The Puzzling Behavior of Spreads during Covid

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Motivation

- Advanced economies in 2020:
  - significant recessions,
  - massive government borrowing and transfers,
  - yet, sovereign spreads barely moved.
- Contrast with Great Recession and Eurozone debt crisis.

The question and approach

Question: Why did spreads not increase during Covid (in Greece)?

1. Model of long-term debt and sovereign default with
   - official lenders (ECB),
   - traded and non-traded goods (Covid lockdowns),
   - transfers to poor households,
   - private sector savings and labor.
2. Quantification of model during 2002-2019.
3. Post-2020: lockdowns, counterfactuals on different horses.

Why did spreads not increase in Greece?

literature

1. Covid shock was perceived as transitory (key: redistributive shock).
2. Pre-2020 bailouts.

Why did spreads not increase in Greece?

▸ literature

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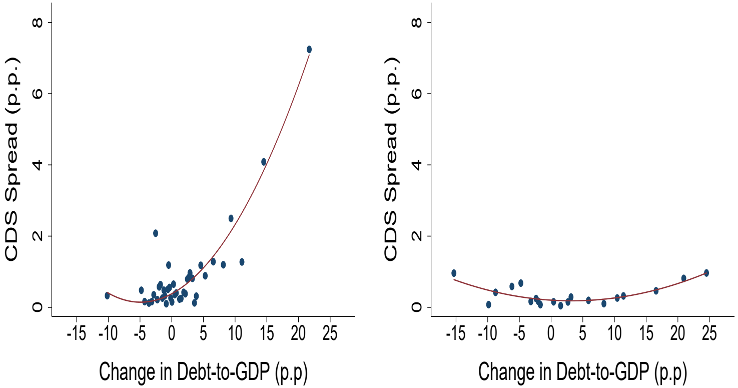
Not quantitatively as important:

- Post-2020 ECB policies – *but* interactions become important.
- Private sector responses.
- Moral hazard, safe rate decline, maturity.

Observations on Spreads and Debts

Spread and Debt-to-GDP for advanced economies

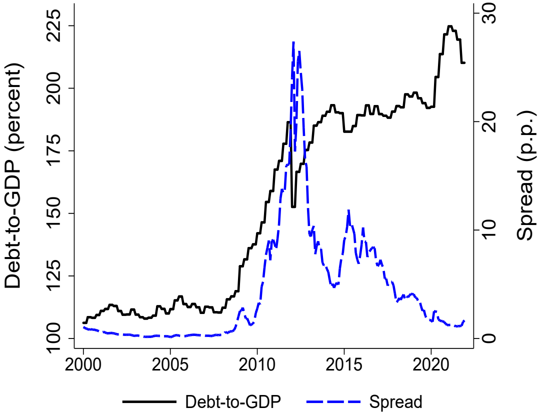
details



(a) Sample 2003-2019

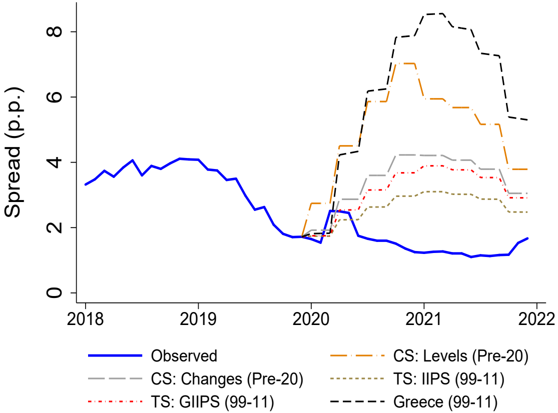
(b) Sample 2020-2022

The experience of Greece



Predicted spread exceeds observed spread in Covid

details



- Our prediction: 5.5pp; Cruces and Trebesch prediction: 4.5pp.

Model (before Covid)

Timing and agents

1. Exogenous state variables realized (eg productivity, gov spending).
2. Government:
   - restructuring debt decision,
   - if restructuring: may receive bailouts from official lenders,
   - if not restructuring: transfers and debt decisions.
3. Private sector:
   - domestic savings, labor, production decisions,
   - foreigners price government debt.

Households

- Optimizing (fraction γ):

$$\max_{c^o_{Tt}, c^o_{Nt}, \ell^o_t, a^o_{t+1}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_c^t \left(\frac{g_t}{\bar{g}}\right)^{\alpha} \left[\frac{c(.)^{1-\sigma}-1}{1-\sigma} - \frac{\chi^o}{1+1/\varepsilon}(\ell^o_t)^{1+1/\varepsilon}\right],$$

$$c^o_{Tt} + p_{Nt}c^o_{Nt} + a^o_{t+1} = (1-\tau_t)w_t\theta^o\ell^o_t + (1+r)a^o_t + T^o_t, \quad a^o_{t+1} \geqslant 0.$$

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- Hand-to-mouth (fraction $1-\gamma$):

$$\max_{c^h_{Tt}, c^h_{Nt}, \ell^h_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_c^t \left(\frac{g_t}{\bar{g}}\right)^{\alpha} \left[\frac{c(.)^{1-\sigma}-1}{1-\sigma} - \frac{\chi^h}{1+1/\varepsilon}(\ell^h_t)^{1+1/\varepsilon}\right],$$

$$c^h_{Tt} + p_{Nt}c^h_{Nt} = (1-\tau_t)w_t\theta^h\ell^h_t + T^h_t.$$

Production

- Traded goods:

$$\max_{\ell_{Tt}} \Pi_{Tt} = y_{Tt} - w_t \ell_{Tt}, \quad \text{subject to} \quad y_{Tt} = z_{Tt} \ell_{Tt}.$$

- Non-traded goods:

$$\max_{\ell_{Nt}} \Pi_{Nt} = p_{Nt} y_{Nt} - w_t \ell_{Nt}, \quad \text{subject to} \quad y_{Nt} = z_{Nt} \ell_{Nt}.$$

[Note: $w_t = z_{Tt}$ and $p_{Nt} = z_{Tt}/z_{Nt}$].

Government liabilities

1. Long-term debt b_t issued to private foreigners at price q_t.
   - Maturity rate λ_p and coupon rate κ_p.
   - Defaultable, priced by competitive risk-neutral lenders.
2. Loans f_t from official lenders.
   - Maturity rate λ_g and coupon rate $\kappa_g = r$.
   - Non-defaultable, with risk-free price of 1.

Restructuring and default

- $\eta_{t+1} > 0$ is restructuring b_t and means:
  - haircut $\bar{\eta}$ on b_{t+1}; new λ and κ; may receive bailouts, $\hat{\delta}_t|\eta_{t+1}$,
  - utility cost $C(\eta_{t+1}, s_t)$; exclusion from issuing b_{t+1}.

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- Evolution of default state:

$$d_{t+1} = \begin{cases} 0 & \text{if } \eta_{t+1} = 0 \text{ and } d_t = 0, \\ 0 & \text{if } \eta_{t+1} = \bar{\eta} \text{ or } d_t = 1, \quad \text{with probability } \psi, \\ 1 & \text{if } \eta_{t+1} = \bar{\eta} \text{ or } d_t = 1, \quad \text{with probability } 1 - \psi. \end{cases}$$

Government in good standing ($d_t = \eta_{t+1} = 0$)

$$V^n(s_t, \eta_{t+1}, \hat{\delta}_t) = \max_{b_{t+1}, T_t} \left\{ \zeta U_t^o + (1-\zeta) U_t^h + \beta_g \mathbb{E}_t V(s_{t+1}) \right\},$$

subject to:

$$g_{Tt} + p_{Nt} g_{Nt} + T_t + (\lambda_p + \kappa_p) b_t + (\lambda_g + \kappa_g) f_t =$$
$$\tau_t y_t + q_t (b_{t+1} - (1-\lambda_p) b_t) + \hat{\delta}_t,$$

$$T_t = \gamma T_t^o + (1-\gamma) T_t^h = \gamma \xi T_t^h + (1-\gamma) T_t^h,$$

$$f_{t+1} = (1-\lambda_g) f_t + \hat{\delta}_t,$$

domestic private sector equilibrium and $q(s_t, \eta_{t+1}, \hat{\delta}_t, b_{t+1}, T_t)$.

Government in bad standing ($d_t = 1$ or $\eta_{t+1} > 0$)

cost function

$$V^d(s_t, \eta_{t+1}, \hat{\delta}_t) = \max_{T_t} \Big\{ \zeta U_t^o + (1-\zeta) U_t^h - C(\eta_{t+1}, s_t) + \beta_g \mathbb{E}_t V(s_{t+1}) \Big\},$$

subject to:

$$g_{Tt} + p_{Nt} g_{Nt} + T_t + (\lambda_d + \kappa_d) b_t + (\lambda_g + \kappa_g) f_t = \tau_t y_t + \hat{\delta}_t,$$

$$T_t = \gamma T_t^o + (1-\gamma) T_t^h = \gamma \xi T_t^h + (1-\gamma) T_t^h,$$

$$b_{t+1} = (1 - \eta_{t+1})(1 - \lambda_d) b_t,$$

$$f_{t+1} = (1 - \lambda_g) f_t + \hat{\delta}_t,$$

domestic private sector equilibrium and $q(s_t, \eta_{t+1}, \hat{\delta}_t, b_{t+1}, T_t)$.

Government restructuring decision

▸ taste shocks

$$V(s_t) = \max_{\eta_{t+1} \in \{0, \bar{\eta}\}} \Big\{ d_t \bar{V}^d(s_t, \eta_{t+1}) +$$

$$(1 - d_t)\Big(\mathbb{I}\{\eta_{t+1} > 0\} \bar{V}^d(s_t, \eta_{t+1}) + \mathbb{I}\{\eta_{t+1} = 0\} \bar{V}^n(s_t, \eta_{t+1})\Big) \Big\},$$

where

$$\bar{V}^d(s_t, \eta_{t+1}) = \int V^d(s_t, \eta_{t+1}, \hat{\delta}_t) \mathrm{d}F(\hat{\delta}_t | \eta_{t+1}, s_t),$$

$$\bar{V}^n(s_t, \eta_{t+1}) = \int V^n(s_t, \eta_{t+1}, \hat{\delta}_t) \mathrm{d}F(\hat{\delta}_t | \eta_{t+1}, s_t).$$

Equilibrium

risk premium

Given stochastic processes $z_T, z_N, g_T, g_N, \tau, \hat{\delta}, \delta$,

allocations $c_i^j(x), \ell^j(x), \ell_i(x), a'(x)$ for $j = \{o, h\}$ and $i = \{T, N\}$, prices $w(x), p_N(x), q(x)$, government policies $\eta'(s), b'(s, \hat{\delta}), T(s, \hat{\delta})$ such that

- households maximize their values and firms maximize their profits,
- government maximizes their value,
- price $q(x)$ such that foreigners break even,
- non-traded goods market clears: $c_N + g_N = y_N$.

[Notation: $s = (z_T, z_N, g_T, g_N, \tau, \delta, d, f, b, a)$ and $x = (s, \eta', \hat{\delta}, b', T)$.]

Quantification

Strategy

1. Mapping model objects to data counterparts.
2. Parameterization during 2002-2019.
3. Extend model and assess its performance during Covid.

Mapping model to data: private sector

- Sectoral classification.
- Fill in gaps between national accounts and model.
- Adjust wages, productivity, labor for compositional changes.
- Variables are divided by population and deflated with p_T.
- Normalize such that $y_{19} = p_{N19} = \ell^j_{19} = z_{i19} = 1$ in the data.

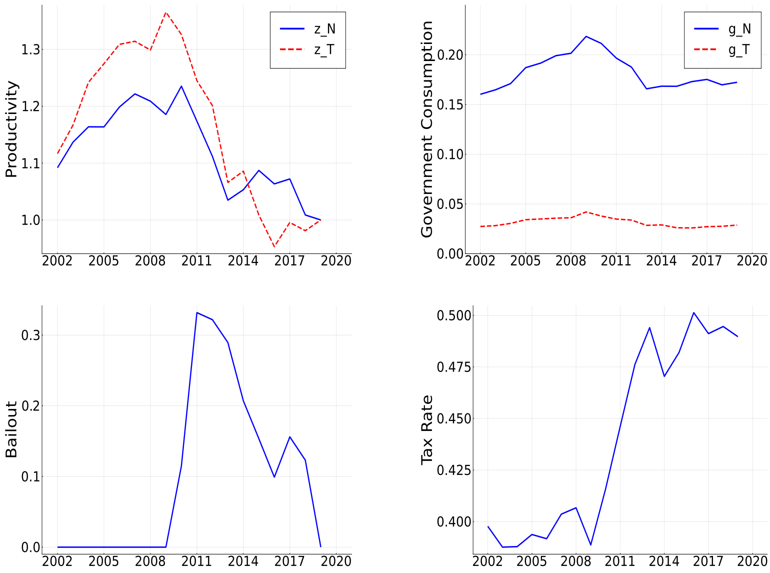
Mapping model to data: government sector

summary

- Default is $d_{12} = 1$. Reentry is $d_{19} = 0$.
- Transfers from national accounts, including Covid SNA items.
- Calculate maturity and coupon rates.
- Use government budget constraint to calculate issuances.
- Stocks b_t, f_t from maturities and issuances and a_t residually.

Exogenous driving processes

▸ bond parameters



Parameterization

1. Parameters of stochastic processes estimated from the data.
2. Parameters set without solving the model.
3. Parameters set by solving the model.

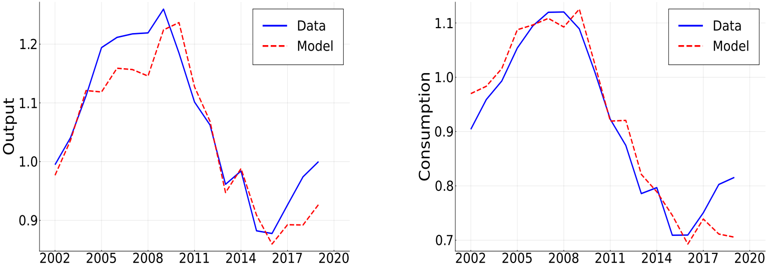
Parameters estimated by solving the model

more

Parameter	Value	Parameter	Value
θ^o/θ^h	4.95	ξ	0.87
α	0.90	ζ/γ	0.60
ε	0.56	σ	1.16
β_c	0.97	β_g	0.96

Time series in the model vs the data

▸ more ▸ spread



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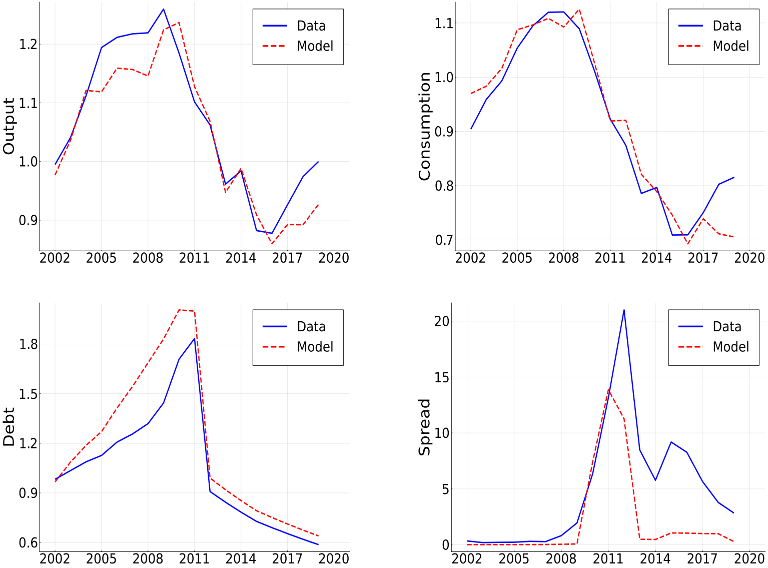


The Covid Period

Extending the model to Covid

- Constraints on N consumption and h labor supply:

$$\mathbb{I}(\text{lock}_t = 1)\,(c_{Nt} - \bar{c}_N) \leqslant 0,$$

$$\mathbb{I}(\text{lock}_t = 1)\left(\ell_t^h - \bar{\ell}\right) \leqslant 0,$$

$$\pi_\ell = \text{Prob}(\text{lock}_{t+1} = 1 \big| \text{lock}_t = 1) = 0.5.$$

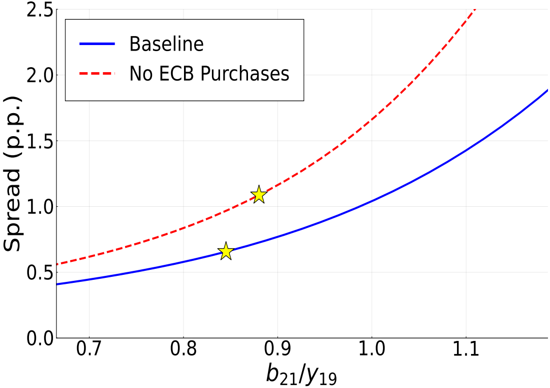
- Feed in realized $\text{lock}_{20} = 1$ and $\text{lock}_{21} = 0$.
- ECB purchases begin in 2020 without restructuring.

Performance of model during Covid

Year	Statistic ($\times 100$)	Data	Model
2020	$\log y_{20} - \log y_{19}$	-8.1	-8.1
	$\log c_{20} - \log c_{19}$	-4.1	-10.5
	$(b_{21} - b_{20})/y_{19}$	12.0	12.0
	$(T_{20} - T_{19})/y_{19}$	6.1	9.0
	$(a_{21} - a_{20})/y_{19}$	4.4	3.9
	$\text{spread}_{20} - \text{spread}_{19}$	0.1	0.4
2021	$\log y_{21} - \log y_{19}$	-4.0	-2.9
	$\log c_{21} - \log c_{19}$	1.4	2.7
	$(b_{22} - b_{20})/y_{19}$	21.0	17.3
	$(T_{21} - T_{19})/y_{19}$	5.5	3.7
	$(a_{22} - a_{20})/y_{19}$	5.4	-5.8
	$\text{spread}_{21} - \text{spread}_{19}$	0.0	0.0

Counterfactuals

ECB purchases through PEPP, $\hat{\delta}_{t \geqslant 20} = 0$



- b_{21} increases by only $1/3$ of missing $\hat{\delta}_{20} = 0.1$.

Counterfactuals

	$(100 \times \Delta \log)$			$(\Delta$ p.p.$)$
(relative to 2020 model)	c	b	T	spread
$\hat{\delta}_{t \geqslant 20} = 0$	-6.3	3.5	-7.3	0.5

Counterfactuals

empirical AP more

	$(100 \times \Delta \log)$			$(\Delta$ p.p.$)$
(relative to 2020 model)	c	b	T	spread
$\hat{\delta}_{t \geqslant 20} = 0$	-6.3	3.5	-7.3	0.5
$\hat{\delta}_{t < 20} = 0$	-1.0	-5.8	-1.4	0.7
$\bar{q}b^{\text{new}} = 0.71(\bar{q}b + f)$	-5.2	-5.5	-6.2	2.3
$\bar{\eta} = 0.73$	-6.2	-4.7	-7.3	1.8

Counterfactuals

empirical AP more

	(100 × Δ log)			(Δ p.p.)
(relative to 2020 model)	c	b	T	spread
$\hat{\delta}_{t\geqslant 20} = 0$	−6.3	3.5	−7.3	0.5
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$\bar{\eta} = 0.73$	−6.2	−4.7	−7.3	1.8
$\pi_{\ell} = 0.85$	−8.8	−7.1	−10.3	2.4

Counterfactuals

▸ empirical AP ▸ more

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$\hat{\delta}_{t \geqslant 20} = 0$	−6.3	3.5	−7.3	0.5
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$\bar{\eta} = 0.73$	−6.2	−4.7	−7.3	1.8
$\pi_\ell = 0.85$	−8.8	−7.1	−10.3	2.4
(relative to 2021 model)				
$\text{lock}_{21} = 1$	−16.2	6.6	1.7	1.0
$\text{lock}_{21} = 1, \pi_\ell = 0.85$	−22.1	−3.9	−5.0	3.7

Understanding the nature of the Covid shock

rare disasters

	$(100 \times \Delta \log)$			$(\Delta$ p.p.$)$
(relative to 2020 model)	c	b	T	spread
$\pi_\ell = 0.85$	-8.8	-7.1	-10.3	2.4
persistent z shocks	13.0	-3.7	-3.6	-0.4
permanent z shocks	9.5	-6.0	-6.6	-0.2

Understanding the nature of the Covid shock

rare disasters

(relative to 2020 model)	c (100 × Δ log)	b	T	spread (Δ p.p.)
$\pi_\ell = 0.85$	-8.8	-7.1	-10.3	2.4
persistent z shocks	13.0	-3.7	-3.6	-0.4
permanent z shocks	9.5	-6.0	-6.6	-0.2

(relative to 2019 model)	$w\theta^h\ell^h$ (100 × Δ log)	$w\theta^o\ell^o$
lockdowns	-43	2
persistent z shock	-10	-7
permanent z shock	-9	-8

Interactions of ECB purchases

more

$\hat{\delta}_{t\geqslant 20} = 0$ **and ...**	$(100 \times \Delta \log)$			(Δ p.p.)
(relative to 2020 model)	c	b	T	spread
$\hat{\delta}_{t<20} = 0$	-8.5	-2.9	-10.1	1.9
$\pi_\ell = 0.85$	-15.3	-0.6	-17.3	5.1
(relative to 2021 model)				
$\text{lock}_{21} = 1, \pi_\ell = 0.85$	-32.4	-1.0	-15.8	12.9

Conclusion

Taking stock

- Why did spreads not increase during Covid?
  1. Covid shock perceived as transitory.
  2. Pre-2020 bailouts.
- ECB purchase policy during Covid:
  - On its own, policy did not affect spreads much.
  - But poor households received massive transfers.
  - Would matter more for spreads had Covid been more persistent.

Extra Slides

Contributions to literature

back

1. Quantitative models of sovereign spreads.
    - Arellano (AER08); Chatterjee, Eyigungor (AER12); Gordon, Guerron-Quintana (RED18); Bocola, Dovis (AER19).
2. Official lenders to governments.
    - Fink, Scholl (JIE16); Callegari, Marimon, Wicht, Zavalloni (RED23); Liu, Marimon, Wicht (JIE23).
3. Fiscal policy and debt crises.
    - Cuadra, Sanchez, Sapriza (RED10); Arellano, Bai, Mihalache (RES23); Bianchi, Ottonello, Presno (JPE23); Chodorow-Reich, Karabarbounis, Kekre (AER23).

Details of cross sectional data

back

- Fiscal space database from World Bank.
- CDS spreads (5 year) from Bloomberg and J.P. Morgan.
- Debt-to-GDP ratio from IMF and World Bank.
- Sample restrictions:
    1. Advanced economies.
    2. $>$ 10 percent of debt held by foreigners (excl Switzerland, Japan).
    3. CDS spreads below 100 percent (excl Greece 2012).

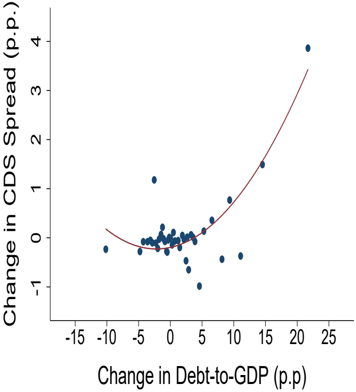
Some episodes of high spreads

back

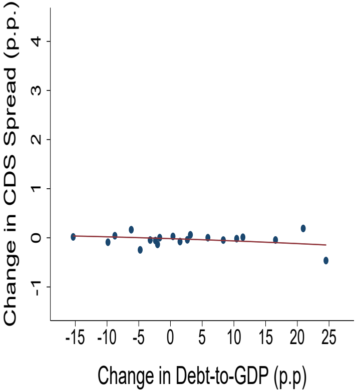
Country	Year	Spread	Debt-to-GDP	Δ Debt-to-GDP
Greece	2011	29	175	28
Greece	2015	17	179	-3
Cyprus	2015	11	79	14
Greece	2013	10	184	17
Cyprus	2013	10	103	24
Portugal	2012	9	129	15
Portugal	2011	8	114	14
Ireland	2011	7	110	24
Latvia	2009	7	36	18
Croatia	1999	7	30	7
Korea	1998	6	14	4
Spain	2012	4	90	20
Italy	2012	4	126	7

Spread and Debt-to-GDP for advanced economies

▸ back



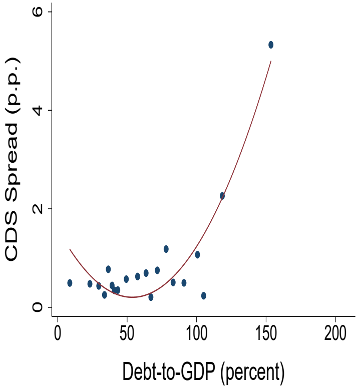
(a) Sample 2003-2019



(b) Sample 2020-2022

Spread and Debt-to-GDP for advanced economies

back



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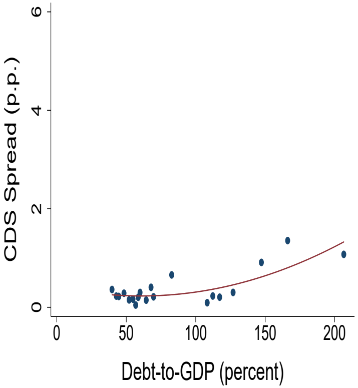

(b) Sample 2020-2022

Predicting spreads

back

1. Cross-sectional predictions:
   - Spread *level* on change in debt-GDP and change in log GDP.
   - Spread *change* on change in debt-GDP and change in log GDP.

2. Time series predictions:

$$\text{Spread}_{it} = d_i + d_t + \beta \left(\frac{\text{Debt}}{\text{GDP}} \right)_{it} + \gamma \text{Controls}_{it} + u_{it}.$$

   - For regressions with only Greece, drop fixed effects.
   - Baseline control: log GDP in 12 months leading to month t.
   - Robustness to controls (GDP growth, trade balance, political risk).

Predicted spread without controls

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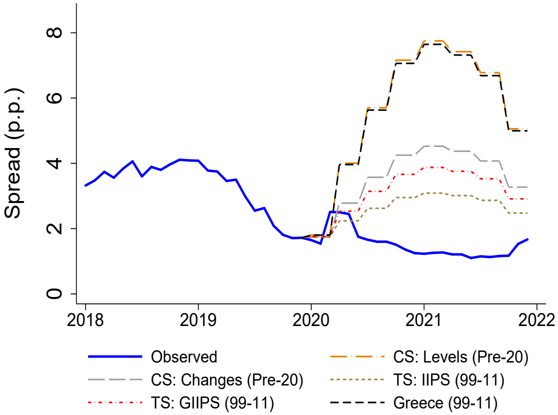

Predicted spread with all controls

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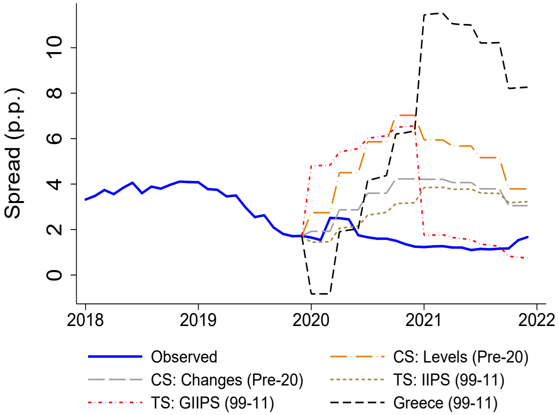


Greece debt is mostly held by foreigners

back

	Government Debt Held by Foreigners	
(percent)	2019	2009
Greece	89	74
Lithuania	73	70
Ireland	58	65
Finland	53	69
Norway	50	43
Portugal	49	65
France	49	52
Germany	48	55
Spain	44	38
Italy	32	41
United Kingdom	29	23
United States	25	23
Japan	12	5
Switzerland	7	6

Cost of restructuring

back

- Utility cost of default:

$$C(\eta_{t+1}, s_t) = \begin{cases} \mu + \mu_T \log(z_{Tt}) + \mu_N \log(z_{Nt}), & \eta_{t+1} > 0, \\ 0, & \eta_{t+1} = 0. \end{cases}$$

- Because debt is long term and recovery is nonzero, need issuance cost i_t to prevent maximum dilution:

$$i_t = i\left(\mathbb{E}_t[\mathbb{I}\{\eta_{t+2}(s_{t+1} > 0\}]\right) q_t(b_{t+1} - (1-\lambda_p)b_t),$$

$$i(x) = \begin{cases} \frac{1}{2}\left(1 + sin\left(\left(\frac{x-\bar{d}}{1-\bar{d}} - \frac{1}{2}\right)\pi\right)\right), & b_{t+1} - (1-\lambda_p)b_t > 0, \\ 0, & b_{t+1} - (1-\lambda_p)b_t \leqslant 0. \end{cases}$$

Taste shocks

back

- Additive taste shocks to the government's objective function.
- When $d_t = 0$:
  - $\upsilon_t(\bar{\eta})$ associated with choosing $\eta_{t+1} = \bar{\eta}$,
  - $\upsilon_t(0, b')$ associated with choosing $\eta_{t+1} = 0$ and $b_{t+1} = b'$.
- When $d_t = 1$:
  - $\upsilon_t(\bar{\eta})$ associated with choosing $\eta_{t+1} = \bar{\eta}$,
  - $\upsilon_t(0)$ associated with choosing $\eta_{t+1} = 0$.
- Scale parameters are large enough to ensure convergence.

Stochastic processes I

back

- Productivity process for $j = \{T, N\}$:

$$\log z_{jt} = (1 - \rho_j)\bar{z}_{jt} + \rho_j \log z_{jt-1} + \epsilon^z_{jt}, \quad \epsilon^z_t \sim N(0, \Sigma_z),$$

$$\bar{z}_{jt} = \bar{z}_{jt-1}.$$

- Government spending process for $j = \{T, N\}$:

$$\log g_{jt} = \bar{g}_{jt} + \beta_{g_j N} \log z_{Nt} + \beta_{g_j T} \log z_{Tt} + \beta_{g_j NT} \log z_{Nt} \log z_{Tt} + \epsilon^g_{jt}, \quad \epsilon^g_{jt} \sim N(0, \sigma^2_{g_j}),$$

$$\bar{g}_{jt} = \bar{g}_{jt-1}.$$

- Tax process: $\tau_t = \tau_{t-1}$ with $\tau_t \in \{\tau_L, \tau_H\}$.

Stochastic processes II

▸ back

- Official flows take three values:

$$\delta_g \left[g_T + p_N g_N + (\lambda_d + \kappa_d) b + (\lambda_g + \kappa_g) f \right], \quad \delta_g = \{0, \delta_L, \delta_H\}$$

- Transition matrices of bailouts:

$$\hat{\delta} | (\delta, \eta' = \bar{\eta}) = \begin{bmatrix} 1 - \pi_{\hat{\delta}} & \pi_{\hat{\delta}}/2 & \pi_{\hat{\delta}}/2 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \quad \hat{\delta} | (\delta, \eta' = 0) = 1.$$

$$\delta' | \hat{\delta} = \begin{bmatrix} 1 & 0 & 0 \\ \pi_\delta & 1 - \pi_\delta & 0 \\ 0 & \pi_\delta & 1 - \pi_\delta \end{bmatrix}.$$

Bond price function

▸ back

$$
\begin{aligned}
q(x_t) &= \frac{1}{1+r}\mathbb{E}_t\Bigg[\Big((1-d_{t+1})\mathbb{I}\{\eta_{t+2}(s_{t+1})=0\}\Big)\Big[\lambda_p+\kappa_p+(1-\lambda_p)q(x_{t+1})\Big] \\
&+ \Big(d_{t+1}+(1-d_{t+1})\mathbb{I}\{\eta_{t+2}(s_{t+1})>0\}\Big)\Big[\lambda_d(\eta_{t+2},\hat{\delta}_{t+1})+\kappa_d(\eta_{t+2},\hat{\delta}_{t+1}) \\
&+ (1-\eta_{t+2})(1-\lambda_d(\eta_{t+2},\hat{\delta}_{t+1}))q(x_{t+1})\Big]\Bigg].
\end{aligned}
$$

Risk premium

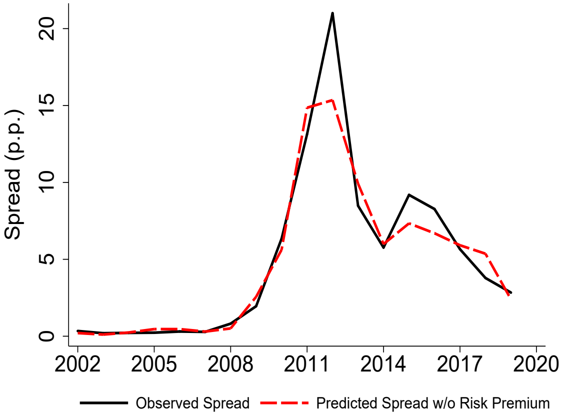
▸ back

We abstract from risk premium:

1. Predicted sovereign spread tracks very closely observed spread.
   - Prediction based only on model-consistent state variables.
   - Prediction not based on creditor-side variables.
2. Premium decreased by 4 percentage points in Covid? Implausible.

Observed vs predicted spread

back



Sectoral classification

back

Traded	Non-traded
agriculture, forestry, and fishing	electricity, gas, steam
mining and quarrying	water supply, sewerage, waste
manufacturing	construction
land transport and pipelines transport	wholesale and retail trade
water transport	warehousing
air transport	postal and courier
	information and communication
	financial and insurance
	professional, scientific, and technical
	administrative and support services
	public administration and defence
	education
	human health and social work
	arts, entertainment, and recreation
	accommodation and food service
	other services

Gaps between national accounts and model

back

- In our model:

$$\begin{aligned} y &= p_T y_T + p_N y_N \\ &= w(\ell_T + \ell_N) \\ &= p_T(c_T + g_T) + p_N(c_N + g_N) + \text{nx}. \end{aligned}$$

- National accounts:

$$\begin{aligned} \text{GDP} &= \text{VA}_T + \text{VA}_N + \text{Taxes on Products} \\ &= WL + RK \\ &= P_T(C_T + X_T + G_T) + P_N(C_N + X_N + G_N) + \text{NX}. \end{aligned}$$

Using labor share to scale down model variables

back

$$s_\ell = \frac{\text{Compensation} \times \left(1 + \frac{\text{Total Hours}-\text{Hours Employees}}{\text{Hours Employees}}\right)}{\text{GDP} - \text{Taxes on Products}}.$$

$$p_N y_N = s_{\ell N} \times \text{VA}_N + \frac{\text{VA}_N}{\text{VA}_N + \text{VA}_T} \times s_\ell \times \text{Taxes on Products},$$

$$y_T = s_{\ell T} \times \text{VA}_T + \frac{\text{VA}_T}{\text{VA}_N + \text{VA}_T} \times s_\ell \times \text{Taxes on Products},$$

$$p_N g_N = (6/7) s_\ell \times \text{Government Consumption},$$

$$g_T = (1/7) s_\ell \times \text{Government Consumption},$$

$$c_N = y_N - g_N,$$

$$p_T c_T = s_\ell \times (\text{Hh Consumption} + \text{Gross Capital Formation}) - p_N c_N,$$

$$nx = y_T - c_T - g_T = s_\ell \times \text{NX}.$$

Adjustment of wages for composition

back

- Unadjusted wages:

$$w^u = \frac{s_\ell \times \text{GDP}}{\text{Total Hours including Self Employed}}.$$

- Adjusted wages:

$$w = w^u \frac{\text{Total Hours including Self Employed}}{\text{Labor Services in KLEMS}}.$$

  Project adjustment on observables to extrapolate missing data.

- Adjust labor input for compositional changes:

$$\ell_N = \frac{p_N y_N}{w}, \qquad \ell_T = \frac{y_T}{w}.$$

Taxes and transfers

back

$$\tau = \frac{s_\ell \times \text{Government Revenue}}{y}.$$

$$T = s_\ell \times (\text{D}.6 + \text{D}.39 + \text{D}.99).$$

where

$$\begin{aligned} \text{D}.6 &= \text{social contributions and benefits} \\ \text{D}.39 &= \text{other subsidies on production} \\ \text{D}.99 &= \text{other capital transfers} \end{aligned}$$

- D.39 increased from 3.1b (2019) to 6.9b (2020) and 9.6b (2021).
- D.99 increased from 1.5b (2019) to 7.5b (2020) and 5.3b (2021).
- Paycheck protections to self-employed allocated to D.99.

Maturity, coupon rates, price of debt

back

[Data: Maturity of new issuances and the residual maturity of total debt stock (Greek QPDB, Bloomberg).]

$$\lambda_p = 0.10, \kappa_p = 0.05, \lambda_g = 0.04, \kappa_g = 0.02.$$

$$\lambda_d = \begin{cases} 0.07 & \text{if } t < 2015, \\ 0.05 & \text{if } t \geqslant 2015. \end{cases}, \quad \kappa_d = \begin{cases} 0.05 & \text{if } t = 2011, \\ 0.10 & \text{if } 2012 \leqslant t \leqslant 2014, \\ 0.03 & \text{if } t \geqslant 2015. \end{cases}$$

$$q_t = \frac{\lambda_p + \kappa_p}{\lambda_p + \text{spread}_t + r}.$$

Issuances of private debt and loans

back

$$\text{issuance}_t = g_{Tt} + p_{Nt} g_{Nt} + T_t - \tau_t y_t + \underbrace{(\lambda_p + \kappa_p) b_t + (\lambda_g + \kappa_g) f_t}_{\text{Maturing Stock and Gov Interest}} + \text{buyback}_t.$$

$$q_t(b_{t+1} - (1-\lambda_p) b_t) = \begin{cases} \text{issuance}_t & \text{if } t < 2018 \text{ and } d_{t+1} = 0, \\ 0 & \text{if } t = 2018, \\ \text{issuance}_t & \text{if } t = 2019, \\ \text{issuance}_t - \text{PEPP}_t & \text{if } t \geqslant 2020. \end{cases}$$

$$\hat{\delta}_t = f_{t+1} - (1 - \lambda_g) f_t = \begin{cases} \text{issuance}_t & \text{if } t < 2018 \text{ and } d_{t+1} = 1, \\ \text{issuance}_t & \text{if } t = 2018, \\ 0 & \text{if } t = 2019, \\ \text{PEPP}_t & \text{if } t \geqslant 2020. \end{cases}$$

Stock of debt and assets

back

- Stock of b_t from law of motion given $\lambda_p, \bar{\eta}, \lambda_d,$ issuance, q.
- Stock of f_t from law of motion given $\lambda_g, \hat{\delta}_t$.
- a_0 to match initial Wealth/GDP in External Wealth of Nations:

$$a_{t+1} = y_t - c_t - g_{Tt} - p_{Nt} g_{Nt} + (1+r)a_t + q_t(b_{t+1} - (1-\lambda_p)b_t) + (f_{t+1} - (1-\lambda_g)f_t) - (\lambda_p + \kappa_p)b_t - (\lambda_g + \kappa_g)f_t.$$

- $r = 0.02$ implies our wealth roughly matches External Wealth of Nations in 2020.

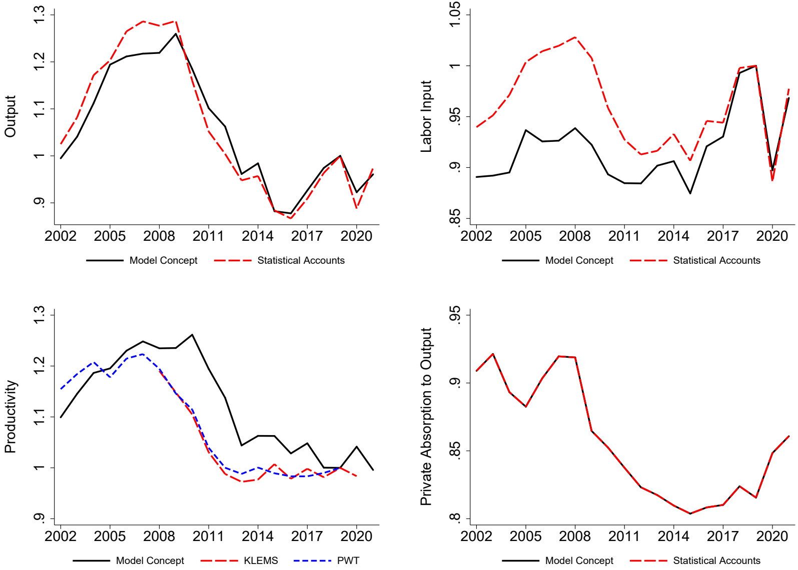
Official loans in 2010

back

- We choose $\eta'_{11} = \bar{\eta}$ because 2012 is first year w/o private debt flows.
- However, Greece received some official loans in 2010.
- To accommodate this we augment $f_{t+1} = (1 - \lambda_g) f_t + \hat{\delta}_t + \tilde{\delta}_t$.
  - $\tilde{\delta}_t$ realized at the beginning of the period,
  - $\tilde{\delta}_t$ independent over time,
  - $\tilde{\delta}_{10} > 0$ unexpectedly realized.

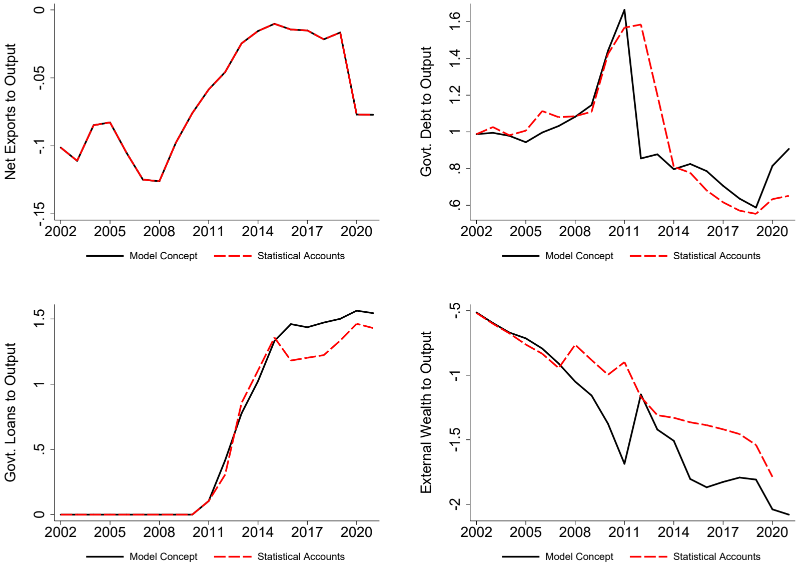
Model concepts vs national accounts I

back



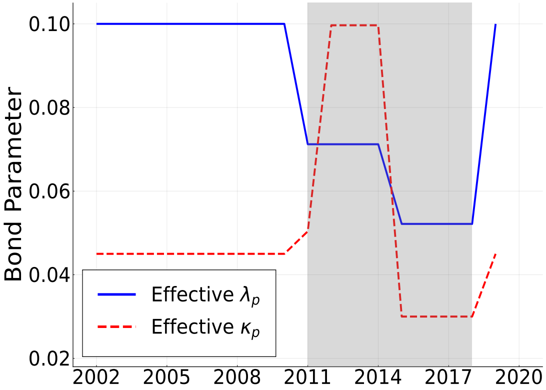
Model concepts vs national accounts II

back



Realized bond parameters

back



Parameters of stochastic processes

back

Parameter	Value	Parameter	Value
ρ_N	0.86	ρ_T	0.84
$\bar{z}_N$	0.23	$\bar{z}_T$	0.32
$\beta^{11}_{\bar{z}_N}$	−0.29	$\beta^{11}_{\bar{z}_T}$	−0.42
σ_{z_N}	0.03	σ_{z_T}	0.04
$\sigma_{z_N z_T}$	0.45		
$\beta_{g_N N}$	0.95	$\beta_{g_N T}$	0.34
$\beta_{g_T N}$	−0.05	$\beta_{g_T T}$	1.34
$\beta_{g_N NT}$	1.72	$\beta_{g_T NT}$	1.72
σ_{g_N}	0.04	σ_{g_T}	0.04
$\bar{g}_N$	−1.98	$\bar{g}_T$	−3.77
$\beta^{11}_{\bar{g}_N}$	0.15	$\beta^{11}_{\bar{g}_T}$	0.15
$\beta^{20}_{\bar{g}_N}$	0.10	$\beta^{20}_{\bar{g}_T}$	0.10
τ_L	0.40	τ_H	0.48
δ_L	0.35	δ_H	0.65
π_δ	0.25	π_ℓ	0.50

Parameters set without solving the model

back

Parameter	Value	Explanation
ω_c	0.30	expenditure share of traded goods, private sector
ω_g	0.14	expenditure share of traded goods, government
ϕ	0.44	substitution elasticity, private, traded and non-traded goods
γ	0.40	share of optimizing households
r	0.02	risk-free rate
κ_p	0.04	coupon rate, government debt in good credit standing
λ_p	0.10	maturity rate, government debt in good credit standing
$\kappa_d(.)$	$[0.03, 0.10]$	coupon rate, government debt in bad credit standing
$\lambda_d(.)$	$[0.05, 0.07]$	maturity rate, government debt in bad credit standing
κ_g	0.02	coupon rate, government loans
λ_g	0.04	maturity rate, government loans
$\bar{\eta}$	0.47	haircut on government debt
ψ	0.14	reentry rate
$\bar{d}$	0.80	issuance cost parameter
ν_1	0.00	taste shock parameter
ν_2	0.25	taste shock parameter

Parameters set by solving the model

back

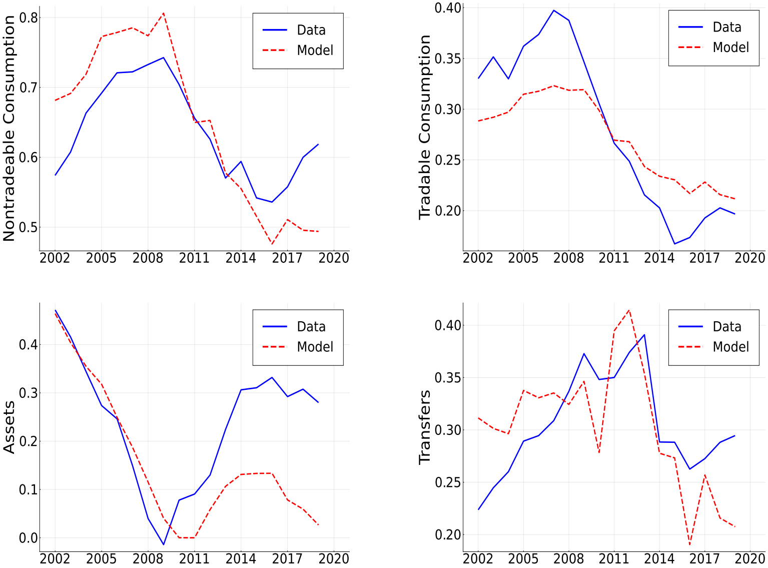
Parameter	Value	Parameter	Value
θ^o	1.79	β_c	0.97
θ^h	0.36	α	0.90
χ^o	0.84	ζ	0.24
χ^h	0.46	β_g	0.96
σ	1.16	μ	0.05
ε	0.56	μ_N	0.11
ξ	0.87	μ_T	0.09
		$\pi_{\hat{\delta}}$	0.74
$\bar{c}_N$	0.71	$\bar{\ell}$	0.66

Moments for estimation of parameters

back

Statistic ($\times$100)	Data	Model
$\log y_{09} - \log y_{02}$	26.5	24.7
$\log y_{05} - \log y_{04}$	8.2	−0.2
$\log y_{15} - \log y_{09}$	−37.7	−31.5
$\log b_{10} - \log b_{03}$	79.8	91.0
$\log a_{10} - \log a_{03}$	−32.5	−40.4
$\log a_{15} - \log a_{10}$	22.0	13.3
$\log T_{09} - \log T_{02}$	14.9	3.5
spread_{10}	6.3	7.4
spread_{11}	13.1	13.9

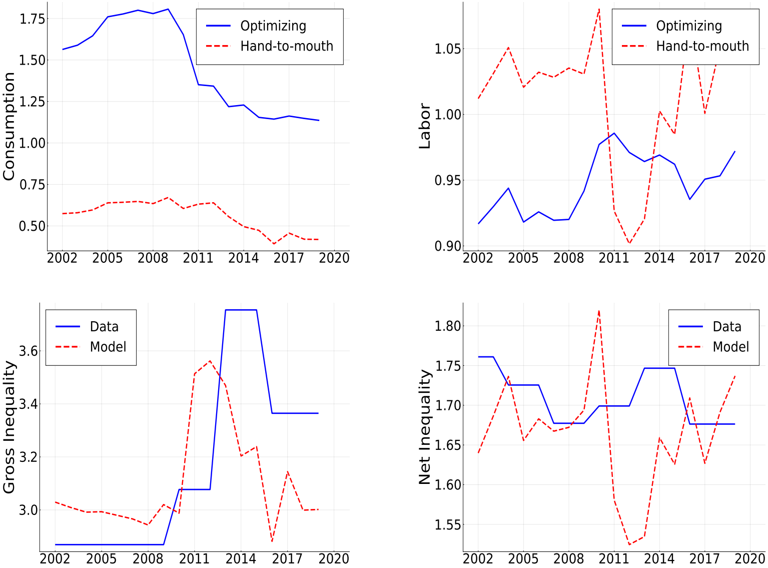
Time series in the model vs the data



▸ back

Time series in the model vs the data

back



Calculation of spread

back

- In most years, spread calculated using standard convention:

$$\text{spread}_t = \frac{\lambda_p + \kappa_p}{q_t} - \lambda_p - r.$$

- In 2010, q_t calculated using post-regime change.
- In 2011, q_t calculated after default but before $\hat{\delta}_t$ realized.
- In 2012, q_t calculated before haircut is applied.

Loans vs purchases

back

- Profits of lender who purchases v_t of private debt:

$$\Pi_t^g = (\bar{r}_t - r)\bar{q}_t v_t = (\lambda_p + \kappa_p) v_t - (\lambda_p + r)\bar{q}_t v_t,$$

where $\bar{q}_t, \bar{r}_t$ is average price/interest on debt purchased.

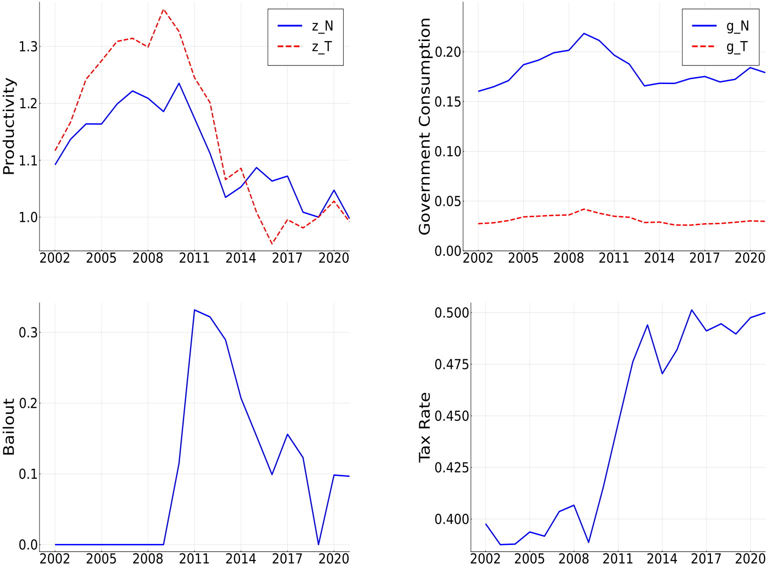
- Government budget constraint with rebated Π_t^g:

$$\begin{aligned} g_{Tt} + p_{Nt} g_{Nt} + T_t + (\lambda_p + \kappa_p) b_t + (\lambda_g + \kappa_g)(f_t + \bar{q}_t v_t) \\ = \tau_t y_t + q_t (b_{t+1} - (1 - \lambda_p) b_t) - i_t \\ + \hat{\delta}_t + q_t (v_{t+1} - (1 - \lambda_p) v_t) + (\lambda_g - \lambda_p)\bar{q}_t v_t. \end{aligned}$$

- f_t, v_t equivalent for allocations.

The other exogenous driving processes during Covid

back



Official loans during Covid

back

- Before Covid:

$$\hat{\delta}|(\delta, \eta' = \bar{\eta}) = \begin{bmatrix} 1-\pi_{\hat{\delta}} & \pi_{\hat{\delta}}/2 & \pi_{\hat{\delta}}/2 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \quad \hat{\delta}|(\delta, \eta' = 0) = 1.$$

$$\delta'|\hat{\delta} = \begin{bmatrix} 1 & 0 & 0 \\ \pi_\delta & 1-\pi_\delta & 0 \\ 0 & \pi_\delta & 1-\pi_\delta \end{bmatrix}.$$

- Augmented process:

$$\delta_t|(\hat{\delta}_{t-1}, \mathrm{lock}_t = 1, \mathrm{lock}_{t-1} = 0) = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & \pi_\delta & 1-\pi_\delta \end{bmatrix},$$

same $\hat{\delta}$.

Supply vs demand origins of Covid

back

Year	Statistic ($\times 100$)	Data	Model, $\bar{\ell}$, $\bar{c}_N$	Model, $\bar{\ell}$	Model, $\bar{c}_N$
2020	$\log y_{20} - \log y_{19}$	-8.1	-8.1	-6.9	1.3
	$\log c_{20} - \log c_{19}$	-4.1	-10.5	2.4	-8.9
	$(b_{21} - b_{20})/y_{19}$	12.0	12.0	12.3	3.0
	$(T_{20} - T_{19})/y_{19}$	6.1	9.0	10.0	3.6
	$(a_{21} - a_{20})/y_{19}$	4.4	3.9	-5.2	1.9
	$\text{spread}_{20} - \text{spread}_{19}$	0.1	0.4	0.4	0.0
2021	$\log y_{21} - \log y_{19}$	-4.0	-2.9	-2.2	-3.3
	$\log c_{21} - \log c_{19}$	1.4	2.7	1.8	3.5
	$(b_{22} - b_{20})/y_{19}$	21.0	17.3	17.6	9.7
	$(T_{21} - T_{19})/y_{19}$	5.5	3.7	4.0	5.2
	$(a_{22} - a_{20})/y_{19}$	5.4	-5.8	-13.8	-7.4
	$\text{spread}_{21} - \text{spread}_{19}$	0.0	0.0	0.0	0.0

Comparison with empirical estimates

back

- Model-based estimates:
  - ECB purchases reduce spread by 0.5 p.p. in 2020.
  - 2010s loans reduce spread by 2-2.5 p.p. in 2012-2018.
- Empirical estimates:
  - Trebesch and Zettelmeyer (2018): ECB purchases of Greek bonds in 2010 reduce yield by 0.8-1.9 p.p.
  - Rostagno et. al. (2021): APP reduces yields by 0.5 p.p. in 2014; PEPP reduces yield by 0.5 p.p in 2020; cumulative QE effect 2 p.p.
  - Malliaropulos and Migiakis (2023): Global QE reduced spread (BBB-AAA) by 0.7 p.p. in Covid.

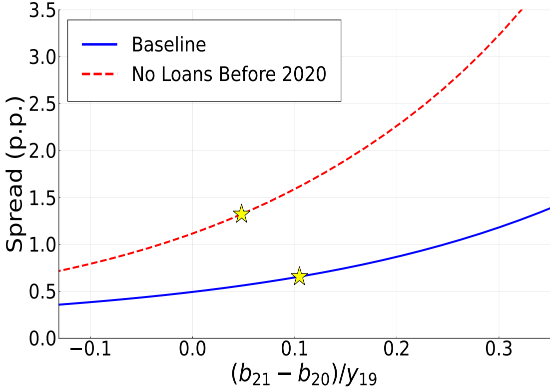
More counterfactuals

back

	$(100 \times \Delta \log)$			$(\Delta$ p.p.)
(relative to 2020 model)	c	b	T	spread
$\pi_{\hat{\delta}} = 0.9$	0.1	0.2	0.2	0.0
$\pi_{\hat{\delta}} = 0.1$	−0.4	−0.7	−0.5	−0.2
$\lambda_p = 0.04$	−0.3	2.5	−0.4	0.4
$\bar{\eta} = 0.22$	7.1	6.9	8.8	−0.6
$\varepsilon = 0.1$	−1.4	−2.6	−3.9	0.7
$a' = a$	−2.5	−2.2	−4.1	0.0
$r = 0.03$	−1.2	−0.7	−0.7	−0.3
$r = 0.01$	0.4	−0.2	−0.1	0.4

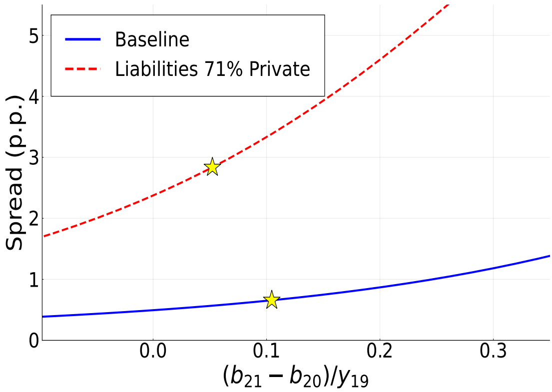
Old bailouts, $\hat{\delta}_{t<20} = 0$

back



- $f_{20} = 0 \implies$ higher b_{20}, less fiscal space.

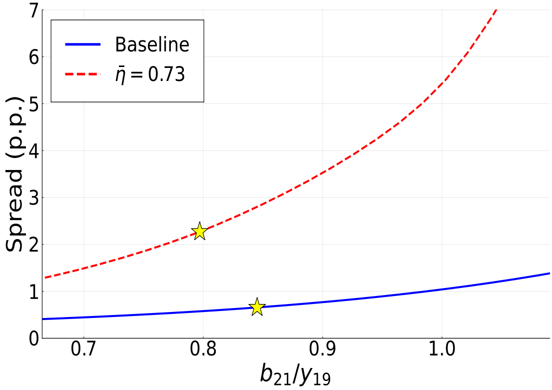
Changing composition of debt



- more private debt $\Longrightarrow$ more default risk.

Higher haircuts

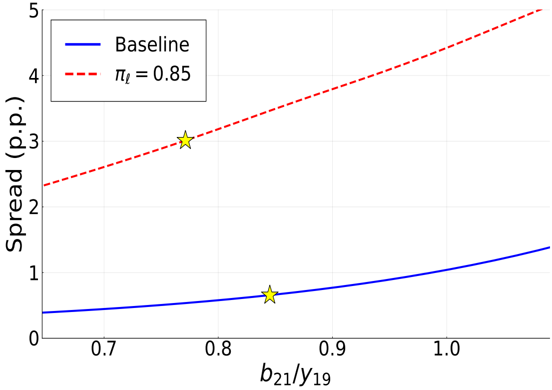
more



- higher $\bar{\eta} \implies$ more default risk.

Beliefs about persistence of Covid

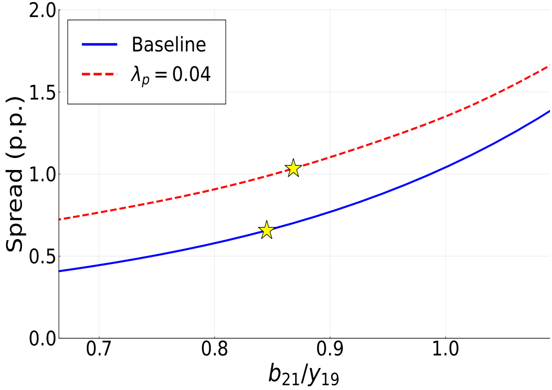
more



- Distributional concerns drive higher spreads.

Lengthening maturity

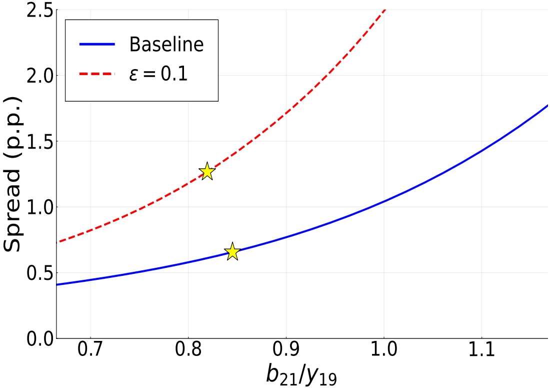
back



- longer maturity $\Longrightarrow$ dilution, riskier debt.

Inelastic labor

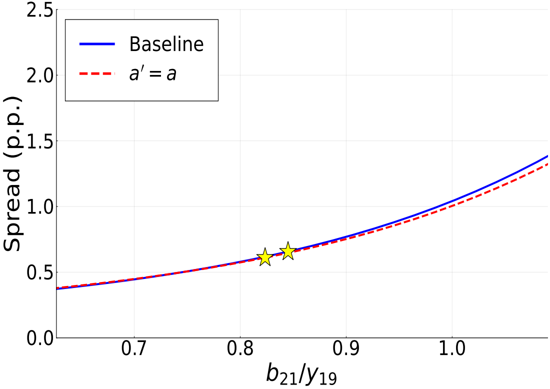
back



- lower cost of $T \implies$ more default risk.

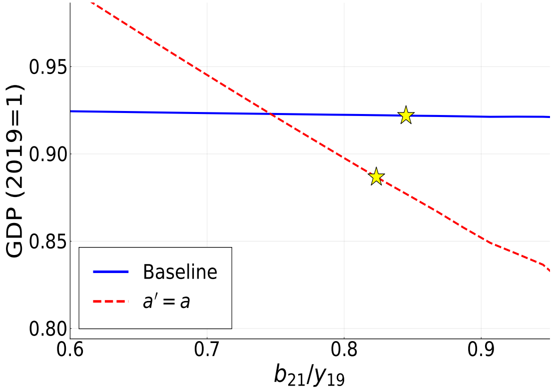
Inelastic savings

back



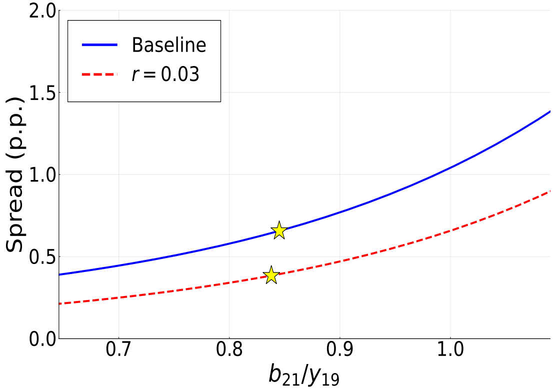
Importance of endogenous savings

back



Higher safe rates

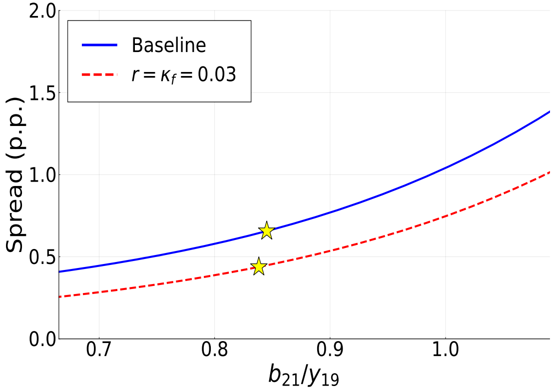
back



- lower distance $1/\beta_g - 1$ and $r \implies$ less incentive to borrow

Higher safe and coupon rates

back



Rare disasters literature

back

- $\pi_\ell = 0.85$ matches duration of Greek depression in 2009-2016.
- Barro and Ursua (ARE12) rare disasters sample:
  - Mean output decline of 21 percent.
  - Mean duration of 4 years.
  - 16 percent of disasters $\geqslant 6$ years.

Interactions of old bailouts

back

$\hat{\delta}_{t<20} = 0$ **and ...**	$(100 \times \Delta \log\ )$			$(\Delta$ p.p.)
(relative to 2020 model)	c	b	T	spread
$\hat{\delta}_{t\geqslant 20} = 0$	-8.5	-2.9	-10.1	1.9
$\pi_\ell = 0.85$	-5.2	-6.6	-6.5	4.1
(relative to 2021 model)				
$\text{lock}_{21} = 1, \pi_\ell = 0.85$	-19.9	-3.6	-2.8	5.8