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

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  - Countries spend on defense for *deterrence*,
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- How to optimally manage disaster risks?
- Application to avoiding wars.

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- How much to spend on defense? How defense spending should respond to shocks?
- Which aspects of defense spending are more relevant? What are the effects on bond prices?
- How to finance it? Use taxes or debt?

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Findings

- Smooth tax distortions *over time* as opposed to *across states*,
- Higher levels and more volatile debt under endogenous disasters,
- Qualitatively different dynamics of debt and taxes,
- Results driven by the *risk management* motives.

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).

- Disaster Risk

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

- Climate Disaster Management

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

Model: Primitives

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- Risk Management : Government can invest in defense stock DS_t that affects the disaster probability.

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

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- Insurance : Defense stock also helps to meet additional spending needs when the disaster occurs. Formally, spending need in the disaster state is:

$$g_t - \mathcal{IS}(DS_{t-1}, \phi g^e)$$

Model: Households

Representative household with utility

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Optimality Conditions

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

Model: Government and resource constraints

The government budget is

$$b_t + g_t + D_t - \mathcal{I}_t \mathcal{S}(DS_{t-1}, g_t^e \phi) = \tau_t z_t h_t + Q_t b_{t+1}$$

DS_t evolves according to:

$$DS_t = DS_{t-1}(1-\delta) + D_t - \mathcal{I}_t \mathcal{S}(DS_{t-1}, g_t^e \phi)$$

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The resource constraint is

$$g_t + D_t + c_t - \mathcal{I}_t \mathcal{S}(DS_{t-1}, g_t^e \phi) = z_t h_t.$$

Bonds market clearing: $b_t^h + b_t^g = 0$. Positive bond allocation $b_t^g > 0$ means households are lending to government.

Implementability Constraints

Define the primary surplus as $s_t \equiv \tau_t z_t h_t w_t - g_t - D_t + \mathcal{I}_t \mathcal{S}(DS_{t-1}, g_t^e \phi)$

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Substitute away bond prices and taxes in the government budget consistently with household's rationality to get

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

Multiply by $u_c(c_t)$:

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

Optimal Fiscal Policy

Given initial conditions, the Ramsey Planner chooses stochastic sequences of $\tau(s^t), B(s^{t-1}), b(s^{t-1})\ c(s^t), l(s^t)$ to maximize $\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t (u(c_t) + v(l_t))$ subject to:

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

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

$$\zeta_L: \quad b_{t+1} > \underline{M} \qquad \zeta_U: \quad b_{t+1} < \bar{M}$$

Analysis: Defense Spending

Spending on D_t

$$\underbrace{\mu_t^D}_{\text{Marginal Benefit}} = \underbrace{-v'(l_t)\frac{\partial l_t}{\partial D_t} - \mu_t \frac{\partial \Omega_t}{\partial D_t}}_{\text{Marginal Cost}}$$

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$$\mu_t^D = \underbrace{\beta \frac{\partial P^W(DS_t, \xi_t)}{\partial DS_t} \mathbb{E}_t^x \left(U(c_{t+1}^W, l_{t+1}^W) - U(c_{t+1}^N, l_{t+1}^N) \right)}_{\text{Risk Management}} + \underbrace{\beta \mathbb{E}_t \left(\mu_t \frac{\partial s_{t+1} u'(c_{t+1})}{\partial DS_t} \right)}_{\text{Insurance}} +$$

$$\underbrace{\beta \mathbb{E}_t \left(\mu_{t+1}^D (1-\delta) - \frac{\mathcal{I}_t \partial \mathcal{S}(DS_{t-1}, g_t^e \phi))}{\partial DS_{t-1}} \right)}_{\text{Future Terms}}$$

Analysis: Prices

In Aiyagari et al. (2002), spending needs are exogenous and debt reallocates taxes across periods. Higher debt leads to higher prices.

$$Q_t = \frac{\mathbb{E}_t u'(c_{t+1})}{u'(c_t)} \quad \text{with } c_t = c(b_t, \tau_t, g_t) \quad \text{and} \quad c_{t+1} = c(b_{t+1}, \tau_{t+1}, g_{t+1})$$

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Higher debt today means lower taxes today and higher taxes tomorrow:

$$\frac{\partial Q_t}{\partial b_{t+1}} = \underbrace{-\frac{\mathbb{E}_t u'(c_{t+1})}{u'(c_t)^2} u''(c_t) \frac{\partial c_t}{\partial \tau_t} \frac{\partial \tau_t}{\partial b_{t+1}}}_{\text{lower } \tau_t > 0} + \underbrace{\frac{\mathbb{E}_t(u''(c_{t+1}))}{u'(c_t)} \frac{\partial c_{t+1}}{\partial \tau_{t+1}} \frac{\partial \tau_{t+1}}{\partial b_{t+1}}}_{\text{higher } \tau_{t+1} > 0} > 0$$

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Assume the planner issues debt and uses it to purchase D_t:

$$\frac{\partial Q_t}{\partial b_{t+1}} = \underbrace{\frac{\partial P^W}{\partial D_t} \frac{\partial D_t}{\partial b_{t+1}} \mathbb{E}_t^x \left(\frac{u'(c_{t+1}^W) - u'(c_{t+1}^N)}{u'(c_t)} \right)}_{\text{Risk Management} < 0} + \underbrace{\frac{\partial Q_t}{\partial c_t} \frac{\partial c_t}{\partial D_t} \frac{\partial D_t}{\partial b_{t+1}}}_{\text{Resource constraint } < 0} +$$

$$\mathbb{E}_t^x \left(\underbrace{\frac{\partial Q_t}{\partial c_{t+1}} P^W \frac{\partial c_{t+1}}{\partial DS_t}}_{\text{Insurance} < 0} \frac{\partial DS_t}{\partial b_{t+1}} + \underbrace{\frac{\partial Q_t}{\partial c_{t+1}} \frac{\partial c_{t+1}}{\partial b_{t+1}}}_{\text{Higher } \tau_{t+1} > 0} \right)$$

Analysis: Debt

Optimality condition for debt

$$\mu_t = \mathbb{E}_t(n_{t+1}\mu_{t+1}),\ \text{where } n_{t+1} \equiv \frac{u'(c_{t+1})}{E_t(u'(c_{t+1}))}$$

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$$\begin{aligned}\mu =& P^W(DS,\xi)\mathbb{E}_{g'|g}[\mathbb{E}_{\xi'|\xi}[n(g',\xi',\mu,b,DS,\mathcal{I})\mu(g',\xi',\mu,b,DS,\mathcal{I})]]+\\ &(1-P^W(DS,\xi))\mathbb{E}_{g'|g}[\mathbb{E}_{\xi'|\xi}[n(g',\xi',\mu,b,DS,\mathcal{I}))\mu(g',\xi',\mu,b,DS,\mathcal{I}))]]\end{aligned}$$

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This nests this Aiyagari et al. (2002) model:

$$\mu = \mathbb{E}_{g'|g}[n(g',\mu,b)\mu(g',\mu,b)]$$

Analysis: Taxes

Assume additively separable preferences.

- Under complete markets (Lucas and Stokey, 1983):

$$\tau_t = \frac{\mu(\epsilon_{cc} + \epsilon_{hh})}{1 + \mu(1 + \epsilon_{hh})}$$

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  - Smoothing across states implies $\mu_t - \mu_{t-1}$ is small, typical of Aiyagari et al. (2002).
  - Smoothing over time means that sometimes $\mu_t - \mu_{t-1}$ is allowed to be large.

Planner chooses smoothing over time versus smoothing across states

Under quasi-linear preferences:

$$\mu_t = P^W(D_t, \xi_t)\mu_{t+1}^W + (1 - P^W(D_t, \xi_t))\mu_{t+1}^N$$

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Proposition

Assuming the economy is on the left-hand side of the Laffer curve and the *Insurance* motive is absent:

$$\frac{\partial \mu_{t+1}^W}{\partial D_t} > \frac{\partial \mu_{t+1}^N}{\partial D_t}$$

Optimal financing of defence spending sacrifices smoothing across states to smoothing over time.

Calibration

Exogenous Processes:

- $ln(g_t) = \mu^g + \phi^g ln(g_{t-1}) + \epsilon_t^g$ - US Federal government expenditure excluding defense.
- $ln(\xi_t) = \mu^\xi + \phi^\xi ln(\xi_{t-1}) + \epsilon_t^\xi$ - very persistent, $\rho^\xi = 0.977$.

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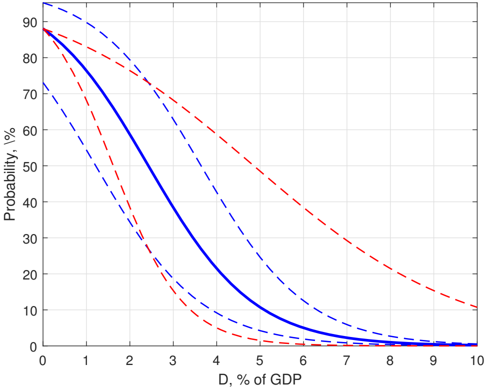
Other parameters: $U(c,l) = \frac{c^{1-\gamma}}{1-\gamma} + B\frac{l^{1-\eta}}{1-\eta}$, with $\gamma = 2, \eta = 1.8, B = 2.77$ (leisure 2/3 of the time endowment).

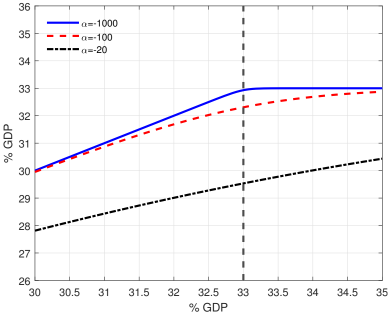
Calibration: Disaster Probability

$$P^W(DS,\xi) = \frac{1}{1 + e^{-\beta_1 - \beta_2 \frac{DS}{\xi}}}$$

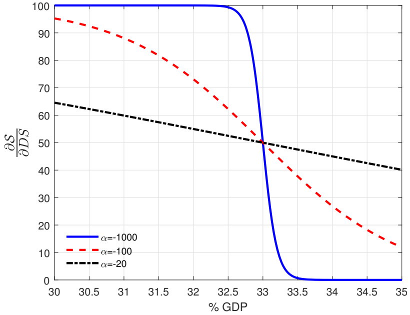


Calibration: Insurance Channel

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



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



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

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

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:

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

- Plus the constraints.

Solution Method: Parameterized Expectations

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

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

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 $\mathcal{ANN}(g_t, \xi_t, \lambda_{t-1}, b_{t-1}, DS_{t-1}, \mathcal{I}_t)$, 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.

Results

- Long-run averages over multiple realizations of ξ_t and g_t
- Impulse-Responses to ξ_t and g_t shocks
- War Episodes

Results

- Long-run averages over multiple realizations of ξ_t and g_t

  ⇒ Higher borrowing and lower taxes when disasters are endogenous.

  ⇒ Debt more volatile.

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Results

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  - $\Rightarrow$ Higher borrowing and lower taxes when disasters are endogenous.
  - $\Rightarrow$ Debt more volatile.
- Impulse-Responses to ξ_t and g_t shocks
  - $\Rightarrow$ Expenditure (g_t) shocks: cutting D allows to mitigate a fall in prices. Debt responds more strongly.
  - $\Rightarrow$ Uncertainty (ξ_t) shocks: opposite response of debt.
- War Episodes

Results

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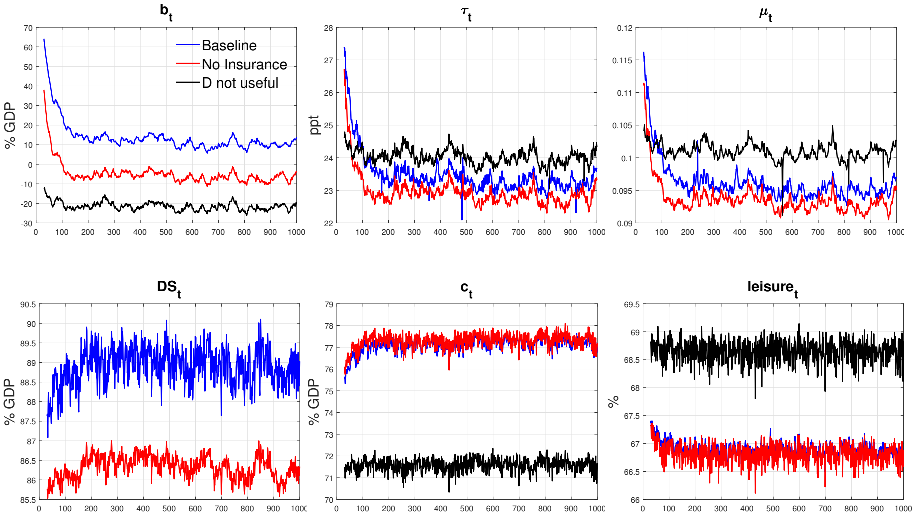
- War Episodes

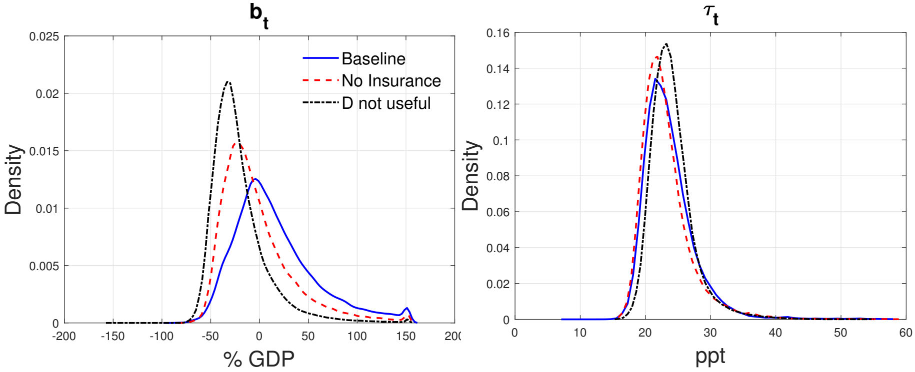
  $\Rightarrow$ Stronger debt response and more stable prices allow for smoother consumption.

More debt and lower taxes in the long-run



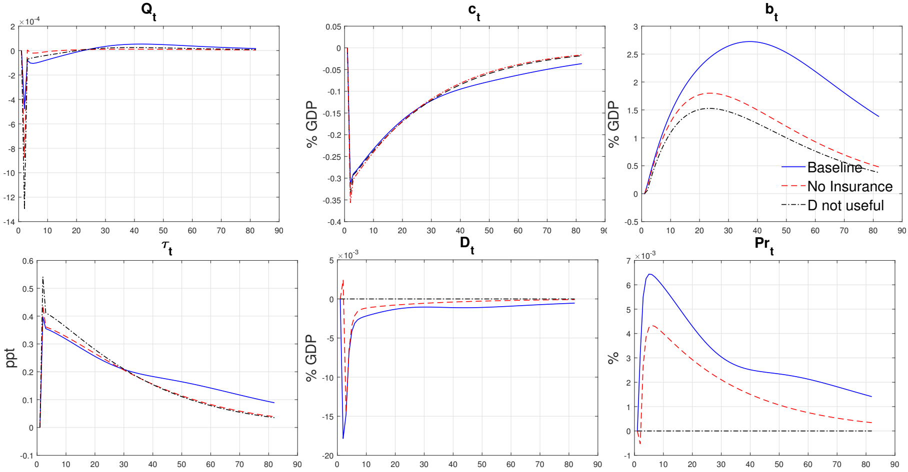
- Figures show ensemble averages $(E_i(x_t))$ over 200 realizations.

Volatile debt - a way to absorb shocks



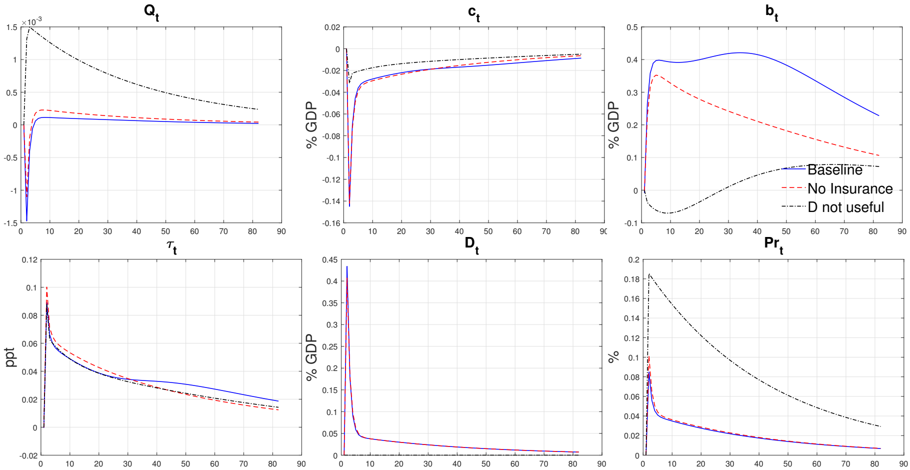
- Figures show ergodic distributions of debt and taxes from 200 simulations of 1000 periods.

g_t shock: cutting D_t allows to mitigate a fall in prices



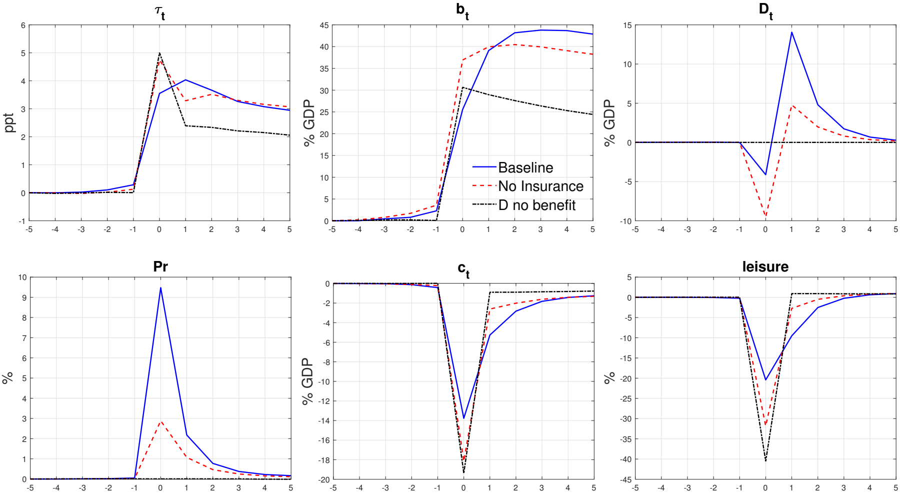
- Figures show impulse-response functions to a one standard deviation expenditure shock.

ξ_t shock: Opposite response of debt



- Figures show impulse-response functions to a one standard deviation ξ_t shock.

War Episodes: more borrowing and smoother consumption during the war



- Figures show median dynamics during the war episode. Dynamics are obtained from 200 simulations of 1000 periods.

Summary

- First model that studies the optimal management of disaster risks.
- When disasters are endogenous:
  - The planner on average issues more debt and uses it more actively.
  - Mitigation of disaster risks allows to smooth bond prices and taxes.
  - Dynamics mostly driven by the *Risk Management* motives.

Summary

- First model that studies the optimal management of disaster risks.
- When disasters are endogenous:
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  - Dynamics mostly driven by the *Risk Management* motives.

Future Directions

- Microfound disaster probability.
- Make government debt risky, so that defense spending has larger effects on spreads.

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