Modelling inequality in IAMs

Francis Dennig

IAMC in Tsukuba on 4th December, 2019
The representative agent: an (in)appropriate fiction

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  - whose choices accurately describe the aggregate outcomes in the economy (the descriptive fiction)
  - whose welfare is the correct objective to be maximised as a matter of economic policy (the prescriptive fiction)
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- Both fictions are grounded in theoretical results that make them appropriate in some contexts, but not in others.
- These “representative agent theorems” tell us:
  - Under what conditions aggregate behaviour is well described by the choices of a single decision maker and what these choices look like (descriptive).
  - Under what additional normative beliefs, and political realities policy that maximises the representative agent’s utility can be viewed as optimal (prescriptive).
Quick overview

- First I will outline the theoretical conditions under which these two fictions are appropriate for consumption and climate modelling.
- After that I will then show you some results in which my co-authors and I drop representative agents for normative reasons.
The descriptive fiction

- When does the behaviour of a single agent describe the aggregate demand of an economy

**Theorem (due to Gorman):** a representative agent exists, when preferences are homothetic and the income distribution is fixed and independent of prices.

Homothetic preferences imply linear Engel curves, or equivalently, an income elasticity of energy demand of one for all population groups.

Given that the income distribution does change exogenously, the time frame has to be chosen so that this change is negligible.
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Is Pareto efficiency the appropriate objective?

The standard approach (due to Musgrave) is to reason that:
- a - Pareto efficient outcomes maximise the total amount of resources
- b - if the distribution of such resources seems undesirable, there are more efficient tools for redistribution than through differential Pigouvian taxes.
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Discounting and growth

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  - If global average income was the same in 2100 as today, that ratio would be 3.5:1.
  - The remaining factor 10 is due to the implicit normative stance that the future will be better able to bear damage on account of being richer.
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But if there is also inequality in this richer future, it should matter which part of the income distribution bears the damage.

For example, if damage in 2100 falls predominantly on an income group that has the same income as today’s average, 3.5 dollars of damage should be worth a dollar of current mitigation investment.
We took the RICE model, and add representation of the sub-regional income distribution based on World Bank national income distribution data.

We parameterised the damage distribution to have constant elasticity with respect to income:

\[ d_i = \frac{c_i^\xi}{\sum_i c_i^\xi} \]

And considered optimal policy for the range \( \xi = [-1, 1] \).
Optimal global carbon prices for different distributions of damage

A. Carbon price
B. Annual emissions
C. Temperature increase
What is the right value for the elasticity of damage?

- We don’t know
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- Mendelsohn, Emanuel, Chonabayashi, and Bakkensen provide the following log-log regression table in their analysis of tropical cyclone damage

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<tr>
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<th>constant</th>
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<tbody>
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- But put the estimates into the appendix
In the global climate policy context there is not tax authority that can be relied upon to ease adverse distributional impacts of carbon prices. In such an environment, it is questionable to proceed by pretending that a representative agent with global average income bears the cost of a carbon price and reaps the benefit from mitigated climate change. Optimal policy should directly model the distributional consequences, and carbon prices ought to be different in regions with different income levels and abatement capacities. Even if utilities are homothetic and identical, Pareto efficiency is not normatively appealing on its own. The theoretical argument stems from Chilchilnisky and Heal (1994) and Sandmo (2007). We compute the extent of this effect in the RICE model, and compare the outcome to differences in ambition following the Paris Agreement.
Global climate policy with regional carbon prices

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- Even if utilities are homothetic and identical, Pareto efficiency is not normatively appealing on its own.
- The theoretical argument stems from Chilchilnisky and Heal (1994) and Sandmo (2007).
- We compute the extent of this effect in the RICE model, and compare the outcome to differences in ambition following the Paris Agreement.
The RICE model

- Consists of 12 macro regions
- Outdated and rather conservative damage functions
- Very basic mitigation cost structure based on assumption of backstop price and emission-to-output ratio projections
- Usually uses Nordhaus-Yang-Negishi weights (see Anthoff, Dennig, Emmerling WP for one reason why these are a terrible idea)
- Without these weights, optimal carbon prices vary considerably across regions, as we show below
A utilitarian approach to burden sharing

- We run the RICE model under two settings
  - The standard optimisation, which yields a globally uniform carbon price (mitigation cost minimization)
  - A utilitarian optimisation, which yields different carbon prices in different regions
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- We run the RICE model under two settings
  - The standard optimisation, which yields a globally uniform carbon price (mitigation cost minimization)
  - A utilitarian optimisation, which yields different carbon prices in different regions
- These yield different optimal emissions pathways, which we compare to the current INDCs
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Gains of differential vs uniform carbon prices

**a. All People Through 2200**

- Few Sacrifice
- Many Benefit

**b. Regional Gains in 2120**

- Consumption Increase (as %)
- Log Per Capita Consumption

- Circles Proportional to 2120 Population
- Africa
- India
- OthAsia
- China
- MidEast
- Europe
- Russia
- EU
- Japan
- USA

- Cost-Minimization

- Poorer Populations
- Richer Populations
Disaggregation and Nordhaus-Yang-Negish weights

- When you submit an IAM with any disaggregation in consumption, at least one reviewer always asks about Negishi weights.

\[
\omega_{rt} = \frac{1}{U'(c_{rt})} \sum_{R} \frac{1}{U'(c_{jt})}
\]

\[
W_N = \sum_{t=1}^{T} \sum_{r=1}^{L} \omega_{rt} U(c_{rt}) \beta_t
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Disaggregation and Nordhaus-Yang-Negish weights

- When you submit an IAM with any disaggregation in consumption, at least one reviewer always asks about Negishii weights.
- What they mean are time-varying (or Nordhaus-Yang) Negishii weights:

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\[ W^N = \sum_{t=1}^{T} \sum_{r=1}^{R} L_{rt} \omega_{rt} U(c_{rt}) \beta^t \]
Greater discounting the future of regions with low growth

- The Nordhaus-Yang-Negishi weights modify the pure rate of time preference (a preference parameter) by inserting technology parameters into it

\[ \rho_{NYNeg}^{rt} = \rho - g_{rt} + \bar{g}_t \]
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It does not seem satisfactory to modify time-preferences just in order to make uniform carbon prices optimal in the face of observed frictions in capital flows.
Why they are used in Nordhaus Yang 1996

- The RICE model calibrates regional differences in productivity
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- The RICE model calibrates regional differences in productivity.
- In the first best this would yield counter-factual cross-regional capital flows.

Implementing frictions against these flows without further changes would yield an optimum with regionally different carbon prices. To avoid this, Nordhaus and Yang adjust the Negishi weights across regions for every period.
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To avoid this Nordhaus and Yang “... *adjust* the Negishii weights across regions for every period.” My emphasis.
Thank you