A Generalized Equilibrium Approach to Balance the Residual Abatements Resulting from COP-21 Agreement

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Overview

At COP-21 more than 160 countries have proposed the so-called INDCs[1] that define the GHG abatements they are commited to realize until Year 2030. It is well recognized that these commitments are not sufficient for reaching the goal of maintaining global warming under a 2 degree threshold. So there will be negotiations on further abatements and on sharing the burden among different groups of countries. In this paper we formulate a game where the equilibrium corresponds to a fair distribution among the groups of countries of a the global extra emission budget up to 2050 that is compatible with the 2 degree target in 2100. One assumes that there will be a market based mechanism equivalent to an international emissions trading scheme, with complete banking and borrowing. Each group of countries corresponds to a player. Each player receives a share of the global extra emission budget. The player's strategy is the schedule of permits supply on the market over the planning horizon (2020-2050). The payoff is defined from the welfare losses taking into account the abatement cost and the net cost/revenue from permits trading. An equilibrium solution is computed for each possible allocation of the global extra budget. One then searches the allocation that would balance the welfare losses. The result is an assessment of the remaining burden and its sharing among different groups of countries, which is required to finish the job as agreed at COP-21.

Methods

Definition of the global extra emissions budget. We use recent publications from climate modelers where the 2 degree target is placed in relation with a global cumulative amount of GHG emissions over the remaining of the century. Meinshausen et al. (2009) has computed the cumulative emissions budget of CO_2 for the 2000-2050 period that is required to limit the temperature increase to 2°C. Their results shows that the cumulative Kyoto-gas emissions budget is 1,500 Gt CO_2 with a probability to exceed 2°C equal to 25% and 2,000 Gt CO_2 with a probability of 50%. Given that around 510 Gt CO_2 were emitted between 2000–2010, and that the global cumulative emissions from 2011 to 2030 resulting from the INDCs (see UNFCCC (2015)) is estimated to 750 Gt CO_2 the residual budget up to 2050 is equal to 250 Gt CO_2 (740 Gt CO_2) depending on the associated probability (respectively 25 or 50 %).

Modelling welfare losses. The CGE model GEMINI-E3 (Bernard et al. (2008)) is used to compute welfare losses due to abatement cost and gains due to the trading of emissions permits We performed a statistical analysis of a sample of 200 GEMINI-E3 numerical simulations to estimate payoff functions that are used in a game theory model.

Equilibrium in permit supply strategies. We model emissions trading, banking and borrowing using an optimal control formalism as in Rubin (1996). However we introduce a noncooperative equilibrium for an open-loop differential game, by distinguishing different groups of countries as players aiming at minimizing their respective welfare losses, knowing the strategy choices of the other players. The groups of countries are defined as the "natural" coalitions that appear in climate negotiations. Main industrialized regions have been split: USA, EU28 and Russia are independently represented. We represent the main emerging countries that are China, India. We define a region that will be impacted by climate change agreements due their losses in oil revenues, it is represented by the Organization of the Petroleum Exporting Countries (OPEC). Then the rest of the World are aggretated in five regions. The *Least Developed Countries* (LDC) represents countries with the lowest socioeconomic development. The other industrialized countries are aggregated in one region (HIG). The remaining countries that are not part of the previous countries/groups are allocated within three groups representing respectively other Asian countries (called ASI which includes South Korea, Indonesia, Pakistan, Thailand), Latin America (called LAT in which we find Mexico, Brazil, Argentina, etc.) and Rest Of the World (ROW) which includes for example Turkey, South Africa and Jordan.
Using an approach initially proposed by Helm (2003) we can relate welfare losses or gains to the permit supply strategies. The open-loop Nash equilibria are computed using PATH algorithm.

Fair allocation of global extra emissions budget. We use a Rawlsian criterion to define a fair allocation that will lead to an equilibrium solution that optimizes the worse welfare variation among the different players.

[1] Intended Nationally Determined Contributions.

Taking into account uncertainties on economic and climate dynamics. We extend the model to a game played on an event tree, with robust equilibrium solution.

Results

Our numerical experiments based on a worldwide CGE demonstrates the following points:

- The implementation of an international emission trading of CO2 minimizes the global welfare loss even within a non-cooperative game framework because it equalizes marginal abatement cost across countries/regions;
- The allocation of shares of the safety budget represents the key variable of the negotiation. We show that an appropriate allocation can compensate losses coming from terms of trade following the worldwide decrease of energy consumption. But it could also be used for example to implement financial transfer to developing countries to promote adaptation against climate change;
- We find an equilibrium equalizing welfare losses that leads to reasonable discounted welfare losses and carbon prices.
- Using the concept of robust dynamic game model, we obtain a balanced robust equilibrium solution for which the discounted welfare loss is slightly higher but still acceptable.

Conclusions

The paper generalizes the game model proposed in Haurie et al. (2014) and Babonneau et al. (2013) and, most importantly, applies it to the assessment of the extra burden and its possible fair sharing that is implied in the COP-21 agreement. It shows that an international agreement with reasonable discounted welfare losses for all groups of countries can be designed.

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