# Green Asset Pricing

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# Disclaimer

This paper should not be reported as representing the views of the European Central Bank (ECB). The views expressed are those of the authors and do not necessarily reflect those of the ECB.

# Plan

# Motivations

Motivations:

- Evidence of the effects of $CO_2$ emissions on macro aggregates (e.g. GDP, consumption ...)
- Evidence of the impact of emissions on financial aggregates (e.g. the natural interest rate)
- Financial market reactions to $CO_2$ emissions mitigation policies are important for macro-financial stability (e.g. ECB Lagarde's recent statements)

Aims:

- Bridging the gaps between macro, finance, and climate.
- How to design an optimal environmental policy under a unified framework?

# Plan

1. Introduction
2. Objectives
3. A Green Asset Pricing Model
4. Estimation
5. Results
6. Main Takeaways
7. Bibliography

# Objectives of the paper

1. What are the asset pricing implications if investors care about $CO_2$ emissions?

2. How does an environmental policy affect the valuation of assets and macro aggregates?

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# Contributions

**Theoretical:** a green interpretation of asset pricing models

- Negative impact of emission through a non separable dis-utility

**Applied:** an empirical assessment of $CO_2$ on assets valuation

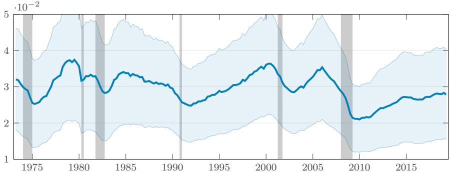
- Estimate the model on US data: using inversion filter, matching moments, and particle filter

**Policy-oriented:** design and benefits of an optimal policy

- Introduce an environmental policy to internalize the social cost of $CO_2$
- Measure the welfare & asset pricing implications under a laissez-faire and an optimal policy world

# Takeaways

1. Emission externality as a source of risk
2. Carbon tax/Premit market is procyclical




3. Benefits of the tax critically depend on emission abatement technology
4. The presence of an environmental policy is potentially helpful to monetary policy issues (such as the ZLB)

# Plan

# Some evidence on climate risk and macro-finance

- Emissions increase risk aversion and affect stock returns in the US (Levy and Yagil, 2011)
- Consumption's seasonal patterns: purchase peaks of fans, air-conditioning during heat waves / electricity consumption peaks during cold/heat waves (Mensur et al. (2017))
- Different levels of damages on consumption and investment (Fired et al. (2021))
- Real life examples: purchasing organic food (more expensive), substitution train vs flight, etc.

# Greening this framework

**Main assumption:**

$$u\left(c_t - \phi x_t\right) \neq u(c_t) - \phi log(x_t)$$

**Implications:**

- $u_x < 0$: **externality** $\rightarrowtail$ disutility increases when emissions rise (Stokey (1998), Acemoglu et al. (2012));
- $u_{cx} > 0$: **compensation effect** $\rightarrowtail$ marginal consumption rises following a rise in emissions (Michel and Rotillon, 1995).
- $-cu_{cc}/u_c = \sigma c_t/(c_t - \phi x_t)$ : **risk aversion increases in emissions** $\rightarrowtail$ higher emissions increase precautionary saving.
- We will estimate $\phi$ and measure whether the data favors $\phi > 0$.

# Household

- We consider the Jermann (1998)'s model, an extension of Lucas Jr (1978) with endogenous production function and consumption habits.

Households maximize their lifetime utility:

$$\max_{\{c_t, k_{t+1}, i_t, b_{t+1}\}} E_0 \sum_{t=0}^{\infty} \beta^t \frac{(c_t - \phi_t x_t)^{1-\sigma}}{1-\sigma}, \tag{1}$$

subject to their budget constraint:

$$c_t + i_t + p_t^B (b_{t+1} - b_t) + T_t = w_t N + r_t k_t + b_t, \tag{2}$$

# Firms

Firms maximize profits:

$$d_t = y_t - w_t N_t - r_t k_t - f(\mu_t) y_t - e_t \tau_t, \tag{3}$$

the production function

$$y_t = \varepsilon_t^A k_t^\alpha (\Gamma_t N_t)^{1-\alpha}, \tag{4}$$

and emission curve

$$e_t = (1 - \mu_t) \varphi_1 y_t^{1-\varphi_2} \varepsilon_t^X \Psi_t. \tag{5}$$

# Emissions Externality

The concentration process of carbon dioxide in the atmosphere

$$x_{t+1} = \eta x_t + e_t, \tag{6}$$

with $\eta$ the linear rate of continuation of $CO_2$-equivalent emissions.

- Rest of world emissions $e_t^{ROW}$ is neglected but not critical as $\mathrm{corr}(e_t, e_t^{ROW})$ is high
- Emissions is a wide concept that, we narrow down to greenhouse gases

# Public authority

The government sets the environmental policy

$$g_t + b_t = p_t^B(b_{t+1} - b_t) + T_t + \tau_t e_t, \tag{7}$$

# A tale of equilibriums

Is a carbon tax/permit market desirable? We examine three possible equilibriums:

1. The centralized economy;
2. The decentralized economy (or competitive economy/laissez faire);
3. The decentralized economy under an environmental policy;

# The social cost of carbon

From the social planner problem, the carbon price is given by:

$$V_t^X = \beta \frac{\lambda_{t+1}}{\lambda_t}(\phi + (1-\eta)V_{t+1}^X) \tag{8}$$

Versus what we usually see in the literature:

$$V_t^X = \beta \frac{\lambda_{t+1}}{\lambda_t}(\text{Prod. Damages} + (1-\eta)V_{t+1}^X) \tag{9}$$

Intuitively:

- The marginal cost of one additional unit $CO_2$ emissions is set to its marginal utility loss

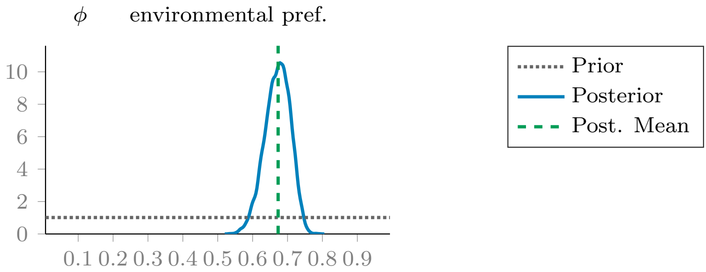
# Plan

# Estimation strategy

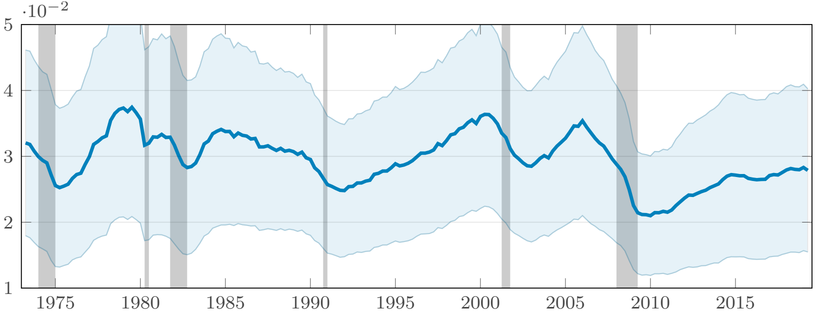
- Bayesian estimation (non-linear up to second order)
- Estimate the Laissez-faire equilibrium
- U.S. quarterly data over the sample time period 1973Q1 to 2018Q4
- 4 observables: (i) consumption growth, (ii) investment growth, (iii) output growth, and (iv) emissions growth.

# Plan

# The dis-utility parameter



# The procyclicality of the tax



# Role of the abatement technology

- Our simulation of environmental tax relies on two calibrated parameters from Nordhaus (2014) for the abatement cost function:

$$f(\mu_t) = \theta_1 \mu_t^{\theta_2}$$
$$\text{with } \theta_1 = 0.056 \text{ and } \theta_2 = 2.8$$

- These parameters characterize the efficiency of the abatement technologies.
- How sensitive are our results? Minimally for $\theta_2$ but considerably for $\theta_1$.

# Role of the abatement technology

| | Laissez-faire | Optimal policy | | |
|---|---|---|---|---|
| | Estimation (1972-2019) | $\theta_1 = 0.05607$ | $\theta_1 = 0.56797$ | $\theta_1 = 6.8844$ |
| $E(\mu_t)$ | 0.0000 | 0.5557 | 0.2236 | 0.0592 |
| $E(f(\mu_t))$ | 0.0000 | 0.0099 | 0.0044 | 0.0013 |

# Risk aversion

| | Laissez-faire | Optimal policy | | |
|---|---|---|---|---|
| | Estimation (1972-2019) | $\theta_1 = 0.05607$ | $\theta_1 = 0.56797$ | $\theta_1 = 6.8844$ |
| $E(RRA_t)$ | 33.0317 | 12.6003 | 19.6796 | 27.3069 |

# Asset pricing implications

| | Laissez-faire | Optimal policy | | |
|---|---|---|---|---|
| | Estimation (1972-2019) | $\theta_1 = 0.05607$ | $\theta_1 = 0.56797$ | $\theta_1 = 6.8844$ |
| $400E\left(r_t^F\right)$ | 3.3726 | 5.4547 | 4.7414 | 3.9938 |
| $400E\left(r_{t+1}^B - r_t^F\right)$ | 1.3411 | 0.6252 | 0.9185 | 1.1437 |

# Economic implications

| | Laissez-faire | Optimal policy | | |
|---|---|---|---|---|
| | Estimation (1972-2019) | $\theta_1 = 0.05607$ | $\theta_1 = 0.56797$ | $\theta_1 = 6.8844$ |
| $E(c_t)$ | 0.5248 | 0.5222 | 0.5335 | 0.5436 |
| $E(x_t)$ | 847.2176 | 356.9114 | 632.3473 | 777.5918 |
| $E(\mathcal{W}_t)$ | -256546.0687 | -9393.3011 | -43390.5842 | -124779.0558 |
| $E(\frac{\tau_t e_t}{y_t})$ | 0.0000 | 0.0217 | 0.0422 | 0.0566 |

# Robustness Exercises

We find significantly close results to our initial inversion filter estimates when using the following techniques:

- Matching moments
- Particle filter
- Log utility case

We find that our non-separable specification is able to reproduce stylized facts that the separable case is unable to do:

- $u\left(c_t - \phi x_t\right)$ versus $u(c_t) - \phi log(x_t)$

# Plan

# Main Takeaways

Emissions externality as a source of risk

- The carbon tax is pro-cyclical
- The optimal policy eliminates fluctuations in RRA that are "excessive"

Welfare

- The tax reduces consumption
- The effect on welfare is still largely positive
- However, it critically depends on emission abatement technology
- Improve existing technology first?

# Plan

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Thank you!