Sovereign debt sustainability, the carbon budget and climate damages

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Research question

- Two contemporaneous challenges: managing the risk of growing public indebtedness and dealing with the consequences of climate change.
  - ⇒ consequences of climate damages on public debt sustainability?
  - ⇒ consequences of transition costs on public debt sustainability?
- These climate-related issues have entered into policy discussions
  - ⇒ revision of European budgetary rules
  - ⇒ revision of IMF Public Debt Sustainability Framework
- First academic paper to address this critical issue by estimating national *fiscal* (or *debt*) *limits* in advanced economies under the Paris Agreement's carbon constraints, while taking into account:
  - the economic costs of reducing carbon emissions,
  - climate damages,
  - the degree of political coordination in the transition.
- At the intersection of two literature domains:
  - macro-financial research on fiscal limits and debt sustainability,
  - macro-climate research on the economic costs of environmental policies and climate change.

Scarce Literature on the Impact of Climate Change on Sovereign Debt Sustainability

- Emerging research links climate change economics with fiscal policies, highlighting how climate change and mitigation efforts impact government finances.
- Consequences of climate damages:
  - Climate vulnerability leads to higher sovereign borrowing costs, particularly in high-risk and developing countries (Beirne, Renzhi, and Volz, 2021; Cevik and Jalles, 2022).
  - Stronger institutions in emerging markets can mitigate the negative impact of temperature on sovereign bond performance (Boehm, 2022).
- Fewer studies examine the consequences of transition policies:
  - Transition policies towards low-carbon economies can lower borrowing costs (Battiston and Monasterolo, 2020; Collender et al., 2023). Need for climate-smart investments to avoid credit downgrades and fiscal strains (Klusak et al., 2023; Zenios, 2022).
  - Important challenges for high-debt countries (IMF, 2023 and Seghini and Dees, 2024 use dynamic general equilibrium models to analyze how different mitigation policies –e.g., carbon taxes, public investments– impact GDP, public debt, and default risks)
- Established vital link between climate change costs and public debt sustainability $\longrightarrow$ need for integrated fiscal and environmental strategies, and further research on incorporating climate considerations into sovereign debt sustainability models.

- No default as long as: debt-to-GDP $\leq$ **fiscal limit**

  $\Longrightarrow$ Involuntary default framework

- Climate-related challenges affect both sides of this inequality: this paper concentrates on the impact on fiscal limits through the growth channel.
- Fiscal Limit: the maximum debt-to-GDP ratio a government can accumulate without losing its repayment credibility.
- Main determinants: *growth rate*, risk-free interest rate, future potential primary surpluses.

Main Results

- Transition scenario
  $\Longrightarrow$ In the short term, fiscal limits are initially lower due to abatement costs, highlighting sustainability issues related to specific transition challenges for countries like Italy and France.
  $\Longrightarrow$ If the transition is successfully coordinated at a global level, fiscal limits converge to higher and stable levels.
- vs Business-as-usual/Uncoordinated Transition
  $\Longrightarrow$ Climate policies initially lower fiscal limits compared to BAU scenarios.
  $\Longrightarrow$ If the transition globally fails or is not undertaken at all (BAU), growth rates are impacted by increasingly severe climate damages $\Rightarrow$ plunging fiscal limits.
- Policy Implication: importance of coordinated, prompt transition policies to mitigate climate impacts, safeguard fiscal sustainability, and support the financing of a green economic transition.

Integrating a model for fiscal limits with climate considerations I

- Extension of the model by Collard, Habib, and Rochet, 2015, incorporating a reduced-form growth rate function related to carbon emissions:

$$b_t^M = \max_{d_t} b(d_t) = \max_{d_t} \frac{d_t}{R(d_t)} = \max_{d_t} \frac{d_t}{R}\left[1 - \mathrm{PD}(d_t)\right] \quad \text{(risk-neutral investors)}$$

$$\text{Default if:} \quad g_{t+1} \equiv \frac{\eta(E_{t+1})}{\eta(E_t)} e^{\mu_0 + \epsilon_{t+1}} < \frac{d_t}{\alpha + b_{t+1}^M}, \quad \text{where} \quad \epsilon_j \sim_{i.i.d.} N(0, \sigma_0^2)$$

d: face value of debt-to-GDP, b: govt. borrowing-to-GDP, α: maximum primary surplus, PD: prob. of default, R: gross risk-free rate, g: gross GDP growth rate, μ_0 and σ_0: "green" post-transition growth rate and volatility, E: carbon emissions.

- The abatement cost function $\eta(\cdot)$ is adapted and calibrated for 31 advanced economies by referencing the OECD's empirical results in developing the "Environmentally Adjusted Multifactor Productivity" (Cárdenas Rodríguez, Haščič, and Souchier, 2018):

$$\eta(E_t) = E_t^{\beta} = e_t \bar{E}^{\beta} \approx [(c + e_t)\bar{E}]^{\beta} \tag{1}$$

β: short-term abatement cost parameter, c: CCS parameter, $\bar{E}$: national carbon budget

- Maximum sustainable borrowing (MSB):

$$b_t^M = \max_{d_t} \frac{d_t}{R}[1 - F(x_t)] = \frac{\gamma e^{\mu_0}}{R}(\alpha + b_{t+1}^M)\frac{\eta(E_{t+1})}{\eta(E_t)} = \frac{\alpha}{\eta(E_t)} \sum_{j=1}^{+\infty} \left(\frac{\gamma e^{\mu_0}}{R}\right)^j \eta(E_{t+j}) \qquad (2)$$

where $\gamma \equiv \max_x x[1 - F(x)] = x_M[1 - F(x_M)]$,

$$x_t \equiv \frac{d_t}{[\alpha + b_{t+1}^M]e^{\mu_0} \frac{\eta(E_{t+1})}{\eta(E_t)}}$$

$F(\cdot)$: c.d.f. of the log-normally i.i.d. random shock $\exp(\epsilon)$,
γ: constant borrowing factor (net of growth)

- Fiscal limit/ maximum sustainable debt (MSD):

$$d_t^M = x_M(\alpha + b_{t+1}^M)e^{\mu_0} \frac{\eta(E_{t+1})}{\eta(E_t)} \equiv \frac{R}{1 - F(x_M)} b_t^M. \qquad (3)$$

Data

Country	μ	σ	μ_0	σ_0	β	Debt/GDP$_{2020}$	MPS(α)	NDC 2021-25 (E_0)	CB 2026 ($\bar{E}_1$)
France	1.57	1.48	1.88	1.43	6.4	115.2	3.65	2.035	7.329
Italy	0.73	1.94	1.03	1.68	10.1	155.3	6.55	1.880	6.769

Table: Columns 1-5 (%), based on Cárdenas Rodríguez, Haščič, and Souchier, 2018 (period 1990-2013): average GDP growth rate (μ), its volatility (σ), average "green" GDP growth rate adjusted for pollution increase/reduction (μ_0), and its volatility (σ_0), and the short-term abatement cost parameter (β).
Columns 6-7 (%), IMF data: historical maximum primary surplus ($\alpha = \max_t \frac{s_t}{Y_t}$) and debt-to-GDP in 2020.

Columns 8-9 ($GtCO_2$): based on EU "National Determined Contribution" and IPCC 2°C-67% prob. scenario global carbon budget 2020 (1150 $GtCO_2$) on a per-capita basis.

5-year period, $r = R - 1 = 2.44\%$, $c = 1\%$.

Government's maximization problem I

$$\max_{\{E_t\}} b_0^M \quad \text{s.t.} \quad \sum_{t=1}^{+\infty} E_t \leq \bar{E}_1, \quad E_t \geq 0 \tag{4}$$

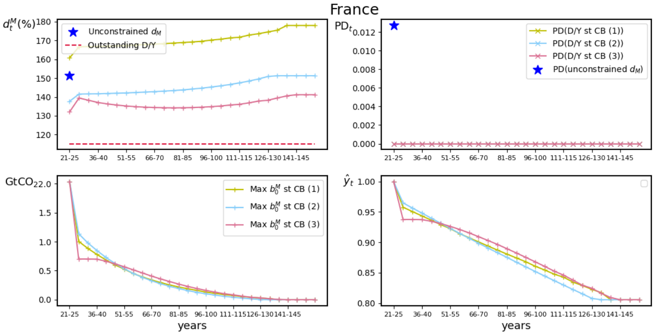
Fiscal limits in the transition – OECD countries

Three long-term scenarios on the green growth rate:

(1) optimistic: $\mu_0 \neq \mu$, $\sigma_0 \neq \sigma$;

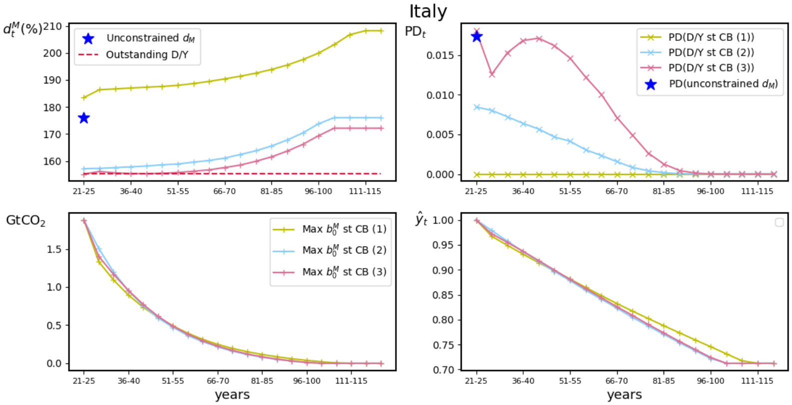
(2) parallel hypothesis (PL): $\mu_0 = \mu$, $\sigma_0 = \sigma$;

(3) pessimistic: $\mu_0 = \mu[1 - m(E_t)]$, where $m(E_t) = \sqrt{\theta \sum_1^t e_t}$, $\theta = 0.0121$.[a]

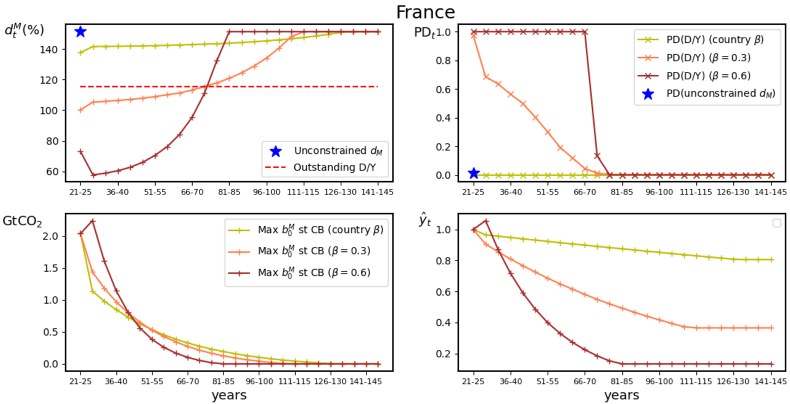


[a] Ratio of success rate of clean over dirty technology: calibrated as the product of the ratio of number of citations per patent (1.43 as in Dechezlepretre, Martin, and Mohnen, 2017) and the inverse of the ratio of pass-through years (5/8 as in Perrons, Jaffe, and Le, 2021)
$\Longrightarrow$ success rate of green over dirty technology = 89%
$\Longrightarrow$ $\mu_0 = \mu(1 - 11\%)$, at the end of the transition $\Longrightarrow$ $\theta = 0.0121$.

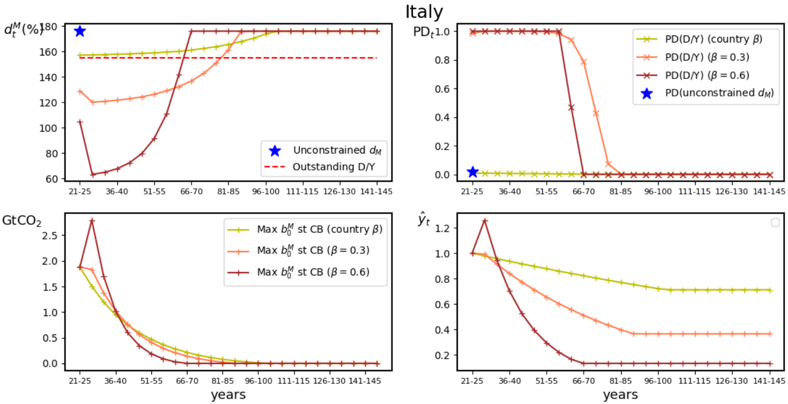
⇒ Long-term green growth prospects: Italian sustainability at risk?



Higher values of β imply unsustainable debt for Italy and France. PL scenario. I



Higher values of β imply unsustainable debt for Italy and France. PL scenario. II



Welfare Maximization

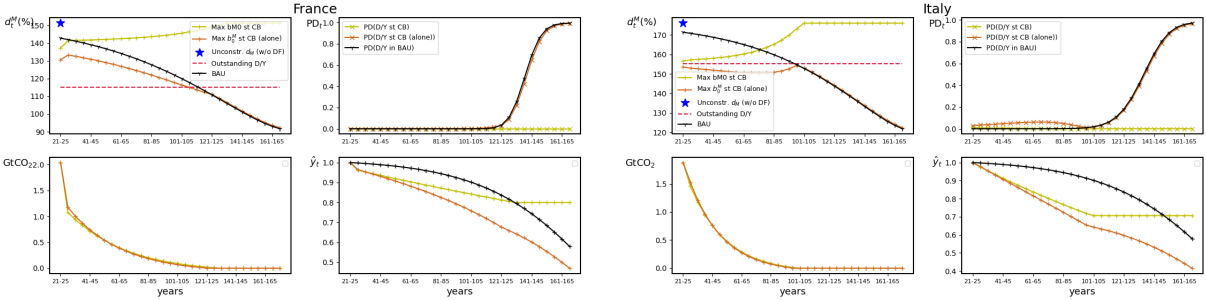
Climate damages and the need for global coordination

Climate damages are introduced through the exponential function proposed by Dietz and Venmans, 2019 Dietz and Venmans, 2019:

$$D(T_t) = \exp\left(-\frac{\rho}{2}T_t^2\right), \text{ where } T_t = \zeta C_t. \quad (5)$$

T_t: global average temperature increase, C_t: global cumulative emissions since 1850

⇒ A globally coordinated transition (light green) stabilizes climate damages and growth, then avoiding the plummeting fiscal limits of a business-as-usual scenario (black) or a “solitary” transition (orange). PL scenario.



▸ US ▸ Shift period

Concluding remarks

- During the early stages of the transition, fiscal limits are lower than their long-term *stationary* values, assuming a globally successful transition scenario (2°C).

  High emissions' abatement costs can push countries like Italy and France from sustainable to unsustainable current debt-to-GDP ratios.

- A coordinated transition initially results in lower fiscal limits than in a BAU scenario, due to the negative impact of emission cuts on GDP growth.

  However, by 2080, these coordinated actions prove more advantageous for all countries than in a BAU or uncoordinated transition scenario, where fiscal limits continue to plunge and currently outstanding debt-to-GDP becomes unsustainable for many countries.

⇒ **Coordinated efforts are needed to stabilize climate damages, economic growth and fiscal limits**, supporting sustainable public debt and the green transition financing.

Appendix – Debt sustainability in the transition. $r = 2.44\%$.

Back to Main Presentation

Country	Green b_M			Max b_o^M st cb			Green d_M			d_o^{M*} st cb			D/Y
	(1)	(2)-*chr*	(3)	(1)	(2)	(3)	(1)	(2)-*chr*	(3)	(1)	(2)	(3)	
Australia	788.12	906.13	499.36	598.63	685.19	520.54	896.47	1031.30	568.35	680.93	779.85	592.45	57.80
Austria	142.12	122.82	112.87	137.23	118.87	113.69	162.83	140.75	129.35	157.22	136.22	130.29	83.20
Belgium	312.88	268.56	246.81	277.51	240.13	228.22	357.46	306.99	282.14	317.05	274.50	260.88	112.80
Canada	464.49	436.02	387.14	416.43	391.53	366.77	532.28	500.19	444.12	477.20	449.15	420.75	117.80
Czech Republic	105.62	67.03	60.80	80.49	53.96	51.12	122.04	77.80	70.56	93.01	62.62	59.32	37.70
Denmark	343.90	321.94	305.62	326.14	305.91	296.70	395.43	370.42	351.65	375.01	351.98	341.39	42.10
Estonia	96.49	85.78	74.38	87.42	78.25	72.32	116.28	103.97	90.16	105.36	94.84	87.66	19.00
Finland	209.65	195.63	186.41	202.21	189.01	183.96	245.50	229.20	218.40	236.79	221.45	215.53	69.00
France	155.79	132.38	123.55	140.75	120.51	115.60	177.91	151.26	141.17	160.73	137.69	132.08	115.20
Germany	150.52	118.03	112.27	132.01	105.26	102.25	173.22	135.84	129.21	151.92	121.14	117.68	68.70
Greece	74.60	68.48	66.94	69.51	64.14	63.36	87.47	80.71	78.89	81.50	75.59	74.68	211.90
Hungary	251.81	194.65	184.00	215.23	170.13	164.85	290.92	225.66	213.32	248.67	197.24	191.11	80.00
Ireland	343.16	312.12	246.77	307.96	281.28	247.90	404.25	368.51	291.36	362.78	332.11	292.69	58.40
Italy	181.85	153.35	149.95	160.27	136.92	135.18	208.18	176.05	172.14	183.48	157.18	155.19	155.30
Japan	158.54	132.72	128.91	139.54	118.07	116.09	181.92	152.56	148.18	160.11	135.72	133.45	259.00
Latvia	47.49	43.08	37.30	42.60	38.88	35.91	57.60	52.33	45.31	51.66	47.24	43.62	43.30
Lithuania	64.34	47.60	40.52	52.84	40.25	36.82	76.66	57.30	48.78	62.95	48.45	44.33	46.60
Luxembourg	238.31	189.23	158.42	190.61	154.69	139.57	277.52	220.78	184.83	221.97	180.48	162.84	24.80
Netherlands	221.35	188.70	173.96	197.02	169.46	161.49	254.62	217.01	200.05	226.62	194.88	185.71	52.80
New Zealand	312.92	319.08	280.35	287.89	293.41	273.93	360.12	367.39	322.79	331.31	337.83	315.40	43.10
Norway	1290.37	1050.44	910.25	1234.88	1009.14	947.84	1475.18	1202.54	1042.05	1411.74	1155.26	1085.08	46.80
Poland	193.97	188.81	152.94	189.04	184.06	173.13	225.23	219.19	177.54	219.51	213.67	200.98	57.40
Portugal	104.74	94.15	89.29	97.31	87.85	85.16	120.33	108.47	102.87	111.80	101.22	98.12	135.20
Slovak Republic	15.77	12.56	9.85	13.00	10.52	9.14	18.37	14.66	11.50	15.15	12.28	10.67	59.70
Slovenia	78.94	67.95	62.39	68.32	59.52	56.72	91.80	79.36	72.87	79.45	69.52	66.25	79.80
Spain	132.82	126.41	116.79	120.23	114.73	109.51	152.77	145.75	134.66	138.30	132.28	126.26	120.00
Sweden	226.70	200.15	186.13	207.06	183.92	176.29	262.10	231.60	215.38	239.39	212.83	204.00	39.60
Switzerland	127.76	116.64	109.36	116.41	106.91	102.88	146.22	133.48	125.14	133.24	122.35	117.73	42.40
Turkey	184.91	215.05	185.59	159.01	182.66	168.09	217.35	255.52	220.51	186.90	217.03	199.72	39.50
United Kingdom	301.47	246.01	224.31	271.39	223.85	211.87	345.71	282.47	257.56	311.22	257.03	243.27	102.60
United States	212.25	191.23	166.66	178.57	161.54	149.12	242.97	219.13	190.97	204.42	185.10	170.88	134.20

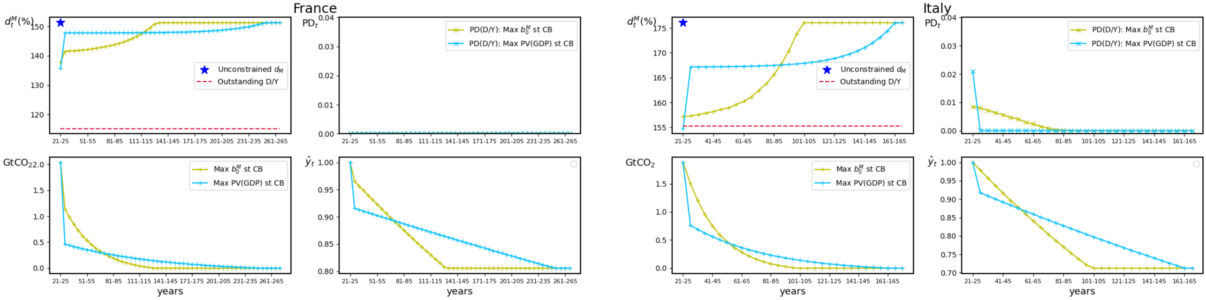
Appendix – Current debt sustainability versus “welfare” maximization

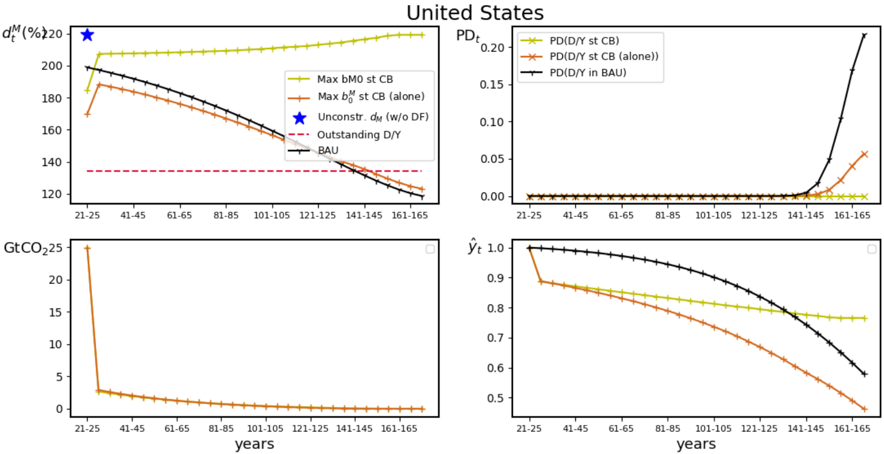
▸ Back to Main Presentation

$$\max_{\{E_t\}} \sum_{t=0}^{+\infty} \frac{\mathbb{E}_0[Y_t]}{R^t} = \frac{Y_0}{\eta(E_0)} \sum_{t=0}^{+\infty} \left(\frac{\bar{g}}{R}\right)^t \eta(E_t) \quad \text{s.t.} \quad \sum_{t=1}^{+\infty} E_t \leq \bar{E}_1, E_t \geq 0 \tag{6}$$

$\bar{g} = e^{\mu_0 + 1/2\sigma_0^2}$: expected green gross growth rate. $\gamma e^{\mu_0} < \bar{g}$

$\Rightarrow$ Maximizing welfare under the carbon budget, instead of the current MSB, leads to an initial faster transition, to save carbon budget for the future. PL scenario.





Back to damage function

App. – When MSD in a successful global transition overcomes BAU scenario.

Back to DF

	Shift period
Australia	2021-25
Austria	2021-25
Belgium	2026-30
Canada	2026-30
Czech Republic	2076-80
Denmark	2026-30
Estonia	2061-65
Finland	2041-45
France	2026-30
Germany	2066-70
Greece	2071-75
Hungary	2076-80
Ireland	2026-30
Italy	2071-75
Japan	2061-65
Latvia	2066-70
Lithuania	2071-75
Luxembourg	2051-55
Netherlands	2041-45
New Zealand	2026-30
Norway	2021-25
Poland	2021-25
Portugal	2041-45
Slovak Republic	2026-30
Slovenia	2071-75
Spain	2046-50
Sweden	2051-55
Switzerland	2046-50
United Kingdom	2031-35
United States	2026-30