Suboptimal climate policies: non-uniform and indirect taxation of CO_2

John Hassler, Per Krusell, and Conny Olovsson

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But, as Oswald and Stern (VoxEU, 2019) point out: economists are still largely absent from this research area! So why are we largely absent?

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- No research since has questioned this basic insight.
- Thousands of (famous) economists have signed a petition urging the adoption of a carbon tax.

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So there is nothing conceptually interesting to work on!

What we set out to acheive

Aim:

- Make case that there are plenty of important and nontrivial things for (macro)economists to work on!
- Illustrate by example: show how to address important questions, yielding interesting answers. . .
- . . . while doing it far from adequately (thus indicating that much more work is sorely needed)!

An opportunity for economics?

Key message:
IAMs are super-helpful, though perhaps not for what they have been used for so far. . .

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Note:

- we are not pushing for a (classic) case of "second-best" policy;
- we are pushing for quantitative analysis, for example computing how much more certain policy packages hurt our welfare (than, say, a global carbon tax) if the goal is to limit warming by x degrees by 2200.

Contribution, I

Methods: we offer a framework—an IAM—for quantitative analysis of policy, designed so that it can be built upon further.
Key features:

- it is decentralized;
- it is rich enough to ask important questions;
- it is bad enough that you can see what more can be done (not on purpose, though); and
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The equilibrium is very easy to solve for. This is not key, however.
We use the framework to ask quantitative questions and showcase one (less quantitative) extension.

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Showcase application: endogenous, directed technical change into green vs. fossil energy.

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- Regions $2, ..., r$—the *oil consuming regions*—have no conventional oil, but imports it from region 1.
- With extraction in period t given by $\sum_{i=2}^{r} e_{1,i,t}$, the law of motion for the stock of oil (R_t) is given by

$$R_{t+1} = R_t - \sum_{i=2}^{r} e_{1,i,t}, \text{ s.t. } R_t \geq 0, \ \forall t.$$

Oil-consuming regions

- Energy services in each region are produced by local competitive firms that combine different energy sources as inputs.
- We allow for the inclusion of I additional unconventional fossil fuels ($e_{n+j}, j = 1, ..., I$) that are highly substitutable with conventional oil.

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- The oil composite is then given by

$$O_{i,t} = \widetilde{I} \left(\lambda_1^{oil} e_{1,i,t}^{\rho_h} + \sum_{j=1}^{I} \lambda_{j+1}^{oil} e_{n+j,i,t}^{\rho_h} \right)^{\frac{1}{\rho_h}},$$

where e_1 is conventional oil and ρ_h determines the EOS.

Oil-consuming regions

Energy services (E) are then produced by a representative firm by combining oil and additional energy inputs (e_κ) according to

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Finally, the resource constraint is given by

$$C_{i,t} + K_{i,t+1} = A_{i,t} L_{i,t}^{1-\alpha-\nu} K_{i,t}^{\alpha} E_{i,t}^{\nu} - p_{1,t} e_{1,i,t} - \sum_{k=2}^{n+l} p_{k,i,t} e_{k,i,t},$$

Emissions and the carbon cycle

- Usage of fossil energy sources generates CO_2 emissions. Total emissions from region i in period t are then given by

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- The atmospheric stock of excess carbon (following Golosov et al., 2014) is

$$S_t = \sum_{s=0}^{t} (1 - d_{t-s}) \sum_i M_{i,s}$$

  where $1 - d_{t-s}$ measures the share of emissions remaining in atmosphere s periods after it was emitted.

Climate and damages

- Climate: borrow two temperature (T_t—surface, T_t^L—deep oceans) energy budget model from DICE/RICE.

$$\begin{aligned}
T_{t-1} &= T_{t-1} + \sigma_1 \left(\frac{\eta}{\ln 2} \ln \left(\frac{S_{t-1}}{S_0} \right) - \kappa T_{t-1} - \sigma_2 \left(T_{t-1} - T_{t-1}^L \right) \right) \\
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- Damages: aggregate TFP is a function of S_{t-1}, and exogenous trend $z_{i,t}$;

$$A_{i,t} = e^{(z_{i,t} - \gamma_i S_{t-1})}$$

γ_i is lost share of GDP flow in region i per unit of excess carbon in atmosphere.

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Restrictions:

- no trade between oil consumers (so MPK different across)
- no borrowing/lending between oil region and rest (oil producers "hand-to-mouth")

Properties of the equilibrium

1. All firms maximize profits, all agents maximize utility, and all markets clear.
2. Our combined assumptions imply that the equilibrium is determined sequentially without forward-looking components.
3. Given a world market price of oil, all equilibrium conditions have closed form solutions.
4. In each period, finding the equilibrium is only a matter of finding the equilibrium oil price where the supply is predetermined by $(1-\beta)\,R$.
5. Can be solved in a millisecond!

The equilibrium allocation in equations

- $R_{t+1} = \beta R_t, \quad K_{i,t+1} = \frac{\alpha\beta}{1-\nu}\left(1+\Gamma_i\right)\hat{Y}_{i,t},$
  $\hat{Y}_{i,t} = \left(1-\nu\right) A_{i,t} L_{i,t}^{1-\alpha-\nu} K_{i,t}^{\alpha} E_{i,t}^{\nu},$
- $P^O_{i,t} = \widetilde{I}^{-1}\left(\left(\lambda_1^{oil}\right)^{\frac{1}{1-\rho_h}} \hat{p}_{1,i,t}^{\frac{\rho_h}{\rho_h-1}} + \sum_{j=1}^{I}\left(\lambda_{j+1}^{oil}\right)^{\frac{1}{1-\rho_h}} \hat{p}_{n+j,i,t}^{\frac{\rho_h}{\rho_h-1}}\right)^{\frac{\rho_h-1}{\rho_h}},$
- $P_{i,t} = \left(\lambda_1^{\frac{1}{1-\rho}}\left(P^O_{i,t}\right)^{\frac{\rho}{\rho-1}} + \sum_{j=2}^{n}\lambda_j^{\frac{1}{1-\rho}}\hat{p}_{j,i,t}^{\frac{\rho}{\rho-1}}\right)^{\frac{\rho-1}{\rho}},$
- $E_{i,t} = \left(\nu\frac{e^{\left(z_{i,t}-\gamma_{i,t}S_{t-1}\right)}L_{i,t}^{1-\alpha-\nu}K_{i,t}^{\alpha}}{P_{t,i}}\right)^{\frac{1}{1-\nu}},$
- $O_{i,t} = \left(\lambda_1\frac{P_{i,t}}{P^O_{i,t}}\right)^{\frac{1}{1-\rho}} E_{i,t},$
- $e_{j,i,t} = \frac{O_{i,t}}{\widetilde{I}}\left(\widetilde{I}\lambda_j^{oil}\frac{P^O_{i,t}}{\hat{p}_{j,i,t}}\right)^{\frac{1}{1-\rho_h}}, \quad j \in \{1, n+1, ..., n+I\},$
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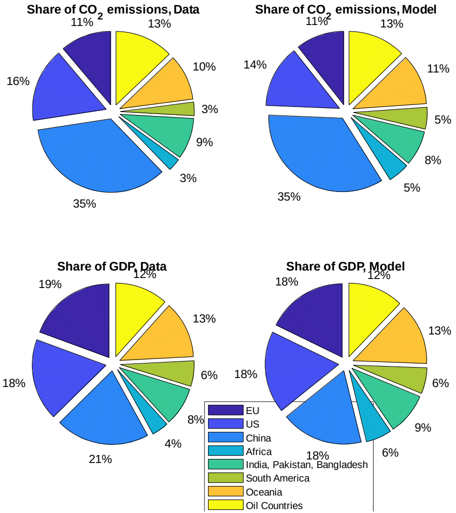
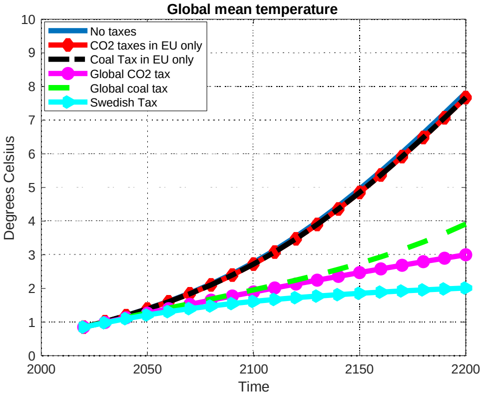
- TFPs in rich world grow at common rate, fast-growing and some convergence in rest.

Model and data



Preliminaries



No policy action (or only EU action or not taxing coal) leads to huge warming, even under average climate sensitivity ($3^o C$).
Modest (EU-level) tax helps a lot if global.

Suboptimal policy I: Non-uniform carbon taxes

- Let some regions off the hook, but increase the carbon tax in all other regions so that $T = 2.6^o C$ in 2165 (150 years from the starting year).
  1. Africa and India do not implement any policy at all.
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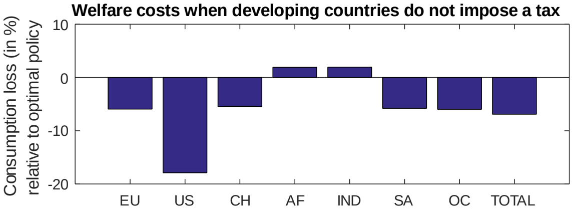
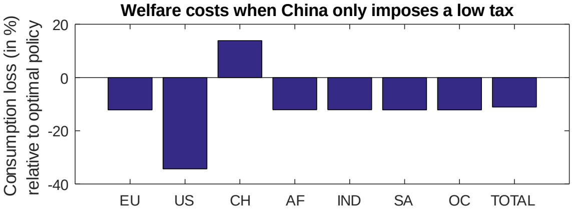
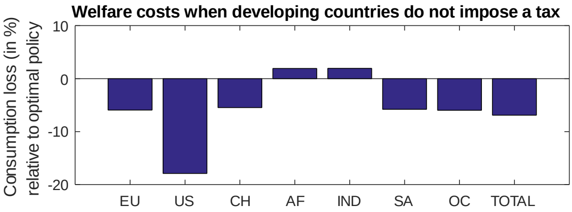
     - Requires carbon tax to increase 5.3 times in all other regions.
  2. China only participates marginally in mitigating global warming.
     - Requires carbon tax to increase 20 times in all other regions.
     - If China does not contribute at all, it becomes impossible to limit the temperature increase to $2.6^o C$



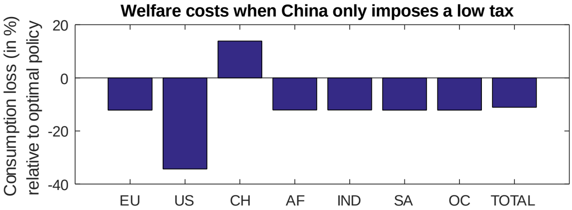
Welfare costs when developing countries do not impose a tax



Welfare costs when China only imposes a low tax



Welfare costs when developing countries do not impose a tax



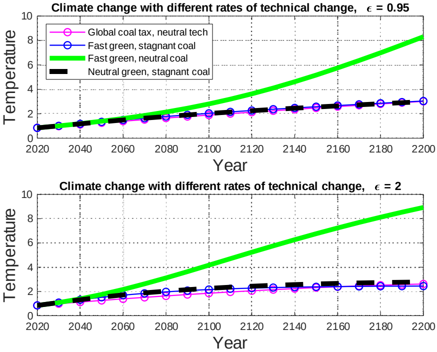
Welfare costs when China only imposes a low tax

- Africa and India only experience welfare gains of just below 2 percent in the first experiment. The other regions lose between 6 and 18 percent relative to the optimal policy.
- Large losses when China does not participate.

Suboptimal policy II: faster technical change in green energy

- Assume faster exogenous technological change in green energy and stagnant in coal.
    - The result is a 2% yearly reduction in the relative price of renewables and 2% increase in the relative price of coal.
    - Recall that energy prices are measured in terms of the final goods. Since output grows by 2%/year, a stagnant coal technology implies 2% higher prices per year.

Experiment - exogenous technical change



- Technological change achieves roughly the same as a global coal tax.
- Green technical change not enough: coal must become more expensive! Higher substitution elasticity does not help.

Endogenous technology

Straightforward application of our work in Hassler, Krusell, and Olovsson (2017) to the case of R&D into green and fossil production.

Calibration more iffy: what, really, does the R&D production function look like?

Theoretical insight: a per-unit tax can be used to tilt the R&D decisions in a desired direction, whereas an ad-valorem tax does not.

Reason: a tax on the value of fossil fuel induces technical change into making that good cheaper—if you produce fossil more effciently you save also on tax payments. This effect cancels with the more obvious effect (taxed goods are used less).

Conclusion

We construct an IAM and use it to obtain quantitative answers to important questions.

Some of the answers were very surprising to us. They seem of value to policymakers.
To do:

- ask more policy questions
- work on weaknesses of IAM—there are many

Examples of weaknesses:

- one-sector (e.g., agriculture missing)
- no trade (no "production leakages")
- no intertemporal markets