

How Ricardian Are We?

Jonathan J. Adams



Christian Matthes



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Question: How Ricardian Are Households?

How much of their future tax burden do households take into account today?

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Object of Interest

θ = degree to which future taxes offset the consumption effect of a current transfer

$\theta = 1$: full tax offset. $\theta < 1$: debt-financed transfers raise consumption.

From the Ricardian Question to Two MPCs

- MPC: consumption response to an extra dollar of net worth.
- MPC-DFT: response to a dollar transferred today and financed by future taxes.

A Common Relationship

$$\text{MPC-DFT} = \text{MPC}(1 - \theta) \quad \implies \quad \theta = 1 - \frac{\text{MPC-DFT}}{\text{MPC}}.$$

This relationship holds across the theories we use to motivate our empirical approach.

This paper:

- Theory: derive a consumption function; compare coefficient restrictions.
- Identification: use external macro shocks as instruments.
- Estimation: jointly estimate consumption and expectations.
- Application: connect government debt to foreign borrowing.

The Consumption Function

Start With Two Household Conditions

$$n_{t-1} + y_t = c_t + \tau_t + \bar{B}q_t + \beta n_t,$$

$$q_t = \beta \tilde{\mathbb{E}}_t \left[\frac{\gamma}{\bar{C}} (c_t - c_{t+1}) \right] + z_t^d.$$

Household expectations $\tilde{\mathbb{E}}$ allow bounded rationality:
one source of non-Ricardian behavior.

- c : consumption; n : wealth; y : income; τ : net taxes.
- q : bond price; z^d : Euler wedge.
- β : discount factor; γ : curvature.

Steady-state deviations; bars denote steady-state levels.

Definitions and assumptions

Forward Iteration Gives A Consumption Function

Define the perceived present value of a flow x_t :

$$\tilde{v}_t^x = x_t + \beta \tilde{\mathbb{E}}_t[\tilde{v}_{t+1}^x].$$

Consumption function

$$c_t = (1 - \beta)(n_{t-1} + \tilde{v}_t^y - \tilde{v}_t^r) + D_q \tilde{v}_t^q + \zeta_t.$$

Here $D_q = \bar{C}/\gamma - (1 - \beta)\bar{B}$; ζ_t is the consumption disturbance.

The income, tax, and bond-price PVs depend on unobserved expectations.

Derivation

Government debt b and spending g satisfy

$$b_{t-1} = \tau_t - g_t + \bar{B}q_t + \beta b_t.$$

Objective liability under the no-bubble condition

$$\beta \mathbb{E}_t[v_{t+1}^\tau] = b_{t-1} - \tau_t + v_t^g - \bar{B}v_t^q.$$

- $v_t^x = x_t + \beta \mathbb{E}_t[v_{t+1}^x]$ is a rational PV.
- This is an accounting identity, not a household belief.

The restriction on future tax beliefs

$$\tilde{\mathbb{E}}_t[\tilde{v}_{t+1}^T] = \theta \mathbb{E}_t[v_{t+1}^T].$$

- $\theta = 1$: households account for the full future liability.
- $\theta = 0$: future taxes do not enter their decision.
- Current taxes are observed without attenuation.

Income and bond-price beliefs need not use the same θ .

Two Coefficients Recover θ

After the government-budget substitution,

$$c_t = \phi_n n_{t-1} + \phi_\tau \tau_t + \cdots + \zeta_t.$$

In this baseline derivation,

$$\phi_n = 1 - \beta, \quad \phi_\tau = -\phi_n(1 - \theta).$$

From two MPCs to θ

$$\theta = 1 + \frac{\phi_\tau}{\phi_n}$$

Wealth MPC: ϕ_n . MPC-DFT: $-\phi_\tau$.

The MPC relationship holds across our specifications. Full consumption equation

What Happens with Other Specifications?

The two-MPC relationship remains

$$\theta = 1 - \frac{\text{MPC-DFT}}{\text{MPC}} = 1 + \frac{\phi_{\tau}}{\phi_n}.$$

- Discounting wedges: a different wealth MPC and PV weights.
- External habits: a habit state and a lower wealth MPC.
- Hand-to-mouth households: different debt and spending restrictions, and income controls.

Discounting

Habits

Hand-to-mouth

Conditional model restrictions

Expectations and PV restrictions

Identifying the Consumption Function

Why Is OLS Biased?

$$c_t = \phi_n n_{t-1} + \phi_\tau \tau_t + \cdots + \zeta_t.$$

ζ_t is the unobserved consumption disturbance.

- This disturbance also moves wealth, income, and returns.
- Endogeneity biases the OLS estimate of ϕ_τ .

We need regressor variation that is orthogonal to ζ_t .

Partial-regression argument

Ricardian limit

I.i.d. versus persistent shocks

External shock $\longrightarrow$ Regressors $\longrightarrow c_t$

Instrument Requirements

- Relevance: the shock moves consumption determinants.
- Exclusion: it does not enter the consumption residual.

Barnichon and Mesters (2020).

Moments and rank

Testing the IV Strategy

Population Regressions Isolate Identification Bias

- A closed economy with capital and government debt.
- Vary true θ and the size of demand shocks.
- Calculate coefficients from population moments.

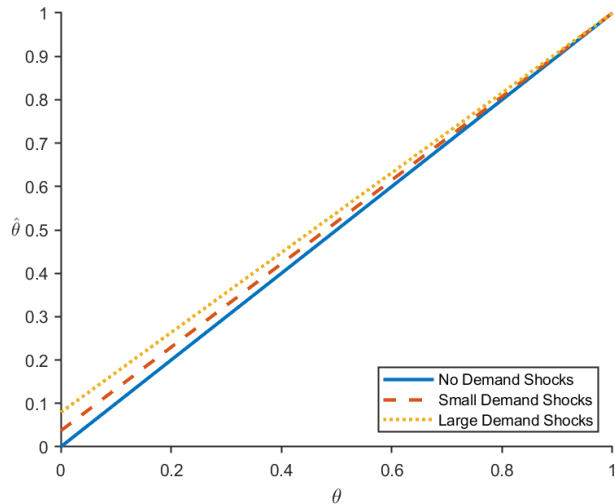
Model and calibration

Three Regressions, Different Sources of Variation

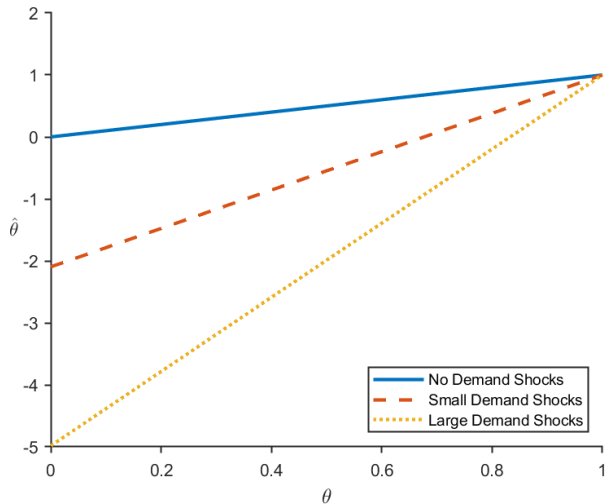
- OLS: the full consumption equation.
- Lag-IV: instrument with lagged aggregates.
- Shock-IV: instrument with external innovations.

Regressions and transformation

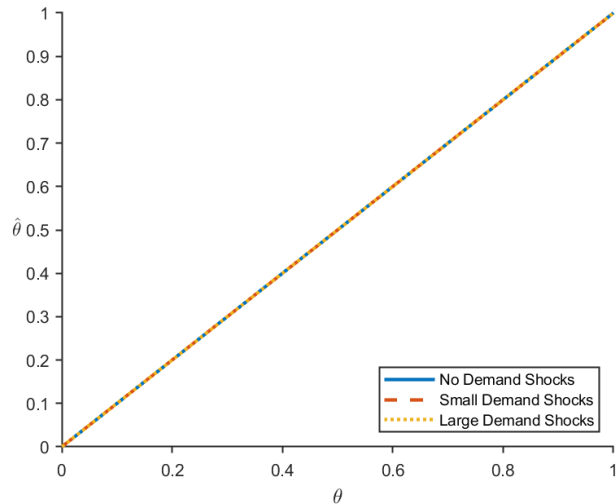
Demand Shocks Bias Population OLS



Persistent Demand Shocks Invalidate Lagged IVs



External-Shock IV Recovers the Target in This Design



Why Go Beyond Standard IV?

Why Bayesian Inference Is Useful Here

1. Economic restrictions enter as prior support, including $0 \leq \theta \leq 1$.
2. Priors regularize a parameter-rich system in a short macro sample.
3. State-space methods accommodate noisy instruments and unequal sample coverage.
4. Compare prior and posterior distributions and assess prior sensitivity.

Inference is conditional on the state-space model and the prior.

B-HIVE: Bayesian Hybrid IV Estimator.

Model equations

Unknown Present Values: Estimate the State Dynamics

$X_t \in \mathbb{R}^m$ collects the predictors, excluding consumption.

$$X_t = \mu_X + \sum_{\ell=1}^p A_\ell X_{t-\ell} + G\varepsilon_t,$$

$$\zeta_t = \rho_\zeta \zeta_{t-1} + h_c \varepsilon_{c,t}, \quad |\rho_\zeta| < 1.$$

$\varepsilon_t = (\varepsilon_{c,t}, \varepsilon'_{X,t})' \stackrel{\text{i.i.d.}}{\sim} N(0, I_{m+1})$; $\varepsilon_{c,t}$ is the consumption innovation.

ρ_ζ controls residual persistence; h_c scales the innovation.

The companion state $\bar{X}_t$ determines the time-varying PV terms:

$$v_t^j = s_j'(I_{mp} - \beta F)^{-1} \bar{X}_t, \quad j \in \{y, g, q\}.$$

F : VAR companion matrix; s_j : series selector. PV constants enter the intercept.

Estimate β , ρ_ζ , dynamics, and consumption slopes jointly.

Noisy, Incomplete Instruments: Use Measurement Equations

w_t contains the external shock measures:

$$w_t = \mu_w + M_X X_{t-1} + \underbrace{\begin{pmatrix} 0 & M_{-c} \end{pmatrix}}_M \begin{pmatrix} \varepsilon_{c,t} \\ \varepsilon_{X,t} \end{pmatrix} + \eta_t.$$

M_{-c} : loadings on non-consumption shocks; $\eta_t \sim N(0, \Sigma_\eta)$ is independent measurement noise.

Exclusion is imposed on the shock loadings

No direct loading on $\varepsilon_{c,t}$; $M_X X_{t-1}$ absorbs predictable variation.

R_t selects the instruments observed in quarter t :

$$w_t^{\text{obs}} = R_t w_t, \quad \text{Var}(R_t \eta_t) = R_t \Sigma_\eta R_t'.$$

The Kalman filter uses the available rows; missing values are inferred from the model and observed data.

Short Samples, Many Parameters: Regularize Jointly

ψ : all model parameters; $\mathcal{Y}^{\text{obs}}$: available data.

$$\underbrace{\pi(\psi \mid \mathcal{Y}^{\text{obs}})}_{\text{joint posterior}} \propto \underbrace{L_{\text{KF}}(\mathcal{Y}^{\text{obs}} \mid \psi)}_{\text{state-space likelihood}} \underbrace{\pi(\psi)}_{\text{prior}}.$$

- Minnesota shrinkage disciplines the VAR dynamics.
- Consumption prior: $\phi_\tau = -\phi_n(1 - \theta)$, $\theta \sim U(0, 1)$.

Priors matter when instruments are weak

Priors on shock loadings and noise imply a prior on instrument relevance.

Prior specification

Unidentified directions

B-HIVE: The AR(1) Benchmark System

$Z_t = (n_{t-1}, b_{t-1}, \tau_t, y_t, q_t, v_t^y, v_t^g, v_t^q)'$; ϕ : consumption slopes.

$$c_t = \phi_0 + \phi' Z_t + \zeta_t, \quad \zeta_t = \rho_\zeta \zeta_{t-1} + h_c \varepsilon_{c,t},$$

$$X_t = \mu_X + \sum_{\ell=1}^p A_\ell X_{t-\ell} + G \varepsilon_t,$$

$$v_t^j = s_j' (I_{mp} - \beta F)^{-1} \bar{X}_t, \quad j \in \{y, g, q\},$$

$$w_t = \mu_w + M_X X_{t-1} + M \varepsilon_t + \eta_t.$$

$$\varepsilon_t = (\varepsilon_{c,t}, \varepsilon_{X,t}')' \stackrel{\text{i.i.d.}}{\sim} N(0, I_{m+1}), \quad \underbrace{Ge_c \text{ unrestricted}}_{\text{endogenous predictors}}, \quad \underbrace{Me_c = 0}_{\text{instrument exclusion}}.$$

$e_c = (1, 0, \dots, 0)'$ selects the consumption innovation; h_c scales it; $|\rho_\zeta| < 1$.

One structural equation, not a full equilibrium model.

Consumption equation

Empirical Results

Observables

Quarterly U.S. data, 1951:Q4–2019:Q4. Total personal consumption is the dependent variable.

- household net worth
- market value of federal debt
- personal taxes net of transfers
- personal income net of transfers
- government expenditures
- real 3-month Treasury bill yield

These are the six variables in X_t ; VAR(4) dynamics generate the present values.

28 External Instruments for Six Structural Shocks

Benchmark Design

Several noisy measures can load on the same structural shock.

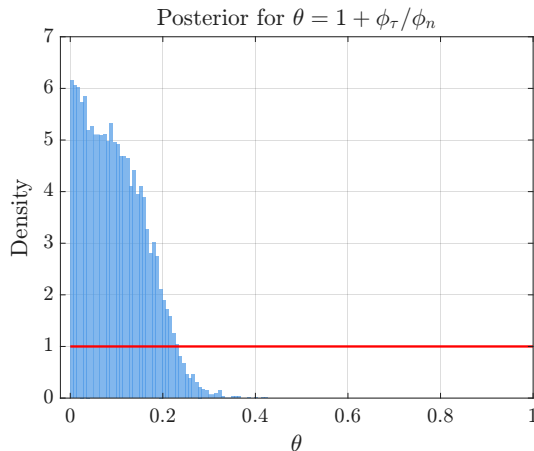
- 7 government-spending measures: defense and R&D news, transfers, housing purchases
- 8 tax measures: legislation, speeches, bond-market and borrowing news
- 8 monetary measures: high-frequency surprises and Fed-document news
- 2 technology measures: utilization-adjusted TFP and patent news
- 2 oil measures: supply disruptions and OPEC news
- 1 uncertainty measure: gold-price surprises

Exclusion Restriction

Each instrument loads on its assigned shock, not on the consumption innovation. The six-instrument robustness check retains one series per shock.

Instrument appendix

Main Result I: Limited Tax Internalization



Share Reflected In Current Consumption

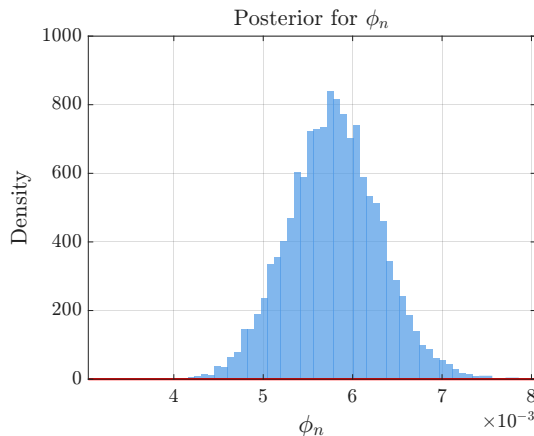
$$\theta = 0.092$$

90% credible interval:

$$[0.008, 0.218]$$

- $\theta = 1$ is the Ricardian benchmark.
- Under the tax-belief interpretation, the median is about 9 percent.
- Most posterior mass lies far below one, conditional on the specification and priors.
- The maintained prior has $0 < \theta < 1$; this is not a point-null test of $\theta = 1$.

Main Result II: A Modest And Precisely Estimated Generic MPC



Quarterly MPC

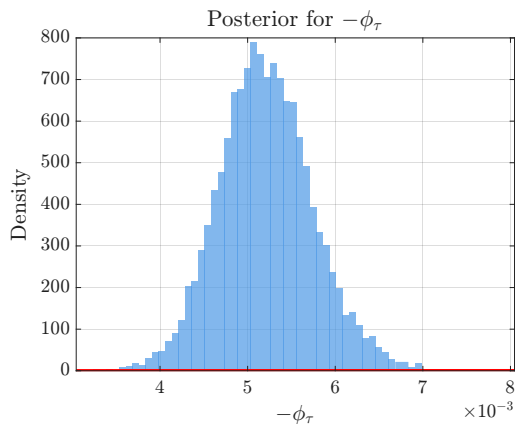
$$\text{MPC} = 0.00579$$

90% credible interval:

$$[0.00495, 0.00663]$$

- Aggregate marginal propensity to consume out of net worth.
- About 0.58 cents of quarterly consumption per additional dollar of wealth.
- Annual-rate equivalent: $4\phi_n = 0.0232$, or 2.32 cents.
- For scale: 3.2 cents per dollar of stock wealth per year in Chodorow-Reich, Nenov, and Simsek (2021).

Main Result III: Debt-Financed Transfers Move Consumption



MPC Out Of Debt-Financed Transfers

$$\text{MPC-DFT} = 0.00519$$

90% CI: [0.00436, 0.00614]

$$\text{MPC-DFT} = -\phi_\tau = \phi_n(1 - \theta)$$

- For Ricardian households this would be zero.
- The median implies 0.52 cents of additional quarterly consumption per dollar transferred.

Robustness: Changes to the Consumption Specification

- Distortionary taxes: add the present value of tax rates to the consumption equation.
- Nonseparable utility: allow marginal utility of consumption to depend on hours worked.
- External habits: add a weighted average of past consumption. Retain the benchmark tax–wealth restriction, with IID residuals and a theory-centered wealth prior.

Results: Alternative Consumption Specifications

Specification	θ	Annual-rate MPC $4\phi_n$	Tax coefficient ϕ_τ
Benchmark: six X_t , 28 IV	.092 [.008,.218]	.0232 [.0198,.0265]	−.00519 [−.00614, −.00436]
Distortionary taxes	.335 [.077,.674]	.0159 [.0123,.0198]	−.00266 [−.00408, −.00112]
Nonseparable utility	.263 [.072,.447]	.0217 [.0184,.0256]	−.00397 [−.00481, −.00320]
External habits	.189 [.040,.368]	.0559 [.0485,.0648]	−.01144 [−.01383, −.00845]

Other robustness checks

Government Debt and Foreign Borrowing

Economic question

How much of the long-run decline in U.S. net foreign assets can the increase in government debt explain?

- Government debt rises from 26% to 98% of GDP over 1976–2025.
- Net foreign assets fall by 75.4 percentage points of GDP.
- Use short-run evidence on consumption to assess long-run external balances.

Model and accounting

Foreign Saving Finances Part Of Domestic Spending

Foreign households receive endowment income Y_t^* , consume C_t^* , and hold bonds B_t^* . They pay no domestic taxes:

$$Y_t^* + B_{t-1}^* = C_t^* + Q_t B_t^*.$$

They have the same preferences and subjective expectations:

$$Q_t = \beta \tilde{\mathbb{E}}_t \left[\left(\frac{C_{t+1}^*}{C_t^*} \right)^{-\gamma} \right].$$

The bond price Q_t adjusts so domestic and foreign holdings sum to D_t .

Foreign bond holdings determine the external position

NFA denotes net foreign assets; CA denotes the current account balance.

$$\text{NFA}_t = -Q_t B_t^*, \quad \text{CA}_t = \text{NFA}_t - \text{NFA}_{t-1}.$$

Foreign Borrowing Can Cushion Investment Crowding Out

With trade deficit $TD_t = Y_t^* - C_t^*$, the resource constraint is

$$Y_t + TD_t = C_t + I_t + G_t.$$

Holding output and government spending fixed:

Closed non-Ricardian economy

$$\Delta I_t = -\Delta C_t$$

Higher consumption displaces domestic investment.

Open non-Ricardian economy

$$\Delta I_t = -\Delta C_t + \Delta TD_t$$

Foreign saving finances part of the consumption increase.

Foreign borrowing provides another margin of adjustment.

The Debt Increase Arrives Through Repeated Surprises

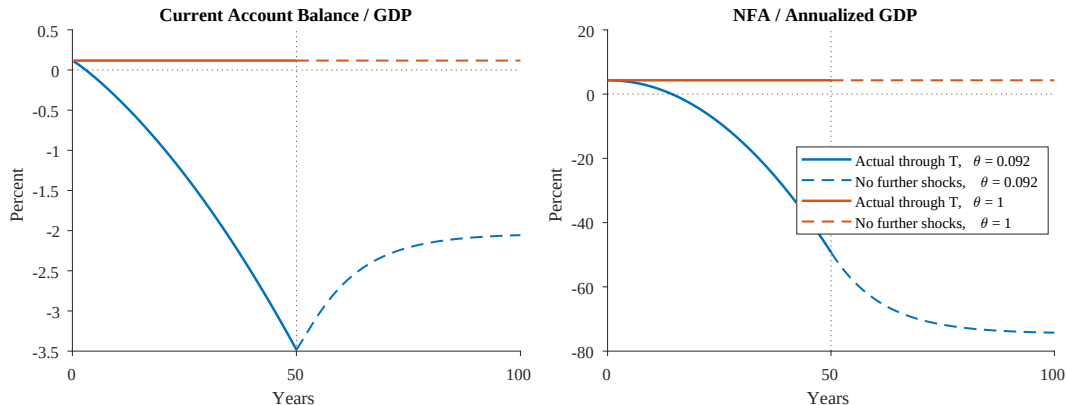
26% $\longrightarrow$ 98%

Government debt / annualized GDP

- Match the 50-year increase, 1976–2025.
- Each innovation is unexpected; future shocks are forecast as zero.
- Shocks stop in year 50; debt then reverts.

Timing and forecasts

A Fifty-Year Increase in Government Debt: External Balances



Blue: $\theta = 0.092$; orange: Ricardian ($\theta = 1$).

Solid: through year 50; dashed: subsequent paths with no further shocks.

Complete figure

Fifty-Year Outcomes

Statistic	Data	Non-Ricardian Model	Ricardian Model
Initial government debt/GDP	26%	26%	26%
Government debt/GDP in year 50	98%	98%	98%
Average budget deficit/GDP	3.78%	3.08%	3.08%
Average current account/GDP	−2.40%	−1.43%	0.12%
50-year investment/GDP trend	0.23%	−0.11%	0.00%
Initial NFA/GDP	4.3%	4.3%	4.3%
NFA/GDP in year 50	−71.1%	−49.2%	4.3%
Explained share of NFA decline	—	71.0%	0.0%

Data: 1976–2025. Ratios: percent of GDP; debt and NFA use annualized GDP.

Investment: private nonresidential fixed investment; trend: annual OLS slope $\times$ 50, in pp.

Conclusion

- Identification: use external shocks to estimate the consumption equation without specifying a full equilibrium model.
- B-HIVE: estimate consumption, expected future sums, and noisy shock measurements jointly, including periods with missing observations.
- U.S. evidence: the benchmark implies little Ricardian offset ($\theta = 0.092$).
- Application: government borrowing raises foreign liabilities; foreign saving can cushion the crowding out of domestic investment.

Theory

Method

Instruments

Debt experiment

Additional Slides

- [Theory and aggregate versus micro evidence](#)
- [Population regression details](#)
- [Dynamic moments and identification](#)
- [Priors and instrument relevance](#)
- [Forecasting variables, instruments, and income restriction](#)
- [Open-economy model and additional results](#) [Calibration](#)

[Conclusion](#)

One Dollar Today Need Not Add One Dollar Of Wealth

Consider a debt-financed transfer.

Current resources	+1
Objective future-tax present value	+1
Perceived future-tax present value	$+\theta$

$$\Delta c = \text{MPC} \times (1 - \theta).$$

Hold inherited wealth, income, spending, and prices fixed.

We seek this partial response, not the total policy effect.

Micro Designs Miss the Shared Future Tax Burden

Current transfer

Who receives an extra dollar?

Future taxes

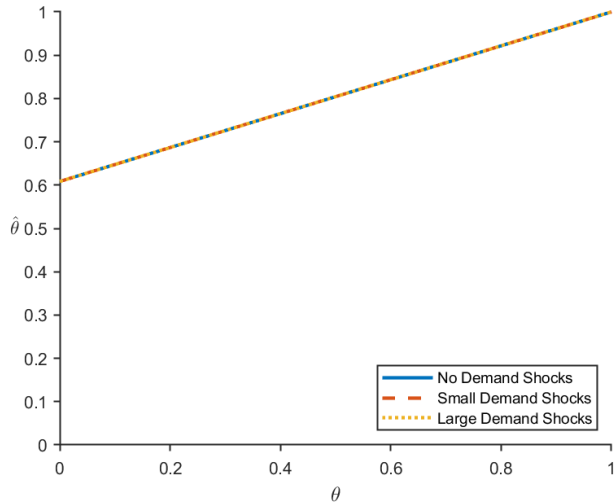
Who will pay for it?

A future tax burden shared by treated and untreated households drops out of their comparison.

We need aggregate variation in resources and future taxes.

Missing intercept

A Tax Shock Gives a Total Response, Not the Tax Slope



Lack Of Identification Appears As Prior Reversion

If the likelihood does not depend on ψ_2 conditional on ψ_1 ,

$$L_{\text{KF}}(\mathcal{Y}^{\text{obs}} \mid \psi_1, \psi_2) = L_{\text{KF}}(\mathcal{Y}^{\text{obs}} \mid \psi_1),$$

then, when the posterior is well defined,

$$\pi(\psi_2 \mid \psi_1, \mathcal{Y}^{\text{obs}}) = \pi(\psi_2 \mid \psi_1).$$

- Independent priors: the marginal posterior for ψ_2 also equals its prior.
- Dependent priors: learning about ψ_1 can change the marginal posterior for ψ_2 .

A weakly identified parameter need not have a wide posterior.

One Shock Supplies A Sequence Of Moment Conditions

Instrument i measures a non-consumption shock $k(i) \neq c$:

$$w_{i,t}^\perp \equiv w_{i,t} - \mu_{w,i} - (M_X)_i X_{t-1} = M_{i,k(i)} \varepsilon_{k(i),t} + \eta_{i,t}.$$

$$r_i^Z(h) \equiv \text{Cov}(Z_{t+h}, w_{i,t}^\perp), \quad r_i^c(h) \equiv \text{Cov}(c_{t+h}, w_{i,t}^\perp).$$

The Structural Equation Holds Along the Response Path

$$r_i^c(h) = \phi' r_i^Z(h), \quad h = 0, 1, 2, \dots$$

A shock's dynamic path can separate slopes that its impact response cannot.

Structural-shock IV: Barnichon and Mesters (2020). Across-horizon restrictions: Lewis and Mertens (2022).

Moment condition

Identification Depends On Dynamic Rank, Not Shock Counts

Stack instruments and horizons $h = 0, \dots, H$:

$$\mathbf{r}_H^c = \mathcal{R}_H \phi, \quad (\mathbf{r}_H^c)_{(i,h)} = r_i^c(h), \quad (\mathcal{R}_H)_{(i,h),\cdot} = r_i^Z(h)'.$$

Conditional Rank Requirement

With predictor dynamics and β held fixed, $\text{rank}(\mathcal{R}_H) = 8$ identifies the eight consumption slopes.

- Count independent response directions, not shock labels.
- One shock can supply several directions through its dynamic path.
- Nearly collinear responses weakly identify some slope combinations.

This is not a full identification condition for the joint likelihood.

Rank condition

One shock

Estimate the Wealth and Tax Responses Jointly

$$\theta^{(s)} = 1 + \frac{\phi_{\tau}^{(s)}}{\phi_n^{(s)}}$$

- Estimate the wealth and tax coefficients jointly.

Benchmark: six X_t , 28 instruments, 15,000 particles.

273 quarters; AR(1) residual.

Maintained conventions

Priors Encode Economic Support And Regularize The Dynamics

Consumption Parameters

$$\phi_n \mid \beta \sim U(1 - \beta, 1), \quad \frac{\phi_\tau}{\phi_n} \sim U(-1, 0),$$

so

$$\theta = 1 + \frac{\phi_\tau}{\phi_n} \sim U(0, 1).$$

Shared PV discount: $\beta \sim \text{Beta}(31.5, 3.5)$ (mean 0.90, standard deviation 0.05).

Macro Dynamics

- Hierarchical Minnesota VAR prior with estimated hyperparameters.
- Stationary initialization requires $\rho(F) < 1$; $\beta\rho(F) < 1$ keeps present values finite.
- $\rho_\zeta \sim N(0, 0.2^2)$, truncated to $(-0.95, 0.95)$.

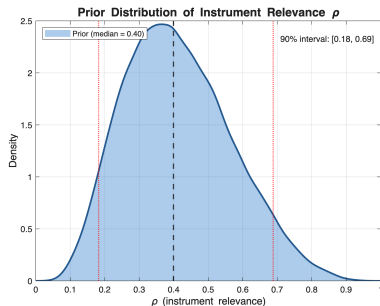
Remaining Parameters

- Scale-adjusted, zero-centered Normal priors for unrestricted coefficients.
- Gamma priors for sign-normalized direct shock loadings.
- Proper priors on M and Σ_η imply the relevance prior shown next.

Prior For Instrument Relevance

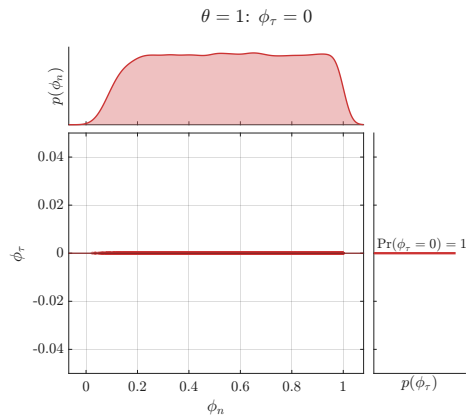
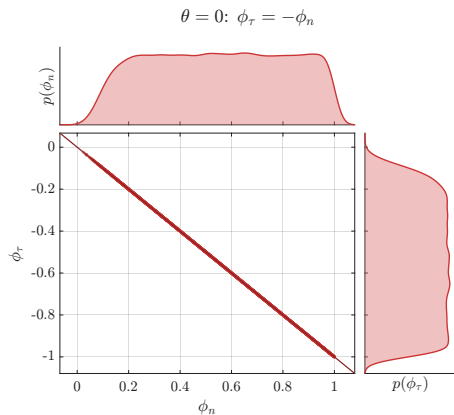
Instrument Relevance

$\rho_i = \frac{M_i^2}{M_i^2 + \sigma_{\eta,i}^2}$ = share of the residualized instrument's variance attributable to its assigned structural shock rather than measurement error.



- Priors: $M_i \sim \text{Gamma}(20, 0.025)$, $\sigma_{\eta,i}^2 \sim \text{Gamma}(4, 0.1)$.
- Median 0.40; 90% interval [0.18, 0.69].
- Little mass near $\rho_i = 0$ (pure noise) or $\rho_i = 1$ (perfect measure); no strong first stage imposed.
- Primitive measurement priors induce a prior on relevance, so we report that implication explicitly. (Giannone, Lenza, and Primiceri, 2026)

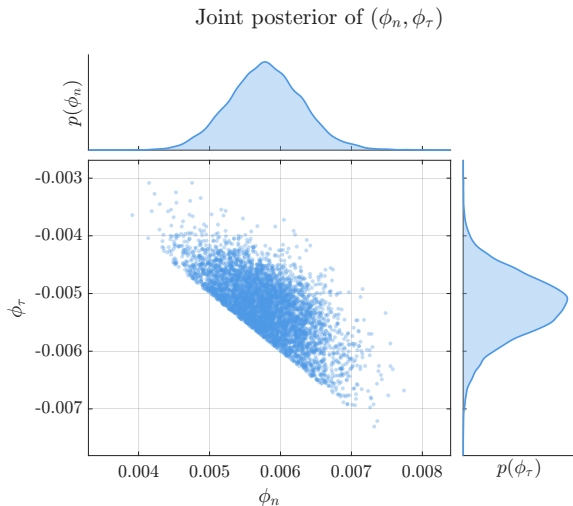
Two Benchmark Values Of θ Imply Different Joint Distributions



Interpreting θ

$\phi_\tau = (\theta - 1)\phi_n$: no internalization lies on the diagonal; Ricardian equivalence lies on the horizontal axis.

The Joint Posterior Determines θ



Draw-By-Draw Mapping

$$\theta^{(s)} = 1 + \frac{\phi_\tau^{(s)}}{\phi_n^{(s)}}.$$

- The slope from the origin, not either marginal alone, determines θ .
- Mass near $\phi_\tau = -\phi_n$ produces values near $\theta = 0$.
- Higher- θ draws occur when $-\phi_\tau$ is small relative to ϕ_n .

Related Work and Robustness

Different Designs, Same Qualitative Conclusion

Contemporaneous work: Eichenbaum, Guerreiro, and Obradovic (2026), “Ricardian Non-Equivalence.”

Their Design

Randomized survey thought experiments: respondents report consumption plans after hypothetical debt-financed transfers.

Our Design

Aggregate time series + structural-shock IVs: estimate the consumption function directly.

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Their Design

Randomized survey thought experiments: respondents report consumption plans after hypothetical debt-financed transfers.

Our Design

Aggregate time series + structural-shock IVs: estimate the consumption function directly.

- Their survey measures planned spending after hypothetical transfers; our quarterly aggregate MPC–DFT is 0.00519. The designs and response horizons differ.
- Both approaches imply that households do not fully offset debt-financed transfers **in anticipation of future taxes**.

Robustness: Forecasting Variables and Instruments

- Benchmark: six variables in X_t and 28 instruments.
- Larger X_t vector: add forecasting variables to the VAR; keep the consumption equation unchanged.
- Six instruments: use one external instrument per shock.

[Six-instrument sources](#)

Robustness: Survey Forecasts and the Income Restriction

- Survey forecasts: replace the income PV with Michigan income forecasts, and current q_t with a real-rate PV proxy.
- Income restriction: the coefficients on current income and the present value of current and future income sum to the wealth coefficient. Same regressors; one fewer parameter.
- Both retain 28 instruments and AR(1) ζ_t .

Results: Data, Instruments, and the Income Restriction

Specification	θ	Annual-rate MPC $4\phi_n$	Tax coefficient ϕ_τ
Benchmark: six X_t , 28 IV	.092 [.008,.218]	.0232 [.0198,.0265]	-.00519 [-.00614, -.00436]
Larger X_t vector	.076 [.006,.258]	.0230 [.0191,.0269]	-.00520 [-.00633, -.00399]
Six X_t , six instruments	.172 [.015,.587]	.0230 [.0185,.0272]	-.00468 [-.00612, -.00221]
Survey forecasts	.562 [.057,.954]	.0154 [.0113,.0219]	-.00169 [-.00413, -.00017]
Income-sum restriction	.083 [.006,.339]	.0290 [.0241,.0350]	-.00645 [-.00804, -.00481]

- Larger X_t gives similar estimates; survey forecasts leave a wide interval for θ .
- Income restriction: similar median θ ; both MPC magnitudes rise about 25%.

Domestic Households Save In Capital And Bonds

Production uses capital K_{t-1} and productivity A_t ; α is the capital share and R_t the rental rate:

$$Y_t = K_{t-1}^\alpha A_t^{1-\alpha}, \quad R_t = \alpha \frac{Y_t}{K_{t-1}}.$$

With depreciation δ , investment is $I_t = K_t - (1 - \delta)K_{t-1}$. At bond price Q_t and lump-sum taxes T_t , the household budget is

$$Y_t + B_{t-1} = C_t + T_t + I_t + Q_t B_t.$$

Saving decisions

With discount factor β and relative risk aversion γ ,

$$Q_t = \beta \tilde{\mathbb{E}}_t[(C_{t+1}/C_t)^{-\gamma}],$$
$$1 = \beta \tilde{\mathbb{E}}_t[(C_{t+1}/C_t)^{-\gamma}(R_{t+1} + 1 - \delta)].$$

Fiscal Policy and Bounded Rationality

Total debt is $D_t = B_t + B_t^*$, including foreign holdings B_t^* . Government spending G_t/A_t is fixed; taxes adjust to satisfy

$$G_t + D_{t-1} = T_t + Q_t D_t.$$

Productivity-scaled debt follows an exogenous process:

$$\frac{D_t}{A_t} - \bar{b} = \rho_B \left(\frac{D_{t-1}}{A_{t-1}} - \bar{b} \right) + \epsilon_t^B, \quad \mathbb{E}_t[\epsilon_{t+1}^B] = 0.$$

Here $\bar{b}$ is long-run scaled debt, ρ_B its persistence, and ϵ_t^B an unexpected iid innovation.

Current taxes are observed; future tax beliefs are attenuated

Let v_t^τ and $\tilde{v}_t^\tau$ denote rational and perceived tax-PV deviations after scaling by productivity.

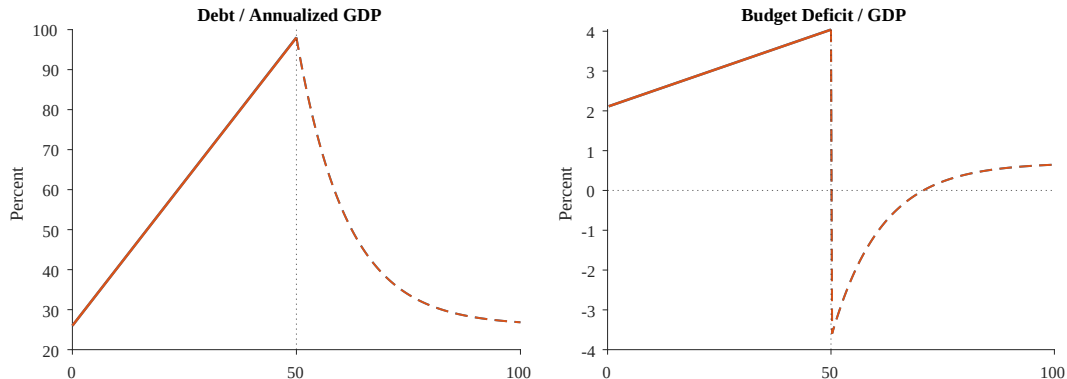
$$\tilde{\mathbb{E}}_t[\tilde{v}_{t+1}^\tau] = \theta \mathbb{E}_t[v_{t+1}^\tau].$$

Calibration

Calibration inputs

Parameter	Value	Meaning
θ	0.092	Tax-expectation attenuation
Wealth MPC	0.010	Quarterly consumption response
β	0.990	Quarterly discount factor
γ	1	Relative risk aversion
ρ_B	0.978	Persistence of scaled debt

A Fifty-Year Increase in Government Debt: Fiscal Balances



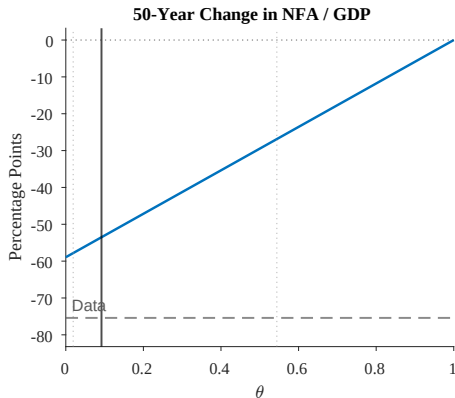
Blue: $\theta = 0.092$; orange: Ricardian ($\theta = 1$). Horizontal axes: years.

Solid: through year 50; dashed: subsequent paths with no further shocks.

Complete figure

◀ Back

Less Ricardian Behavior Means A Larger NFA Decline



At $\theta = 0.092$:

- Model NFA decline:
53.5 percentage points.
- Observed decline:
75.4 percentage points.

Model / data: 71.0%.

Why the Future Tax Response Drops Out

A transfer design compares recipients with non-recipients.

- Transfer receipts differ across households.
- The associated future tax burden can be shared.
- A time effect absorbs that shared burden.

The comparison identifies a response to current resources, not the response to the financing burden.

The Benchmark Specification Makes Additional Choices

- One discount factor for the income, spending, and bond-price PVs.
- Prior support restricts the reported ratio to $0 \leq \theta \leq 1$.
- A finite-dimensional forecasting and shock-measurement model.

These are maintained empirical choices, not restrictions shared by every theoretical extension.

Theory Notation And Baseline Assumptions

c_t, y_t, τ_t	Consumption, net income, net taxes
n_{t-1}, b_{t-1}	Inherited financial wealth and government debt
q_t, g_t	One-period bond price and government spending
$\bar{C}, \bar{B}$	Steady-state consumption and debt
β, γ	Discount factor and relative risk aversion
z_t^d, ζ_t	Euler wedge and consumption disturbance

Baseline: separable utility, unconstrained saving, and terminal conditions allowing forward iteration.

Households know current variables; beliefs are linear.

From Future Spending To Current Consumption

The Euler equation implies

$$\tilde{\mathbb{E}}_t[c_{t+1}] = c_t + \frac{\bar{C}}{\beta\gamma}(z_t^d - q_t).$$

Forward iteration of the household budget gives

$$\tilde{v}_t^c = n_{t-1} + \tilde{v}_t^y - \tilde{v}_t^r - \bar{B}\tilde{v}_t^q.$$

Combining them yields the generic consumption equation, with

$$\zeta_t = -\frac{\bar{C}}{\gamma}z_t^d + \beta\tilde{\mathbb{E}}_t[\zeta_{t+1}].$$

The perceived PVs use recursively iterated household beliefs.

The Full Baseline Consumption Equation

Define the net-resource bracket

$$\mathcal{W}_t(\theta) = n_{t-1} - \theta b_{t-1} + \tilde{v}_t^y \\ - (1 - \theta)\tau_t - \theta v_t^g + \theta \bar{B} v_t^q.$$

Then

$$c_t = \kappa \mathcal{W}_t(\theta) + D_q \tilde{v}_t^q + \zeta_t, \\ \kappa = 1 - \beta, \quad D_q = \bar{C}/\gamma - \kappa \bar{B}.$$

Government solvency and the tax-belief restriction suffice. No common attenuation for income and prices is assumed.

PV conventions

Current Income Already Enters Its Present Value

η_y is the proportionality factor for expected discounted future income:

$$\widetilde{v}_t^y = y_t + \eta_y(v_t^y - y_t).$$

Multiplying by the income-wealth coefficient ϕ_n gives

$$\phi_y = \phi_n(1 - \eta_y), \quad \phi_{v^y} = \phi_n\eta_y.$$

$$\boxed{\phi_y + \phi_{v^y} = \phi_n}$$

Individual equality $\phi_y = \phi_n$ generally requires $\eta_y = 0$.

Use compatible units and retain any separate HtM income term. If $\eta_y = \theta$

Bond Prices Enter Through Two Channels

Baseline coefficients; common PV discount factor. Let $\tilde{v}_t^q = (1 - \eta_q)q_t + \eta_q v_t^q$.

$$\underbrace{\phi_n \theta \bar{B} v_t^q}_{\text{government accounting}} + \underbrace{D_q \tilde{v}_t^q}_{\text{household valuation}}.$$

Thus

$$\begin{aligned}\phi_q &= (1 - \eta_q) D_q, \\ \phi_{v^q} &= \phi_n \theta \bar{B} + \eta_q D_q.\end{aligned}$$

Here $D_q = \bar{C}/\gamma - \phi_n \bar{B}$.

Habits and interest taxes alter this coefficient structure.

Stronger restrictions

Symmetric Beliefs Give Stronger Bond-Price Restrictions

In the baseline,

$$\phi_q + \phi_{v^q} = \bar{C}/\gamma + \phi_\tau \bar{B}.$$

The extra assumption $\eta_q = \theta$ gives

$$\phi_q = (1 - \theta)D_q, \quad \phi_{v^q} = \theta\bar{C}/\gamma.$$

- With fixed $\bar{B}$, $D_q = \bar{C}/\gamma - \phi_n \bar{B}$ also binds.
- Bond-price units satisfy $q_t = -\bar{Q}^2 r_t^{(1)}$.
- Yield coefficients need the corresponding sign and scale change.

Symmetry Is Stronger Than The Income-Sum Restriction

Impose $\eta_y = \eta_q = \theta$ and $\phi_n = 1 - \beta$. The additional mappings are

$$\begin{aligned}\phi_y &= -\phi_\tau, & \phi_{vy} &= \phi_n + \phi_\tau, \\ \phi_b &= \phi_{vg} = -(\phi_n + \phi_\tau), \\ \phi_q &= (1 - \theta)D_q, & \phi_{vq} &= \theta\bar{C}/\gamma.\end{aligned}$$

Here ϕ_b multiplies inherited debt; ϕ_{vg} multiplies the government-spending PV.

Tax beliefs alone do not imply this full mapping. [Discounting distinction](#)

One-Time Attenuation Is Not A Discount Factor

The one-time rule scales the future tail:

$$\widetilde{v}_t^x = x_t + \theta(v_t^x - x_t).$$

For predictor companion matrix F , the rational PV uses

$$(I - \beta F)^{-1}, \quad \text{not } (I - \beta \theta F)^{-1}.$$

- The second expression compounds θ across horizons.
- Current observations remain unattenuated in the first rule.
- No separate current- g_t term is created: its PV is objective.

A Discounting Wedge Changes Household Valuation

Government discount factor: β . Household discount factor: $\beta\omega$.

$$v_t^x = x_t + \beta \mathbb{E}_t[v_{t+1}^x],$$

$$\tilde{v}_t^x = x_t + \beta\omega \mathbb{E}_t[\tilde{v}_{t+1}^x].$$

With rational expectations, the wealth MPC becomes

$$\phi_n = 1 - \beta\omega.$$

The paper uses this wedge for finite horizons and as an approximation to occasionally binding constraints.

Tax mapping and its assumptions

The Scalar Tax Mapping Needs Tax-PV Dynamics

With rational expectations, assume

$$v_t^\tau = \rho_\tau v_{t-1}^\tau + \varepsilon_t^\tau.$$

Then the discounting wedge implies

$$\theta = \omega \frac{1 - \beta \rho_\tau}{1 - \beta \omega \rho_\tau}, \quad \phi_\tau = -(1 - \beta \omega)(1 - \theta).$$

- The coefficient pattern matches the behavioral equation.
- The household and government PV discount factors still differ.

Naive And Sophisticated Beliefs Imply Different Mappings

Add cognitive attenuation λ to discount wedge ω . Retain the AR(1) tax-PV assumption.

$$\theta_{cd} = \begin{cases} \omega\lambda \frac{1 - \beta\rho_\tau}{1 - \beta\omega\lambda\rho_\tau}, & \text{sophisticated,} \\ \omega\lambda \frac{1 - \beta\rho_\tau}{1 - \beta\omega\rho_\tau}, & \text{naive.} \end{cases}$$
$$\phi_n = 1 - \beta\omega, \quad -\phi_\tau = \phi_n(1 - \theta_{cd}).$$

Naive beliefs attenuate once; sophisticated beliefs compound. Recovering ω, λ also requires β, ρ_τ and a mechanism.

Habits Change The Wealth MPC

External habits follow

$$x_t = \rho_x x_{t-1} + \chi_c c_{t-1}, \quad 0 < \rho_x < 1, \quad 0 < \chi_c < 1 - \rho_x.$$

Household forecasts respect this law. For utility over $C_{i,t} - X_t$,

$$\kappa^h = (1 - \beta) \left(1 - \frac{\beta \chi_c}{1 - \beta \rho_x} \right).$$

$$\phi_n = \kappa^h, \quad \phi_\tau = -\kappa^h(1 - \theta).$$

The tax ratio survives; $\phi_n = 1 - \beta$ does not. [Full habit equation](#)

Habits Also Add A State And Change Price Sensitivity

Using the baseline net-resource bracket $\mathcal{W}_t(\theta)$,

$$\begin{aligned}c_t = & \kappa^h \mathcal{W}_t(\theta) \\ & + \left(\frac{\bar{C} - \bar{X}}{\gamma} - \kappa^h \bar{B} \right) \tilde{v}_t^q \\ & + \alpha^x x_t + \frac{\bar{C} - \bar{X}}{\bar{C}} \zeta_t,\end{aligned}$$

$$\alpha^x = \frac{\beta(1 - \rho_x)}{1 - \beta\rho_x}, \quad \bar{X} < \bar{C}.$$

The PV discount factor remains β . The price coefficient and disturbance scale also change.

Net-resource bracket

The HtM Mapping Can Produce A Negative Theta

Let λ be the unconstrained population share. In the paper's rational-expectations two-agent model,

$$\phi_n = 1 - \beta, \quad \phi_\tau = -(1 - \lambda).$$

Hence

$$\theta = 1 - \frac{1 - \lambda}{1 - \beta}.$$

- $\theta < 0$ when the constrained share exceeds $1 - \beta$.
- Debt loads with λ , not θ .

The derivation uses common taxes, zero steady-state debt, and constant government spending.

Full two-agent equation

Constrained Income Adds A Separate Term

Let $\kappa = 1 - \beta$ and λ be the unconstrained share. The two-agent consumption equation is

$$\begin{aligned} c_t = & \kappa [n_{t-1} - \lambda b_{t-1} + v_t^y \\ & - (1 - \theta)\tau_t - \lambda v_t^g] \\ & + \lambda \frac{\bar{c}}{\gamma} \tilde{v}_t^g + \varsigma_t^C + \lambda \zeta_t, \\ \varsigma_t^C = & (1 - \lambda) [y_t^C - (1 - \beta) v_t^{y,C}]. \end{aligned}$$

y_t^C is constrained income; $v_t^{y,C}$ is its PV. Constant constrained income makes $\varsigma_t^C = 0$. Income-sum caveat

The Income-Sum Restriction Depends On The Representation

Retaining ς_t^C separately leaves the coefficient on aggregate income wealth equal to $1 - \beta$.

If both groups receive the same income process, $y_t^C = y_t$,

$$(1 - \beta)v_t^y + \varsigma_t^C = (1 - \lambda)y_t + \lambda(1 - \beta)v_t^y.$$

Then

$$\phi_y + \phi_w = (1 - \beta) + \beta(1 - \lambda) \neq \phi_n.$$

The bare sum restriction is not universal under HtM. Constrained-income term

Non-Separable Utility Adds A Labor-Growth Term

The consumption equation gains

$$\alpha^\ell \beta \tilde{\mathbb{E}}_t[\tilde{v}_{t+1}^{dl}],$$

where hours deviations ℓ_t enter through

$$\tilde{v}_t^{dl} = \ell_t - \ell_{t-1} + \beta \tilde{\mathbb{E}}_t[\tilde{v}_{t+1}^{dl}],$$

$$\alpha^\ell = -\frac{\bar{C}}{\gamma} \frac{u_{CL}(\bar{C}, \bar{L})}{u_C(\bar{C}, \bar{L})}.$$

Baseline coefficient restrictions hold conditional on this term. Its exogeneity does not follow from the derivation. Risk-sharing wedge

Imperfect Risk Sharing Adds An Endogenous Euler Wedge

Let $\widehat{\mathcal{W}}_t$ be the aggregate Euler wedge's deviation from its steady-state value of one.

$$\widetilde{v}_t^w = \widehat{\mathcal{W}}_t + \beta \widetilde{\mathbb{E}}_t[\widetilde{v}_{t+1}^w].$$

The consumption equation gains

$$-\frac{\bar{c}}{\gamma} \beta \widetilde{\mathbb{E}}_t[\widetilde{v}_{t+1}^w].$$

- This follows from the specified aggregate Euler representation.
- Treating the term as an exogenous disturbance needs extra assumptions.

Interest-Income Taxes Create A Tax-Rate PV

Let $\bar{\tau}^i$ be the steady-state interest tax rate and τ_t^i its deviation. The steady-state wedge is

$$\omega = \frac{1}{1 - \bar{\tau}^i(1 - \beta)}, \quad \phi_n = 1 - \beta\omega.$$

The new tax-rate present value satisfies

$$\tilde{v}_t^i = \tau_t^i + \beta\omega\mathbb{E}_t[\tilde{v}_{t+1}^i].$$

Retain rational expectations and AR(1) tax-PV dynamics for the scalar θ mapping of the discount-wedge model.

Consumption and price coefficients

Interest Taxes Also Change The Bond-Price Coefficient

Use $\mathcal{W}_t(\theta)$ with the discount-wedge PV conventions:

$$c_t = \phi_n \mathcal{W}_t(\theta) + \left(\frac{\bar{C}}{\gamma} \alpha^q - \phi_n \bar{B} \right) \tilde{v}_t^q - \alpha^i \tilde{v}_t^i + \zeta_t,$$

$$\alpha^q = \omega(1 - \beta\omega\bar{\tau}^i), \quad \alpha^i = -\frac{\bar{C}}{\gamma}\beta\omega^2(1 - \beta).$$

For $0 < \bar{\tau}^i < 1$ and $0 < \beta < 1$, the wedge has $\omega > 1$. It is not a survival probability in this model.

Net-resource bracket

Model Restrictions Must Match The Mechanism

- Wealth MPC: $\phi_n = 1 - \beta$ in the baseline;
 $1 - \beta\omega$ with a discounting wedge; κ^h with habits.
- Debt and spending PV: $\phi_b = \phi_{v^g} = -\phi_n\theta$
in the behavioral, wedge, and habit derivations; not HtM.
- The ratio: $\theta \equiv 1 + \phi_\tau/\phi_n$ reports an object;
it does not itself constrain the coefficient vector.

Imposing government solvency on the predictor VAR would be a separate restriction from the consumption equation.

Expectations Add Their Own Conditional Restrictions

- **Income sum:** $\phi_y + \phi_w = \phi_n$ requires a common wealth coefficient and proportional valuation of future income.
- **Symmetry:** $\eta_y = \eta_q = \theta$ is stronger than the baseline restriction on future tax beliefs.
- **PV discounting:** one common β is an empirical choice, not the generic implication of a household discounting wedge.

Baseline PV definitions are

$$v_t^x = x_t + \beta \mathbb{E}_t[v_{t+1}^x],$$

$$\tilde{v}_t^x = x_t + \beta \tilde{\mathbb{E}}_t[\tilde{v}_{t+1}^x].$$

Eight Consumption Slopes, Plus an Intercept

$$c_t = \phi_0 + \phi_n n_{t-1} + \phi_b b_{t-1} + \phi_\tau \tau_t \\ + \phi_y y_t + \phi_q q_t + \phi_{v^y} v_t^y + \phi_{v^g} v_t^g + \phi_{v^q} v_t^q + \zeta_t.$$

Equivalently, $c_t = \phi_0 + \phi' Z_t + \zeta_t$, with

$$Z_t = (n_{t-1}, b_{t-1}, \tau_t, y_t, q_t, v_t^y, v_t^g, v_t^q)'.$$

Current income and bond prices enter separately from their present values.

Predictor Dynamics and Shock Measurements

Predictors exclude consumption; the residual is a latent state:

$$X_t = \mu_X + \sum_{\ell=1}^p A_{\ell} X_{t-\ell} + G\varepsilon_t,$$

$$\zeta_t = \rho_{\zeta} \zeta_{t-1} + h_c e'_c \varepsilon_t, \quad |\rho_{\zeta}| < 1,$$

$$w_t = \mu_w + M_X X_{t-1} + M\varepsilon_t + \eta_t.$$

- $\varepsilon_t = (\varepsilon_{c,t}, \varepsilon'_{X,t})' \stackrel{\text{i.i.d.}}{\sim} N(0, I_{m+1})$; ζ_t is AR(1).
- $Ge_c \neq 0$ is allowed; instrument exclusion is $Me_c = 0$.
- $\eta_t \sim N(0, \Sigma_{\eta})$ is independent measurement noise.

e_c selects the consumption innovation; $X_t \in \mathbb{R}^m$.

The Same Dynamics Form the Present Values

For the centered companion state $\bar{X}_t \in \mathbb{R}^{mp}$,

$$\bar{X}_t = F\bar{X}_{t-1} + \bar{G}\varepsilon_t.$$

$$v_t^j = s_j'(I_{mp} - \beta F)^{-1}\bar{X}_t, \quad j \in \{y, g, q\}.$$

- s_j selects the relevant income, spending, or price series.
- A common β and the dynamics F are jointly estimated.
- PV constants enter ϕ_0 ; unstable PV draws have zero prior density.

Population Experiment: Model and Calibration

- Closed economy; fixed spending; zero steady-state debt and NFA.
- Tax, demand, TFP, investment, and risk shocks.
- Vary θ and demand-shock size: $0, 2\bar{C}, 3\bar{C}$.

Discount factor	0.990	Capital share	0.39
Depreciation	0.02	Relative risk aversion	1
Productivity growth	0.006879	Debt persistence	0.978
Other shock persistence	0.5	Tax innovation std. dev.	10

TFP, investment, and risk innovation standard deviations: 1. Existing draft figures; no new numerical reproduction.

The IV Exercise Uses One Known Composite

$$U_t = \frac{n_{t-1}}{1 + g_A} + \tilde{v}_t^y + \frac{(1 + g_A)\bar{C}}{\gamma(1 - \beta_A)}\tilde{v}_t^q.$$
$$c_t = (1 - \beta_A)U_t - \frac{(1 - \beta_A)\theta}{1 + g_A}b_{t-1} + \phi_\tau\tau_t + \zeta_t^c.$$

- Current taxes and lagged debt are exogenous regressors.
- Lag-IV uses lagged c , k , and consol values; shock-IV uses TFP, investment, and risk innovations.

$\beta_A = \beta(1 + g_A)^{1-\gamma} = \beta$ here; g_A is productivity growth.

From Population Coefficients to Implied Theta

The true tax coefficient is

$$\phi_{\tau} = -(1 - \beta_A)(1 - \theta).$$

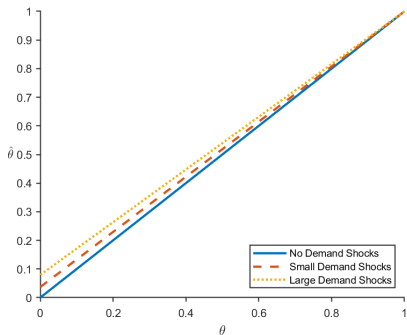
Every panel uses the same transformation:

$$\theta^{\text{implied}} = 1 + \frac{\phi_{\tau}^{\text{regression}}}{1 - \beta_A}.$$

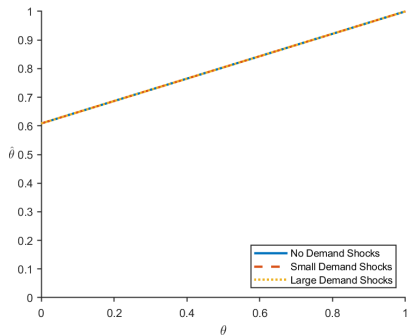
- The denominator uses the known true discount factor.
- The tax-shock-only regression estimates a total response, so its transformation is a pseudo- θ .

Population OLS and the Tax-Shock Regression

Full-equation OLS



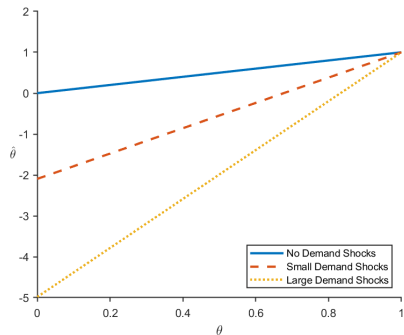
Tax shock only



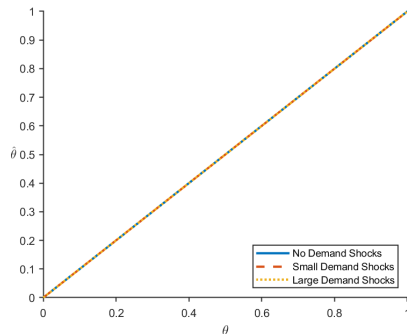
Endogenous controls and total responses are different identification problems.

Lagged Instruments and External-Shock Instruments

Lagged aggregates



TFP, investment, and risk innovations



External innovations satisfy exclusion and relevance in this design.

One Shock Gives Moments at Several Horizons

Remove the predictable component of instrument i :

$$\begin{aligned}w_{i,t}^\perp &= w_{i,t} - \mu_{w,i} - (M_X)_i X_{t-1} \\ &= M_{ik} \varepsilon_{k,t} + \eta_{i,t}.\end{aligned}$$

Under exclusion and serial independence,

$$\text{Cov}(w_{i,t}^\perp, c_{t+h} - \phi_0 - \phi' Z_{t+h}) = 0, \quad h \geq 0.$$

The measured innovation is non-consumption, $k \neq c$; measurement noise is orthogonal to structural shocks.

Dynamic Responses Determine the Moment Directions

For centered states, with dynamics and PV mapping held fixed,

$$\bar{X}_t = F\bar{X}_{t-1} + \bar{G}\varepsilon_t, \quad Z_t = S\bar{X}_t \in \mathbb{R}^d.$$

An instrument with nonzero loading M_{ik} gives

$$\text{Cov}(Z_{t+h}, w_{i,t}^\perp) = M_{ik} S F^h \bar{G} e_k,$$

$$\text{Cov}(c_{t+h}, w_{i,t}^\perp) = M_{ik} \phi' S F^h \bar{G} e_k.$$

Here $d = 8$; e_k selects measured shock k .

Rank Is a Property of the Response Paths

The external-shock moments identify all d slopes if

$$\text{span} \{ SF^h \bar{G} e_k : k \in \mathcal{K}, h \geq 0 \} = \mathbb{R}^d.$$

- $\mathcal{K}$ contains the measured non-consumption shocks.
- Dynamics and the PV mapping are held fixed; $d = 8$ here.
- Assume stationary dynamics and correctly specified measurements.

This is a condition for these moments, not a complete identification theorem for the joint likelihood.

One Shock Can Supply Several Directions

For $g = \bar{G}e_k$, define

$$\mathcal{K}(F, g) = \text{span}\{g, Fg, F^2g, \dots\}.$$

If $\dim \mathcal{K}(F, g) = mp$ and $\text{rank}(S) = d$, then

$$\text{span}\{SF^h g : h \geq 0\} = \mathbb{R}^d.$$

Full rank need not mean strong identification.

Nearly collinear response paths can provide little information about particular slopes.

I.i.d. Residuals Add a Lag-Covariance Channel

For centered variables, write

$$c_t = H_c \bar{X}_t + \zeta_t, \quad H_c = \phi' S, \quad \Sigma = \text{Var}(\bar{X}_t).$$

If $\zeta_t = h_c \varepsilon_{c,t}$ is i.i.d., then for $s \geq 1$,

$$\text{Cov}(c_t, \bar{X}_{t-s}) = H_c F^s \Sigma.$$

Predictable covariation can inform the slopes without external instruments, subject to the rank of this mapping.

Persistence Adds Covariance with the Residual

If $\zeta_t = \rho_\zeta \zeta_{t-1} + h_c \varepsilon_{c,t}$,

$$\begin{aligned} \text{Cov}(c_t, \bar{X}_{t-s}) &= H_c F^s \Sigma \\ &\quad + h_c \rho_\zeta^s [(I - \rho_\zeta F)^{-1} \bar{G} e_c]'. \end{aligned}$$

- The simple i.i.d. covariance formula no longer applies.
- The AR(1) likelihood may still identify slopes under its restrictions.
- Residualized external-shock moments remain valid under exclusion.

Stationary dynamics, $|\rho_\zeta| < 1$, unit-variance innovations.

Shock Labels Are Distinct from Consumption Slopes

Let $H_\varepsilon = h_c e'_c$. Orthogonal relabelings take the form

$$\begin{aligned}\varepsilon_t &\mapsto Q\varepsilon_t, \\ (\bar{G}, M, H_\varepsilon) &\mapsto (\bar{G}Q', MQ', H_\varepsilon Q').\end{aligned}$$

- Allowed rotations preserve the consumption-shock structure and measurement restrictions.
- Rotating an unmeasured non-consumption block can preserve the Gaussian likelihood, but need not preserve the prior.
- The interpretation of ϕ is unchanged; its identification still depends on the remaining information.

Unidentified Directions Retain Their Conditional Prior

If the likelihood does not depend on ψ_2 conditional on ψ_1 ,

$$p(\mathcal{D} \mid \psi_1, \psi_2) = p(\mathcal{D} \mid \psi_1),$$

then, when the posterior is well defined,

$$p(\psi_2 \mid \psi_1, \mathcal{D}) = p(\psi_2 \mid \psi_1).$$

- The marginal posterior can change through prior dependence.
- Weak identification need not produce a wide posterior.

Why Can the Tax Coefficient Be Biased?

Let W_t contain an intercept and the other regressors:

$$\tilde{\tau}_t = \tau_t - \text{proj}(\tau_t \mid W_t).$$

The population partial-regression formula is

$$\phi_{\tau}^{\text{OLS}} - \phi_{\tau} = \frac{\text{Cov}(\tilde{\tau}_t, \zeta_t^c)}{\text{Var}(\tilde{\tau}_t)}.$$

When controls respond to both tax and demand shocks, partialling them out can correlate residual taxes with demand shocks.

Why bias vanishes at $\theta = 1$

Ricardian Neutrality Separates Fiscal and Real Variation

Net worth contains bonds ($\bar{Q}$: steady-state bond price):

$$n_{t-1} - b_{t-1} = \bar{Q}^{-1} k_{t-1}.$$

At $\theta = 1$, fiscal shocks do not move private capital or the real PVs. With debt persistence ρ_B and productivity growth g_A ,

$$\tau_t = [(1 + g_A)^{-1} - \bar{Q}\rho_B] b_{t-1} + \epsilon_t^\tau.$$

Controlling for lagged debt and the real regressors leaves

$$\tilde{\tau}_t = \epsilon_t^\tau, \quad \text{Cov}(\tilde{\tau}_t, \zeta_t^c) = 0.$$

The Tax Coefficient Can Be Unbiased Despite Endogeneity

The Ricardian-limit argument uses the population design:

- Fixed spending, zero steady-state debt, and a closed economy.
- Fiscal innovations orthogonal to non-fiscal shocks.
- Lagged debt retained as a separate regressor.

Other controls remain correlated with the demand shock. For the grouped regression, use $U_t - b_{t-1}/(1 + g_A)$ and retain b_{t-1} .

Continuity and nondegenerate residual tax variation give convergence as $\theta \rightarrow 1$; they do not establish monotone bias in general.

Appendix: The Two-Country Accounting

- Domestic households own firms and capital; foreigners receive endowment income.
- Both trade one-period government debt; its price Q_t clears the market.
- Domestic lump-sum taxes adjust to the budget. Foreigners pay no domestic tax.

Holdings: B_t domestic, B_t^* foreign; current account: CA_t .

$$\text{Government debt} = B_t + B_t^*, \quad NFA_t = -Q_t B_t^*.$$

$$CA_t = NFA_t - NFA_{t-1} = Q_{t-1} B_{t-1}^* - Q_t B_t^*.$$

The current account includes net interest; negative values denote deficits.

Appendix: Household And Financial Calibration

Parameter	Value	Interpretation
θ	0.092	Tax-expectation attenuation
β	0.990	Annual discount factor 0.961; quarterly MPC 0.010
$\bar{Q}$	0.983	Steady-state bond price, $\beta(1 + g_A)^{-\gamma}$
ρ_B	0.978	Persistence of productivity-scaled debt
γ	1	Relative risk aversion

Parameters are quarterly. The initial balanced-growth path matches 1976 debt and NFA.

Production and foreign economy

Appendix: Production And The Foreign Economy

All non-fiscal shocks are zero.

Parameter	Value	Interpretation
α	0.39	Capital share
g_A	0.0069	Quarterly productivity growth; 2.78% annually
μ	3.94	Foreign income / domestic output
δ	0.022	Quarterly depreciation
$\bar{G}$	0	Steady-state government spending

The size of the foreign economy affects the bond-price response; it does not impose a proportional foreign portfolio share.

Household calibration

Appendix: Debt And Deficits, Model And Data

Data cover 1976–2025.

	Data	$\theta = 0.092$	$\theta = 1$
Initial government debt	26	26	26
Year-50 government debt	98	98	98
Average budget deficit	3.78	3.08	3.08
Average primary deficit	1.68	−1.05	−1.04
Average current account	−2.40	−1.43	0.12
Investment/GDP trend (pp)	0.23	−0.11	0.00

Budget deficits include net interest; primary deficits exclude it. Ratios are percent of endogenous GDP; debt uses annualized GDP. The investment trend is the annual OLS slope multiplied by 50 years. Data averages weight years equally; model averages weight quarters equally.

Appendix: Net Foreign Assets, Model And Data

Data cover 1976–2025.

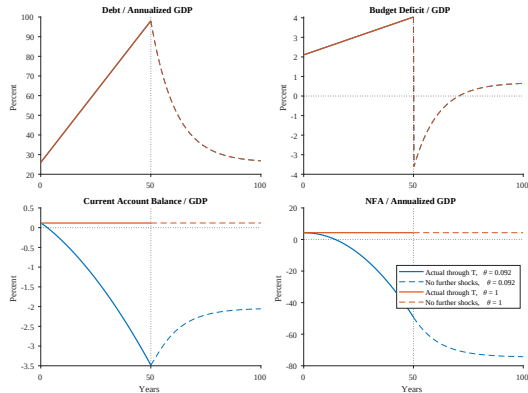
	Data	$\theta = 0.092$	$\theta = 1$
Initial NFA	4.3	4.3	4.3
Year-50 NFA	−71.1	−49.2	4.3
Change in NFA (pp)	−75.4	−53.5	0.0
Model / observed NFA decline (%)	–	71.0	0.0

NFA is measured at market value, in percent of annualized endogenous GDP. Changes are percentage points; the final row is not an estimated causal share.

Debt and deficits

Units

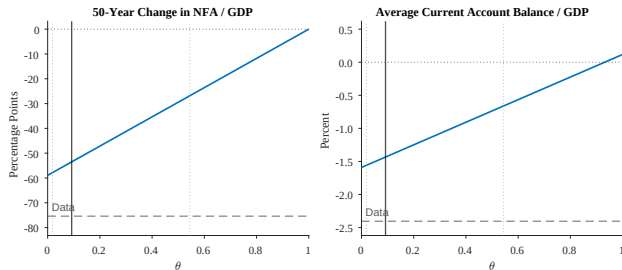
Appendix: The Complete Fifty-Year Debt Experiment



Solid: outcomes through year 50. Dashed: subsequent no-shock outcomes.

Subsequent paths

Appendix: The Complete Comparison Across Values Of Theta



- Black line: $\theta = 0.092$; gray lines: its 90% interval $[0.019, 0.544]$.
- At those endpoints, model NFA declines equal 35.6%–76.7% of the observed decline.
- This varies θ only, not uncertainty in every calibration input.

Appendix: Units And Comparison Conventions

- All ratios use endogenous GDP. Debt and market-value NFA are divided by annualized GDP.
- Budget deficits and current accounts: quarterly flows / quarterly GDP. No additional annualization is needed.
- Investment/GDP trend: annual OLS slope $\times$ 50 years, in percentage points.
- Model flow averages weight quarters equally; data averages weight years equally.
- Stock paths include period 0; flow paths begin in period 1.

The reported NFA change is a percentage-point change in its GDP ratio.

Appendix: Debt Surprises And Subsequent Paths

- Each date's shock returns debt to the smooth 50-year path. Households do not anticipate subsequent surprises.
- After year 50, shocks stop and debt reverts.
- Dashed paths follow the actual law of motion with no further shocks. They also equal rational conditional forecasts at year 50.

Initial NFA is 4.3% of GDP. By year 100, debt is 26.8% of annualized GDP and NFA is -74.3% of GDP. The international asset position has a unit root.

[Experiment](#)[Paths](#)

Appendix: The Six-Instrument Robustness Check

Shock	External series	Source
Gov. spending	Defense R&D appropriations	Fieldhouse and Mertens (2023)
Tax	News in presidential speeches	Lieb et al. (2024)
Monetary policy	News in Federal Reserve documents	Aruoba and Drechsel (2024)
Oil	OPEC oil-supply news	Känzig (2021)
Uncertainty	Intraday gold-price surprises	Piffer and Podstawski (2018)
Technology	Patent-application news	Miranda-Agrippino et al. (2025)

- Retain six of the benchmark's 28 instruments, one per structural-shock category.
- Coverage is uneven across series, which is one reason the state-space formulation matters.

Appendix: Legacy Expectations–Discounting Illustration

How The Decomposition Works

Under additional assumptions on tax dynamics, $\phi_n = 1 - \beta\omega$ and $-\phi_\tau = (1 - \beta\omega)(1 - \theta_{cd})$, so the two reduced-form moments discipline the discounting wedge ω and behavioral attenuation.

Mechanism	λ	ω
Naive cognitive discounting	0.14	
Sophisticated cognitive discounting	0.85	
Discounting wedge + rational		0.85
Discounting wedge + naive C.D.	0.30	0.97
Discounting wedge + sophisticated C.D.	0.88	0.97

Legacy Cleveland: $\theta = .136$, quarterly MPC = .036; $\beta = .995$, $\rho_\tau = .978$. Not the current benchmark.

- In this legacy calibration, matching θ alone requires a large discounting wedge.
- Matching both MPC and MPC-DFT requires non-rational expectations as well.

From The Estimate To General Equilibrium

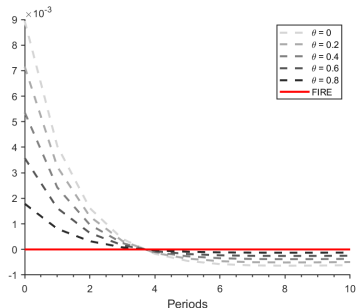
- Embed the estimated consumption function in a simple closed-economy RBC model with capital.
- A debt-financed tax cut makes households feel richer when $\theta < 1$.
- So consumption rises on impact, saving falls, and investment is crowded out.
- This is the equilibrium implication the semi-structural estimate is pointing to.

Mechanism

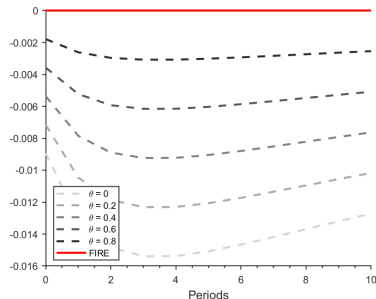
lower taxes today $\Rightarrow$ higher perceived wealth $\Rightarrow$ higher $c_t \Rightarrow$ lower $i_t \Rightarrow$ lower k_{t+1}

Equilibrium Implication: Government Debt Crowds Out Capital

Consumption response



Capital response



- Negative tax shock = debt-financed transfer.
- The smaller is θ , the stronger is the rise in consumption and the fall in capital.
- Our estimate lies between the $\theta = 0$ and $\theta = 0.2$ cases, toward the stronger-crowding-out end.