Optimal Fiscal Policy under Endogenous Disaster Risk: How to Avoid Wars?

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Disclaimer: The views here do not represent the views of the Federal Reserve Bank of Chicago or the Federal Reserve System.

Motivation

- We are experiencing a period of rising geopolitical uncertainty.
- European countries are responding by boosting defense spending.
  (The "Readiness 2030" package targets €800bn in defense spending via fiscal flexibility)
- Policymakers weight asset sales, defense bonds, or pausing deficit rules.
- How to optimally finance defense spending?

This Paper

- We develop an optimal fiscal policy framework with:
  - Incomplete markets.
  - Endogenous disaster risk.
- A home planner maximizes welfare by choosing
  - Distortionary labor taxes.
  - Non-state-contingent debt.
  - Defense investment (D), which builds defense capital (DS).
- Where a foreign country decides to engage in conflict taking into account DS, which leads to an equilbirium probability of war $P(DS)$.
- Accumulated DS provides:
  - Deterrence: reduces the likelihood of conflict ($P(DS) \downarrow$).
  - Insurance: mitigates the impact if a disaster occurs.

Main mechanism

- **Tax Smoothing:**

$$\underbrace{\mu_t}_{\substack{\text{Tightness of}\\ \text{implementability constraint}}} = \mathbb{E}_t[\mu_{t+1}] = P(DS) \cdot \mu_{t+1}^{\text{War}} + (1 - P(DS)) \cdot \mu_{t+1}^{\text{Peace}}$$

  - *Across states:* minimize $\mu_{t+1}^{\text{War}} - \mu_{t+1}^{\text{Peace}}$.
  - *Over time:* minimize $P(DS)$.

- **Mechanism:**
  - $\uparrow DS \rightarrow \downarrow P(DS) \rightarrow \downarrow \mathbb{E}_t[\mu_{t+1}]$→smoothing→↓ current μ_t.
  - Lower expected tightness tomorrow → lower tightness today.
  - Bring future advantages to present → borrow.
  - More borrowing $\rightarrow \uparrow \mu_{t+1}^{War} - \mu_{t+1}^{Peace}$.
  - Time smoothing $\succ$ cross-state smoothing.

Literature

- Optimal Fiscal Policy

  Barro (1979), Lucas and Stokey (1983), Aiyagari et al. (2002), Niemann and Pichler (2011), Ferriere and Karantounias (2019), Karantounias (2023), Michelacci and Paciello (2019), Angeletos et al. (2023).

- Disaster Risk

  Rietz (1988), Barro (2006), Barro (2009), Gourio (2012).

- Climate Disaster Management

  Douenne et al. (2022), Barrage (2019), Cai and Lontzek (2019), Hong et al. (2023).

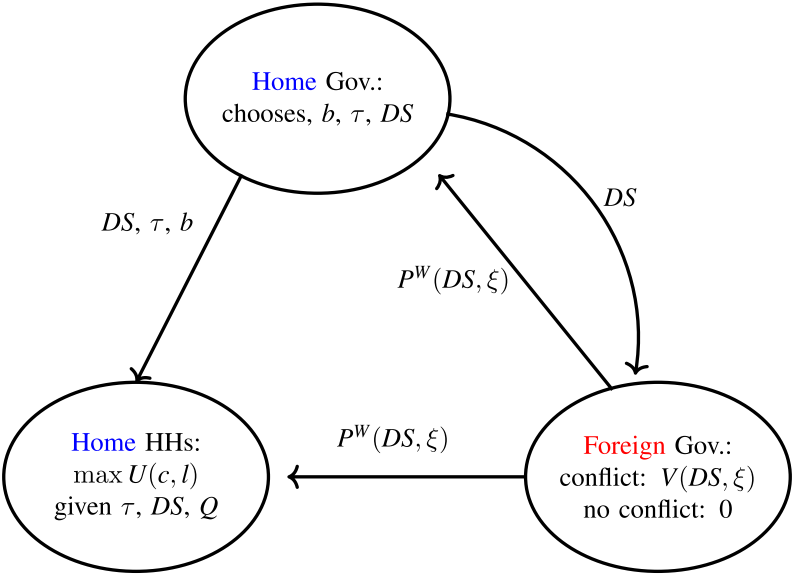
- Military Conflicts

  Pflueger and Yared (2024), Federle et al. (2025), Levine and Ohanian (2024), Antonova et al. (2025).

Plan

- Model
- Insights from the planner FOCs
  (The paper presents several analytical results in a two-period model)
- Calibration
- Quantitative results
- Policy applications
  - Application 1: Should we allow higher deficit for defense?
  - Application 2: Role of Maastrich-type deficit constraints.

Model: sketch



Foreign government

Takes decision at the end of period t, after observing home country's policies (DS_t) and shocks. War occurs at beginning of $t+1$.

War Payoff: $V(DS_t, \xi_t)$

$\Rightarrow$ DS_t: home country's defense capital $\left(\frac{\partial V}{\partial DS} < 0\right)$.

$\Rightarrow$ ξ_t: foreign preference for conflict $\left(\frac{\partial V}{\partial \xi} > 0\right)$.

Stochastic component: idiosyncratic shock $\epsilon_t \sim$ Logistic.

Decision: choose war if $V(DS_t, \xi_t) + \epsilon_t \geq 0$.

Probability of war: $P(\mathcal{I}_{t+1} = 1) = \frac{1}{1+e^{-V(DS_t,\xi_t)}}$.

Home households

Representative household with utility:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \cdot U(c_t, l_t).$$

Budget constraint:

$$c_t + Q_t b_{t+1} = (1 - \tau_t) w_t h_t + b_t$$

Optimality conditions:

$$\begin{aligned} (1 - \tau_t) \cdot u'(c_t) \cdot w_t &= v'(l_t), \\ u'(c_t) \cdot Q_t &= \beta \mathbb{E}_t u'(c_{t+1}). \end{aligned}$$

Home government

- Faces exogenous spending shock g_t and war risk shock ξ_t from foreign government.
- In case of war, it faces an additional spending g^e, such that $\left(g_t^W = g_t + g^e\right)$, and a productivity drop from z to $z^W < z$. See data
- It invests in defense stock DS_t

$\Rightarrow$ for deterrence (higher DS means lower P):

$$P(\mathcal{I}_t = 1) = P^W(DS_{t-1}, \xi_{t-1}), \qquad \text{with } \partial P^W_{DS} < 0 \text{ and } \partial P^W_{\xi} > 0,$$

$\Rightarrow$ and for insurance: in case of war a fraction ϕ of g^e can be met by depleting the defense stock such that

$$DS_t = DS_{t-1}(1-\delta) + D_t - \mathcal{I}_t \cdot \underbrace{\mathcal{S}\left(DS_{t-1}(1-\delta) + D_t, \phi g^e\right)}_{\text{A smooth version of the } \min(.,.) \text{ operator}} .$$

Home government: implementability constraint

The government budget is:

$$b_t = \underbrace{\tau_t z_t h_t - g_t - \overbrace{\left(D_t - \mathcal{I}_t \mathcal{S}(DS_{t-1}(1-\delta) + D_t, \phi g^e)\right)}^{\text{Investment in } DS:\ DS_t - (1-\delta)DS_{t-1}}}_{\text{Surplus: } s_t} + Q_t b_{t+1}.$$

The resource constraint is:

$$c_t + g_t + \text{Investment in } DS_t = z_t h_t.$$

Substitute away Q_t and τ_t with household's rationality to get the implementability constraint:

$$u'(c_t) \cdot b_t = \underbrace{u'(c_t) s_t}_{\Omega_t} + \beta \mathbb{E}_t \left[u'(c_{t+1}) \cdot b_{t+1} \right].$$

Home government: Ramsey planner

Given initial conditions, the Ramsey Planner chooses stochastic sequences

$$\{\tau(s^t), D(s^t), c(s^t), l(s^t), DS(s^{t-1}), b(s^{t-1})\}_{t=0}^{\infty}$$

to maximize

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[u(c_t) + v(l_t)\right]$$

subject to

$$\mu_t^D: \quad DS_t = DS_{t-1}(1-\delta) + D_t - \mathcal{I}_t \mathcal{S}(DS_{t-1}(1-\delta) + D_t, \phi g^e),$$

$$\mu_t: \quad u_c(c_t) \cdot b_t = \Omega_t + \beta \mathbb{E}_t \left[u_c(c_{t+1}) \cdot b_{t+1}\right],$$

$$\zeta_L: \quad b_{t+1} > \underline{M}, \qquad \zeta_U: \quad b_{t+1} < \bar{M}, \qquad \zeta^D: \quad D_t \geq 0.$$

Home government: Ramsey policy for defense spending

Today's marginal cost μ_t^D equals the expected future marginal benefits:

$$\mu_t^D = \underbrace{\beta \frac{\partial P(DS_t,\xi_t)}{\partial DS_t} \mathbb{E}_t^{g,\xi}\left(U_{t+1}^W - U_{t+1}^N\right)}_{\text{Deterrence}} + \underbrace{\beta\, P(DS_t,\xi_t)\mathbb{E}_t^{g,\xi}\left(\mu_{t+1}\frac{\partial \Omega_{t+1}}{\partial DS_t} + \nu_{l,t+1}\frac{\partial l_{t+1}}{\partial DS_t}\right)}_{\text{Insurance}}$$

$$+\ \beta\mathbb{E}_t\left[\mu_{t+1}^D\left(\underbrace{(1-\delta) - \mathcal{I}_{t+1}\frac{\partial \mathcal{S}(DS_t(1-\delta)+D_{t+1},\phi g^e))}{\partial DS_t}}_{\text{Undepreciated stock of DS net of losses in cases of war}}\right)\right].$$

Deterrence: more DS lowers P^W

$\Rightarrow \frac{\partial P(DS_t,\xi_t)}{\partial DS_t} < 0.$

Insurance: more DS raises future surplus and reduces labor

$\Rightarrow \frac{\partial \Omega_{t+1}}{\partial DS_t} > 0$ and $\frac{\partial l_{t+1}}{\partial DS_t} < 0.$

Home government: Ramsey policy for debt

Today's marginal benefit μ_t equals the expected future marginal cost:

$$\mu_t \;=\; \mathbb{E}_t(n_{t+1}\,\mu_{t+1})\,, \qquad n_{t+1} \equiv \frac{u'(c_{t+1})}{\mathbb{E}_t[u'(c_{t+1})]},$$

a weighted average of war (μ^W) and peace (μ^N).

Quasilinear simplification (risk-neutral kernel)

$$\mu_t \;=\; \mathbb{E}_t(\mu_{t+1}) \;=\; \underbrace{P^W(DS_t,\xi_t)}_{\text{war prob.}}\,\mathbb{E}_t^{g,\xi}\left[\mu^W_{t+1}\right] + \underbrace{\left(1 - P^W(DS_t,\xi_t)\right)}_{\text{no war prob.}}\,\mathbb{E}_t^{g,\xi}\left[\mu^N_{t+1}\right]$$

- Borrowing to finance g shifts taxes to the future similarly across states.
- Borrowing to finance DS shifts weights as deterrence lowers $P^W(.)$.

$\Longrightarrow$ Smaller rise in $\mathbb{E}_t[\mu_{t+1}]$ than for g $\Rightarrow$ more debt for defense.

Calibration: overview

- Preferences: $\beta = 0.96$ (annual), $u(c) = \log c$, $v(l) = -B\frac{(1-l)^{1+\eta}}{1+\eta}$.

  $\eta = 1$ (Frisch elasticity $= 1$, consistent with literature).

  $B = 16.99 \Rightarrow$ average hours $= 1/3$ in N-state first-best.

- Technology: $F(z,h) = zh$.

  $z^N = 1$ (normalization), z^W calibrated from disaster episodes.

- g_t: gov. consumption + investment (net of *defense* investment).

  Data: NIPA Table 3.9.5, 1947–2023.

  Estimate (ρ^g, σ^g) from linearly detrended, deflated series.

  Choose μ_g so the model gov. share matches 13.12% of GDP.

- D_t: defense investment (military equipment, structures, IP products).

  Data: NIPA Fixed Asset Tables, 1929–2023.

  DS_t: stock of defense capital (sum of the above categories).

  Category-weighted depreciation $\delta = 9.31\%$(annual).

Calibration: geopolitical risk index (GPRI)

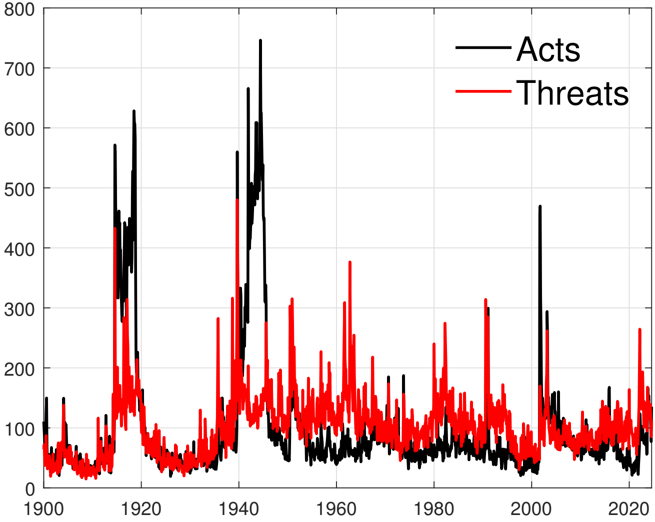
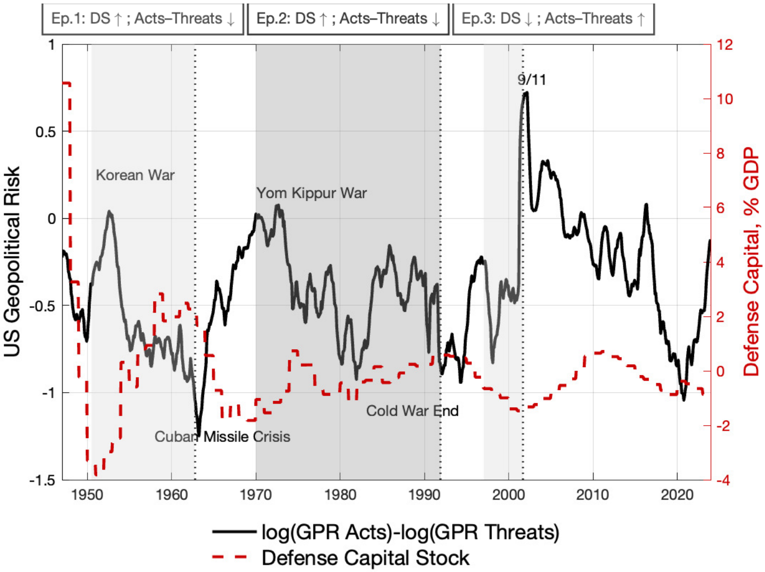


Figure: GPRI (Caldara & Iacoviello 2022).

Calibration: stock built up when threats dominate



Calibration: disasters & insurance

- Underlying idea:

  GPRI *Threats* index $\Rightarrow$ underlying geopolitical risk.

  GPRI *Acts* index $\Rightarrow$ realized events (disasters).

- **Disaster** identification: normalize GPRI *acts* $\in [0, 1]$.

  Define disasters when index > 0.5.

  Two episodes: WWII, September 11.

  Disaster gov. spending increase: $g^e = 0.0568$ (17.5% of GDP).

  Disaster output loss: $z^W = 0.9653$. See data

- Discipline **insurance** motive of *DS* using WWII and September 11. Compare increase in government spending g^e explained by defense:

  $\phi = 0$ if defense does not increase at all.

  $\phi = 1$ if entire increase in g^e is due to defense.

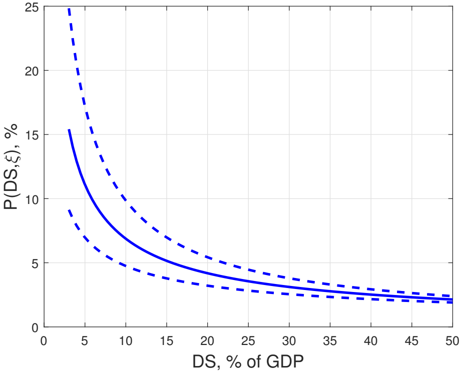
  Average across episodes $\Rightarrow$ $\phi = 0.98$.

Calibration: deterrence

Exploit GPRI and estimate: $P(DS,\xi) = \frac{1}{1+e^{-\beta_1 - \beta_2 \log(DS) - \beta_3 \log(\xi)}}$.

- Map to data:
  - GPRI *acts* $\in [0,1] \approx P(.)$.
  - GPRI *threats* $\approx \xi$.
  - *DS* from NIPA.
- Estimates:
  - $\beta_1 = -2.99$.
  - $\beta_2 = -0.76$ (< 0).
  - $\beta_3 = 0.87$ (> 0).
- Interpretation:
  - $\partial P / \partial DS < 0$ (deterrence).
  - $\partial P / \partial \xi > 0$ (risk).

Figure: Estimated probability.



External Solution

Results

- **Long-run averages:**
  - ⇒ Higher borrowing when disasters are endogenous. ▸▸ Histogram
- **Increase in geopolitical risk:**
  - ⇒ Endogenous disaster risk calls for borrowing. ▸▸ Results
- **Increase the *deterrence* motive:**
  - ⇒ Planner sacrifices tax smoothing across states. ▸▸ Results

Policy applications

- The Maastricht criteria constrain EU member states' fiscal policy by requiring the annual government deficit to not exceed 3% of GDP.

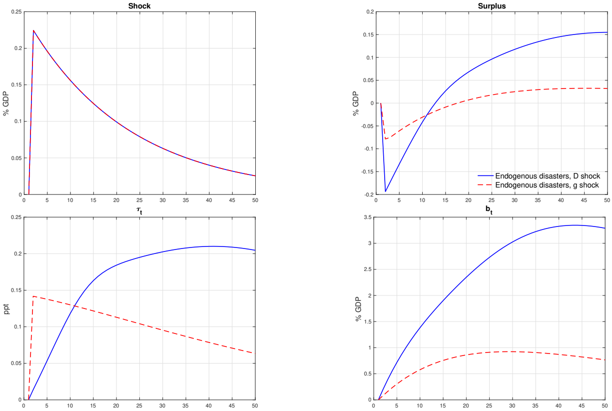
- Should we allow higher deficit for defense in the short run?

◦ **Application 1**: Compute the IRFs to a positive g_t and ξ_t shocks, calibrated to yield the same rise in D_t/Y_t as g_t/Y_t.

- Do deficit constraints reduce debt levels in the long run?

◦ **Application 2**: We impose a constraint such that current surplus is non-negative, $s_t > 0$, during peace time.

Application 1: should we allow higher deficit for defense?



- Borrowing to finance g shifts taxes to the future similarly across states.
- Borrowing to finance DS shifts weights as deterrence lowers $P^W(.)$.

$\Longrightarrow$ Smaller rise in $\mathbb{E}_t[\mu_{t+1}]$ than for g $\Rightarrow$ more debt for defense.

Application 2: do deficit constraints reduce debt levels?

We impose a constraint such that current surplus $s_t > 0$ during peace time.

		Endogenous disasters	Endogenous disasters with constraint	Exogenous disasters	Exogenous disasters with constraint
	Debt and Taxes, % GDP				
1	$\mathbb{E}(\Delta b_{t+1}/Y_t \mid \mathcal{I}_t = 1)$	24.34	24.82	26.76	28.28
2	$\mathbb{E}(\Delta b_{t+1}/Y_t \mid \mathcal{I}_t = 0)$	-2.68	-2.73	-3	-3.16
3	$\mathbb{E}(b_t/Y_t)$	86.57	92.30	74.91	87.73
	Defense, % GDP				
	$\mathbb{E}(DS_t/Y_t)$	5.63	5.63	-	-
	$\mathbb{E}(D_t/Y_t \mid war_t = 0)$	0.73	0.74	-	-

The constraint induces the planner:

1. To accumulate debt faster during war time.
2. To decumulate debt faster during peace time.
3. To borrow more overall.

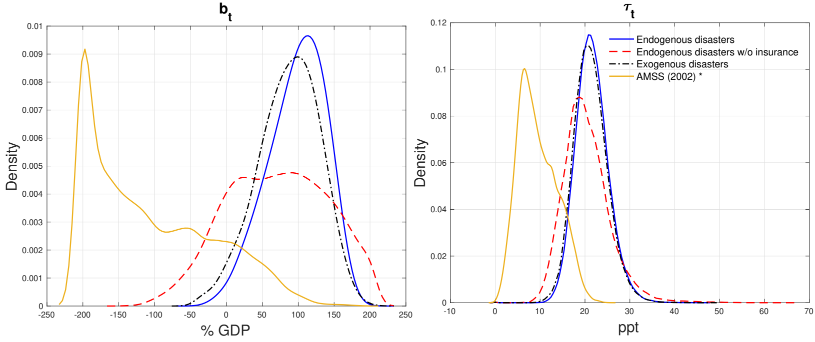
$\Longrightarrow$ Removing the deficit constraint would lead to less debt on average.

Taking stock

- We integrate endogenous disaster management in optimal fiscal policy:
  - Novel trade-off between time and cross-state smoothing.
  - Defense spending makes expected future distortions less likely, hence it justifies higher debt levels.
  - Time smoothing increasingly more preferred as *deterrence* becomes stronger.
  - Optimal to run three times larger deficits to finance defense shocks compared to g_t shocks.
- Extensions:
  - Integrate war damage/sovereign default/inflation risk, where $\frac{\partial Q}{\partial D}$ could become positive. Borrowing potentially more attractive.
  - In a "No Commitment" setting, $\frac{\partial Q}{\partial D}$ considerations more relevant.

Thank you!

Endogenous disasters increase average debt



- The figure shows ergodic distributions from 200 runs of 5000 periods.

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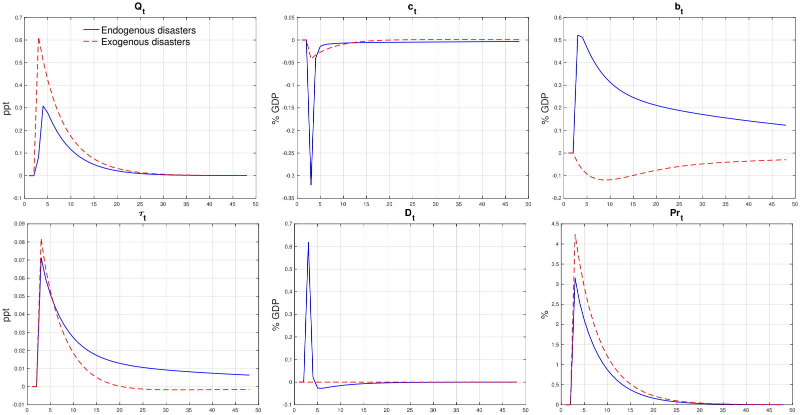
Increase in geopolitical risk



- The figure shows the IRF to a one standard deviation ξ_t shock.

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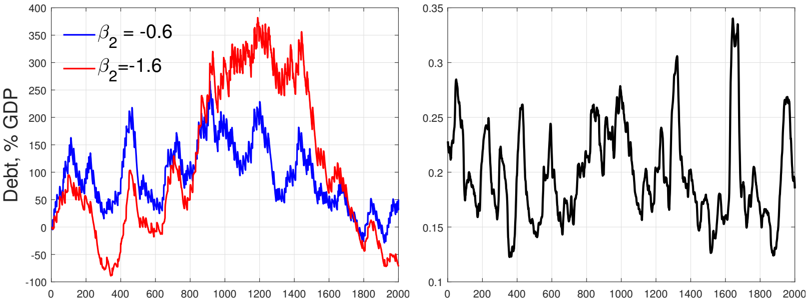
Smoothing over time but not across states I

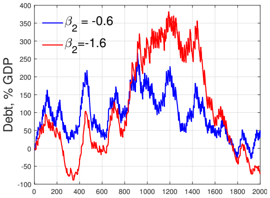
(a) b_t with high and low β_2 (b) ξ_t



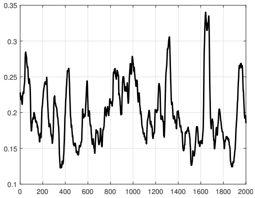
More *deterrence* motive (lower β_2)$\rightarrow$ b_t responds more to ξ_t, therefore it is already high when wars are more likely.

Smoothing over time but not across states II

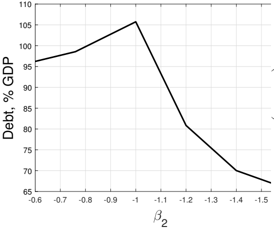
(a) b_t with high and low β_2



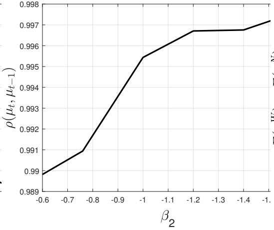
(b) ξ_t



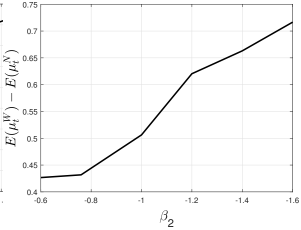
(a) $\mathbb{E}_t(b_t)$



(b) $\rho(\mu_t, \mu_{t-1})$



(c) $\mathbb{E}(\mu_t^W) - \mathbb{E}(\mu_t^U)$



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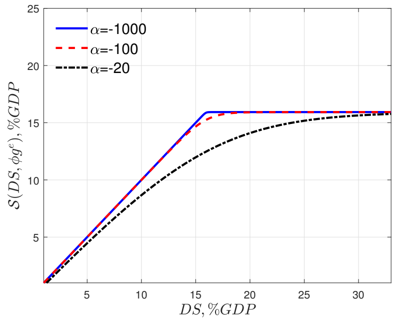
Calibration: Insurance Channel I

$$\mathcal{S}(DS, g^e) = \frac{1}{\alpha} \log\left(e^{\alpha DS} + e^{\alpha \phi g^e}\right),$$

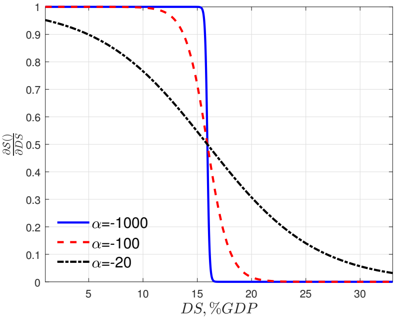
where

$$\lim_{\alpha \to \infty} \mathcal{S}(DS, g^e) = \max(DS, \phi g^e) \quad \text{and} \quad \lim_{\alpha \to 0} \mathcal{S}(DS, g^e) = \frac{DS + \phi g^e}{2}.$$

Calibration: Insurance Channel II



(a) $\mathcal{S}(DS, g^e)$.



(b) $\frac{\partial \mathcal{S}(DS, g^e)}{\partial DS}$.

Calibration: Untergeted Moments

Description	Moments	Model	Data
Defense Stock to GDP, %	$\mathbb{E}(DS_t/Y_t)$	5.62	18.50
Defense Investment to GDP, %	$\mathbb{E}(D_t/Y_t)$	2.21	2.13
Gov. Spending to GDP, %	$\mathbb{E}(g_t + D_t)$	15.91	15.95
Disaster Probability, %	$\mathbb{E}(P(DS_{t-1}(1-\delta) + D_t, \xi_t))$	10.59	7.30
Debt to GDP, %	$\mathbb{E}(b_t/Y_t)$	86.23	64.02
Tax Rate, %	$\mathbb{E}(\tau_t)$	20.44	17.21

Figure: Data and model responses, comparing to LP estimates using military news shocks Ramey and Zubairy (2018).

Solution Method: Parameterized Expectations

The model equilibrium consists of the following system:

- c_t:

$$0 = u'(c_t) + v'(l_t)\frac{\partial l_t}{\partial c_t} + \mu_t\left(\frac{\partial(s_t u'(c_t))}{\partial c_t}\right) - u''(c_t)b_t(\mu_t - \mu_{t-1})$$

- b_{t+1}:

$$\mu_t = \frac{E_t(u'(c_{t+1})\mu_{t+1})}{E_t(u'(c_{t+1}))}$$

- D_t:

$$0 = v'(l_t)\frac{\partial l_t}{\partial D_t} + \mu_t\left(\frac{\partial s_t u'(c_t)}{\partial D_t}\right) + \mu_t^D$$

- DS_t:

$$\mu_t^D = \beta\frac{\partial P^W(DS_t,\xi_t)}{\partial DS_t}\mathbb{E}_t^x\left(U(c_{t+1}^W, l_{t+1}^W) - U(c_{t+1}^N, l_{t+1}^N)\right) + \beta\mathbb{E}_t\left(\mu_{t+1}\frac{\partial s_{t+1}u'(c_{t+1})}{\partial DS_t}\right) +$$
$$\beta\mathbb{E}_t\left(\mu_{t+1}^D(1-\delta) - \mu_{t+1}^D\frac{\mathcal{I}_{t+1}\partial\mathcal{S}(DS_t, g_{t+1}^e\phi))}{\partial DS_t}\right)$$

- Plus the constraints.

Solution Method: Parameterized Expectations I

The model equilibrium consists of the following system:

- c_t:

$$0 = u'(c_t) + v'(l_t)\frac{\partial l_t}{\partial c_t} + \mu_t\left(\frac{\partial(s_t u'(c_t))}{\partial c_t}\right) - u''(c_t)b_t(\mu_t - \mu_{t-1})$$

- b_{t+1}:

$$\mu_t = \frac{E_t(u'(c_{t+1})\mu_{t+1})}{E_t(u'(c_{t+1}))}$$

- D_t:

$$0 = v'(l_t)\frac{\partial l_t}{\partial D_t} + \mu_t\left(\frac{\partial s_t u'(c_t)}{\partial D_t}\right) + \mu_t^D$$

Solution Method: Parameterized Expectations II

- DS_t:

$$
\begin{aligned}
\mu_t^D =& \beta \frac{\partial P^W(DS_t, \xi_t)}{\partial DS_t} \mathbb{E}_t^x \left(u(c_{t+1}^W) + v(l_{t+1}^W) - u(c_{t+1}^N) - v(l_{t+1}^N) \right) + \beta \mathbb{E}_t \left(\mu_{t+1} \frac{\partial s_{t+1} u'(c_{t+1})}{\partial DS_t} \right) \\
& \beta \mathbb{E}_t \left(\mu_{t+1}^D (1-\delta) - \mu_{t+1}^D \frac{\mathcal{I}_{t+1} \partial \mathcal{S}(DS_t, g_{t+1}^e \phi))}{\partial DS_t} \right)
\end{aligned}
$$

- Plus the constraints.

Solution Method: Parameterized Expectations I

Project the terms in the integral on the state variables, i.e.

$$u_c(c_t) \approx \Psi(g_t, \xi_t, \mu_{t-1}, b_{t-1}, DS_{t-1}, \mathcal{I}_t)$$

Perform the projection $\Psi(.)$ using an *Artificial Neural Network* ($\mathcal{ANN}$).

Solution algorithm:

1. Generate a sequence of shocks. Simulate the model using some educated guess.
2. Train the network using an educated guess for model dynamics.
3. Given the projection $\mathcal{ANN}(g_t, \xi_t, \mu_{t-1}, b_{t-1}, DS_{t-1}, \mathcal{I}_t)$, simulate the model using the optimality conditions.
4. Train the $\mathcal{ANN}$ given the simulated data. Check if the $\mathcal{ANN}$ predictions are consistent with the simulated data. If not, go back to step 3.

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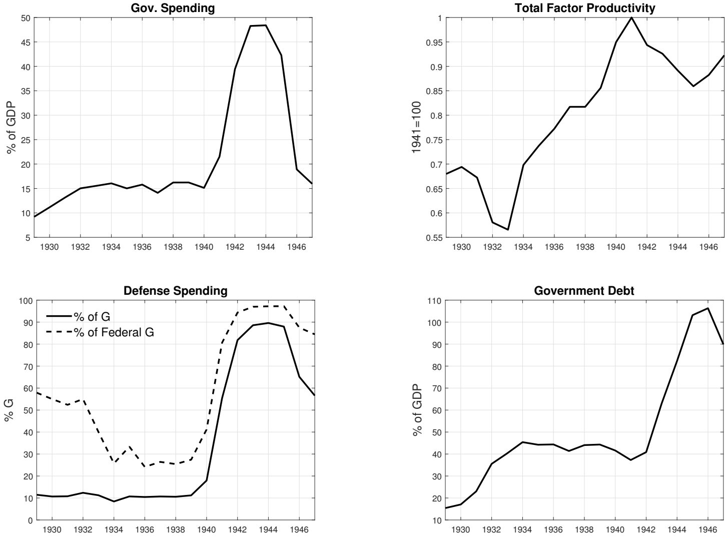
What is a war? U.S. WWII Example



Back Gvt Problem Back Calibration

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