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International trade and the negotiability of global climate change agreements☆

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ABSTRACT

This paper examines the incentives for individual countries to engage in global negotiations to reduce carbon emissions in order to prevent global warming. To reduce carbon emissions a country reduces consumption of its own good. The direct effect of reducing its own consumption is that consumption declines and with it utility. However, reducing carbon emissions also lowers global temperatures and that increases utility. The trade-off between these two effects determines the incentive for countries to reduce carbon emissions. We find that larger countries are more likely to participate because a given percentage reduction in output will result in a larger reduction in global temperatures. Longer time horizons also lead to greater willingness to participate. The presence of international trade makes carbon reduction agreements more likely because reducing the output of your own (export) good has a positive terms of trade effect which reduces the cost of output reduction.

1. Introduction

Global warming negotiations aim at achieving carbon emission reductions in the presence of external effects across countries. The first round of global negotiations in this vein concluded in Kyoto 1997, and continued in Copenhagen in 2009. At that point there was to be an agreement that would be in force for the period after 2012. These negotiations proved to be a failure and there was no agreement reached. Our purpose here is to shed light on this failure by examining the incentives of individual countries to participate in global negotiations to reduce carbon emissions.

Hence, we focus on individual country incentives to participate in negotiations, rather than the outcome of such negotiations. Effectively, what we do here is to investigate whether the core of the cooperative game represented by the country strategy space over possible actions on climate change is empty or not.

Climate change is a classic global externality problem that has been analyzed either explicitly or implicitly by Shapley and Shubik (1969), Barrett (1994), Uzawa (1999) and others. They examine cooperation in a game theoretic context and primarily use the core as the equilibrium concept. In the no externality case, Scarf (1967) established the non-emptiness of the core. Debreu and Scarf (1963) later showed how in a replica economy the core of the economy collapses to the competitive equilibrium, establishing a form of equivalence between the core and competitive equilibria. Shapley and Shubik (1969) showed by notes and examples that the core of an economy with external diseconomies may be empty. In cases where own agent actions to internalize externalities (i.e. reduce carbon emissions) have little own effect (such as with small countries), but at substantial cost, there is little incentive to act or join cooperative arrangements. Shapley and Shubik (1969) implicitly discuss a case with non transferable utility, but where transferable utility is allowed (as in Uzawa (1999)) the non emptiness of the core will be reversed due to the joint gains from internalization.

This strain of research shows that small players (small countries in our case) have little incentive to participate in cooperative arrangements which either fully or partially internalize externalities unless there are side payments. This is because small countries bear the costs of their carbon mitigation actions, but being small the benefits from resulting improvements in global climate are also quite small. Large countries will have more incentive to participate as their actions, which while costly to them, can have a significant impact on themselves via temperature change. This earlier literature concludes that the core of a game with global warming but without transferable utility may be empty. It thus suggests that, where side payments do not occur, a fully participatory

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collective global agreement on carbon emission reduction may not be feasible since there is an incentive to free-ride without punishment. Sub-global agreements with penalties by participants on non-participants to force participation may be feasible, but we do not analyze these here.

In addition, we discuss how the presence of international trade influences country willingness to participate in global climate change negotiations and why. These negotiations are aimed at reducing global temperatures by having countries mutually agree to reduce carbon emissions and in this way jointly internalize the associated global externalities from own country emissions. In practice, what form actual negotiations take will depend on agreements struck between participants, including penalties on non-participants. Here, we limit our discussion to the participation decision and do not discuss the form that cooperative arrangements will take. We emphasize the potential contribution of international trade in facilitating individual country participation in negotiations.

We will present numerical simulation results which not only bear on these issues but also allow us to evaluate whether participation is made more likely by allowing for the presence of international trade. We follow an analytical structure of a global warming game originally due to Uzawa (1999), but unlike Uzawa, transferable utility (or side payments) is not allowed. We first discuss the case with a single consumption good and allow country endowments to be put aside to reduce global temperature change (i.e. reduce carbon emissions). For this structure, in the symmetric case there exists a critical country size such that countries larger than this are willing to participate and negotiate reductions in carbon emissions, while countries smaller than the critical size are not willing to do so. We then investigate the model implications for the asymmetric case using 2006 data on a series of large economies (US, EU, Japan, China, India, Russia, Brazil, and Rest of the World) using a global structure and explore the role of preferences and other parameters on the critical country size for decisions on participation.

We use data on consumption and trade for the economies we analyze along with growth profiles for these countries, and various damage and temperature change assumptions for business as usual scenarios and undertake numerical investigation with our analytical structure. The base data is for a single 50 year period 2006–2056 with assumed yearly growth rates over the period. We use calibration to a temperature change function for prospective changes in temperature under a business as usual scenario out to both 2036 and 2056, and use various estimates of associated damage over the ranges as reported by Stern (2006) and Mendelsohn (2006).

We then generalize the analysis to the case of N goods and N countries so as to allow for the presence of international trade. We use this combined Armington trade and global warming model to investigate the impact of international trade on the decision of individual countries to participate in global negotiations to reduce emissions. In this structure, the presence of trade produces positive terms of trade effects from lowered domestic sales of the own country goods enhancing direct country gains from lowered temperatures from own country actions on global climate change. It also reduces the costs of actions since reductions in consumption are spread over many goods and so the forgoing marginal utility of consumption from consumption restraint is less adversely affected compared to the one homogeneous good case.

Our numerical results also show that countries that may not be willing to participate in the one good case may be willing to participate in the N good case with international trade. These results therefore, suggest that international trade can be a positive factor in motivating participation in international negotiation on climate change. Our results also show that the incentive to join such negotiations varies greatly with the prospective size of damages. The likelihood of positive participation increases with the severity of damage from the externality. We later argue that as we introduce international trade between countries into the model it likely makes agreement easier to reach. We first set out the theoretical model. We begin with the one-good case, and then move to the N good, N country case. Empirically based analyses follow.

2. A theoretical model of climate change negotiation participation

To begin we first assume that there are N countries in the world and each owns and consumes the same good. We assume that consumption of the good by the country directly generates emissions of carbon which in turn raise global temperatures. Hence, countries face a trade-off between consumption and global temperature change. This trade-off is different for large and small countries. Small country consumption has little or no effect on global temperature change whereas large country consumption does have a significant effect on global temperatures.

Since carbon emissions accumulate in the atmosphere leading to higher temperatures over time it is essential that we look at long run models. Here, we analyze a 50 year model. In this 50 year period, we focus on changes in consumption (use of one good) and utility, and measure change in these variables relative to the outcome of zero growth over the period. The utility function is thus defined over 50 year changes on consumption and temperature change.

We use as our benchmark a business as usual (BAU) scenario which reflects current observed growth rates remaining unchanged over 50 years with no global or single country emission limitation initiatives in place. The actual change in consumption for each country if over this time period relative to a stationary state is ΔR_i, while the total potential output of each country is given by $\Delta\overline{R}_i$. Countries can decide to consume less than their potential, but since global temperature change over the period is linked to global consumption, consuming at less than potential reduces global temperature change. Consumption in each country is given by $\Delta R_i < \Delta\overline{R}_i$, where ΔR_i defines actual consumption change over the model period, and $\Delta\overline{R}_i$ is potential consumption change. $\Delta\overline{R} = \sum\Delta\overline{R}_i$ is world potential consumption change.

The utility of each country from both consumption and temperature change over the period is reflected in a utility change function with arguments given by its own change in consumption as well as the temperature change of the world, ΔT. Damage from climate change thus appears in utility form, not as production damage as in many other papers.

We initially assume that the utility change function for each country has a Cobb–Douglas form given by Eq. (1). Later we use CES and alternative forms.

$$\Delta U_i = \Delta U_i(\Delta R_i, \Delta T) = \Delta R_i^{\ \alpha} \cdot \left(\frac{C - \Delta T}{C}\right)^{\beta} \tag{1}$$

In this specification C can be thought of the global temperature change at which all economic activity ceases (say 10 °C). In this case, as ΔT approaches C utility goes to zero. In this form, as ΔT goes to zero there is no welfare impact of temperature change. Utility change over the model period (2006–2056) increases as temperature change decreases. The share parameter β reflects the severity of damage (in utility terms) from temperature change. Later we calibrate β using various damage estimates from business as usual global temperature change scenarios reported by Stern (2006) and Mendelsohn (2006).

Global temperature change, in turn, is determined by the change in carbon emissions over the period across all countries in the model. We adopt a simple temperature change function and assume that emissions over the period by each country equal the change in consumption times country emission intensity (emissions/GDP) so as to allow for differing emission intensities by country. Defining the emission intensity of country i as e_i, we use a simple power function in Eq. (2) for global temperature change as a function of total changes in emissions by all countries over the model period.

$$\Delta T = g\left(\sum e_i \Delta R_i\right) = a\left(\sum e_i \Delta R_i\right)^b + c \tag{2}$$

In this structure, a carbon reduction commitment by country i implies reduced consumption, and this has both positive and negative effects on the utility of country i. On one hand, a reduction in consumption lowers utility for country i ($\Delta U_i < 0$) by reducing consumption ($\Delta R < 0$), but on