The macrofinancial and policy underpinnings of climate stress testing scenarios: Are they fit for purpose?

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Motivation

- A growing practice in the running of climate stress tests is the use of the **NGFS scenarios** as a reference point for the analysis of climate risks (e.g. Alogoskoufis et al., 2021; ACPR/Banque de France, 2021).

- However, the NGFS scenarios suffer from the following two **limitations**:

  1. They rely on a macroeconomic modelling approach that does not take into account **double materiality** (Gourdel et al., 2022) and the endogeneity of climare risks (Battiston et al., 2021; Chenet et al., 2021).

  2. Climate policies explored by NGFS are **confined to carbon pricing**, ignoring other climate policies, such as environmental regulation and green public investment.

Motivation

- In climate stress testing exercises, the **outputs of NGFS scenarios** (like carbon prices and the level of GDP) are typically used as inputs for analysing sector-level and bank-level exposures.

- This means that, if the impact of climate policies or physical events on GDP is **underestimated** in the NGFS scenarios, the climate effects on defaults and asset prices in the stress testing exercises might be underestimated as well.

Motivation

- We use an ecological stock-flow consistent model, the **DEFINE model** (Dafermos et al., 2017, 2018, Dafermos and Nikolaidi, 2019, 2021), to demonstrate the importance of the limitations.

- We **calibrate** the NGFS scenarios in the model and show how the evolution of key macroeconomic and financial variables differs between **two versions** of the model:

  1. a version in which banks' decisions and financial position have **no feedback effects** on the macroeconomy (as is the case in the NGFS modelling framework) and

  2. a version in which these **feedback effects** are present.

- We also run scenarios in which carbon pricing is accompanied by **green public investment** and **environmental regulation**.

Outline

The **DEFINE** (Dynamic Ecosystem-FINance-Economy) model is a global ecological stock-flow consistent model.

Ecosystem

- Matter, waste and recycling
- Energy
- Emissions and climate change
- Ecological efficiency and technology

Macroeconomy and financial system

- Output determination
- Firms
- Households
- Banks
- Government sector
- Central banks

Balance sheet matrix

	Households	Firms	Banks	Government sector	Central banks	Total
Conventional capital		$+\Sigma K_{C(PRI)it}$		$+K_{C(GOV)t}$		$+K_{Ct}$
Green capital		$+\Sigma K_{G(PRI)it}$		$+K_{G(GOV)t}$		$+K_{Gt}$
Durable consumption goods	$+DC_t$					$+DC_t$
Deposits	$+D_t$		$-D_t$			0
Conventional loans		$-\Sigma L_{Cit}$	$+\Sigma L_{Cit}$			0
Green loans		$-\Sigma L_{Git}$	$+\Sigma L_{Git}$			0
Conventional bonds	$+\bar{p}_C b_{CHt}$	$-\bar{p}_C b_{Ct}$			$+\bar{p}_C b_{CCBt}$	0
Green bonds	$+\bar{p}_G b_{GHt}$	$-\bar{p}_G b_{Gt}$			$+\bar{p}_G b_{GCBt}$	0
Government securities	$+SEC_{Ht}$		$+SEC_{Bt}$	$-SEC_t$	$+SEC_{CBt}$	0
High-powered money			$+HPM_t$		$-HPM_t$	0
Advances			$-A_t$		$+A_t$	0
Total (net worth)	$+V_{Ht}$	$+V_{Ft}$	$+CAP_t$	$-SEC_t+K_{C(GOV)t}+K_{G(GOV)t}$	$+V_{CBt}$	$+K_{Ct}+K_{Gt}+DC_t$

- Key **features** of the model: (a) both quantity and price rationing of credit; (b) distinction between green and dirty investment; (c) feedback effects of debt on economic activity; (d) temperature dynamics; (e) endogenous technical change; (f) material flow analysis; (g) damages affect both demand-side and supply-side factors.

- For more information see: www.define-model.org

Investment and finance

- Firms have a desired **overall investment**. It depends positively on the profit rate and sales and negatively on the loan interest rate and bond yields.

- A part of this investment is **green**. The proportion of green investment depends on the carbon tax and the interest rate differential.

- Firms **finance desired green investment** via (1) retained profits; (2) bonds; (3) bank loans.

- There is **credit rationing**: only a proportion of the demanded loans (1-*CR*) are provided by banks; *CR* is the degree of credit rationing.

Credit rationing

- **Degree of credit rationing** (CR):

$$CR_t = f\left(\overset{+}{dsr}_{t-1}, \left(CAR_{t-1} \overset{-}{-} CAR^{\min}\right)\right)$$

  where dsr is firms' debt service ratio, CAR is banks' capital adequacy ratio and CAR^{min} is banks' minimum capital adequacy ratio.

- The impact of capital adequacy ratio on credit rationing is in line with recent empirical evidence (see e.g. Bridges et al., 2014; Martynova, 2015, Aiyar et al., 2016, Gambacorta and Shin, 2018, Gropp et al., 2018).

Interest rates

- **Spread on loans** (spr):

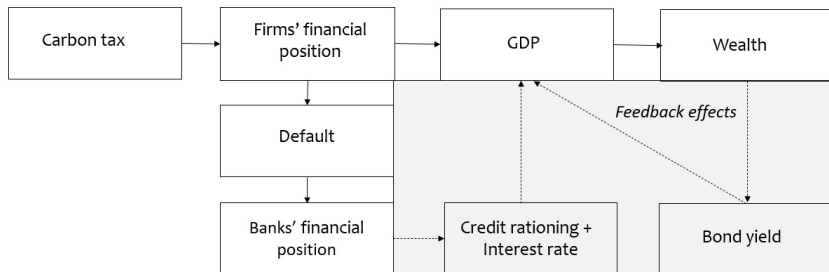$$spr_t = spr_0 - spr_1 \left(CAR_{t-1} - CAR^{\min} \right) + spr_2 dsr_{t-1}$$

- The positive effect of capital adequacy ratio on the interest rates is in line with recent empirical evidence (see e.g. King, 2010; Slovik and Cournede, 2011; Akram, 2014, Meeks, 2017; Barth and Miller, 2018).

The portfolio choice of households

$$
\begin{bmatrix}
\frac{SEC_H}{V_{HF-1}} \\
\frac{B_{CH}}{V_{HF-1}} \\
\frac{B_{GH}}{V_{HF-1}} \\
\frac{D}{V_{HF-1}}
\end{bmatrix}
=
\begin{bmatrix}
\lambda_{10} \\
\lambda_{20} \\
\lambda_{30} \\
\lambda_{40}
\end{bmatrix}
+
\begin{bmatrix}
\lambda'_{10} \\
\lambda'_{20} \\
\lambda'_{30} \\
\lambda'_{40}
\end{bmatrix}
D_{T-1} +
$$

$$
\begin{bmatrix}
\lambda_{11} & \lambda_{12} & \lambda_{13} & \lambda_{14} \\
\lambda_{21} & \lambda_{22} & \lambda_{23} & \lambda_{24} \\
\lambda_{31} & \lambda_{32} & \lambda_{33} & \lambda_{34} \\
\lambda_{41} & \lambda_{42} & \lambda_{43} & \lambda_{44}
\end{bmatrix}
\begin{bmatrix}
int_S \\
yield_{C-1} \\
yield_{G-1} \\
int_D
\end{bmatrix}
+
\begin{bmatrix}
\lambda_{15} \\
\lambda_{25} \\
\lambda_{35} \\
\lambda_{45}
\end{bmatrix}
\frac{Y_{H-1}}{V_{HF-1}}
$$

SEC_H: government securities, B_{CH}: conventional bonds, B_{GH}: green bonds, D: deposits, V_{HF}: household financial wealth, Y_H: household income, D_T: damages, int_S: interest rate on securities, $yield_C$: yield on conventional bonds, $yield_G$: yield on green bonds, int_D: interest on deposits.

The DEFINE model
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Transition scenarios
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Beyond carbon pricing
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Conclusion
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Effects of an increase in carbon tax and the role of financial feedback loops

The Hot House World scenario

- We use a combination of calibration and estimation techniques. For example, we **econometrically** estimate some functions (such as investment, consumption and loans) using panel data for the global economy.
- We run the model for the period 2018-2100. In this paper, we focus on the results for the 2018-2050 period.
- Our baseline scenario is a **Hot House World** scenario that resembles the Hot House World scenario of NGFS.
- The effects of **COVID-19** on economic growth have been taken into account.

Outline

1. The DEFINE model: key features

2. Transition scenarios

3. Moving beyond carbon pricing scenarios

4. Conclusion

- Two transition scenarios are introduced in 2023:
  1. **Orderly Carbon Tax (CT)**: The carbon tax increases in line with the *Net Zero 2050* NGFS scenario.
  2. **Disorderly Carbon Tax (CT)**: We employ the carbon tax from the *Delayed transition* scenario.
- For each scenario, we consider cases **with financial feedback effects** and **without financial feedback effects**.
- In line with the NGFS scenarios, the revenues from carbon taxes are **recycled**.
- The level of recycling is calibrated such that the decline in GDP caused by the increase in the carbon tax is in line with the GDP decline reported in the NGFS scenarios.

Orderly Carbon Tax (CT)

- Both in the scenario with feedback loops and in the scenario without feedback loops, **economic growth does down**.
- However, the reduction in economic activity is **larger** in the Orderly Carbon Tax (CT), with feedback scenario.
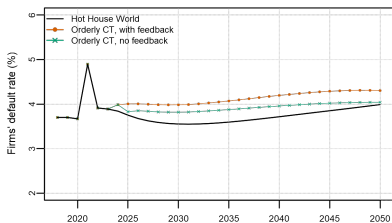
Growth rate of output
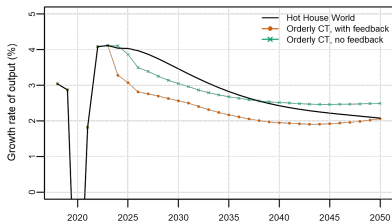
Orderly Carbon Tax (CT)

- Both in the Orderly Carbon Tax (CT), with feedback and in the Orderly Carbon Tax (CT), without feedback, **capital adequacy ratio declines**.
- However, only in the former scenario **credit rationing** increases and reduces the provision of loans. This has implications for the default rate firms.
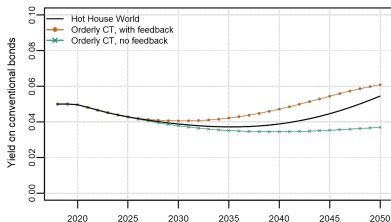
Default rate of loans

Orderly Carbon Tax (CT)

- In the Orderly Carbon Tax (CT), with feedback the **yield on conventional bonds increases**.
- This **reinforces** the reduction in economic activity.

Yield on conventional bonds

Disorderly Carbon Tax (CT)

- In the Disorderly Carbon Tax (CT) scenarios the results are **similar** as in the orderly scenarios.
- The main difference is that the **feedback effects play an even more important** role and the differences between the two versions of the model are magnified.

Growth rate of output
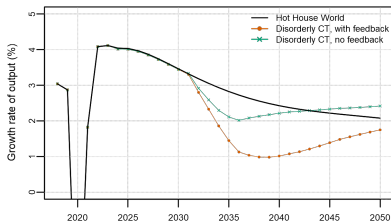
Outline

- Although **carbon pricing** is at the core of climate policymaking, it is misleading to assume that it will be the only game in town in the coming decades.
- From a climate stress testing perspective, it is important to explicitly consider **other policies** as well.
- The following policies are introduced along with carbon prices (with financial feedback effects):
    1. **Green public investment**: The green investment of the government increases from 0.2% to 1% (as a proportion of GDP).
    2. **Energy regulation – not credible**: 50% of the energy capital in the mining and utilities sector is banned in 2030; the announcement is made in 2023 but is not considered credible.
    3. **Energy regulation – credible**: Same as above, but the announcement is perceived as credible.

Green public investment

- Green public investment has **expansionary effects**.
- All macroeconomic and financial indicators are **improved** compared to the scenario in which carbon tax is implemented in isolation.
- So, the transition to a low-carbon economy **can have beneficial effects**.
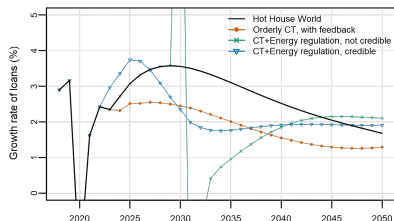
Growth rate of output
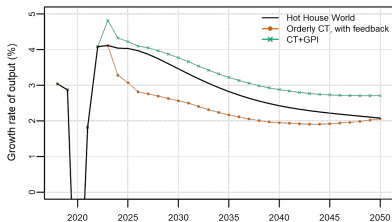
Energy regulation

- The **credible energy regulation** announcement causes a green investment boom.
- The combination of a credible energy regulation policy with a carbon tax policy generates a more **stable** macrofinancial environment.
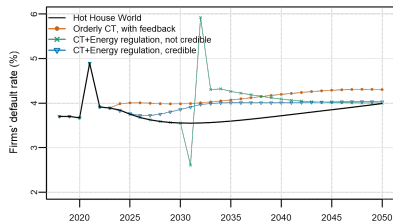
Growth rate of loans

Energy regulation

- This is **not the case** when the energy regulation announcement is not perceived as credible.
- In 2030 there is a **big shock** which initially leads firms to invest quickly in green capital by relying on loans.
- However, this shortly leads to **over-indebtedness** that causes a credit crunch.

Default rate of loans

Outline

1. The DEFINE model: key features

2. Transition scenarios

3. Moving beyond carbon pricing scenarios

4. Conclusion

- We investigated the implications of **two key assumptions** that underline the NGFS scenarios: (i) the lack of macrofinancial feedback loops and (ii) the lack of consideration of climate policies that move beyond carbon pricing.

- Using the DEFINE model we have shown that:
  1. Ignoring double materiality can lead to an **underestimation** of the macrofinancial implications of the climate transition.
  2. Scenarios in which **green public investment** plays a key role in the climate transition can result in lower transition risks.
  3. An abrupt implementation of **environmental regulation** can create significant transition risks.

Key messages

1. The NGFS scenarios need to rely on **modelling approaches** that explicitly formulate macrofinancial feedback loops.

2. The transition scenarios of NGFS need to incorporate policies that capture more accurately the **climate policy landscape**.

3. If the macrofinancial and policy underpinnings of the NGFS scenarios remain unchanged, central banks and financial supervisors should make more efforts to incorporate **feedback loops** (e.g. through the dynamic balance sheets approach). However, this will only partially address the issue.