Climate-Change Adaptation: The Role of Fiscal Policy

FSR Climate Annual Conference

Florence School of Regulation, European University Institute ,
28-29 November 2019

Michele Catalano, Prometeia Associazione
Lorenzo Forni, Università degli Studi di Padova, Prometeia Associazione
Emilia Pezzolla, Prometeia Associazione

FSR
Florence School of Regulation

Climate-Change Adaptation: The Role of Fiscal Policy

Motivation

- **Natural disasters** and weather-related shocks can exacerbate **revenue volatility** and **slow potential GDP growth**
- The government's fiscal position is weakened by the **short-term costs** of disaster relief and the **long-term costs** of reconstruction, especially for developing countries
- **Fiscal policy** can play a key role in **mitigating climate change** and **adapting to its effects**
- This study aims to contribute to a better understanding of **how fiscal policy can help countries adapt** to climate change

Climate-Change Adaptation: The Role of Fiscal Policy

Literature review

→ **Most macroeconomic models focus on assessing mitigation costs:**

- [Stern 2007], [Nordhaus 2007, Nordhaus 2008], [Bonen et al. 2016] use integrated assessment models (IAMs)
- [Heijdra et al. 2006] and [Kotlikoff et al. 2016] use a small open and multi-country overlapping generations (OLG) model, respectively, to assess the intergenerational impact of a current increase in environmental taxes

→ **By contrast, the literature on the macroeconomic implications of climate-change adaptation is relatively limited**

- More recent IAMs include both adaptation and mitigation [Ingham et al. 2013]; [Tol 2007]; [Lecocq 2007b]; [de Briun et al. 2009], [Agrawala et al. 2011]
- [Lecocq and Shalizi 2007a] uses a partial equilibrium optimization model of climate policies to evaluate the role of mitigation, proactive adaptation (ex ante), and reactive adaptation (ex post)

Climate-Change Adaptation: The Role of Fiscal Policy

Our contribution

- The model we use is a **multi-country overlapping generations (OLG) model** (close to Auerbach and Kotlikoff, 1987 and Vogel *et al*., 2014), calibrated for a **small open economy** representative of a **less developed country**

- We propose a **modelling of the impact of climate change** in a standard growth model and **use calibration** to draw some qualitative indications

- The aim of the paper is **to assess the impact of climate change and adaptation policy** on agents' behavior and long-term economic growth

Climate-Change Adaptation: The Role of Fiscal Policy

The model (1/4)

The overlapping generations (OLG) approach allows us:

- to take into account the role of various **long-term drivers**, such as technological and demographic trends, that is the evolution of population and human capital
- to analyze the **determinants of capital accumulation** in a general equilibrium growth model, i.e. the extent to which cohorts save, consume, work and thus affect labour and capital inputs
- to capture the impact of climate change on agents' behavior and, hence, on **economic growth in the long run**
- to introduce a quite detailed description of **fiscal policy** and analyze the role of public investment to adapt to climate change
- to introduce, through the calibration of the model, **nonlinear effects of the fiscal policy**

Climate-Change Adaptation: The Role of Fiscal Policy

The model (2/4)

- **Climate change** is assumed to increase the **depreciation rate of physical capital** via two types of effects:
  - gradual factors: the impact of climate change occurs slowly (e.g. gradual global warming)
  - extreme events: sudden events in a brief period of time (e.g. tornados and droughts)

- **Adaptation** reflects the extent to which public policies reduce the negative influence of climate change on the capital depreciation rate, based on **two different strategies**:
  - preventive actions (investments in coastal defense infrastructure, e.g. dams or water storage)
  - remedial actions (e.g., disaster relief and reconstruction)

- **Two scenarios:**
  - gradual factors
  - gradual factors + extreme events

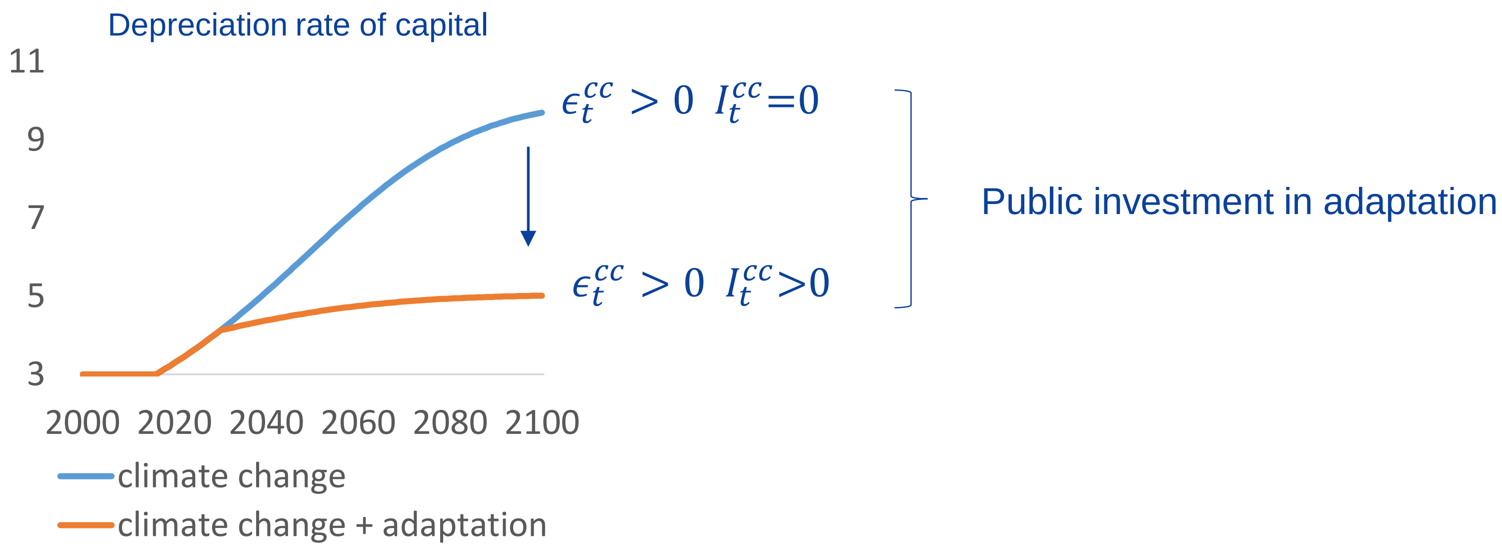
Climate-Change Adaptation: The Role of Fiscal Policy

The model (3/4)

- The **impact of climate change** is reflected in the **depreciation rate of capital**, which tends to increase over time
- The depreciation rate δ_t evolves over time according to a **logistic function** that depends positively on climate shock and negatively on public investment in adaptation:

$$\delta_t = f(\overset{+}{\epsilon_t^{cc}}, \overset{-}{I_t^{cc}})$$

where ϵ_t^{cc} denotes the climate change shock and I_t^{cc} the investment in adaptation.



Climate-Change Adaptation: The Role of Fiscal Policy

The model (4/4)

- The **depreciation rate affects capital accumulation** according to the following equation:

$$K_{t+1} = (1 - \delta_t)K_t + I_t \quad (1)$$

  - K_t : capital stock
  - I_t: investment in physical capital
  - δ_t: depreciation rate of capital

- The government can reduce the impact of climate change on the depreciation rate by increasing **public investment in adaptation $\boldsymbol{I_t^{cc}}$**, but can also rely on donors' grants and a reserve fund:

$$\Delta\, B_t = r_t B_t + expenditure_t - revenues_t \; - donors_t \; - RF_t \; + I_t^{cc} \quad (2)$$

  - $\boldsymbol{I_{cc,t}}$: investment in adaptation
  - RF_t: amount of revenue from household's income taxation used to build up a reserve fund
  - $\boldsymbol{\Delta B_t = B_{t+1} - B_t}$ **:** public debt change

- Investment in adaptation can be financed by incresing public debt, however the country faces a **borrowing constraint** (credit limit) on the international financial markets up to $\overline{NFA_t}$ equal to 160% of GDP:

$$NFA_t \geq \overline{NFA_t} \quad (3)$$

Technical details

Climate-Change Adaptation: The Role of Fiscal Policy

Scenarios and fiscal strategies

Scenario 1: Gradual factors	Scenario 2: Gradual factors + extreme events
→ Without intervention (**Baseline**) → With **early** adaptation → With **late** adaptation	→ Without intervention (**Baseline**) → With **early** adaptation → With **ex ante debt reduction/**reserve fund → With **donors**' grants
Depreciation rate increases gradually to 10%	Depreciation rate increases sharply up to 30%

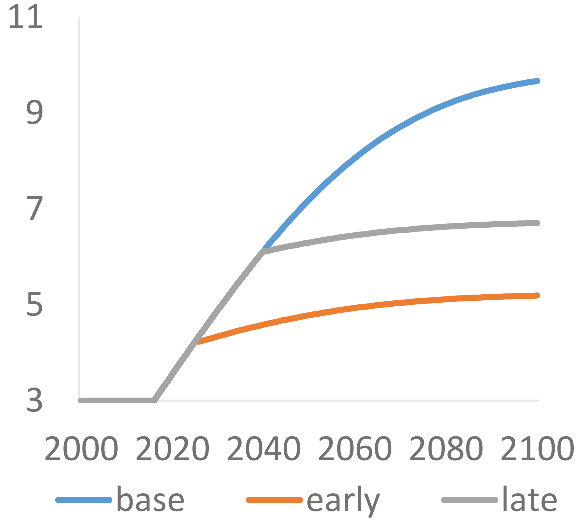
Climate-Change Adaptation: The Role of Fiscal Policy

Results: gradual factors of climate change

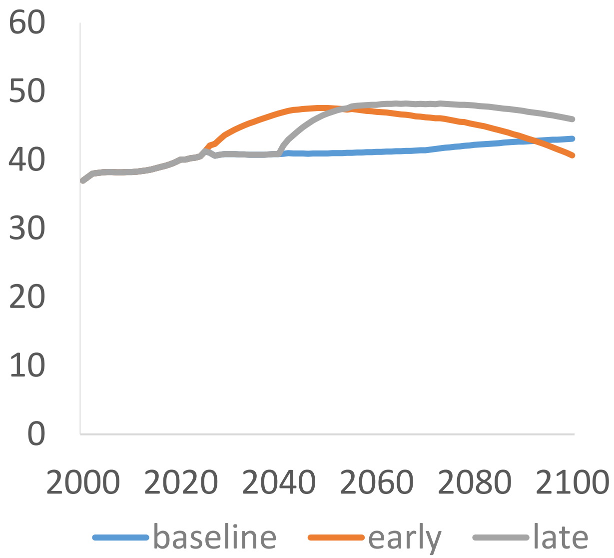
Scenario 1: Gradual factors of climate change

(depreciation rate up to 10%)

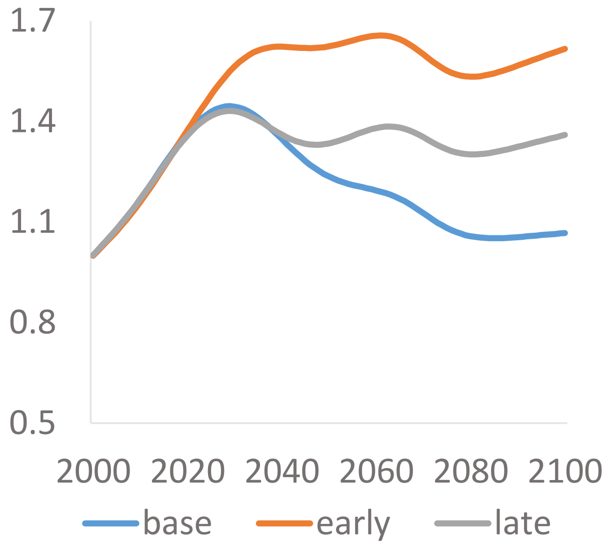
a) Depreciation rate %



b) Debt-to-GDP %



c) Real GDP (2000=1)



Source: Prometeia

Climate-Change Adaptation: The Role of Fiscal Policy

Alternative fiscal instruments to finance adaptation: gradual factors (depreciation rate up to 10%)

Gdp % deviation from the baseline, for different fiscal coverage in early action expenditure

Fiscal instrument	2020	2030	2040	2050	2060	2070	2080	2090	2100
Debt	6.7	21.9	29.9	34.7	39.1	40.4	42.8	46.0	47.7
Capital	24.7	38.0	48.1	54.7	60.8	65.3	70.3	75.1	77.4
Consumption	16.0	34.1	46.7	54.8	62.6	68.0	73.4	78.5	81.0
Labor	15.3	32.7	44.7	52.4	59.9	65.1	70.3	75.1	77.5
Education	-16.4	-34.6	-47.4	-55.6	-63.4	-69.0	-74.5	-79.6	-82.1
Transfers	16.4	34.6	47.3	55.6	63.4	69.0	74.5	79.5	82.5

Debt-to-Gdp deviation from the baseline, for different fiscal coverage in early action expenditure

Fiscal instrument	2020	2030	2040	2050	2060	2070	2080	2090	2100
Debt	4.5	8.0	8.7	7.9	6.0	4.1	1.3	-2.3	-6.8
Capital	-7.0	-9.2	-11.1	-12.2	-12.5	-13.7	-14.9	-15.7	-16.5
Consumption	-2.3	-4.6	-6.4	-7.5	-8.0	-9.0	-10.1	-10.9	-11.5
Labor	-2.2	-4.4	-6.1	-7.2	-7.7	-8.7	-9.7	-10.4	-11.0
Education	2.3	4.6	6.4	7.5	8.0	9.0	10.1	10.9	11.6
Transfers	-2.1	-4.9	-6.3	-7.4	-8.0	-9.0	-10.1	-10.8	-11.5

Source: Prometeia

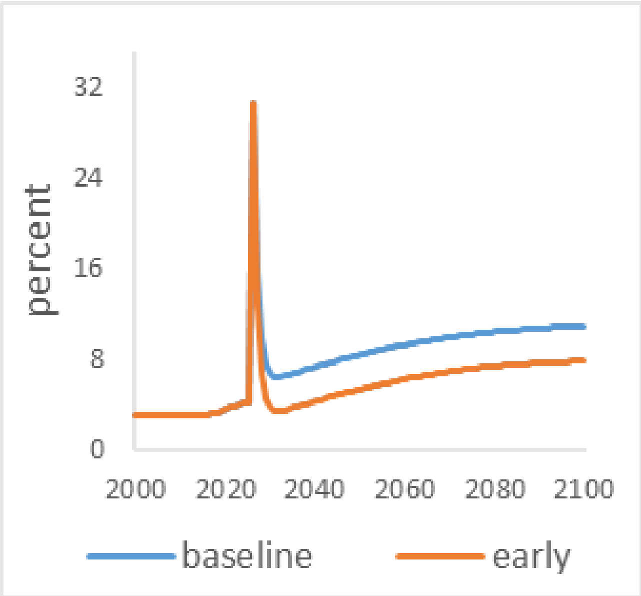
Climate-Change Adaptation: The Role of Fiscal Policy

Results: gradual factors + extreme events

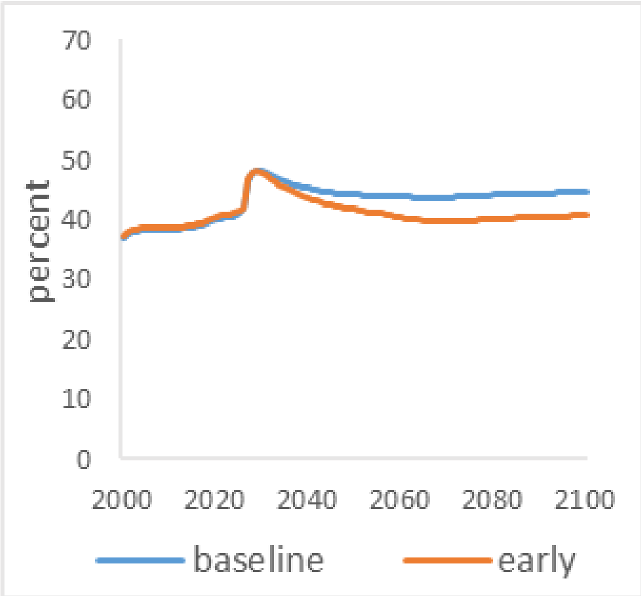
Scenario 2: Gradual factors + extreme events

(depreciation rate up to 30%)

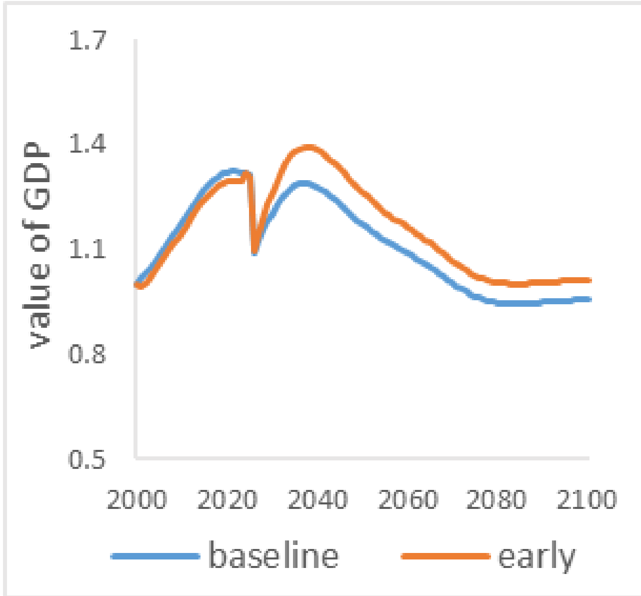
a) Depreciation rate %



b) Debt-to-GDP



c) Real GDP (2000=1)



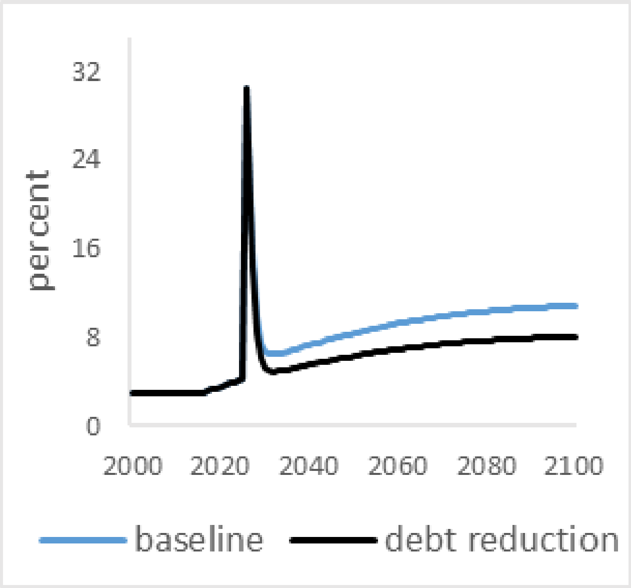
Source: Prometeia

Climate-Change Adaptation: The Role of Fiscal Policy

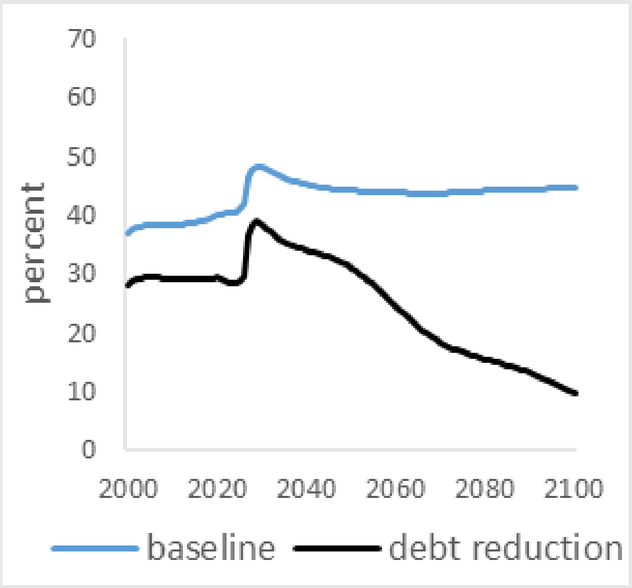
Results: gradual factors + extreme events

Scenario 2: Ex ante debt reduction

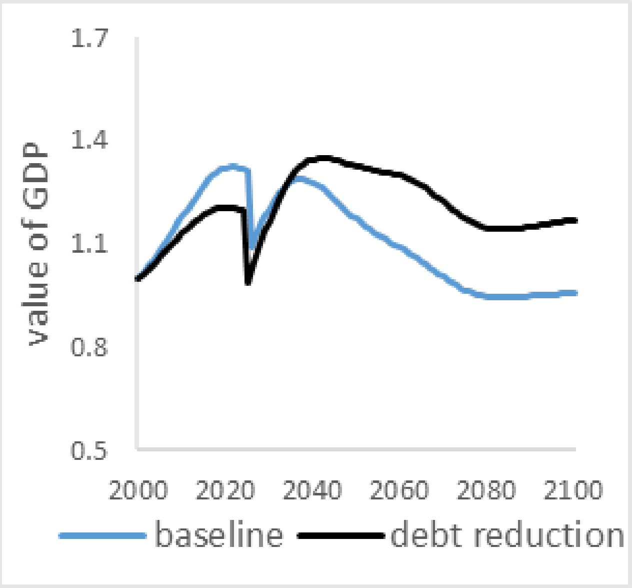
a) Depreciation rate %



b) Debt-to-GDP



c) Real GDP (2000=1)



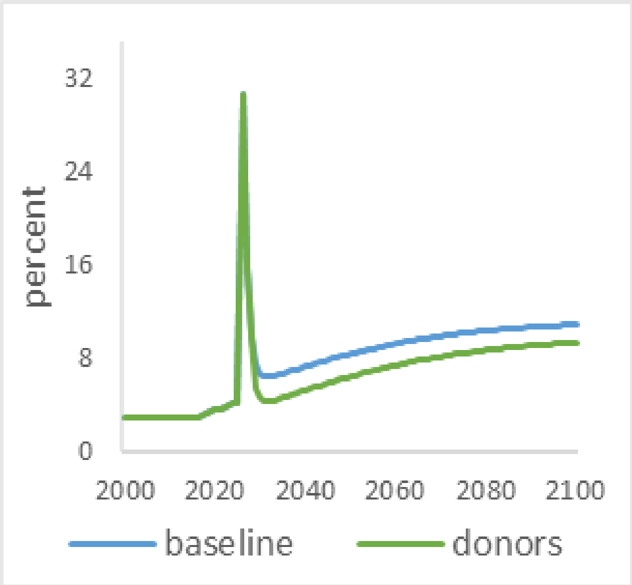
Source: Prometeia

Climate-Change Adaptation: The Role of Fiscal Policy

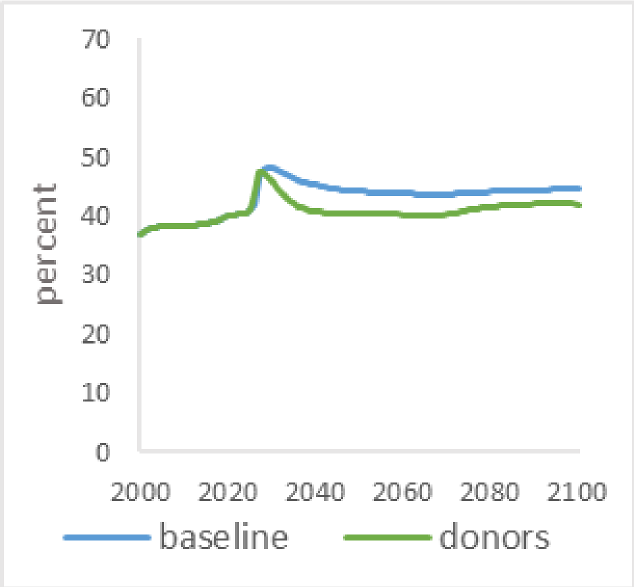
Results: gradual factors + extreme events

Scenario 2: Donors' grants

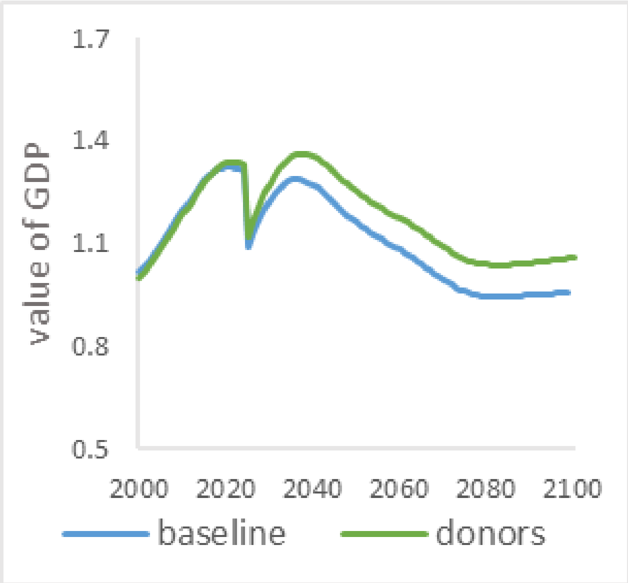
a) Depreciation rate %



b) Debt-to-GDP



c) Real GDP (2000=1)



Source: Prometeia

Climate-Change Adaptation: The Role of Fiscal Policy

Conclusion

- Countries should consider **investing in preventive adaptation spending**: early, preventive action to address climate change is always superior to late, remedial action
- Countries **could combine adaptation spending with public debt reduction**: lower debt eases borrowing constraints when abrupt climate events occur
- Reliance on **donor grants helps reconstruction** but has little effect on debt dynamics
- **Combining adaptation spending, ex ante debt reduction and donors' grants** would increase the resilience of the economy capital stock, keep the dynamics of public debt manageable and maintain adequate fiscal space to cope with natural disasters

Climate-Change Adaptation: The Role of Fiscal Policy

Next steps

→ This paper represents for us a first approach to the issue of climate change

→ Currently, we are taking a further step forward by considering

- 8 areas/regions in the model
- A more detailed sectoral disaggregation
- a climate module for the calculation of emissions, temperature and damage functions à la Nordhaus
- mitigation policies (carbon tax) and not only adaptation policies

Thank you!

Climate-Change Adaptation: The Role of Fiscal Policy

The model: households

- The **households**' life-cycle stream **utility** is given by :

$$U = \sum_{t=s}^{s+\overline{T}} q_{t-s} \frac{u\left[c_{t-s}, (e_t - l_{t-s})\right]^{1-1/\xi}}{1-\frac{1}{\xi}} \frac{1}{(1+\rho)^{t-s}}, \qquad (1)$$

  - $t-s$: age of each cohort at time t born in period s, $\overline{T}$: maximum economic age, that is 100
  - c_t : consumption, l_{t-s} :labour supply measured relative to the time endowment e_t
  - ρ is the pure time discount rate and q_{t-s} is the survival probability in period t
  - ξ defines the intertemporal elasticity of substitution

- Households maximize their discounted lifetime utility at time t in order to choose consumption and leisure (i.e., savings and labour supply), subject to the **dynamic budget constraint**:

$$\begin{aligned} a_{t+1-s} \quad = \quad & \frac{1}{q_{t-s}} (1+r_t)\, a_{t-s} + (1-\tau_{l,t}) w_{t-s} h_{t-s} l_{t-s} + \\ & -(1+\tau_{c,t}) c_{t-s} - if_t + T_{t-s}, \end{aligned} \qquad (2)$$

  - a_{t-s}: wealth at time t of the cohort born in the period s, r_t: interest rate
  - $(1-\tau_{l,t}) w_{t-s} h_{t-s} l_{t-s}$: post-tax labour income, h_{t-s} is the human capital level,
  - $\tau_{l,t}$, $\tau_{c,t}$: tax rates on labour income and consumption, respectively,
  - T_t: pensions
  - If_t: tax imposed by the government to reduce public debt as a precaution (building up a reserve fund)

Climate-Change Adaptation: The Role of Fiscal Policy

The model: firms

- **Firms** produce an aggregate output with physical capital *K*, effective units of labor *L=HN*, and endogenous TFP according to the following **production function:**

$$Y_t = TFP_t K_t^{\alpha} (H_t N_t)^{1-\alpha} \quad (3)$$

  - *HN* denotes the effective labour, with aggregate *N* labor input and *H* human capital index
  - TFP increases due to both capital/labor ratio *K/N* and human capital per worker *H*
  - *α*: capital share, i.e. the share of income spent on capital

- The **endogenous productivity** is given by :

$$TFP_t = \left(\frac{K_t}{N_t}\right)^{g} H_t^{z} \quad (4)$$

  - *g*: contribution of the capital/labour ratio to the TFP
  - *z*: contribution of the human capital to the TFP

- The **aggregate capital stock** evolves according to the following equation:

$$K_{t+1} = (1 - \delta_t) K_t + I_t \quad (5)$$

  - I_t: investment in physical capital
  - δ_t: depreciation rate of capital

Climate-Change Adaptation: The Role of Fiscal Policy

The model: climate change shock

- We model the **climate factors** as an exogenous AR(1) process:

$$\epsilon_{cc,t} = \rho_{cc,t}\,\epsilon_{cc,t-1} + v_{cc,t} \tag{6}$$

  - $\boldsymbol{\rho_{cc,t}}$: persistence parameter
  - $\boldsymbol{v_{cc,t}}$: error term

- **Public investment in adaptation $\boldsymbol{I_{cc,t}}$** is defined as follows:

$$I_{cc,t} = \rho_{I,t} I_{cc,t-1} + \left(1 - \rho_{I,t}\right)\bar{I}_{cc,t} \tag{7}$$

  - $\boldsymbol{\bar{I}_{cc,t}}$: target level of investment in adaptation, $\boldsymbol{\rho_{I,t}}$: persistence parameter

- The **depreciation rate of capital** in the presence of adaptation investment:

$$\delta_t\left(\epsilon_{cc,t}\right) = \frac{(\bar{\delta} - \beta_k I_{cc,t})\,\delta_0 e^{(a0\epsilon_{cc,t})}}{(\bar{\delta} - \beta_k I_{cc,t}) + \delta_0\left[e^{(a0\epsilon_{cc,t})} - 1\right]} \tag{8}$$

  - $\boldsymbol{\delta_0}$: initial value of the depreciation rate, $\boldsymbol{\bar{\delta}}$: long-run value of the depreciation rate affected by climate change
  - $\boldsymbol{a_0}$: damage transmission parameter
  - $\boldsymbol{\beta_k}$: adaptation parameter

Climate-Change Adaptation: The Role of Fiscal Policy

The model: government and financial markets

- The **government** raises taxation on consumption, labor and capital, uses revenues to finance social transfers (pensions, *T*), the education systems *SC* and adaptation to climate change I_t^{cc}. It issues new debt *B* to finance the deficit according to:

$$\Delta B_t \; = \; r_t B_t - \tau_{l,t} w_t L_t - \tau_{c,t} C_t - \tau_{k,t} K_t - \Delta RF_t + r_t RF_t - d_t + \zeta_t T_t + I_t^{cc} + SC_t, \qquad (9)$$

  - $\Delta \boldsymbol{B_t} = \boldsymbol{B_{t+1}} - \boldsymbol{B_t}$ **:** public debt change
  - $\boldsymbol{w_t}, \boldsymbol{T_t}$ and $\boldsymbol{SC_t}$ denote wage, transfers and schooling expenditure, respectively
  - $\boldsymbol{\tau_{k,t}}$: the tax rate on capital, $\boldsymbol{\zeta}$: number of retired people
  - $\boldsymbol{d_t}$ donors' grants
  - $\boldsymbol{RF_t}$ reserve fund → $RF_{t+1} = (1 + r_t) RF_t + \; If_t$

- **Financial markets** allow to allocate net savings among countries, therefore the Net Foreign Asset (NFA) is defined as follows:

$$NFA_t = A_t - K_t - B_t \qquad (10)$$

  - $\boldsymbol{A_t}$: aggregate savings

The country faces a borrowing constraint (credit limit) on the international financial markets up to $\overline{NFA}_t$ equal to 160% of GDP:

$$NFA_t \geq \overline{NFA}_t \qquad (11)$$

back

Confidentiality

Contacts

Bologna
Piazza Trento e Trieste, 3
+39 051 6480911
italy@prometeia.com

Milan
Via Brera, 18
+39 02 80505845
italy@prometeia.com

Rome
Via Tirso, 26
italy@prometeia.com

London
Dashwood House 69 Old Broad Street
EC2M 1QS
+44 (0) 207 786 3525
uk@prometeia.com

Istanbul
River Plaza, Kat 19
Büyükdere Caddesi Bahar Sokak
No. 13, 34394
| Levent | Istanbul | Turkey
+ 90 212 709 02 80 – 81 – 82

Cairo
Smart Village - Concordia Building, B2111
Km 28 Cairo Alex Desert Road
6 of October City, Giza
egypt@prometeia.com

Moscow
ul. Ilyinka, 4
Capital Business Center Office 308
+7 (916) 215 0692
russia@prometeia.com

Prometeia
@PrometeiaGroup
Prometeiagroup
Prometeia

www.prometeia.com