
ENVIRONMENTAL SUBSIDIES TO MITIGATE TRANSITION RISK

Eric Jondeau Gregory Levieuge
Jean-Guillaume Sahuc Gauthier Vermandel

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MOTIVATIONS

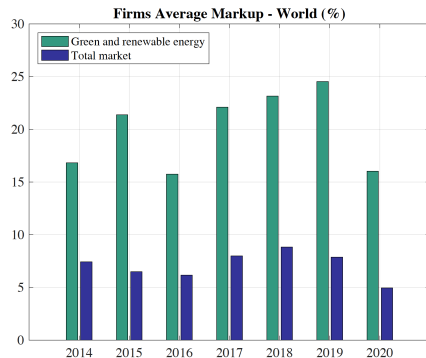
- ▶ Commitment to **zero emissions between 2050 and 2060** to maintain temperatures below 2°C (Paris Agreement)
- ▶ Benchmark models suggest **gradual rise in carbon tax** necessary to reach this target
- ▶ However carbon tax is **permanent negative shock** to firms cost structure. This will be detrimental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

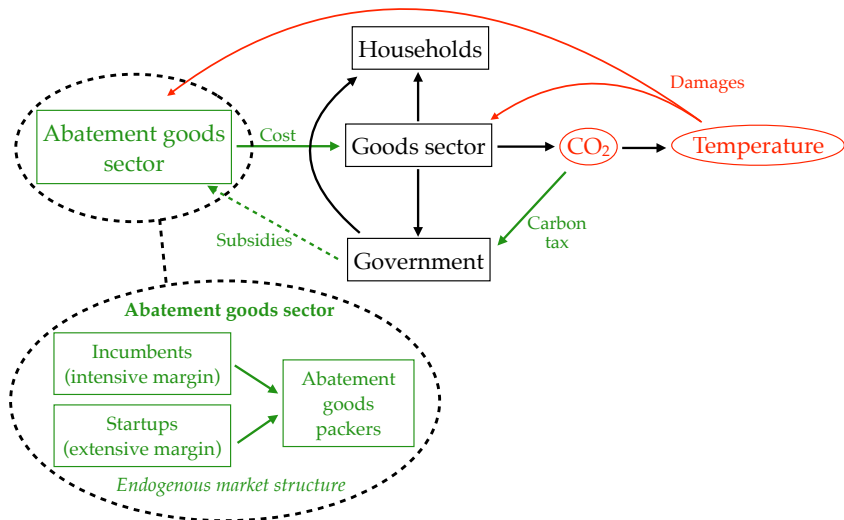
▶ How?

- 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 CO₂ reduction efforts as in last IPCC report (2021)
- We propose various strategies to subsidize firms operating in the abatement sector

PLAN

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- 2 Model**
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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 CO₂ 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. CO₂ 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 CO₂ 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 :

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

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

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

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

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

- ▶ 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

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SOLUTION METHOD

- ▶ System of equations each period:

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

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)

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

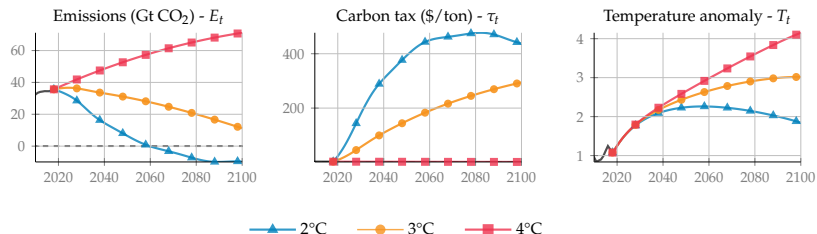
ESTIMATION

- ▶ 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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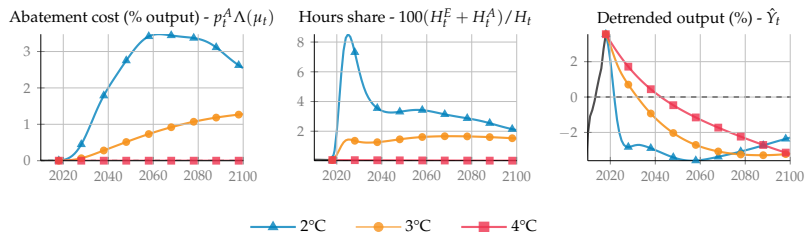
TRANSITION SCENARIOS



Three scenarios for CO₂ emission cuts consistent with IPCC

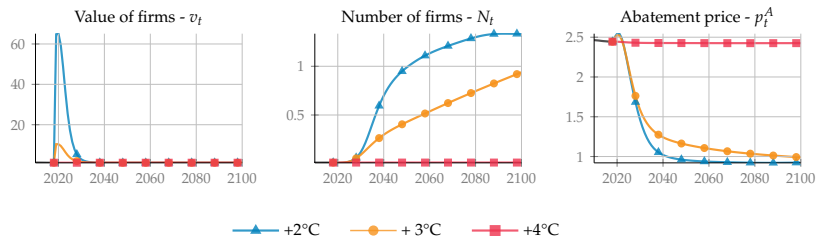
- ▶ Emissions are reduced ...
- ▶ ... through a higher carbon tax ...
- ▶ ... to limit the temperature anomaly
- ▶ Each path of emission cuts (μ_t) is matched by adjusting carbon tax (τ_t)

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



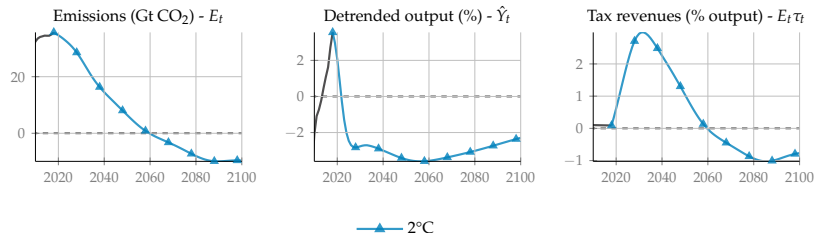
- ▶ As the abatement sector is currently immature, abatement prices are high, which slows down the transition
- ▶ Higher expected profits boost the value of firms ...
- ▶ ... which fosters startup creation ...
- ▶ ... and stronger competition reduces abatement prices

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ENVIRONMENTAL SUBSIDIES

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



- ▶ A quick cut in CO₂ 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 $1-\varsigma$ the share of the carbon tax revenues going to **startups** and **existing firms**

$$s_t^E H_t^E w_t = \varsigma \tau_t E_t$$

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

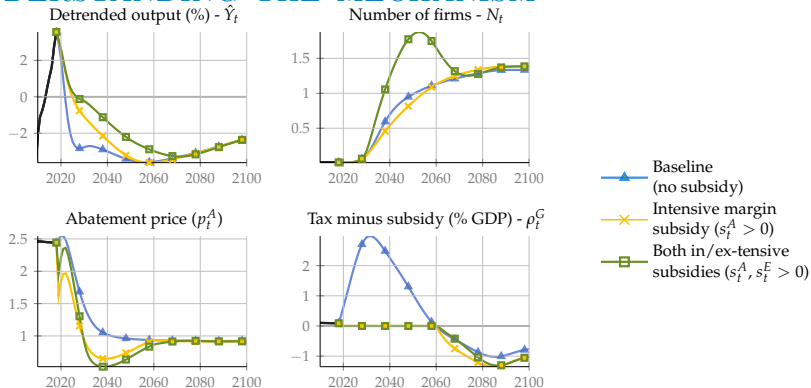
- ▶ Optimal sharing rule across firms: $\varsigma = 60\%$ of carbon tax revenues given to **startups** and $1 - \varsigma = 40\%$ to **existing firms**

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 ζ as long as

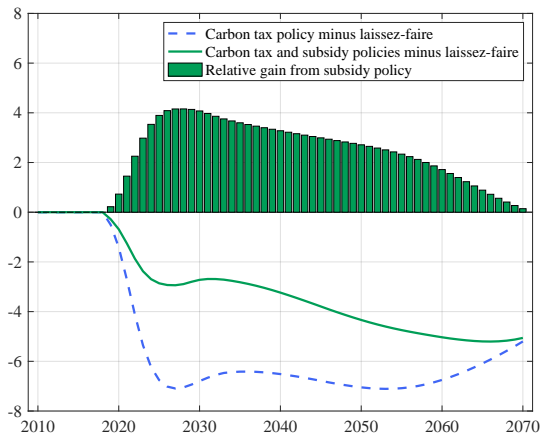
$$\begin{array}{ccc} \text{future gains} & & \text{current loss from short} \\ \text{from competition} & > & \text{term higher abatement price} \end{array}$$

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