How the consideration of the ancillary benefits affects the strategic trade and the environmental policy

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Πανεπιστημίου Μακεδονίας

Επιβλέπων: Σαρτζετάκης Ευτύχιος, Αναπληρωτής Καθηγητής

Δ.Π.Μ.Σ. στην Οικονομική Επιστήμη

Πανεμιστήμιο Μακεδονίας

Θεσσαλονίκη, Ελλάδα

2009

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Abstract

The purpose of this paper is to analyze countries' optimal policies regarding intervention in international emissions trading and implementation of environmental taxes when ancillary benefits of abatement are considered. We construct a model in which we combine both tradable emission permits and pollution taxes. We use a two-country model and in each country there is one firm. These countries are the only suppliers on the international market of a commodity produced by their firms which compete *a-la* Cournot. What it is examined in this paper is the interaction between governments (strategic trade) and the effects on firms' outputs and emissions.

The results prove that governments' intervention policies are affected by the consideration of ancillary benefits. The imposition of the taxes also leads countries to act strategically in the international market. In order to support these results we present in a section a numerical point of view. More specifically, we set values to the parameters and thus we take numerical results of the variables we use in the model. The numerical outcome verifies the reaction functions. In addition, we create a figure so that to have a visual point of view. The downward reaction functions of the taxes are presented on the graph and their segment shows that there is a solution to the problem.

Σύνοψη

Ο σκοπός της εργασίας αυτής είναι να αναλύσει τις άριστες πολιτικές των χωρών όσον αφορά την παρέμβαση στο διεθνές εμπόριο εκπομπών ρύπων και την επιβολή περιβαλλοντικών φόρων, όταν λαμβάνονται υπόψη τα δευτερεύοντα οφέλη της μείωσης των ρύπων. Κατασκευάζουμε ένα μοντέλο στο οποίο συνδυάζουμε τις μεταβιβάσιμες άδειες εκπομπών ρύπων με τους περιβαλλοντικούς φόρους. Χρησιμοποιούμε ένα μοντέλο με 2 χώρες, όπου σε κάθε χώρα υπάρχει μία επιχείρηση. Αυτές οι χώρες είναι οι μοναδικοί προμηθευτές στην διεθνή αγορά ενός προϊόντος που παράγεται από τις εταιρίες τους οι οποίες βρίσκονται σε ανταγωνισμό τύπου Cournot. Αυτό που εξετάζεται στην παρούσα εργασία είναι η αλληλεπίδραση μεταξύ των κυβερνήσεων (στρατηγικό εμπόριο) και τα αποτελέσματα της στην παραγωγή του προϊόντος και στις εκπομπές ρύπων των εταιρειών.

Τα αποτελέσματα αποδεικνύουν ότι οι παρεμβατικές πολιτικές των κυβερνήσεων επηρεάζονται από την αναγνώριση των δευτερευόντων οφελών. Επίσης, η επιβολή των φόρων οδηγεί τις χώρες να δρουν στρατηγικά στην διεθνή αγορά. Για να υποστηρίξουμε τα αποτελέσματα μας παρουσιάζουμε μια αριθμητική εικόνα των πραγμάτων. Ειδικότερα, θέτουμε τιμές στις παραμέτρους ούτως ώστε να λάβουμε αριθμητικά αποτελέσματα για τις μεταβλητές που χρησιμοποιούμε στο μοντέλο. Το αριθμητικό αποτέλεσμα επαληθεύει τις συναρτήσεις αντίδρασης (κάλλιστης απόκρισης). Επιπλέον, κατασκευάζουμε ένα διάγραμμα ώστε να έχουμε και μια οπτική εικόνα. Οι καμπύλες αντίδρασης των φόρων που παρουσιάζονται στο διάγραμμα είναι αρνητικής κλίσης και η τομή τους αποδεικνύει ότι υπάρχει λύση στο πρόβλημα μας.

1. Introduction

Transboundary pollution is related with many important environmental problems urgently calling for solution. Problems like ozone depletion, climate change and marine pollution have been the main subjects of negotiations among countries over the last two decades. Because of the high priority that environmental problems have received at the policy level it is not surprising that there is at the theoretical front a growing effort to analyze international environmental agreements (IEAs).

In this study we present an analysis based on imperfect competition to find out if the consideration of ancillary benefits (or co-benefits) affects these agreements. More specifically we try to calculate the level of the tax that each government will impose by maximizing its social welfare while taking into account the ancillary benefits and the behavior of the other governments. We further calculate the optimal level of output that each firm produces. Initially, we present a general view of the environmental problems and their influence on the economic activity.

Environmental problems are often international by nature. Threats to our environment caused by climate change, loss of biological diversity or pollution of the marine environment are examples of problems which can only be solved through cooperation between the countries. In order to overcome these problems international environmental agreements are signed between countries. The most important of these agreements is the Kyoto Protocol signed in February 2005 for the commitment period of 2008-2012. However, many countries are reluctant to sign such agreements because these agreements are against to their interest.

This behavior may change when ancillary benefits (or co-benefits) are taken into account. They are local benefits generated by climate policy, but are not associated directly with the slowing of climate change. The consideration of ancillary benefits leads to the implementation of environmental taxes by the governments. The permits distributed according to agreements like the Kyoto Protocol are not sufficient to achieve the environmental target and thus governments tax the emissions.

Except for the reduction of the emissions, the implementation of the environmental taxes may also lead governments to act strategically. "If imperfect competition is an important characteristic of some international markets, then firms in these markets may earn pure profits. Protection can shift some of this profit from foreign to domestic firms, and in addition, tariffs can transfer foreign rents to the domestic treasury in the form of tariff revenue", as Brander and Spencer (1984) note.

In our study we try to testify the impact of the ancillary benefits and the environmental taxes on the strategic behavior of the governments. Thus, in our model we combine two instruments to implement an emission constraint: pollution taxes and tradable emission permits. We also consider ancillary benefits and the cost of abatement. In order to support our results, we set values to the parameters. We find out that, indeed, ancillary benefits and environmental taxes affect the strategic behavior of the governments. More specifically, ancillary benefits lead to the reduction of the taxes. Moreover, there is a negative relation between the taxes imposed by the two countries.

In section 2 we present the various international environmental problems raised mainly by the emissions of air pollutants. In section 3 we analyze the international environmental agreements signed in order to tackle these problems. Section 4 extends the analysis to the ancillary benefits and section 5 to the strategic trade. Section 6 sets out the model, while section 7 shows the behavior of the governments and the firms with the use of reaction functions. In section 8 we use simulations to verify the results of section 7. Finally, section 9 contains concluding remarks.

Our study is similar to Pratlong (2005). In both studies two instruments are used to implement an emission constraint: pollution taxes and tradable emission permits (TEP). The difference is that while Pratlong (2005) is concerned with the choice of these two instruments, in this study they are implemented simultaneously.

This study is also similar to Brander and Spencer (1985). B&S (1985) are concerned with strategic trade and the behavior of the governments (subsidies on firms' exports). In our study we also take in account the environmental issues that affect this behavior. In this frame we calculate the best response of the firms by calculating their optimal outputs and of the governments by calculating the tariffs they impose on the firms.

2. International Environmental Problems

International environmental problems include the decline in fresh-water and food resources, the proliferation of toxics, global warming, and the decimation of biological diversity. Further, in a world with rising population pressures and a global economy, precious natural ecosystems face profound threats from those who seek abundant resources, cheap labor, and weak or poorly enforced environmental standards. Though strict domestic regulations can help protect the environment in industrialized nations, they may also drive some of the most harmful extractive activities to less developed regions[1].

In order to solve these problems, countries have to cooperate by signing international agreements. However, this is a very complicated process. A main problem is that each country wants to support its interests and thus may not participate in such agreements. Another important issue is the free-riding behavior by some countries. This means that although the countries sign the agreements, some of them finally do not take measures to achieve the target, because they let the others to do so.

2.1 The Greenhouse effect

The most important environmental problem is the climate change, which is the heating of the surface of a planet due to the high concentration of greenhouse gases. Greenhouse gases are almost transparent to solar radiation but strongly absorb and emit infrared radiation. Thus, greenhouse gases trap heat within the surface-troposphere system. This mechanism is fundamentally different from that of an actual greenhouse, which works by isolating warm air inside the structure so that heat is not lost by convention.

The Earth receives energy from the sun mostly in the form of visible light. The atmosphere is almost transparent to visible light, so that about 50% of the sun's energy reaches the Earth and is absorbed by the surface. Like all bodies with a temperature above absolute zero, the Earth's surface radiates energy in the infrared range. Greenhouse gases are not transparent to infrared radiation so they absorb it. Infrared radiation is absorbed from all directions and is passed as heat to all gases in the atmosphere. The atmosphere also radiates in the infrared range (because of its temperature, in the same way the Earth's surface does) and does so

[1]This information is drawn from http://www.aida-americas.org/aida.php?page=problems, the site of Interamerican Association for Environmental Defence

in all directions. The surface and lower atmosphere are warmed because of the greenhouse gases, making our life on earth possible[2].

For the Earth's temperature to be in steady state so that the Earth does not rapidly heat or cool, this absorbed solar radiation must be very closely balanced by energy radiated back to space in the infrared wavelengths. Since the intensity of infrared radiation increases with increasing temperature, one can think of the Earth's temperature as being determined by the infrared flux needed to balance the absorbed solar flux. The visible solar radiation mostly heats the surface, not the atmosphere, whereas most of the infrared radiation escaping to space is emitted from the upper atmosphere, not the surface. The infrared photons emitted by the surface are mostly absorbed in the atmosphere by greenhouse gases and clouds and do not escape directly to space.

The reason this warms the surface is most easily understood by starting with a simplified model of a purely radiative greenhouse effect that ignores energy transfer in the atmosphere by convection (sensible heat transport, sensible heat flux) and by the evaporation and condensation of water vapour (latent heat transport, latent heat flux). In this purely radiative case, one can think of the atmosphere as emitting infrared radiation both upwards and downwards. The upward infrared flux emitted by the surface must balance not only the absorbed solar flux but also this downward infrared flux emitted by the atmosphere. The surface temperature will rise until it generates thermal radiation equivalent to the sum of the incoming solar and infrared radiation.

A very simple model, but one that proves to be remarkably useful, involves the assumption that this temperature profile is simply fixed, by the non-radiative energy fluxes. Given the temperature at the emission level of the infrared flux escaping to space, one then computes the surface temperature by increasing temperature at the rate of 6.5 °C per kilometre, the environmental lapse rate, until one reaches the surface. The more opaque the atmosphere, and the higher the emission level of the escaping infrared radiation, the warmer the surface, since one then needs to follow this lapse rate over a larger distance in the vertical. While less intuitive than the purely radiative greenhouse effect, this less familiar *radiative-*

[2] The information in this paragraph is drawn from the Intergovernmental Panel on Climate Change Fourth Assessment Report. Chapter 1: Historical overview of climate change science, page 97.

convective picture is the starting point for most discussions of the greenhouse effect in the climate modelling literature.

2.2 Greenhouse gases

Greenhouse gases, which mainly consist of water vapour, they are essential in helping determine the temperature of the Earth; without them this planet would likely be much colder. Although many factors such as the sun and the water cycle are responsible for the Earth's weather and energy balance, if all else was held equal and stable, the planet's average temperature should be considerably lower without greenhouse gases.

Human activities have an impact upon the level of greenhouse gases in the atmosphere, which has other effects upon the system, with their own possible repercussions. The 2007 assessment report compiled by the Intergovernmental Panel on Climate Change (IPCC) observed that "changes in atmospheric concentrations of greenhouse gases and aerosols, land cover and solar radiation alter the energy balance of the climate system", and concluded that "increases in anthropogenic greenhouse gas concentrations is very likely to have caused most of the increases in global average temperatures since the mid-20th century".

When gases are ranked by their contribution to the greenhouse effect, the most important are[3]:

- water vapor, which contributes 36–72%
- carbon dioxide, which contributes 9–26%
- methane, which contributes 4–9%
- ozone, which contributes 3–7%

The contribution to the greenhouse effect by a gas is affected by both the characteristics of the gas and its abundance. For example, on a molecule-for-molecule basis methane is about eight times stronger greenhouse gas than carbon dioxide, but it is present in much smaller concentrations so that its total contribution is smaller. It is not possible to state that a certain gas causes an exact percentage of the greenhouse effect, because the influences of the various gases are not additive. The

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[3] This data is drawn from Kiehl, J. T.; Kevin E. Trenberth (February 1997). "Earth’s Annual Global Mean Energy Budget". *Bulletin of the American Meteorological Society* 78 (2): 197–208

higher ends of the ranges quoted are for the gas alone; the lower ends, for the gas counting overlaps[4].

2.3 Global warming

A very important environmental problem which results from the greenhouse effect and which could threaten the existence of human civilization is the global warming. Global warming is the increase in the average temperature of the Earth's near-surface air and oceans since the mid-20th century and its projected continuation. Global surface temperature increased 0.74 ± 0.18 °C (1.33 ± 0.32 °F) during the last century[5]. The IPCC concludes that increasing greenhouse gas concentrations resulting from human activity such as fossil fuel burning and deforestation are responsible for most of the observed temperature increase since the middle of the 20th century. The IPCC also concludes that natural phenomena such as solar variation and volcanoes produced most of the warming from pre-industrial times to 1950 and had a small cooling effect afterward. These basic conclusions have been endorsed by more than 45 scientific societies and academies of science, including all of the national academies of science of the major industrialized countries[6].

Climate model projections summarized in the IPCC report indicate that the global surface temperature will probably rise a further 1.1 to 6.4 °C (2.0 to 11.5 °F) during the twenty-first century[5]. The uncertainty in this estimate arises from the use of models with differing sensitivity to greenhouse gas concentrations and the use of different estimates of future greenhouse gas emissions. Some other uncertainties include how warming and related changes will vary from region to region around the globe. Most studies focus on the period up to 2100. However, warming is expected to continue beyond 2100 even if anthropogenic emissions stop, because of the large heat capacity of the oceans and the long lifetime of carbon dioxide in the atmosphere[7,8].

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4 This information is drawn from Houghton, John (4 May 2005). *Global warming*. Institute of Physics. p. 1362

5 This data is drawn from IPCC (2007-05-04). "Summary for Policymakers". Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change

6 This information is drawn from Royal Society (2005). "Joint science academies' statement: Global response to climate change".

7 This information is drawn from Archer, David (2005). "Fate of fossil fuel CO2 in geologic time". Journal of Geophysical Research 110 (C9): C09S05.1–C09S05.6.

Increasing global temperature will cause sea levels to rise and will change the amount and pattern of precipitation, probably including expansion of subtropical deserts. The continuing retreat of glaciers, permafrost and sea ice is expected, with the Arctic region being particularly affected. Other likely effects include shrinkage of the Amazon rainforest and Boreal forests, increases in the intensity of extreme weather events, species extinctions and changes in agricultural yields[7].

3. International Environmental Agreements

Since global warming is a truly global environmental problem, international coordination is necessary. However, countries have to voluntarily negotiate and agree upon certain targets and policies to achieve these targets, as there is no global coercive authority to enforce global climate protection. The problem is that many countries are not keen to participate in international environmental agreements because of various reasons, such as free riding incentives.

It is often remarked that international cooperation in trade must hold clues for how international cooperation in environmental protection can be aided. There are, however, fundamental differences between these issues. First, trade is a bilateral activity, even if governed by multilateral rules (today, under the World Trade Organization or WTO). The supply of global public goods, by contrast, is a multilateral endeavour. Sustaining cooperation between just two countries is relatively easy; sustaining cooperation among a large number of countries is much harder (even increasing the number of countries from two to three makes a significant, qualitative difference). Second, trade liberalization is not a public good. Non-parties can be excluded from enjoying the benefits of a trade agreement (indeed, rather than free ride, trade diversion can make non-parties worse off). By contrast, free riding is the most important hindrance to international environmental cooperation.

3.1 Kyoto Protocol

Probably the most important of these agreements is the Kyoto Protocol which was put into effect in February 2005 for the commitment period of 2008-2012. It was adopted in December 1997 and was signed

8 This information is drawn from Solomon, S., et al. (2009). "Irreversible climate change due to carbon dioxide emissions". Proceedings of the National Academy of Sciences 106 (6): 1704–1709

by developed and developing countries. The implementation of the Kyoto targets in greenhouse gas emissions reductions relies on three policy instruments: international emissions' trading (IET), joint implementation (JI) and clean development mechanism (CDM).

International Emissions' Trading (or emission trading) is an administrative approach used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants. The system used in the Kyoto protocol is a *cap and trade* system. A central authority (usually a government or international body) sets a limit or *cap* on the amount of a pollutant that can be emitted. Companies or other groups are issued emission permits and are required to hold an equivalent number of allowances (or credits, or permits) which represent the right to emit a specific amount of the pollutant. The total amount of allowances cannot exceed the cap, limiting total emissions to that level. Companies that need to increase their emission allowance must buy them from those who pollute less. The transfer of allowances is referred to as a trade. In effect, the buyer is paying a charge for polluting, while the seller is being rewarded for having reduced emissions by more than was needed. Thus, in theory, those who can easily reduce emissions most cheaply will do so, achieving the pollution reduction at the lowest possible cost to society.

Market transactions are driven by relative prices of emission reduction opportunities among market participants. For example, a company with a low cost opportunity to reduce emissions below its allocation of emission rights can sell these unneeded rights to a company with limited or uneconomic emission reduction opportunities. Emissions trading systems have been already used in the United States (the Acid Rain Program has been evaluated as very successful) and the European Union, which unilaterally has implemented the Kyoto Protocol for the period 2005 to 2008. There are other applications, but most of them are in a pilot phase (as in the greenhouse gas markets emerging throughout the world).

The overall goal of an emissions trading plan is to reduce emissions. The cap is usually lowered over time - aiming towards a national emissions reduction target. In other systems a portion of all traded credits must be retired, causing a net reduction in emissions each time a trade occurs. In many cap and trade systems, organizations which do not pollute may also participate, thus environmental groups can purchase and retire allowances or credits and hence drive up the price of the remainder according to the law of demand. Corporations can also prematurely retire allowances by donating them to a non-profit entity and then be eligible for a tax deduction.

Because emissions' trading uses markets to determine how to deal with the problem of pollution, it is often touted as an example of effective free market environmentalism. While the cap is usually set by a political process, individual companies are free to choose how or if they will reduce their emissions. In theory, firms will choose the least-costly way to comply with the pollution regulation, creating incentives that reduce the cost of achieving a pollution reduction target.

The Clean Development Mechanism (CDM) is an arrangement under the Kyoto Protocol allowing industrialised countries with a greenhouse gas reduction commitment (called Annex B countries) to invest in projects that reduce emissions in developing countries as an alternative to more expensive emission reductions in their own countries. A crucial feature of an approved CDM carbon project is that it has established that the planned reductions would not occur without the additional incentive provided by emission reductions credits, a concept known as "additionality".

The CDM allows net global greenhouse gas emissions to be reduced at a much lower global cost by financing emissions reduction projects in developing countries where costs are lower than in industrialized countries. However, in recent years, criticism against the mechanism has increased.

The CDM is supervised by the CDM Executive Board (CDM EB) and is under the guidance of the Conference of the Parties (COP/MOP) of the United Nations Framework Convention on Climate Change (UNFCCC).

The purpose of the CDM was defined under Article 12 of the Kyoto Protocol. Apart from helping Annex B countries comply with their emission reduction commitments, it must assist developing countries in achieving sustainable development, while also contributing to stabilization of greenhouse gas concentrations in the atmosphere.

To prevent industrialised countries from making unlimited use of CDM, the framework has a provision that use of CDM be 'supplemental' to domestic actions to reduce emissions. This wording has led to a wide range of interpretations - the Netherlands for example aims to achieve half of its required emission reductions by CDM. It treats Dutch companies' purchases of European Emissions Trading Scheme allowances from companies in other countries as part of its domestic actions.

Thus, it is significant to detect possible incentives for both developed and developing countries, so as to boost them to participate in international agreements on climate change. This will get easier if we ascertain the strategic implications of the so-called ancillary benefits and not only their quantitative and qualitative impacts for climate policy levels.

Joint implementation (JI) is set forth in the Kyoto Protocol to help countries with binding greenhouse gas emissions targets (so-called Annex I countries) meet their obligations. JI is set forth in Article 6 of the Kyoto Protocol. Under Article 6, any Annex I country can invest in emission reduction projects (referred to as "Joint Implementation Projects") in any other Annex I country as an alternative to reducing emissions domestically. In this way countries can lower the costs of complying with their Kyoto targets by investing in greenhouse gas reductions in an Annex I country where reductions are cheaper, and then applying the credit for those reductions towards their commitment goal.

A JI project might involve, for example, replacing a coal-fired power plant with a more efficient combined heat and power plant. Most JI projects are expected to take place in so-called "economies in transition," noted in Annex B of the Kyoto Protocol. Currently Russia and Ukraine are slated to host the greatest number of JI projects. Unlike the case of the Clean Development Mechanism, the JI has caused less concern of spurious emission reductions, as the JI, unlike the CDM, takes place in countries which have an emission reduction requirement.

The process of receiving credit for JI projects is somewhat complex. Emission reductions are awarded credits called Emission Reduction Units (ERUs), where one ERU represents an emission reduction equaling one tone of CO_2 equivalent. The ERUs come from the host country's pool of assigned emissions credits, known as Assigned Amount Units, or AAUs. Each Annex I party has a predetermined amount of AAUs, calculated on the basis of its 1990 greenhouse gas emission levels. By requiring JI credits to come from a host country's pool of AAUs, the Kyoto Protocol ensures that the total amount of emissions credits among Annex I parties does not change for the duration of the Kyoto Protocol's first commitment period.

4. Ancillary Benefits

The reduction of atmospheric greenhouse gas (GHG) accumulation from fuel use would also tend to reduce basic air pollutants and thus, have direct local benefits. These benefits are characterized as ancillary. So, apart from primary benefits, ancillary benefits must be detected, in order to give countries stronger motivation for participation.

Primary benefits are the benefits derived from pursuing climate policy's primary aim, which is climate stabilization at the global level. In contrast, according to the IPCC Third Assessment Report (2001a,b,c), ancillary benefits "…are the monetized secondary or side benefits of mitigation policies on problems such as reductions in local air pollution associated with the reduction of fossil fuels, and possibly indirect effects on congestion, land quality, employment and fuel security".

They are local benefits generated by climate policy, but are not associated directly with the slowing of climate change. They are also characterized as co-benefits and spill-over benefits (IPCC (2001)). According to Markandya and Rubbelke (2004), the main difference between the terms is the relative emphasis given to benefits derived from slowing climate change versus other benefits. The types of impacts being covered are the same under each of these labels.

Moreover, ancillary benefits arise almost immediately after the climate protection measure has been accomplished, contrary to the primary ones which accrue over a time of several decades or longer. "We feel the heart of the analysis of ancillary benefits involves the here and now that is relevant to individual policy makers in a national context", as Krupnick, Burtraw and Markandya (2000, p.3) mention. Additionally, benefits of reduced climate change risks accrue at a global level, while ancillary benefits accrue mainly to those countries undertaking mitigation action. If we fail to consider ancillary benefits correctly, this could lead to a false assessment of the net costs – direct cost of climate policy less ancillary benefits from this policy – of mitigation policy, and a wrong definition of no regrets levels of GHG mitigation. Finally, the accurate estimation of ancillary benefits is important since their underestimation could lead to choose an unnecessarily expensive policy.

No regrets options are by definition GHG emissions reduction options that have negative net costs, because they generate direct or indirect benefits that are large enough to offset the costs of implementing the options. The costs and benefits included in the assessment, in principle, are all internal and external impacts of the options. External costs arise when markets fail to provide a link between those who create the externality and those affected by it; more generally, when property rights for the relevant resources are not well defined. External costs can relate to environmental side-impacts, and distortions in markets for labour, land, energy resources, and various other areas.

As the years pass by, international negotiations on climate change are in the process of intensive search for a post-Kyoto protocol. During these years many changes took place. For example, China is now the larger emitter of greenhouse gases (GHG) and it is necessary that developing countries participate in such an agreement because of their growing emissions.

Recently, by using normal form games, Pittel and Rubbelke (2008) investigated the outcome of international negotiations on climate change under two different scenarios: one with and one without the inclusion of ancillary benefits. They find that if international negotiations are represented as a chicken game, ancillary benefits tend to have a positive influence on the propensity of countries to participate in an international agreement on climate change.

4.1 Developing Countries

Apart from the fact that developing countries' participation is necessary for the success of any international agreement, these countries have also their own incentives to participate. At first, their economies will be negatively affected by climate change. Given that developing countries have limited economic and technological means to adopt to climate changes, the negative effect will be larger for these countries. Secondly, they can obtain additional local benefits by slowing global warming if they participate to climate protection. Aunan et al. (2007), suggests that China will gain important ancillary benefits by the climate protection commitment because its efforts will lead not only to the reduction of GHG emissions but also of particles and NO_X emissions. These reductions, in turn, will improve public health and will increase agricultural yields.

Smith and Haigler (2008, p.19) recently offered some calculations which illustrate the high-degree of ancillary benefit that can result especially in improving efficiency in the household energy sector in developing countries. As they mention "the poor combustion and lack of good ventilation typical in simple household stoves result in high indoor and near-household air pollution exposures. This in turn has been associated with a range of diseases, with best evidence for pneumonia (acute lower respiratory infections) in children and COPD (chronic obstructive pulmonary disease) in women, the two groups receiving the highest exposures".

4.2 Developed Countries

Ancillary benefits in developed countries may not be equivalent to those in developing countries, but they are also significant. In some studies they are represented as a multiple of primary benefits. Pearce (2000) calculates that ancillary benefits are in the range between 0.07 and 6.67 of the primary benefits.

Ekins (1996a, 1996b) suggests that the inclusion of ancillary benefits in cost-benefit analyses will increase the optimal climate policy levels. Apart from the quantitative, there are also qualitative ancillary benefits. The ancillary benefits can only be enjoyed on a local or regional scale, while the primary can be enjoyed globally. Put it differently, ancillary benefits are mainly a private good from the country's or region's point of view, whereas climate protection generated by climate policy is a global public good.

In conclusion, on the one hand, ancillary benefits call for higher globally optimal abatement levels; while on the other hand, they give incentives to countries to participate in international agreements and thus, increase the number of participating countries. In the case that ancillary benefits are important they reduce the free riding incentives that each country has. Free riding benefits are generated from the actions undertaken by other countries but these actions cannot generate ancillary benefits.

5. Strategic trade

Countries often perceive themselves as being in competition with each other for profitable international markets. In this case, governments seek attractive policy tools, like export subsidies and import tariffs, so as to improve the domestic firms' position in the non-cooperative rivalries with foreign firms, enabling them to expand their market share and profits.

As a result, tariffs, taxes and subsidies affect the initial conditions of the game played by the firms. While the terms of trade move against the subsidizing country, their welfare can increase as price exceeds the marginal cost of exports, under imperfect competition. The terms of trade is defined as the ratio of the price a country receives for its export commodity to the price it pays for its import commodity. So, when a country subsidizes its firms, the price of its exports (numerator of the ratio) decreases and thus there is deterioration in its terms of trade. Producing countries have incentives to cooperate and eliminate such subsidies, but they also have an incentive to cheat on any resulting agreements, along the lines of a typical prisoners' dilemma.

Brander and Spencer (1984) study export subsidies as a policy instrument to promote domestic firms in the international market. As they advocate "the central idea is that it is to the advantage of a country to capture a large share of the production of profit-earning imperfectly competitive industries. Export subsidies can be used to carry out such "profit-shifting" policies.

They use a simple Cournot (or Nash quantity) duopoly. Subsidy levels are set by the governments and output levels are set by competing firms. Each firm takes as given the output of its rivals and the subsidy levels. In a two stage model, governments play first, setting simultaneously subsidy levels and then firms choose simultaneously their output levels. Therefore, "firms play Nash against all other players, and governments play Stackelberg against firms and Nash against other governments". Generally, some distortion is needed for a second best policy like subsidies to be in the national interest. The distortion here is imperfect competition.

Also, they assume an economy with identical consumers who receive the same income based on identical endowments and an equal share of the profits of the imperfectly competitive domestic firm. This is the usual assumption in order to abstract from the problem that the national distribution of income affects demand and welfare.

In the model of Brander and Spencer (1984) the domestic and the foreign firm sell their product to a third market, so that there is no consumption in the producing countries. Therefore, strategic trade policies affect only firms' profits and do not affect domestic consumers' surplus. The reaction functions are downward sloping as marginal revenue declines with an increase in the output of the other firm. Therefore, an increase in the export subsidy increases domestic exports, while a domestic subsidy reduces the output of the foreign firm.

As regards to the domestic subsidy, it lowers price, increases domestic profit and lowers foreign profit. The subsidy actually increases domestic welfare net of the subsidy. In their simple case with all production for export, domestic surplus net of the subsidy, is the profit of the domestic firm (earned from exports) minus the cost of the subsidy.

There is a number of works in the literature which apply the strategic trade argument developed by B&S (1984) to the choice of national environmental targets. Markusen (1975) assumes that all markets are competitive, there are no import tariffs and only pollution tariffs can be used to affect the terms of trade. As a result, exporting countries over-internalize environmental damage in order to avoid pollution-related tariffs and improve their terms of trade.

Conrad (1993), Barret (1994) and Kennedy (1994) suggest that under Cournot competition, environmental policy can be used to indirectly subsidize exports by under-internalizing the environmental damage caused from pollution. Conrad (1993), assumes that governments are allowed to control pollution through emission taxes but at the same time subsidies for pollution intensive inputs may be used. Barrett (1994) assumes that governments use emission standards instead of taxes to regulate pollution. Finally, Kennedy (1994) studies a two-country closed economy model and claims that when pollution is transboundary, the eco-dumping effect is reinforced.

The above studies indicate that nations without strict regulatory standards attract accelerated flows of international capital investment, leading to the creation of “pollution havens.” The lack of stringent environmental regulation gives firms an unfair competitive trade advantage, amounting to an environmental subsidy which enables firms to undercut prices in export markets.

In a two-good perfectly competitive neoclassical world, a country has o incentive to subsidize an exported good, because this action will lead to a worsening of the country’s terms of trade. The only case for this to happen is if the county can influence the exported price’s good. Then, an export tax would be appropriate so as to improve the country’s terms of trade.

As regards the environmental regulation and its effects on the competitiveness and the profitability of the firms, there are two conflicting arguments; one that refers to the short run and one to the long run.

1. In the short run there is a conflict between environmental quality and economic prosperity. Governments use regulations in order to internalize the negative externalities caused by the economic system.

However, the internalization of externalities requires abatement activities and therefore, higher operation costs for the firms.

2. There is a relation between environmental standards and competitiveness in the long run. To explain, firms that invest on abatement technology can have in the long run benefits which outweigh the short run costs of investment.

Empirical support is rather neutral about these arguments. However, the behaviour of governments, which do not participate in international environmental agreements, implies that they act only upon the short-run perceived costs of environmental policy.

Section 6 sets out the basic model and shows the reaction of the firms and governments when the ancillary benefits are taken into account. Firms may change their output and the number of emission permits they have. Governments concern about the taxes that they will impose to the firms in order to make them emit less pollutants. In section 7 the conclusions are represented.

6. The model

We use a simple model in order to demonstrate our results. Consider two countries. In each country there is one firm producing a homogeneous product. We denote by q_i the output level of firm i, $i = 1,2$ and we also assume that both firms supply their product to a third market in which there is no other competition. The demand in the third market is assumed linear of the form: $P = a - b(q_i + q_j)$. The two firms compete a-la Cournot-Nash. Firms face a total cost of production $C_i(q_i) = c\ q_i$, where c is a technological parameter representing the constant marginal cost of production and is assumed equal across competing firms.

We further assume that both firms' production results in emissions of a global pollutant and a local pollutant. Emissions of the global pollutant are assumed to be increasing with the level of output, $E_i(q_i) = l_i q_i$, where l_i, $i = 1,2$ is a technological parameter representing the constant marginal rate of emissions generation.

7. The choice of local tax level

We assume that in order to reduce damages from the global pollutant, the two countries participate in a global agreement to reduce emissions. We assume that the global agreement uses a tradable emissions permit policy to achieve its target. According to this policy each government issues a number of permits W_i and distributes them free of charge to the home firm i. After the initial distribution, firms can trade permits in a competitive market, at a price Pe. Although many firms generate the global pollutant and thus, participate in the permits market, only the two firms considered here, produce the homogeneous product whose market we examine in this study.

In order to comply with the regulation, firms can either purchase permits, or reduce their emissions by engaging in abatement effort A_i. We assume that abatement is $A_i = k_i q_i$, where k_i is the abatement per unit of output.

Emissions' abatement is costly. Firms' total cost of abatement is denoted by $g_i A_i^2$, where $g_i > 0$ is a technological parameter expressing the marginal cost of abatement of each firm and is different across firms. Emissions of the global and the local pollutant are related. For simplicity we assume that there is a one to one relationship, that is, the production of one unit of output q_i in country i generates l_i units of the global pollutant and in the same time l_i units of the local pollutant.

When firms engage in abatement of the global pollutant they also reduce the local pollutant and thus, the damages that the local pollutant generates. Given that the emission target was agreed upon based on the global pollutant's damages alone, each government has an incentive to implement an additional local environmental policy targeting the local pollutant. We assume that both countries impose an emission tax per unit of emissions discharged into the local environment.

Thus, if firms engage in abatement, they will produce a double benefit; a reduction in the global pollutant and in the same time a decrease in the local pollutant. There are also two policy instruments: a global tradable permits system and a local environmental tax.

The firms choose their levels of output q_i and abatement per unit of output k_i by maximizing their profits Π_1 and Π_2

$$\Pi_i = [a - b(q_i + q_j)]q_i - cq_i - g_i A_i^2 - Pe(E_i - W_i) - t_i E_i, \qquad (1)$$

where E_i denotes emissions of the global and the local pollutant net of abatement, that is, $E_i = l_i q_i - k_i q_i$, $i = 1,2$.

The first order conditions of the profit maximization are

$$\Pi_i^q = a - 2bq_i - bq_j - c - 2g_i k_i^2 q_i - Pe(l_i - k_i) - t_i(l_i - k_i) = 0\,, \qquad (2a)$$

$$\Pi_i^k = Peq_i - 2g_i k_i q_i^2 + q_i t_i = 0\,. \qquad (2b)$$

Where superscripts denote derivatives with respect to the choice variable.

Solving the equation (2a) with respect to q_i yields firms' reaction function

$$q_i(q_j) = \frac{a - c - l_i Pe - l_i t_i}{2b} - \frac{1}{2} q_j\,, \qquad (3)$$

The second order conditions are.

$$\Pi_1^{qq} = \Pi_2^{qq} = -2(b + g_i k_i^2) < 0\,. \qquad (4)$$

The negative sign of the second order conditions confirms that the reaction functions are downward sloping.

The reaction functions of the two firms show the best response of the firm to any particular output chosen by its rival. The simultaneous solution of equations (3) yields the equilibrium outputs of the two firms:

$$q_i = \frac{a - c - 2l_i(Pe + t_i) + l_j(Pe + t_j)}{3b} \qquad (5)$$

Solving equation (2b) with respect to k_i yields the firm i's abatement per unit of output, as a function of its rival's output,

$$k_i(q_j) = \frac{b(Pe + t_i)}{g_i[a - c - l_i(Pe + t_i) - bq_j]} \tag{6}$$

Substituting the output levels from (5) into (6) we obtain firm i's level of abatement per unit of output as a function of Pe and t_i. Then, we substitute the output levels q_1 and q_2 from (5) into the emissions and abatement functions to derive them as functions of Pe and t_i. Finally, we derive the total output Q and the price P as functions of Pe and t_i.

Each government chooses the level of the tax that it will impose by maximizing its social welfare while taking into account the behaviour of the other government. Each country's social welfare is expressed as the sum of the producer surplus and the ancillary benefits from the reduction in emissions. Note that in our model, we do not consider damages from global emissions since the problem of the global pollutant is dealt with at the international level through the permits system. Moreover, there is no domestic consumer surplus because the product is sold to a third market.

Under these assumptions each country's social welfare function is:

$$\begin{aligned} W_i(t_i, t_j) = P(t_i, t_j)q_i(t_i, t_j) - cq_i(t_i, t_j) - g_i A_i(t_i, t_j) \\ - Pe[E_i(t_i, t_j) - W_i] + d_i A_i(t_i, t_j) \end{aligned} \tag{7}$$

where $d_i A_i(t_i, t_j)$, $i, j = 1,2$ expresses the ancillary benefits gained by firms' abatement effort.

We derive the first order conditions with respect to the tax level, which then yield the reaction function of each country's choice of tax to the other country's tax level:

$$Rt_i(t_j) = \frac{9b(d_i - g_i + Pe) + 2g_i l_i \left[(2l_i - l_j)Pe - (a-c)\right]}{8g_i l_i^2} - \frac{l_j}{4l_i} t_j \tag{8}$$

As it is shown there is a negative relation between the tariffs imposed by the two governments. This means that the higher the tax imposed by country i, the lower the tax imposed by country j. So, the choice of tariff by one government depends on the tariff imposed by the other one. “Each of these tariffs has an impact on the profits of both firms and therefore on the net welfare of both countries”, as Brander and Spencer (1984) note. This fact explains the behaviour of the governments to intervene in the market in order to promote the interest of the local firm.

Note that when the other country sets a zero tax, the home country will set a higher tax the higher are the ancillary benefits d_i, the lower is the cost of abatement g_i, the higher is the permit price, and the lower are the per unit expected profits in the international market $(a-c)$.

Solving the two reaction functions (8) simultaneously yields the equilibrium values for the taxes:

$$t_i = \frac{2g_i g_j l_i l_j(-a + c + 3l_i Pe - 2l_j Pe) - 3b[d_j g_i l_i - 4g_j l_j(d_i + Pe)}{10 g_i g_j l_i^2 l_j} + \frac{g_i(-g_j l_i + 4g_j l_j + l_i Pe)]}{10 g_i g_j l_i^2 l_j} \tag{9}$$

Finally, if we substitute equations (9) into the equations (5) we derive the optimal quantities produced by each firm

$$q_i = \frac{4g_i g_j l_i l_j (a - c - 3l_i Pe + 2l_j Pe) + b[6d_j g_i l_i - 9g_j l_j (d_i + Pe)}{10bg_i g_j l_i l_j} + \frac{g_i(-6g_j l_i + 9g_j l_j + 6l_i Pe)]}{10bg_i g_j l_i l_j} \tag{10}$$

8. Simulations

In this section we present an analysis based on values which we set on the parameters in order to verify the results of the section 7. We also present a graph to show the relation between the taxes imposed by the two governments.

The values we set to the parameters are

$a = 64$, $\mathrm{c} = 30$, $\mathrm{b} = 2/3$, $\mathrm{l}_1 = 0.6$, $\mathrm{l}_2 = 0.8$, $\mathrm{g}_1 = 1.6$, $\mathrm{g}_2 = 1.8$, $\mathrm{Pe} = 6$, $\mathrm{d}_1 = 16$, $\mathrm{d}_2 = 18$, $\mathrm{W}_1 = 16$, $\mathrm{W}_2 = 16$

The results based on these values are

$t_1 = 12.2611$, $t_2 = 3.40417$, $q_1 = 9.805$, $q_2 = 14.955$, $k_1 = 0.582009$, $k_2 = 0.174675$, $A_1 = 5.7066$, $A_2 = 2.61227$, $E_1 = 0.176403$, $E_2 = 9.35173$

As it is shown, the results confirm what arise from the equations in section 7. Governments intervene strategically to the market by imposing taxes. The firms' outputs are also influenced. The values of l_i and k_i, $i = 1,2$ are also valid as $l_i > k_i$, because otherwise the results would make no sense. Finally, abatement and emission values are positive, which is according to what we assume above.

In order to provide another view of our outcome, we present Figure 1. The axes of the graph represent the taxes imposed by the two governments. In section 7 we note that the functions of the taxes are downward sloping and this conclusion is verified at the graph. The reaction functions of the taxes are downward sloping and they are intersected, which means that there is a solution to the problem.

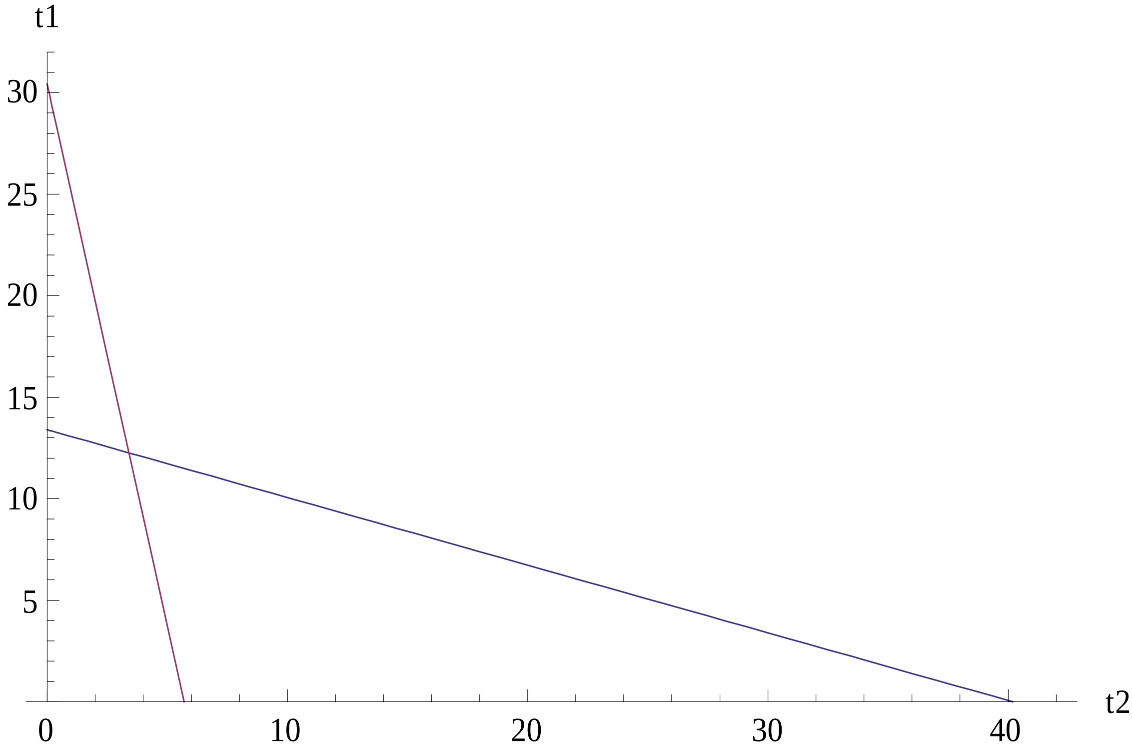

Figure 1

9. Conclusions

This paper analyzes governments' optimal intervention policies and strategic behavior and firms' optimal emission and output amounts when international emissions trading and environmental taxes implementation exist. It is found that considering firms' ancillary benefits of abatement would affect governments' optimal intervention policies directly.

We expect all the variables be positive, something that is verified in the model through the reaction functions and the values set to the parameters. Governments set taxes on per unit of emissions, and firms react by reducing their output. As emissions are positively related to the firms' output, they also decrease. On the contrary, abatement increases, which is reasonable.

This paper adds to the previous literature as we examine a more specific model and try to find values of the variables we use, like optimal taxation and ancillary benefits. Bearing in mind the aim to calculate the taxes, outputs, abatement and emissions, we find that a $12.26 per unit of emissions tax imposed by government 1 would yield 9.8 units of the output produced by the firm 1, while a 3.4 per unit of emissions tax imposed by government 2 would yield 14.9 units of firm's 2 output.

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