Chapter 8 Empirical Strategies

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Introduction and the Identification Challenge

Introduction

Macroeconomic questions often require quantitative answers: Can a theory explain observed growth or volatility? How do the benefits of a policy compare to its costs?

Key challenge: We cannot perform experiments on the economy. We must estimate causal effects from equilibrium data where many variables are jointly determined.

Four empirical strategies, organized by increasing reliance on theory:

1. **Natural experiments**: find plausibly exogenous variation
2. **Structural VARs**: identify causal effects from time series
3. **Structural estimation**: treat the model as the data-generating process
4. **Calibration**: use external evidence to set parameters, then compare model to data

A Simple Model of Fiscal Policy

Representative household with preferences:

$$U_t = \log c_t - \frac{\ell_t^{1+\psi}}{1+\psi} + \gamma\eta_t \log G_t$$

Production: $y_t = A_t \ell_t$. Resource constraint: $y_t = c_t + G_t$.

A planner choosing $\{c_t, \ell_t, G_t\}$ to maximize U_t subject to the resource constraint obtains:

Supply curve:

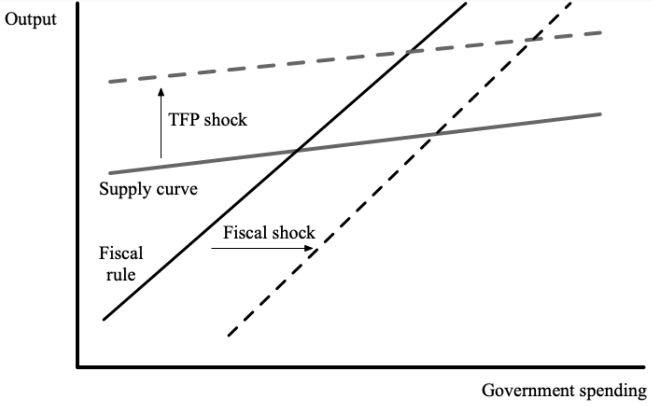
$$y_t = A_t \left(1 - \frac{G_t}{y_t}\right)^{-\frac{1}{1+\psi}}$$

Fiscal rule:

$$G_t = \frac{\gamma\eta_t}{1+\gamma\eta_t} y_t$$

The Identification Challenge

Equilibrium of supply curve and fiscal rule in (G, y) space



Fiscal multiplier: dy/dG when G changes exogenously ($=$ slope of supply curve).

The Identification Challenge

Problem: Data on (G_t, y_t) reflect movements in *both* A_t and η_t. The empirical relationship between y and G does not reveal the slope of either curve.

To estimate the multiplier, we must isolate shifts in the fiscal rule that move the economy **along** the supply curve. All four strategies confront this challenge.

Defining the Multiplier in a Dynamic Economy

In a dynamic setting, the multiplier is not a single number:

- Persistence of G_t matters for the economy's response
- y_t responds on impact and at subsequent dates $\Rightarrow$ an impulse response

Common summary measures:

- **Blanchard-Perotti**: ratio of peak output response to peak spending response
- **Mountford-Uhlig**: cumulative multiplier $= \int$ IRF of y / $\int$ IRF of G

Natural Experiments

Military Spending as a Natural Experiment

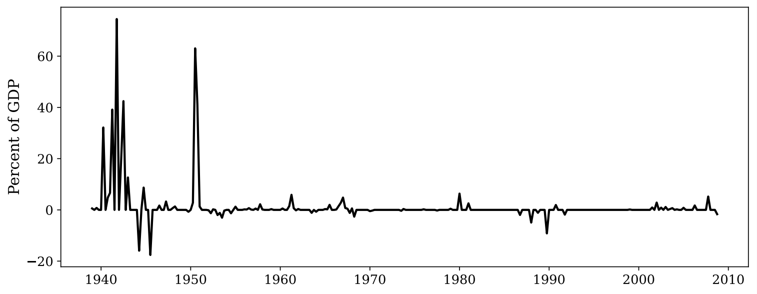
Wars are arguably not caused by economic conditions $\Rightarrow$ war spending is plausibly exogenous to A_t.

Challenge: Spending may have been anticipated before it occurs. If wealth effects matter, the economic impact is felt when agents *learn* about the spending, not when it occurs.

Military Spending as a Natural Experiment

Ramey (2011): Measures the change in expected present value of defense spending each quarter by reading historical newspaper articles.

Change in expected present value of military spending (Ramey, 2011)



Estimated multiplier ≈ 1 (with WWII), ≈ 0.7 (excluding WWII).

Local Projections

Let z_t be exogenous military news. Regress y_{t+h} on z_t for each horizon h:

$$y_{i,t+h} = \beta_{i,h} y_{1,t} + \sum_{j=1}^{J} A_{i,j} y_{t-j} + \varepsilon_{i,h}$$

Varying h traces out an impulse response $\{\beta_{i,h}\}_{h=0}^{H}$. This is a **Jordà (2005) projection**.

Cross-sectional approach: Nakamura and Steinsson (2014) exploit geographic variation in military spending across US states. Estimated multiplier ≈ 1.5.

Caveat: Regional multiplier $\neq$ national multiplier (common effects like taxes and interest rates wash out across states).

Structural Vector Autoregressions

The Structural VAR

$$B_0 Y_t = B_1 Y_{t-1} + B_2 Y_{t-2} + \cdots + B_J Y_{t-J} + \varepsilon_t$$

- $Y_t \in \mathbb{R}^n$: observed data; B_j: $n \times n$ coefficient matrices
- ε_t: structural shocks with causal interpretation, $\text{Var}(\varepsilon_t) = I$
- Each equation represents a structural relationship (e.g., production function, fiscal rule)

Log-linearized example (from the fiscal model, $\bar{\eta} = 1$):

$$\hat{y}_t = \frac{1}{1+\chi}\hat{G}_t + \frac{\chi}{1+\chi}\hat{A}_t, \qquad \hat{G}_t = \hat{y}_t + \frac{1}{1+\gamma}\hat{\eta}_t$$

where $\chi \equiv \frac{\bar{G}/\bar{y}}{(1+\psi)(1-\bar{G}/\bar{y})}$. Endogeneity: G_t is correlated with A_t through the system.

From Structural to Reduced Form

Premultiply by B_0^{-1}:

$$Y_t = \underbrace{B_0^{-1} B_1}_{A_1} Y_{t-1} + \cdots + \underbrace{B_0^{-1} B_J}_{A_J} Y_{t-J} + \underbrace{B_0^{-1} \varepsilon_t}_{u_t}$$

- Reduced-form VAR: can estimate A_j by OLS (no contemporaneous variables)
- Reduced-form residuals u_t are linear combinations of structural shocks
- Var$(u_t) = B_0^{-1} B_0^{-1\prime}$: gives $n(n+1)/2$ restrictions on B_0
- B_0 has n^2 unknowns $\Rightarrow$ need $n^2 - n(n+1)/2 = n(n-1)/2$ additional restrictions

These additional restrictions are **identifying assumptions**.

Identification Strategies

Recursive (Cholesky) identification: Order variables so that the first does not depend on any contemporaneous variable, the second may depend on the first only, etc. Then B_0^{-1} is lower-triangular = Cholesky decomposition of Var(u_t).

Example: Define $\hat{g}_t \equiv \hat{G}_t - \hat{y}_t$. Then $\hat{g}_t = \hat{\eta}_t/(1+\gamma)$ is exogenous, and $\hat{y}_t = \chi\hat{g}_t + \hat{A}_t$. No endogeneity problem.

Blanchard and Perotti (2002): Timing restriction—fiscal policy cannot respond to GDP within a quarter (data lag + legislative lag). Multipliers ≈ 1.

Other approaches: Sign restrictions (Uhlig, 2005), long-run restrictions (Blanchard-Quah, 1989), external instruments.

Limitations of SVARs

Invertibility assumption: Reduced-form innovations u_t are linear combinations of structural shocks ε_t *at the same date*. Requires that Y_t and its lags summarize all relevant information.

If the VAR omits useful information: forecast surprises arise from imperfect information, not structural shocks $\Rightarrow$ mis-identification.

Tension: Richer information set $\Leftrightarrow$ more parameters $\Leftrightarrow$ overfitting.

Appeal of SVARs: Few assumptions on dynamics. **Appeal of structural models**: Explicit mechanisms, welfare analysis, connection to micro data.

VARs vs. Local Projections

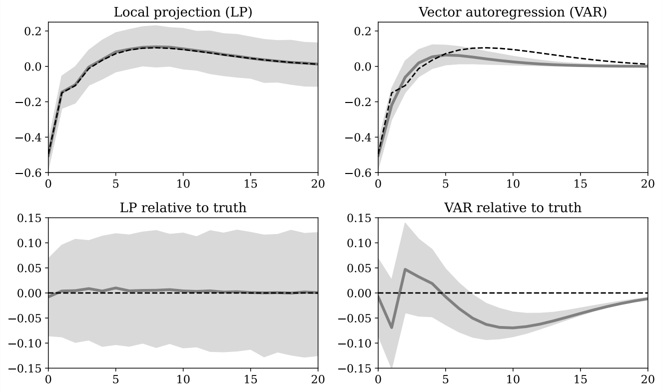
Comparison

Local projection at horizon h: regresses y_{t+h} directly on $y_{1,t}$ (and lags). Estimates one horizon at a time. Flexible but noisy at long horizons.

VAR: Estimates one-step-ahead dynamics; extrapolates IRFs from A^h. Tighter confidence bands but potentially biased if VAR order mis-specified.

Comparison

Bias-variance tradeoff: Bias-variance tradeoff in simulated data



Plagborg-Møller and Wolf (2021): reduced-form VAR IRFs can be combined to replicate LP estimand.

A Structural Model of Fiscal Policy

The Model

Production: $y_t = A_t k_t^{\alpha} \ell_t^{1-\alpha}$

Capital accumulation: $k_{t+1} = (1-\delta)k_t + I_t$

Resource constraint: $y_t = c_t + k_{t+1} - (1-\delta)k_t + G_t$

Exogenous processes:

$$A_t = (1-\rho_A) + \rho_A A_{t-1} + \varepsilon_{A,t}$$

$$\eta_t = (1-\rho_\eta) + \rho_\eta \eta_{t-1} + \varepsilon_{\eta,t}$$

Equilibrium Conditions

Euler equation:

$$\frac{1}{c_t} = \beta \mathbb{E}_t \left[\frac{1}{c_{t+1}} (1 + r_{t+1} - \delta) \right]$$

Labor supply: $w_t / c_t = \ell_t^{\psi}$

Factor prices: $r_t = \alpha y_t / k_t$, $w_t = (1 - \alpha) y_t / \ell_t$

Government: $\gamma \eta_t / G_t = 1 / c_t$ (equates marginal benefit and marginal cost of public spending)

Government budget: $T_t = G_t$ (lump-sum taxes, non-distortionary)

An equilibrium is $\{k_t, c_t, y_t, \ell_t, G_t, r_t, w_t, A_t, \eta_t\}$ satisfying all these conditions.

Intuition for the Fiscal Multiplier

Without investment response: Two ways to finance G:

- Consume less $\Rightarrow$ multiplier $= 0$
- Work more $\Rightarrow$ multiplier $= 1$

Negative wealth effect from lump-sum taxes $\Rightarrow$ both $\Rightarrow$ multiplier $\in (0, 1)$.

With investment response: A third channel—invest less to free resources.

- Transitory shock: reducing I helps smooth $c \Rightarrow$ less need to work more $\Rightarrow$ lower multiplier
- Persistent shock: "borrow from the future" is less effective $\Rightarrow$ higher multiplier

$\Rightarrow$ The fiscal multiplier is **increasing in the persistence** ρ_η.

Structural Estimation

Likelihood in the Static Model

Given observables (y_t, G_t), invert the model to recover shocks:

$$A_t = y_t \left(1 - \frac{G_t}{y_t}\right)^{\frac{1}{1+\psi}}, \qquad \eta_t = \frac{G_t/y_t}{\gamma(1 - G_t/y_t)}$$

Sample likelihood:

$$\text{Prob}(\{G_t, y_t\}_{t=1}^T | \psi, \gamma) = \prod_{t=1}^T p_A(A_t) \times p_\eta(\eta_t)$$

Identification comes from the functional form of the fiscal rule: G/y is not affected by TFP shocks $\Rightarrow$ movements in G/y identify fiscal shocks.

The Kalman Filter

In the dynamic model, states (k_t, A_t, η_t) are unobserved. Linearize:

$$\hat{X}_{t+1} = A(\theta)\hat{X}_t + B(\theta)\varepsilon_{t+1}$$

$$\hat{Y}_t = C(\theta)\hat{X}_t$$

where $X_t = (k_t, A_t, \eta_t)'$, $Y_t = (y_t, G_t)'$, $\theta =$ parameter vector.

With $\varepsilon \sim N(0, I)$: $X_t | Y_{1:t-1} \sim N(X_{t|t-1}, P_{t|t-1})$. Likelihood:

$$\text{Prob}(\{Y_t\}_{t=1}^{T} | \theta) = \prod_{t=1}^{T} N\big(Y_t \,\big|\, C(\theta)X_{t|t-1},\ C(\theta)P_{t|t-1}C(\theta)'\big)$$

The Kalman filter recursively updates $(X_{t|t-1}, P_{t|t-1})$ as new data arrive. Then maximize likelihood (MLE) or use Bayes' rule (Bayesian estimation).

Calibration

Calibration Strategy

Set parameters using evidence **outside** the data of interest (the fiscal multiplier itself).

- $\alpha = 1/3$: capital share from NIPA
- $\delta = 0.019$ (quarterly): from $I/K = 0.076/4$
- $\beta = (1 + \alpha\bar{y}/\bar{k} - \delta)^{-1} = 0.994$: from $\bar{k}/\bar{y} = 3.3 \times 4$ (quarterly)
- $\gamma = 0.3$: ratio of public to private consumption
- ρ_η: report results for a range of values

Calibrating Labor Supply: ψ

$\psi =$ inverse Frisch elasticity of labor supply. Two sources of evidence:

Frisch elasticity: Tax-rate variation $\Rightarrow 1/\psi \approx 1/2$, so $\psi \approx 2$ (Chetty, 2012).

Wealth effects: Golosov, Graber, Mogstad, and Novgorodsky (2021) use lottery winners. Winning \$100 $\Rightarrow$ \$2.30 drop in annual earnings. From the labor supply FOC:

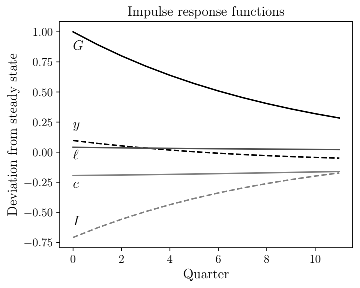
$$\text{change in annual earnings} = -\$2.30 = -\frac{4w\ell}{\psi c} \cdot \frac{r}{1+r} \cdot \$100$$

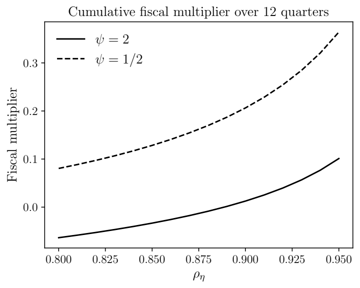
With $r = 0.01$ (quarterly), $w\ell/c = 1.2$: $\psi = 2.1$.

Both sources point to $\psi \approx 2$.

Results

IRFs following a fiscal shock (left); cumulative multiplier over 12 quarters (right)





Left panel: Bulk of adjustment through $\downarrow I$; small $\uparrow \ell$; y initially rises then falls below steady state as k declines. Cumulative multiplier ≈ 0.

Right panel: Multiplier increasing in ρ_η (persistent shocks limit the investment channel). Multiplier larger when ψ smaller (more elastic labor supply).

General Principles of Calibration

1. **Understand the economics**: Know which mechanisms drive the answer; calibrate parameters governing those mechanisms with particular care
2. **Discipline the mechanisms**: Seek evidence that speaks directly to the strength of key channels (micro studies with quasi-experimental variation are especially attractive)
3. **Robustness**: Report sensitivity to parameter values and to the model's assumptions
4. **Model validation**: If additional empirical evidence is available, check whether the calibrated model matches it

Summary

Comparing the Four Strategies

Natural experiments: Compelling identification; may not generalize. Increasingly used as calibration targets.

Structural VARs: Few assumptions on dynamics; flexible IRFs. Limited by invertibility and identification.

Structural estimation: Model = data-generating process. Full likelihood but conclusions depend on the model.

Calibration: Parameters from external evidence; asks whether model mechanisms can explain the data. Transparent about what the model can and cannot do.

Researchers often combine methods: natural experiments $\rightarrow$ calibration targets $\rightarrow$ structural model $\rightarrow$ policy counterfactuals.

Key Takeaways (I)

1. **Identification challenge**: Equilibrium data reflect multiple simultaneous shocks. Estimating a causal effect requires isolating exogenous variation.
2. **Natural experiments**: Military spending (Ramey, 2011), cross-state variation (Nakamura-Steinsson, 2014), lottery winners (Golosov et al., 2021). Local projections (Jordà, 2005) trace out IRFs horizon by horizon.
3. **Structural VARs**: $B_0 Y_t = \sum_{j=1}^{J} B_j Y_{t-j} + \varepsilon_t$. Reduced form estimable by OLS; need $n(n-1)/2$ identifying restrictions on B_0. Recursive/Cholesky, timing restrictions, sign restrictions, long-run restrictions.
4. **VARs vs. local projections**: Bias-variance tradeoff. LP: flexible, wide bands. VAR: tighter bands, potential bias from mis-specification.

Key Takeaways (II)

5. **Structural model**: Dynamic fiscal model with capital. Euler equation, labor supply FOC, factor pricing, government optimality. Multiplier depends on persistence ρ_η and labor elasticity $1/\psi$.
6. **Structural estimation**: Invert model for shocks $\rightarrow$ likelihood. Dynamic models: Kalman filter for unobserved states; linear-Gaussian state-space. MLE or Bayesian.
7. **Calibration**: Set parameters from external evidence (α from factor shares, δ from I/K, ψ from micro studies). Report robustness. Model validation with additional evidence.
8. **Fiscal multiplier**: Wealth effects alone yield multipliers near zero (investment channel absorbs the shock).