Environmental subsidies to mitigate transition risk

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Motivations

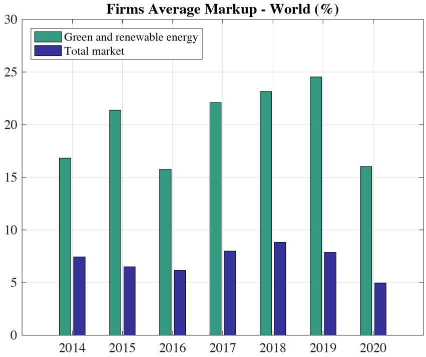
- Commitment to **zero emissions between 2050 and 2060** to maintain temperatures below 2°C (Paris Agreement)
- Benchmark models suggest **gradual rise in carbon tax** necessary to reach this target
- However carbon tax is **permanent negative shock** to firms cost structure. This will be detrimental to the economy (**transition risk**)

Motivations

- How firms reduce their emissions in the wake of high carbon price?
- **Firms purchase abatement goods** (or green goods) to lower their carbon footprint
- Abatement are goods and services that **prevent, limit, minimize or correct environmental damage** to water, air, soil
- Accounted in GDP in environmental goods and services sector (~2% of output in EU)

Motivations

- Net zero carbon transition requires **large entry of new varieties** with low carbon footprint
- However, the markup is high in the green and renewable energy industry, suggesting a **lack of competition**
- Need to **boost green products creation** to reach net zero emissions



This paper:

- **Objective:**

  Could policy actions play a role in boosting the creation of new green products and mitigating transition risk?

- **How?**

  - We develop and estimate an Environmental DSGE model for the world economy

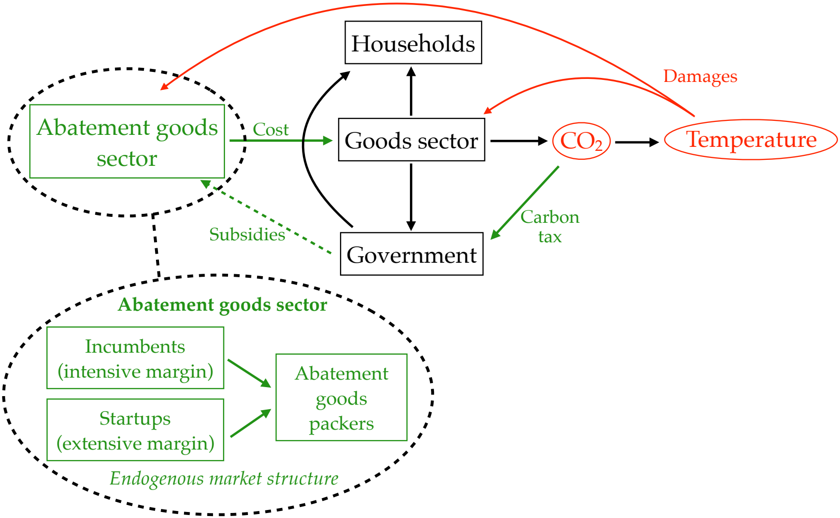
  - The model features endogenous green product variety

  - We provide projections up to horizon 2100, conditional on CO_2 reduction efforts as in last IPCC report (2021)

  - We propose various strategies to subsidize firms operating in the abatement sector

Plan

Model overview



From DICE to E-DSGE

We depart from DICE on 3 aspects:

- Rational expectations and explicit micro-foundations: immune to the Lucas critique
- Presence of cyclical shocks (TFP, spending, temperature, etc.) to capture the business cycle component
- Product creation mechanism in abatement sector *à la* Bilbiie et al. (2012)

Production sector and CO_2 emissions

- Real profits: $\Pi_t = Y_t - w_t H_t - \underbrace{p_t^A \Lambda(\mu_t) Y_t}_{\text{abatement cost}} - \underbrace{\tau_t E_t}_{\text{carbon tax}}$

- Production: $Y_t = \underbrace{(\Phi(T_t) Z_t \varepsilon_{Z,t})}_{\text{TFP}(\Gamma_t)} H_t$

- Emissions: $E_t = \sigma_t (1 - \mu_t) Y_t$ (σ_t: aggr. CO_2 intensity)

Three important variables:

- Abatement effort μ_t (carbon sequestration, solar/wind plants, electrification, etc) with cost function $\Lambda(\mu_t)$

- Damage function $\Phi(T_t)$: Productivity is reduced as CO_2 emissions increase

- p_t^A relative price of abatement goods (in DICE, $p_t^A = 1$)

Abatement goods sector: firm dynamics

- The number of green products N_t:

$$N_t = (1 - \delta_A) \left(N_{t-1} + N_{t-1}^E \right)$$

  δ_A obsolescence rate, N_{t-1}^E number of new products/ startups

- One firm = one product

- Need to determine the production of *existing firms* and the number of *startups*

Abatement goods sector: existing firms

- Their production function:

$$N_t Y_t^A = \Gamma_t H_t^A$$

H_t^A hours worked demand

- In equilibrium, demand from production sector equals supply from existing firms in abatement sector

$$\underbrace{\Lambda\ (\mu_t) Y_t}_{\text{Demand from polluting firms}} = \underbrace{N_t Y_t^A}_{\text{Supply from existing firms}}$$

Abatement goods sector: startups

- To start a new green product, an investor maximizes the gain from creating a new product (v_t) against the startup creation costs (X_t)

- FOC of creation of new green products

$$\underbrace{X_t\left(1 - s_t^E\right)}_{\text{marginal cost}} = \underbrace{v_t}_{\text{marginal gain}}$$

with: X_t a sunk cost, s_t^E a subsidy to startups

- FOC on firms value:

$$v_t = \mathbb{E}_t\left[\beta_{t,t+1}(1-\delta_A)(\Pi_{t+1}^A + v_{t+1})\right]$$

Abatement goods sector: competition effect

- Incumbent production price

$$\tilde{p}_t^A = \underbrace{\frac{\zeta_A}{\zeta_A - 1}}_{\text{markup}} \times \underbrace{\frac{w_t}{\Gamma_t}}_{\text{wage}} \times \underbrace{\left(1 - s_t^A\right)}_{\text{subsidy to intensive margin}}$$

- Aggregate price under monopolistic competition:

$$p_t^A = \underbrace{\tilde{p}_t^A}_{\text{individual prices}} \times \underbrace{\frac{1}{N_t^{1-\zeta_A}}}_{\text{competition effect}}$$

- In what follows: government may implement subsidy policy to incumbents s_t^A or to startups s_t^E

Plan

Solution Method

- System of equations each period:

$$E_t f\left(y_{t+1}, y_t, y_{t-1}, \varepsilon_t\right) = 0$$

  with y vector of endogenous variables, $\varepsilon \sim N(0, \Sigma)$ exogenous shocks

- *Extended path* (Fair and Taylor, 1983, Adjemian and Juillard, 2014):
  - Assume perfect foresight to obtain path-consistent endogenous variables
  - Solve system recursively under rational expectations $E_t\{\varepsilon_{t+s}\} = 0$ with $s > 0$
  - Accurate and fast solution

Estimation

- **Filtering:** *Inversion filter* (Fair and Taylor, 1983, Guerrieri and Iacoviello, 2017)
  - Extract the sequence of innovations recursively ε_t that matches observed variables
- Bayesian perspective, add prior information on parameters $p(\theta)$
- Simulate posterior distribution using Metropolis-Hasting algorithm

Estimation

- We estimate 15 parameters using **Bayesian techniques**
- Inference based on World annual data 1961-2019
- Fully-nonlinear method that **takes into account trends** (no balanced growth) and nonlinear climate change effects (but assumes certainty equivalence)

$$\begin{bmatrix} \text{Real output growth rate} \\ \text{Real consumption growth rate} \\ \text{CO}_2 \text{ Emissions growth rate} \\ \text{Temperature anomaly change} \\ \text{Patents growth rate} \end{bmatrix} = \begin{bmatrix} \Delta \log (Y_t) \\ \Delta \log (C_t) \\ \Delta \log (E_t) \\ \Delta T_t \\ \log \left(N_t^E / N_{t-1}^E \right) \end{bmatrix}$$

Estimation

- Our model features:
  - 5 **cyclical shocks** (from business cycle theory)
  - 4 **deterministic trends** (from DICE)
- Our quantitative method endogenously **disentangles business cycle vs permanent** components in data
- Our methodology also quantifies **both parametric and business cycle uncertainties**
- To our knowledge, **first inference** of macro-climate model with full-information method

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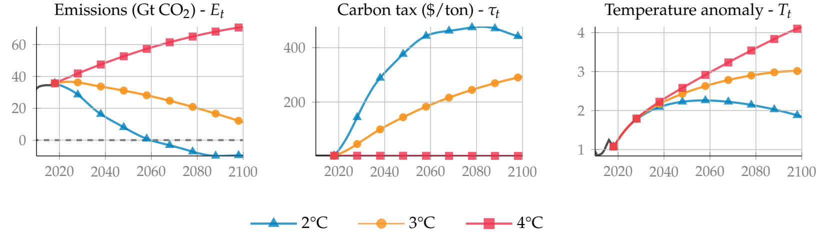
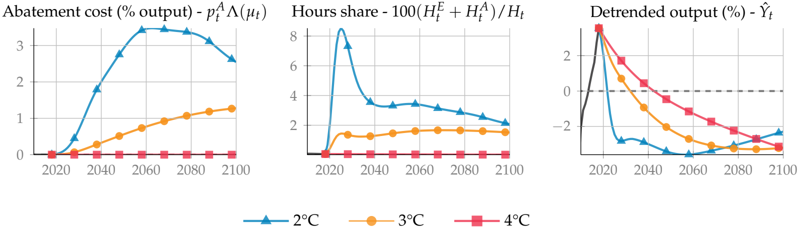
Transition scenarios



Three scenarios for CO_2 emission cuts consistent with IPCC

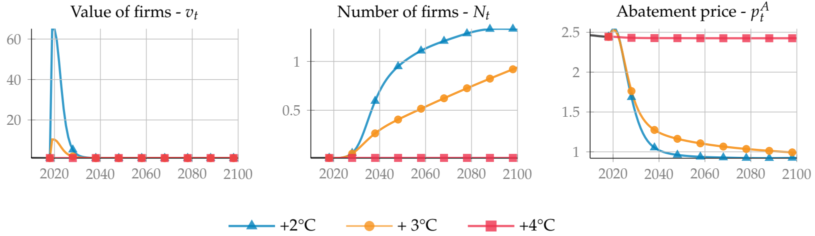
- Emissions are reduced ...
- ... through a higher carbon tax ...
- ... to limit the temperature anomaly
- Each path of emission cuts (μ_t) is matched by adjusting carbon tax (τ_t)

Transition scenarios: macro projections



- The emission cut (μ_t) requires a rise in abatement cost ...
- ... and more hours spent in the abatement sector ...
- ... which results in a GDP persistently below its trend

Dissecting the firm entry mechanism



- As the abatement sector is currently immature, abatement prices are high, which slows down the transition
- Higher expected profits boost the value of firms ...
- ... which fosters startup creation ...
- ... and stronger competition reduces abatement prices

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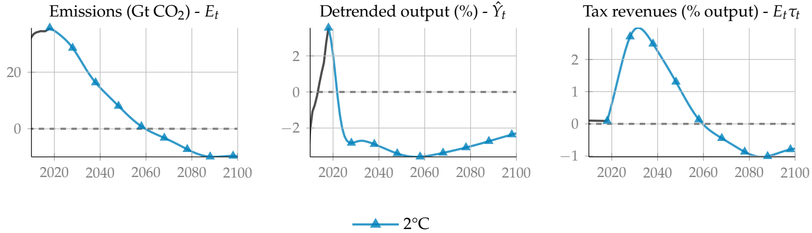
Environmental subsidies

- Consistent with the Paris Agreement, we focus on **the below 2°C scenario**



- A quick cut in CO_2 emissions ...
- ... is very costly in terms of GDP
- Carbon tax revenues can be used to subsidize the abatement sector

Environmental subsidies

- Let s_t^A and s_t^E denote subsidy rates to existing firms and to startups

- How should be split the carbon tax revenues across firms?

- Let ς and 1-ς the share of the carbon tax revenues going to startups and existing firms

$$s_t^E H_t^E w_t = \varsigma \tau_t E_t$$
$$s_t^A H_t^A w_t = (1-\varsigma)\, \tau_t E_t$$

- Optimal sharing rule across firms: $\varsigma = 60\%$ of carbon tax revenues given to startups and $1-\varsigma = 40\%$ to existing firms

What drives the trade-off?

- Subsidizing **installed firms** only:

  → reduce the cost of abatement in short term

  → but impediment to entry, high rents in medium term

- Subsidizing **startups** only:

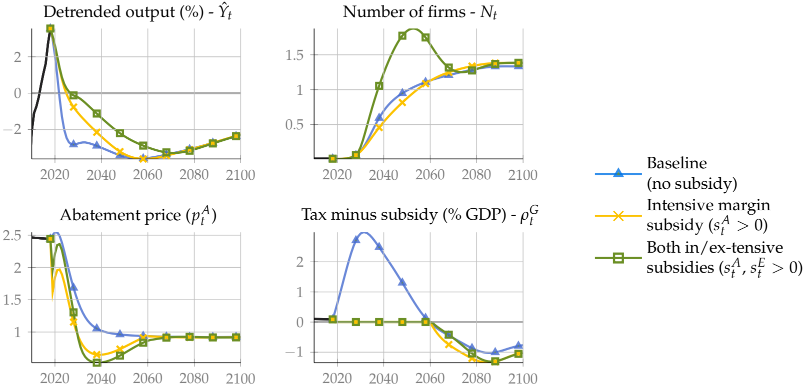
  → firm entry is gradual process: limited effect in short term

  → boost competition and reduce price in medium term

- Welfare increases in ς as long as

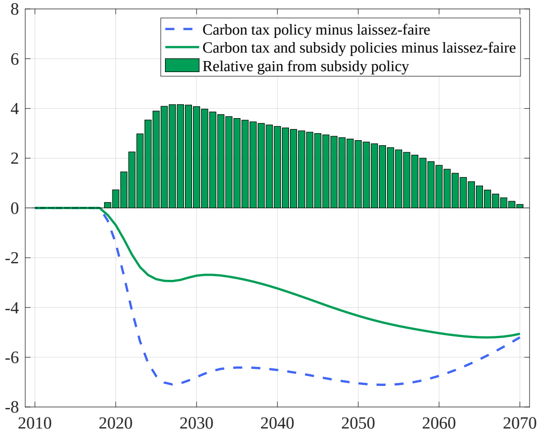
future gains from competition	>	current loss from short term higher abatement price

Understanding the mechanism



- Subsidy to startups boosts the number of firms and competition
- ... reduces abatement prices
- ... and reduces the GDP loss

GDP GAIN



- Subsidy policy saves about \$2.5 trillion GDP per year

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Concluding remarks

- **Product creation matters** to mitigate transition risk
- **Subsidizing the creation** of new green products improves welfare
- **This policy would save up to $2.5 trillion** in world GDP each year