel Leff Yaffe

UC, San Diego

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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**

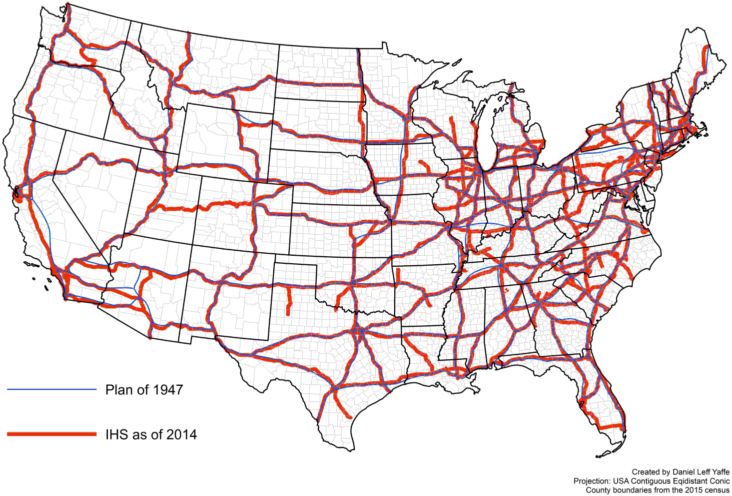
1. Estimate the **relative** multiplier from the **Interstate Highway System (IHS)** construction.
   - Relative multiplier of 1.70.
2. Estimate spillovers across states from the IHS construction.
   - High multicollinearity → hard to uncover spillovers precisely.
   - Preliminary results → aggregate multiplier of at least 1.70.

# 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

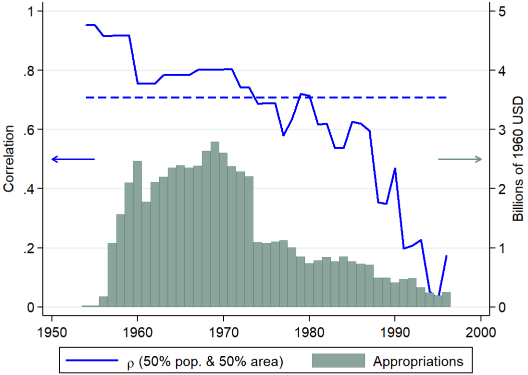
- **Endogeneity** $\rightarrow$ G is not allocated randomly.
- **Anticipation** $\rightarrow$ News about $G$ may directly affect $Y$.
- **Spending Crowd-In** $\rightarrow$ IHS spending affects other types of spending.

# Endogeneity

- Population of 1947 and area shares are correlated with the observed AF ($\sigma_{it}$). 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 $\mu$ since $corr(g_{i,t}, r_{i,t}) \neq 0$.

# Endogeneity

- FE-IV can consistently estimate $\mu$ with the following instrument:

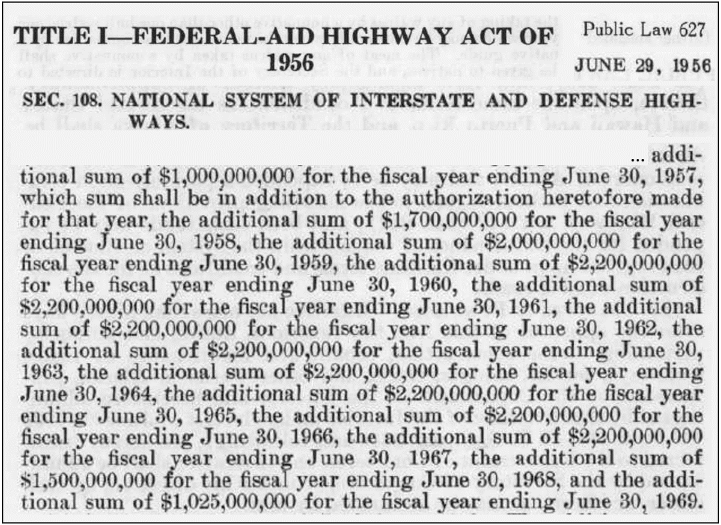
$$z_{i,t} = s_i \sum_i g_{i,t}$$

- If $s_i$ is not known use 2 instruments instead:

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

- 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

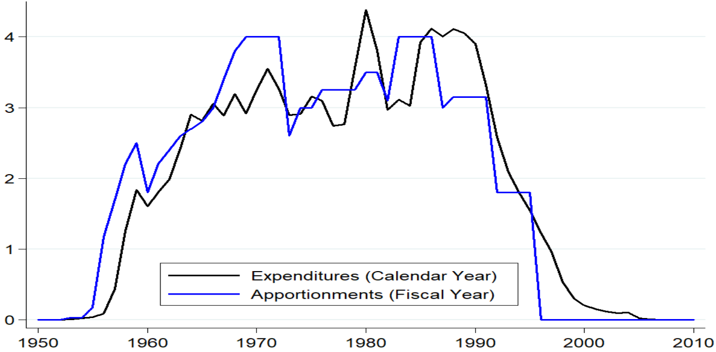
SEC. 108. NATIONAL SYSTEM OF INTERSTATE AND DEFENSE HIGHWAYS.

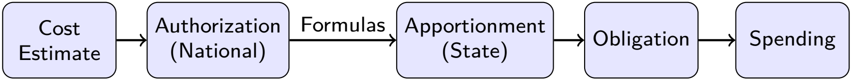
... additional sum of $1,000,000,000 for the fiscal year ending June 30, 1957, which sum shall be in addition to the authorization heretofore made for that year, the additional sum of $1,700,000,000 for the fiscal year ending June 30, 1958, the additional sum of $2,000,000,000 for the fiscal year ending 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 $\mu_H$ instrument $\sum_{h=0}^{H} g_{i,t+h}$ with $\phi_{i,t}$.
  (Local IV Projection)
- The multiplier $\mu_H$ 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. $PDV_{i,t}^{(A)} = \sum_{\tau=0}^{\infty} \beta_t^\tau s_i^{(A)} A_{t+\tau} \rightarrow \phi_{i,t}^{(A)}$

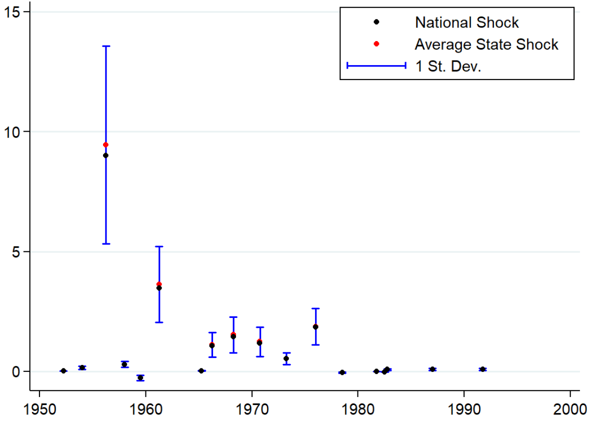
- **Spending Crowd-In** IHS spending may crowd-in other types of $G$ $\rightarrow$ use a broader spending measure.

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

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.

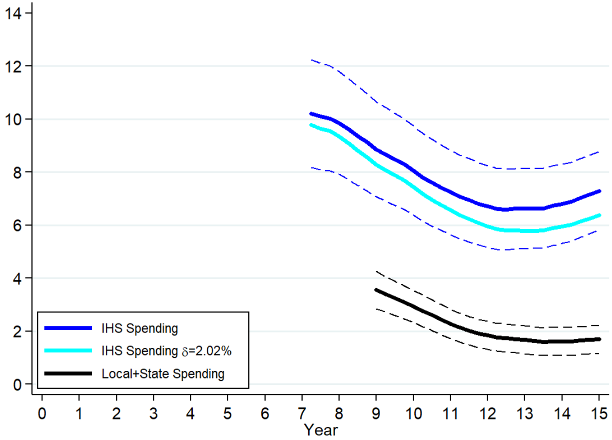
# Cumulative Multiplier at a 15-year horizon

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:
- $\boldsymbol{\beta_y}$ from the **Reduced Form:**

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

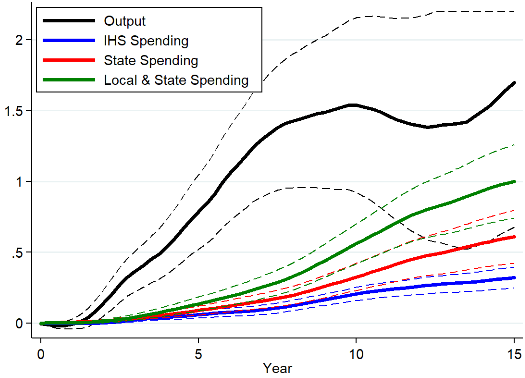
- $\boldsymbol{\beta_g}$ from the **First Stage:**

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

- $\boldsymbol{\beta_{IV}}$ **:**

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

Figure 6: Integral of IRFs for Y and G



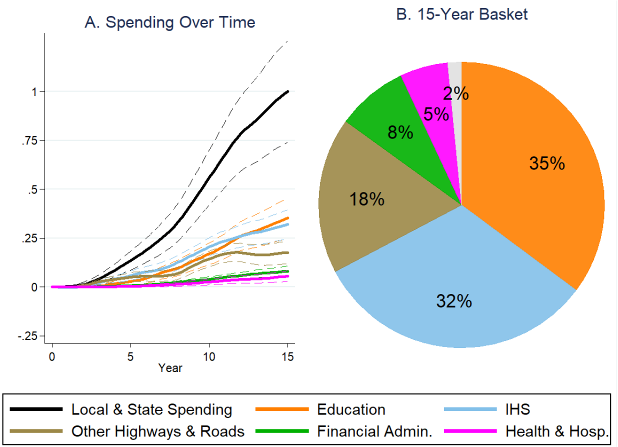

For each USD devoted to IHS construction: (1) states spend $0.90 more, (b) local governments spend $1.20 more.

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



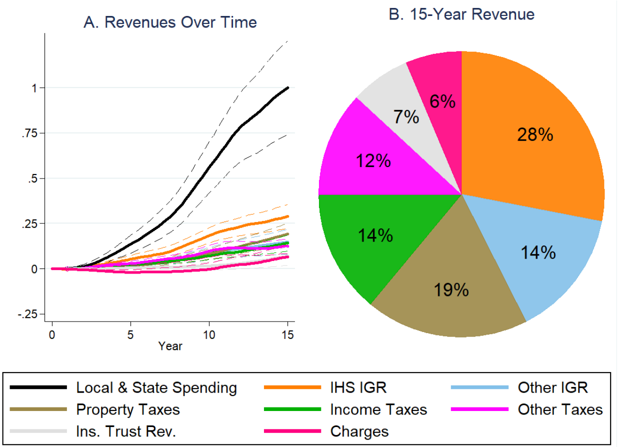

- 5 categories add to 98 cents.

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.

- 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

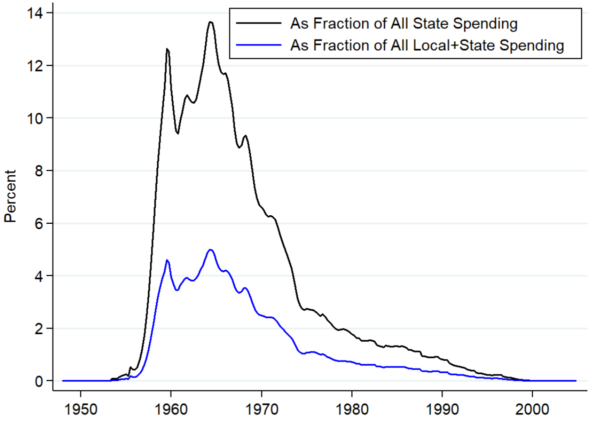
# Control Variables

- 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

# State Expenditures

Figure 9: IHS Spending (%)

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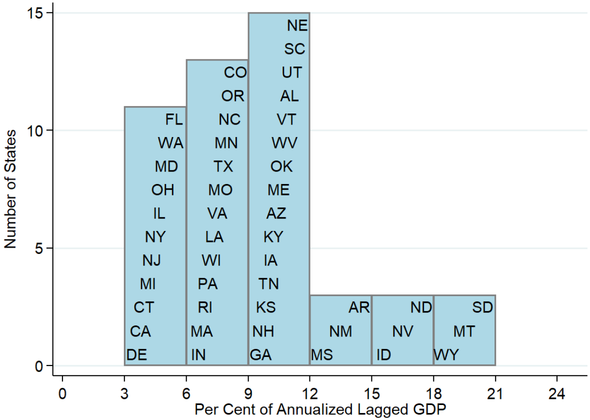
# $Z_{i,1956,60}$: the shock of 1956

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

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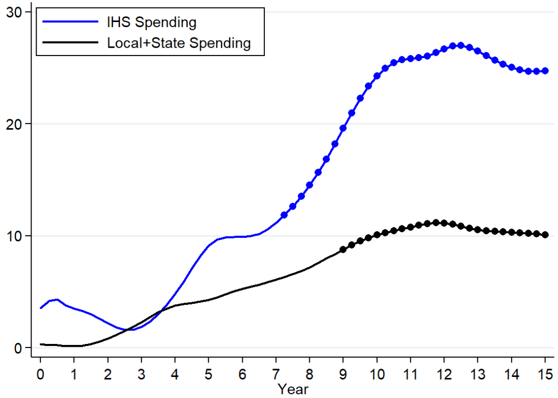
# Instrument Relevance: First stage F-statistic

Figure 11: First stage F-statistic

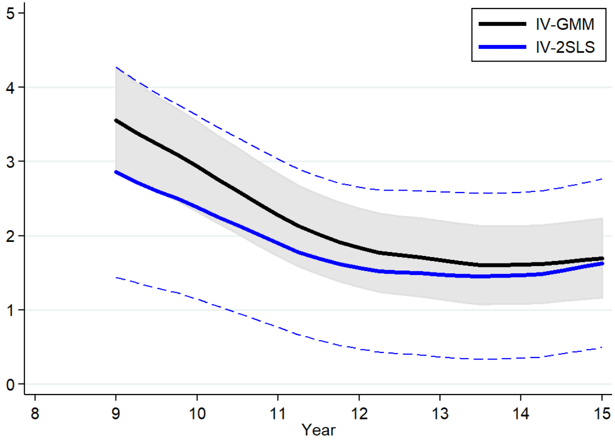



Dots denote horizons where weak instruments are rejected using the the Montiel-Olea & Pflueger (2013) test.

Dynamic Multiplier

# Multiplier

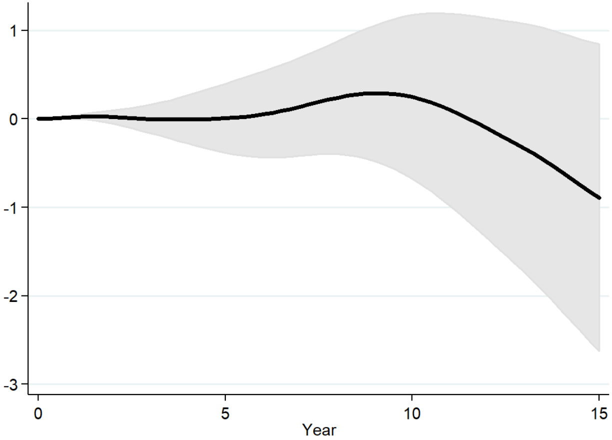
Figure 12: Multiplier at Different Horizons




Dynamic Multiplier

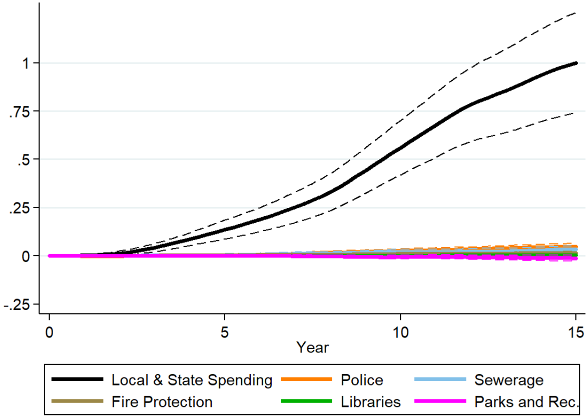
# Multiplier

Figure 13: Effect on Population Growth




Cumulative IRFs

Figure 14: More Spending Categories

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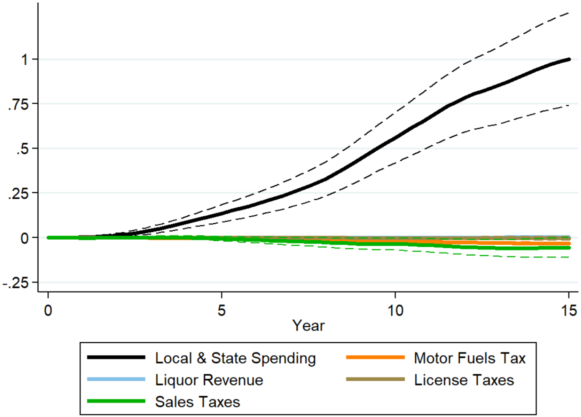
# Other Income Categories

Figure 15: More Income Categories

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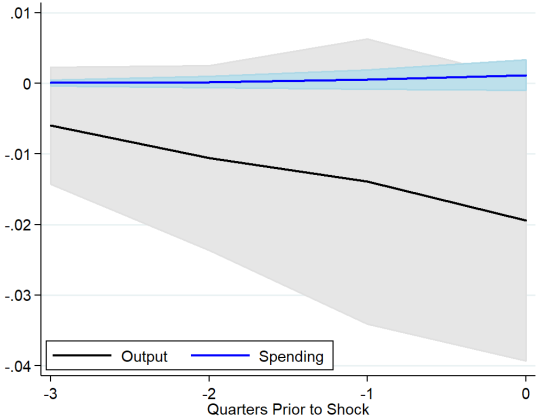
# Testing Anticipation

Figure 16: IRFs Testing Shock Anticipation

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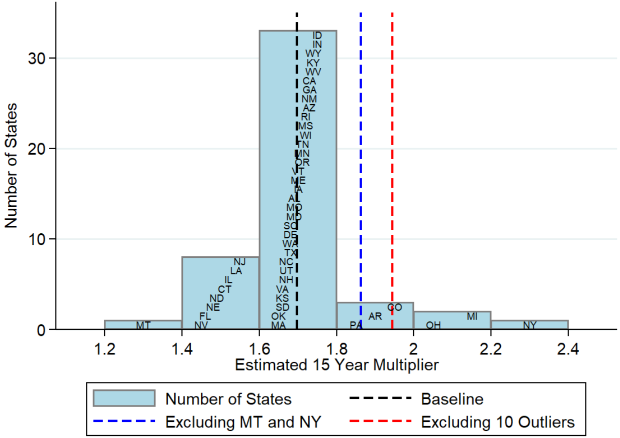
# Outlier Analysis

Figure 17: Outlier Analysis

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