The Strategic Implications of Setting Border Tax Adjustments

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First version: August 2009,

This version: 31 January 2010

Abstract

In order not to see their climate mitigation efforts be in vain by the unlimited growth in China and India, the developed world has started to consider imposing border tax adjustments on imports from these fast developing countries. This paper puts this problem into a game-theoretic perspective. It sets up the problem as a game between the developed world deciding on three regimes of border tax adjustments on the one hand and China and India deciding on setting an emissions reduction target on the other hand. The rest of the world, mainly the underdeveloped world, is an outsider to this game. It turns out that one of the border tax adjustment regimes is optimal, i.e. the one that is closest to an optimal taxation rule, where China and India will choose a positive reduction target for their emissions. The chosen border tax adjustment is however the worst case for the environment.

JEL-classification: C68, C72, D58, D62, F18, H23

Keywords: border tax adjustments, emission permit trading, emerging economies, computable general equilibrium, game theoretic solutions.

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1. Introduction.

Ever since the US walked out of the Kyoto Protocol agreement, there has been an intensive discussion on how to get the emerging economies, in particular China and India, to accept a target on their emissions. Such a target would allow them to be included into an emission permit trading market set up by the developed world. Recently, the developed world, which has set itself high emission targets and sees its efforts nullified by the starkly increasing emissions in these emerging economies, has threatened to increase particular taxes on imports from China, a policy known as border tax adjustments (BTA). The French Presidency recently repeated this threat in the public EU debate on the road to the Copenhagen Summit in December 2009.

This paper considers the implications of imposing border tax adjustments on the trade of goods with China and India. We formulate a game between two players. One player is the region defined by China and India, representing the emerging economies. The other player consists of all the developed regions which have once signed up to climate mitigation obligations under the Kyoto Protocol. The set of strategies of China and India consists of all possible emission reduction targets. The developed world chooses among three types of border tax adjustment regimes. We assume that the same regime is set on this player's imports and exports from China and India. Each regime is characterized by the determination of emissions associated witht the import and export goods, i.e. according to benchmark calculations, actual emissions, or average emissions over all imports c.q. exports. The emission reduction target chosen by China and India will be translated to its endowment in emission permits on a permit market consisting of these two players in the game. The developed world obtains an endowment of permits according to an average of pledges by its members. Given the strategy space of the other player, each player will choose its welfare maximizing strategy. Apart from the two players, the rest of the world plays the role of an outsider whose welfare and emissions are signicantly influences by the outcome of the game.

We apply a computable general equilibrium model to find the level of border tax adjustment on each traded good in the developed world and the consequences on welfare, and global emissions resulting from the strategies chosen by the players. This results in a relationship between the development in the clearing price on the emission permit market and the emission reductions set by China and India. Furthermore, we can calculate the development of each player's welfare for all possible strategy pairs chosen.

The game results in an equilibrium where the developed world chooses one dominant border tax adjustment regime as its optimal strategy, and China and India choose an optimal target for their emission reductions. The optimal regime chosen by the developed world is the one closest to an optimal taxation rule. Under this border tax adjustment regime however, the rest of the world, being an outsider to the game, as well as the environment, are worst off.

We organize the paper in 5 sections. In Section 2, we define the policy of border tax adjustments as it is intended to be implemented by the EU. It follows Alexeeva-Talebi, Löschel, and Mennel (2008) by considering the possible relationships between setting border tax adjustments and what is called integrative emission trading. Section 3 describes the computable general equilibrium model that we use for the computations. We implement the PACE model, see Böhringer and Lange (2005). In Section 4, we define the game between the developed world as one of the players and the emerging economies, China and India as the other player. This section provides the results of the computations with the PACE model in the form of the developement of the emission permit price, the consequences on welfare of each region, and global emissions, from the reduction target set by China and India. Section 5 concludes.

2. On emission trading and border tax adjustments.

The Kyoto Protocol offered the possibility of trading emission permits as an economically efficient way for the developed world to address their mitigation obligations. Greenhouse gas emissions lead to a significant externality on all economic actors in the current economy. The underlying idea to take away this externality is to transfer these greenhouse gas emissions into a regular economic good, the emission permit. This good allows the owner a certain amount of emissions. Each market party is allowed to a certain level of greenhouse emissions as an allocated initial endowment of permits. Each market party should obtain the necessary allowances or permits to cover the emissions associated with their chosen levels of production. In this way, a net demand for permits is created from parties whose production levels require higher emissions than allowed, and a supply of permits is created from parties whose production levels require lower emissions than allowed by their initial endowments. Trading of permits among these parties will settle a market clearing price of emission permits. We know from standard economic theory that, independent of the initial allocation of emission permits over the producers, trade among them results in a market equilibrium that is again efficient.

One of the main problems underlying an emission permit market is the determination of the initial permit endowment for each market party, referring to the required emission reductions they are required to undertake. First, these initial endowments of permits could be derived from the emission reductions promised by the developed countries in the Annex B to the Kyoto Protocol. For the Post-Kyoto period, currently developed countries vie among each other to set high emission reduction goals, to mitigate the consequences of climate change on the global economy.

Another Post-Kyoto discussion in the climate policy debate is what the role of the fast developing countries or emerging economies such as China and India should be in the international effort to mitigate the consequences of climate change on the world economy. The US and others have proposed that, a possible action could be to let them join a currently only Annex B based emission permit market. To that end, they should set themselves appropriate emission reduction goals that can be translated into initial endowments of permits with which they can start trading on the permit markets. Kemfert and Kremers (2003) investigate the consequences of setting some particular emission targets on the economy.

It may be clear that, without a significant participation of the fast growing developing countries, this climate effort would nullify the mitigation efforts made by the developed countries. The emerging economies, China and India, already are or will be among the highest emitting countries in the world. Noncooperation would also give China and India a significant competition advantage on the markets for energy-intensive goods. To protect their own industry for such competition disadvantages, the developed world, to a varying degree have started to increase import or border taxes on goods imported from China and India, as part of a policy known as border tax adjustment.

We refer to Alexeeva-Talebi, Löschel, and Mennel (2008) for a survey of the issues concerned with border tax adjustments. There, border tax adjustment is defined as "the application of a domestic tax on imported goods while exempting exported goods from the tax to make the exported goods' price competitive both nationally and internationally" (see also Bhagwati and Srinivasan (1973) for an early reference to border tax adjustments). Under the regime of installing an emission permit market, a border tax adjustment regime levies an emission quantity-based duty on imports from non-abating countries and compensates domestic exporters with an ad-valorem subsidy on exports. It is interesting to notice that Alexeeva-Talebi, Löschel, and Mennel (2008) introduce so-called Integrated Emission Trading as a sort of extension of border tax adjustment to the emission permit trading market. Under an Integrated Emission Trading regime, foreign producers buy emission certificates for their imports according to the emissions produced. Domestic exporters do not participate in the emission trading scheme. Hence, Integrated Emission Trading thereby imposes an emission based duty on imports from non-abating countries and compensates domestic exporters accordingly. This guarantees that domestic producers keep their interests in emission abatement.

Gros (2009) mentions that the issue of border tax adjustment has been extensively discussed in the literature but that most studies concentrate on competitiveness of the energy intensive industries and carbon leakage. Climate change policy is however motivated by a concern for global welfare. He also mentions that the literature does not show any consensus whether a border tax adjustment is effective or not, i.e. whether it can correct for the distortionary impacts of (national) climate mitigation policies that result in a loss of competitiveness and carbon leakage. Veenendaal and Manders (2008) find that the overall welfare effects of border tax adjustment in Europe is ambiguous since refunds are found to be welfare decreasing for Europe but import levies are welfare increasing. Border tax adjustment turns out to have a modest impact on welfare only. A conclusion that is also reached by McKibben and Wilcoxen (2008).

On the other hand, Majocchi and Missaglia (2001) show that border tax adjustments are more likely to produce a better environment and less unemployment for the EU-15 member states. Demailly and Quiron (2009) and Mathiesen and Maestad (2002) come to similar positive results.

Border tax adjustments occur according to the carbon emissions content of a region's import and exports. Alexeeva-Talebi, Anger, and Löschel (2008) mention these three regimes. In the first regime, say BTA Regime 1, we determine the carbon emissions content following the benchmark emissions associated with the imported or exported good. In our approach, these are included in the data underlying the calibration of the PACE model. A second regime, say BTA regime 2, determines the carbon emissions content as the actual emissions associated with the imported or exported goods. These emissions adjust with each new equilibrium. It is this regime that might be closest to a form of optimal taxation. BTA regime 3 determines the carbon content of the imported and exported goods as an average over the benchmark carbon content over all imported or exported goods. Like regime 1, this regime will not adjust its calculated emissions with any change in equilibrium, hence they lack efficiency. On the other hand, this may be the only regime in accordance with the WTO trade rules.

As defined in Gros (2009) and Alexeeva-Talebi, Löschel, and Mennel (2008), border tax adjustments take the form of a (carbon) tax in the case of imports, and a (carbon) subsidy in the case of exports. We assume that possible revenues from border tax adjustment fall upon the regional income. Border tax adjustments are set by the developed world on all the imports from and exports to regions that lack in the implementation of climate mitigation efforts (see Veenendaal and Manders (2008)). Hence this paper also includes the rest of the world into its policy.

3. Policy Analysis based on Computable general Equilibrium (PACE)

Each player in the game that we define in the next section has to obtain information on the impacts of implementing their strategies in the game to make an assessment. To that end, it needs to have an idea about the world economy. As is often usual in the developed world, this idea of the world economy can be described by an economic model, such as a computable general equilibrium model. Here, we assume that both players assess the impact of choosing a particular strategy in combination with the possible chosen strategies by their opponents in a computable general equilibrium model. The CGE model that we take is the PACE model (see Böhringer and Lange (2005), or Böhringer and Löschel (2004) for the model documentation).

The PACE model is a multi-regional, multi-sectoral computable general equilibrium model. It partitions the world into regions, and each region into production sectors. This paper assumes a partitioning of the global economy into 3 regions, ANX, ChI, and RoW, representing the two players in the game and the outsider. The region ANX represents the developed world. Within the PACE model, it is the aggregation of the EU, USA, Canada, Australia and New Zealand, Japan, Russia, Ukraine, and Indonesia and Malaysia. The region ChI represents the aggregate of China and India as the fast developing countries in the world. The remaining regions in PACE, namely Brazil, Mexico, and the rest of the world, we put into the region RoW which mainly represent the underdeveloped world.

Each region contains the same number of production sectors associated with the regional variant of one of the goods. We distinguish these production sectors into the oil sector (‘oil’), the gas sector (‘gas’), the mining sector (‘omn’), a lumber sector (‘lum’), a paper manufacture and printing sector (‘ppp’), a chemical sector (‘crp’), a non-metallic mineral products sector (‘nmm’), the manufacture of iron and steel (‘i_s’), the manufacture of non-ferrous metals (‘nfm’), an electrical appliances sector (‘ele’), other machinery and equipment (‘ome’), other types of manufacturing and recycling (‘omf’), a construction sector (‘cns’), air transport (‘atp’), and dwellings (‘dwe’). Furthermore, there is a coal sector (‘col’), a crude oil sector (‘cru’), a capital good services sector (‘cgds’), and a transport sector (‘trn’). There is an agricultural sector (‘agr’) and a textiles sector (‘trn’). These sectors follow the GTAP database name conventions.

Two classes of conditions characterize the competitive equilibrium for our model: zero profit conditions and market clearing conditions. The existence of both these conditions follow directly from the assumptions of profit maximization, utility maximization, constant returns to scale of production, and homotheticity of the preferences. The latter class of conditions determines the price of each output good as the unit cost to produce this good. This cost equals the marginal cost as well as the average cost of production.

A region r is represented by a microeconomic consumer r and each production sector i by a microeconomic producer i. The behavior of consumer r can be described as choosing the bundle of consumption goods from his budget set that maximizes his utility. The budget set is determined by his income from selling the primary factors of production, assumed to be owned by this consumer. The primary factors of region r include labor $\underline{L}_r$, capital $\underline{K}_r$, and fossil-fuel resources $\underline{Q}_{ff,r}$ for which the consumer receives a price of w_r, v_r, respectively. We also assume that each region r has obtained $\underline{\mathrm{CO}}_{2r}$ units of emission permits as an initial endowment.

The behavior of producer i can be described as choosing a bundle of production goods from his set of production possibilities that maximizes his profits. The production possibilities set is determined by his technology, which efficiently transfers the goods and production factors as inputs into a particular output good.

The utility function of the consumer is given by a homothetic function while the production technology can be described by a constant returns to scale function. Under these assumptions, Armington (1969) uses a nested structure of constant elasticity of substitution functions to provide a flexible approximation of the economic choices of the economy’s agents. We refer to Diewert and Wales (1987) for a discussion of flexible functional forms. The constant returns to scale assumption on production implies that profit maximization is equivalent to minimizing the cost per unit output while, similarly, the assumption of homothetic utility functions implies that utility maximization is equivalent to minimizing the expenditure per unit of utility.

We use the non-positive profits conditions to describe the cost or expenditure structure of the producer and consumer decisions. These structures can be described as a tree where the root presents the output good or the utility good, and where each good is an aggregate of the goods one level deeper into the tree, according to some kind of constant elasticity function.

The production Y_{ir} of commodity i in region r other than primary fossil fuels is captured by an aggregate production function which characterizes technology through substitution possibilities between various inputs. Nested constant elasticity of substitution cost functions with three levels are employed to specify the substitution possibilities in domestic production between capital, labour, energy and non-energy, intermediate inputs, i.e. material.

At the top level, non-energy inputs are employed in fixed proportions with an aggregate of energy, capital and labour. At the second level, a CES function describes the substitution possibilities between the energy aggregate and the aggregate of labor and capital. Finally, at the third level, capital and labour trade off with a constant elasticity of substitution. As to the formation of the energy aggregate, we allow sufficient levels of nesting to permit substitution between primary energy types, as well as substitution between a primary energy composite and secondary energy, i.e. electricity. We associate levels of emissions with fossil-fuel use, comparable to the approach taken in GTAP-E, i.e. carbon emissions are associated with the demand for each fossil fuel j by a coefficient $a_i^{\mathrm{CO}_2}$. This coefficient is assumed to be the same over all production sectors. If we define an emission permit by the amount of carbon emissions it allows to its owner, we can interpret the emissions associated with fossil fuel use in production sector j as this sector's demand for emission permits.

Final demand C_r in each region is determined by a representative agent RA_r, who maximizes utility subject to a budget constraint with fixed investment. Total income of the representative household consists of factor income and tax revenues. Final demand of the representative agent is given as a CES composite which combines consumption of an energy aggregate with a non-energy consumption bundle. Substitution patterns within the non-energy consumption bundle are reflected by Cobb-Douglas functions. The energy aggregate in final demand consists of the various energy goods trading off at a constant elasticity of substitution.

All goods used on the domestic market in intermediate and final demand correspond to a CES composite A_{ir} of the domestically produced variety and a CES import aggregate M_{ir} of the same variety from the other regions (the Armington good). Domestic production either enters the formation of the Armington good or is exported to satisfy the import demand of other regions.

The tax system includes all types of indirect taxes (production taxes or subsidies *ty*, intermediate taxes *ti*, consumption taxes *tc*, as well as tariffs *tm* and *tx*) which are used to finance a fixed level of public good provision. A lump-sum tax on the representative household balances the public budget. This paper adds a border tax adjustment to the tariffs *tm* as tm_{irs} (1+bta_{irs}) for s=ChI and s=RoW, and r referring to the developed countries. Notice that adding this extra tax on imports provides the developed countries with extra funds to balance the public budget. In case bta < 0, then we speak of a subsidy on the export good. The unit of producing the import aggregate within the Armington nest from separate import goods now includes also the extra costs of border tax adjustments on the imports from ChI in the developed world.

The use of fossil fuel energy in the production of each good makes that the producers have to pay extra for the associated emissions. These costs can be incorporated into the price of the fossil fuel by making this fossil fuel an aggregate good of pure fossil fuel and associated emissions using a Leontief production function with share parameter $a_i^{\text{CO}2}$. Alternatively, one often substitutes this extra Leontief function away and sees that this is equivalent to imposing a Pigouvian carbon tax rate on the use of this fossil fuel. These costs are added in each production sector and region that participates on the emission permit market.

Benchmark data determine parameters of the functional forms from a given set of benchmark quantities, prices, and elasticities. The underlying data base is GTAP7 for the year 2007 which provides a consistent representation of energy markets in physical units as well as detailed accounts of regional production and consumption as well as bilateral trade flow.

The market clearance conditions determine the equilibrium activity levels and utility levels as the demand for each good or the real income. They also determine the price levels of the production factors.

There exist equilibria on the markets for production factors labor, capital, natural resources, and emission permits. These markets are cleared by respectively the wage rate w_r, the capital rent rate v_r, the rate q_{ir}, and the emission price p^{CO_2}. Notice that the labor market and the capital market are regional markets, while the emission permit market is global. The output level Y_{ir}, import level M_{ir}, and the level of Armington goods, A_{ir} supplied to the economy are determined by total demand for the respective goods. The aggregate goods for the producers can be seen as produced on a sector specific market with associated clearing prices. The market conditions for the consumer goods obtain a similar treatment.

Houba and Kremers (2009) include damage coefficients into the standard microeconomic model, and define an equilibrium that includes such damages. To this end, a productivity parameter is split up between a non-damage related productivity parameter a and a damage parameter d. The damage parameter d is such that it represents an improvement in productivity if $d > 1$ and a deterioration in productivity if $d < 1$. If $d = 1$, then no change is found.

We consider damages to the economy as climate damages. These damages are related to the development in certain climate variables such as mean global temperature, precipitation, sun radiation, see level rises. The relation between the damage coefficient on the one side and the development in mentioned climate variables on the other side is referred to as a damage function. With the choice of the damage function, we choose the sensitivity of the economy to climate change.

The development in climate variables can be generated by linking the economic model to a climate model. A climate model takes up the total emissions from the economy at a certain moment, calculates new greenhouse gas concentrations in the atmosphere and, dependent on these concentrations, determines the new mean global temperature, precipitation etc. that results from it. The damage function then relates this to damages in the economic model and as such it is taken as a shock into the economic model to another equilibrium.

1. The application of border tax adjustments in a game theoretic perspective

This section discusses the application of border tax adjustments to enforce cooperation on the mitigation of climate change impacts as a strategic two player game. One player is the developed world, also referred to as ANX, while the other player is given by the group of emerging economies, here China and India, denoted with ChI.

It is in the interest of the developed countries that ChI sets itself an emission reduction limit. Not doing so would mean that the internationally agreed upon climate goals are not reached, and the efforts of the developed world to reduce the negative consequences of climate change on its economy will be in vain. To enforce such an emission reduction target on ChI, the developed world therefore threatens to impose an appropriate border tax adjustment on imports of goods from the regions that have not set any emission reduction target, i.e. the ChI and RoW.

We assume that the developed world, 'ANX' sets an emission reduction target of 15%, which follows from the ambitious goals of the EU to set an emission reduction of 20%, in combination with the less ambitious goals of the other developed regions that would bring this reduction down to 15%, with respect to 1990 emissions. Within the game, we assume that ChI chooses a certain level $\underline{E}_{\text{ChI}}$ of emission reductions between 0 and 1, hence it chooses from a continuum of possible strategies. ChI then proposes a reduction towards $\underline{E}_{\text{ChI}}$ of its benchmark CO_2 emissions. We let $\underline{E}_{\text{ChI}}$ decrease from one in steps of 0.02.

The benchmark equilibrium does not contain a market for emission permits. Emissions are allowed and there is hence no price attached to it. By introducing an emission permit market where ANX imposes a reduction of 15% and ChI imposes itself a reduction of $\underline{E}_{\text{ChI}}$, we introduce a positive price on emissions, PCARB, in the ANX and ChI regions. This price on emissions provides production sectors in ANX and ChI with an incentive to reduce their emissions. These effects are included into the model by application of a damage coefficient d_r. We relate this damage coefficient to CO_2 emissions using the following damage function:

$$d_r = 1 + \frac{1}{50}\left[\left(\frac{\text{benchmark CO}_2\text{ emissions in region } r}{\text{CO}_2\text{ emissions in region } r}\right)^2 - 1\right]$$

In the benchmark equilibrium, $d_r = 1$, hence all damages are taken relative to the benchmark situation. The quadratic function is chosen arbitrarily while we divided by 50 to obtain results that are in line with the other computations, and to obtain a peaked curve in Figure 2 with respect to the results for the Hicksian Equivalent Variation. The choice of damage function to a large extent influences the results in this paper. We take the damage function to summarize the combination of an original damage function and a climate model. The damage coefficient is associated with the utility function of the regional consumer household only. We consider indirect utility and expenditure. With the assumptions underlying the model, we can compute and subtract damages from the Hicksian Equivalent Variation measure, outside the equilibrium computations.

Setting an emission reduction target by $\underline{E}_{\text{ChI}}$ in ChI, in combination with the 15% reduction in ANX results in an emission permit price p_{CO2} on the emission permit market. This price is used by ANX to impose three possible regimes of border tax adjustments. These regimes are defined by how it incorporates the emissions in the imported and exported goods. We distinguish among charging imports in good g of ChI or RoW according to its

1. Benchmark emission intensity:

$$\frac{p_{\text{CO2}} * \text{total benchmark emissions}}{\text{value of production}}$$

in sector g of ChI or RoW.

2. Actual emission intensity:

$$\frac{p_{\mathrm{CO2}} * \text{total actual emissions}}{\text{value of production}}$$

in sector g of ChI or RoW.

3. Average emission intensity:

$$\frac{p_{\mathrm{CO2}} * \text{average benchmark emissions}}{\text{value of production}}$$

over sector g of ChI and RoW.

These are the levels of border tax adjustments set by ANX on the imports of goods from ChI and RoW. We take the negative of these amounts as border tax adjustments set by ANX on the exports of its own goods to ChI and RoW. The strategy space of the ANX region is then given by the 3 regimes of border tax adjustments. We assume that ANX chooses the same regime for taxing imports and exports.

We do not address the issue of optimal taxation in this paper but stick to the practices proposed by the EU. It might be expected that BTA regime 2 is closest to a form of optimal taxation and that BTA regimes 1 and 3 are therefore sure to give inefficient results.

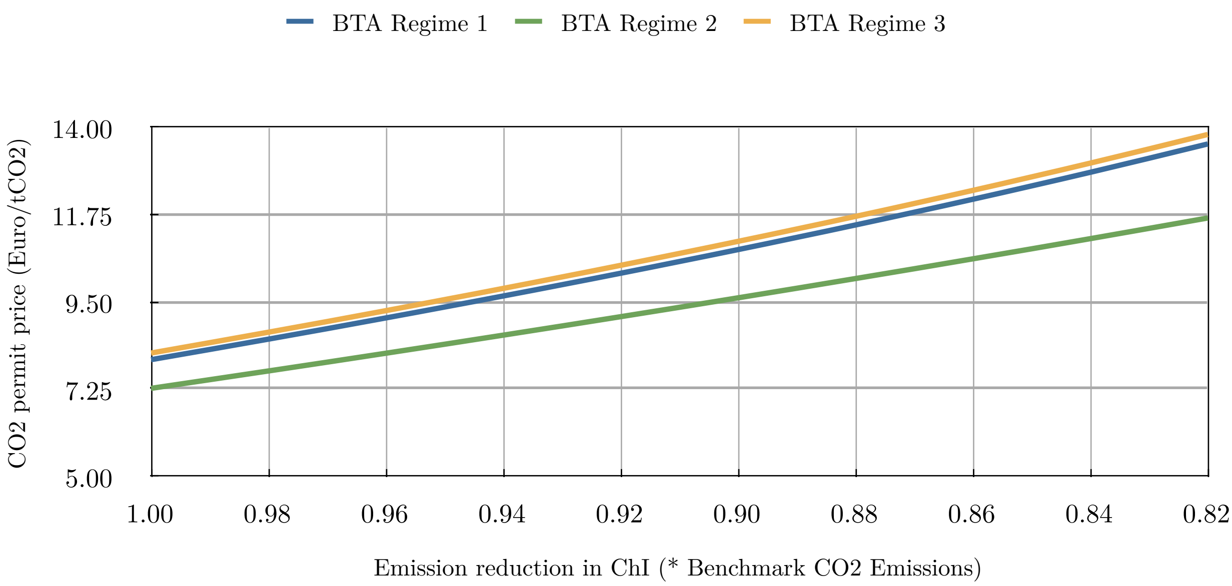

Figure 1: CO_2 permit price (in Euro per tonne CO_2) development according to emission reduction level $\underline{E}_{\mathrm{ChI}}$ ($\underline{E}_{\mathrm{ChI}}$ * Benchmark CO_2 emissions) in ChI. *See also Table 1 in the appendic for the underlying numerical results.*

For each BTA regime, we generate a curve describing the development of the emission permit price over the emission reduction targets $\underline{E}_{\text{ChI}}$ chosen by ChI. This curve describes the marginal costs of abatement in each market party. We let ChI reduce emissions with 2%, 4%, 6%, etc. and obtain Figure 1.

Figure 1 shows a strict increase of the CO_2 price following higher emission reduction targets set in ChI. This region enters the emission permit market with a very high demand for emission permits, a demand that increases more than linear with the increase in ChI's emission reductions. Reducing emissions becomes increasingly harder with the level of emission reduction. Consequently, the emission permit price has to increase more than linear with emission reduction targets in order to clear the underlying permit market.

BTA regimes 1 and 3 are parallel and differ only by using a different constant. It is interesting to see that BTA regime 2, which depends on actual emissions lies significantly lower than in the other regimes. Of course, this regime takes any change in emissions into account, and as Figure 1 demonstrates, is the most (abatement) cost efficient alternative. According to Figure 1, imposing an inefficient BTA regime on goods from ChI (and RoW) leads to significantly higher costs of abatement in ANX and ChI.

Figure 2 describes the development in the Hicksian Equivalent Variation (HEV(r)) including damages for various levels of emission reduction targets set in ChI. The Hicksian Equivalent Variation is a measure for indication policy-induced changes in welfare. It is defined by the amount of income with which the consumer should be compensated for the policy-induced loss in income in order to be as well off in the counterfactual as in the Benchmark equilibrium.

In this paper, we add a damage effect associated with climate change to the determination of the Hicksian Equivalent Variation. The damage coefficient is linked to the regional representative consumer's (indirect) utility. This measure (HEVD(r)) is composed from the original HEV(r) and damage (d_r) in the following way:

$$\text{HEVD}(r) = \text{HEV}(r) + (d_r - 1)^*\text{U}(r),$$

where U(r) denotes the indirect utility of region r. Notice that originally, HEVD(r) = d_r U(r) - $\text{U}^{\text{B}}(r)$, where the latter denotes the benchmark utility level.

The consequences on welfare of BTA regimes 1 and 3 are similar. Any larger effort in reducing emissions in ChI ultimately results in a decrease in welfare to ANX and ChI. The

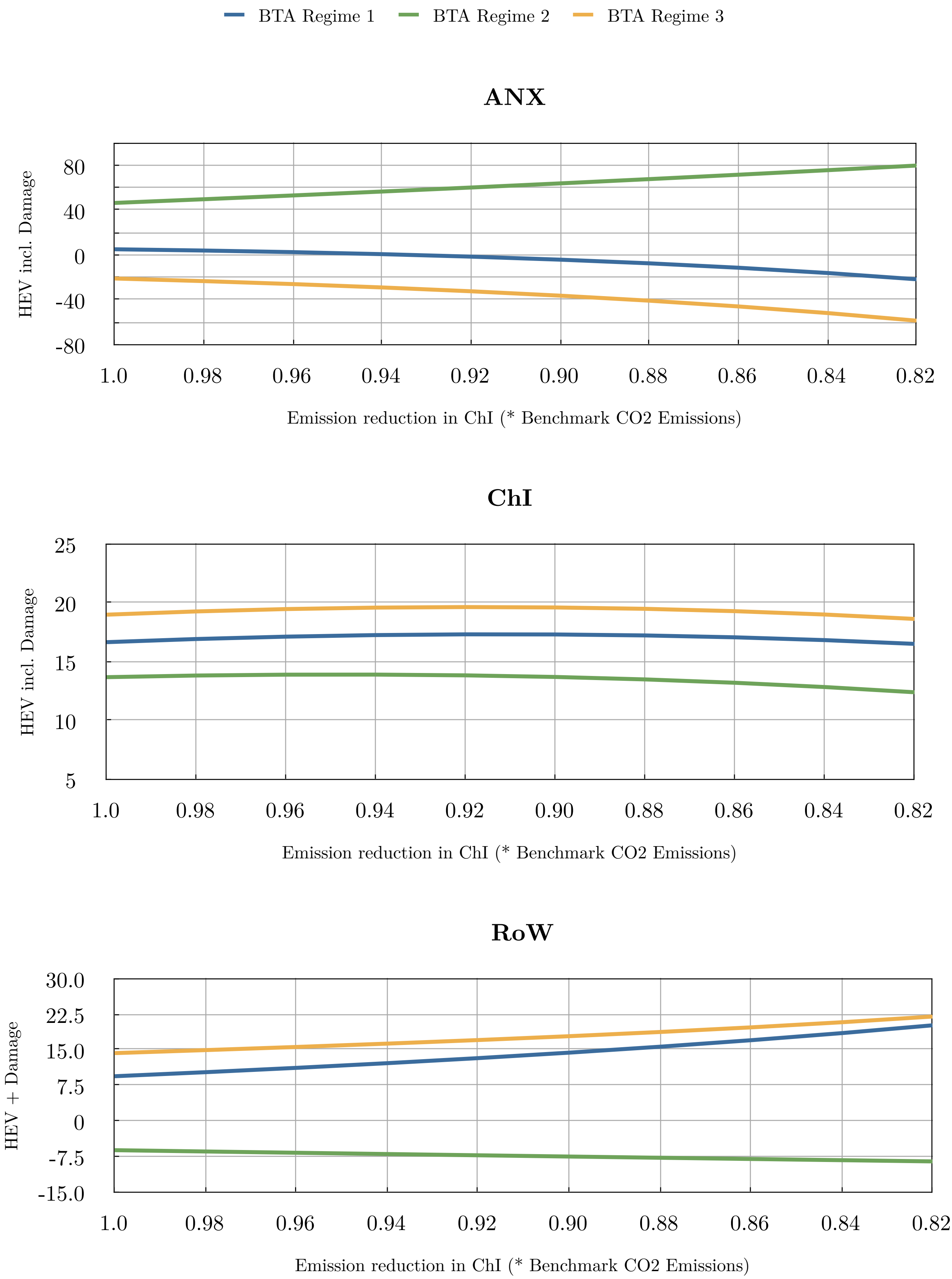

Figure 2: The development of the HEV indicator including damages over various levels of emission reductions $\underline{E}_{\text{ChI}}$ ($\underline{E}_{\text{ChI}}$ * Benchmark CO_2 emissions). *See also Table 2 in the appendix for the underlying numerical calculations.*

figure even shows that ANX, the one that implements these regimes, quickly starts making losses in welfare the more ChI decides to reduce its emissions. Hence, regimes 1 and 3 are obviously a bad choice for ANX to implement.

Only the RoW profits from an increased effort in ChI to reduce emissions. This is partly due to the shift of imports in ANX and ChI towards imports from RoW. Energy-intensive goods in ANX and ChI getting more expensive due to the inclusion of the cost of emissions p_{CO2}. Subsequently, the production of energy-intensive goods is more and more shifted towards the rest of the world, which leads to an increase in emissions in RoW. Hence, here is a leakage effect.

Regime 2 has very different outcomes for ANX and for RoW. Setting border taxes adjusts to the new equilibrium, and whose adjustments in energy use in the production sectors with associated changes in emissions, are now taken account of in setting the levels of border tax adjustments. Welfare according to the Hicksian Equivalent Variation worsens in RoW, while it is all to the benefit of ANX. Apparently, the increase in welfare of RoW due to the aforementioned *leakage effect* experienced under the regimes 1 and 3, are more than compensated away by the border tax adjustments on the goods from and to RoW towards the inclusion of higher emissions. The latter effect we refer to as the *border tax adjustment effect*. For ChI, the development of its welfare follows a peaked curve, implying the existence of an optimal reduction target, given the BTA regime chosen by ANX.

Figure 2 makes it clear that BTA regime 2 is the optimal, i.e. welfare maximizing choice among the three regimes, for ANX. On this curve, there exists an optimal emission reduction target for ChI, that is a reduction target of 8% of it benchmark emission levels. For RoW, BTA regime 2 is about the worst choice ANX could make, since welfare is significantly lower under this regime compared to the other regimes. In this way, RoW is a victim of the game for emission reductions between ANX and ChI.

What can we say about the consequences of this game between ANX and ChI with RoW as the outsider, on the environment? We measure this with the consequences of setting the emission reduction target in ChI on the global emissions. Notice that the emissions in ANX are given by its binding benchmark emissions (12.90 $GtCO_2$) for each possible reduction target in ChI. The emissions in ChI are given by its benchmark emissions multiplied with this reduction target. RoW does not have an emission target, hence its emissions follow from the model calculations. Global emissions then follow from adding these three numbers for each target set in ChI. This provides Figure 3.

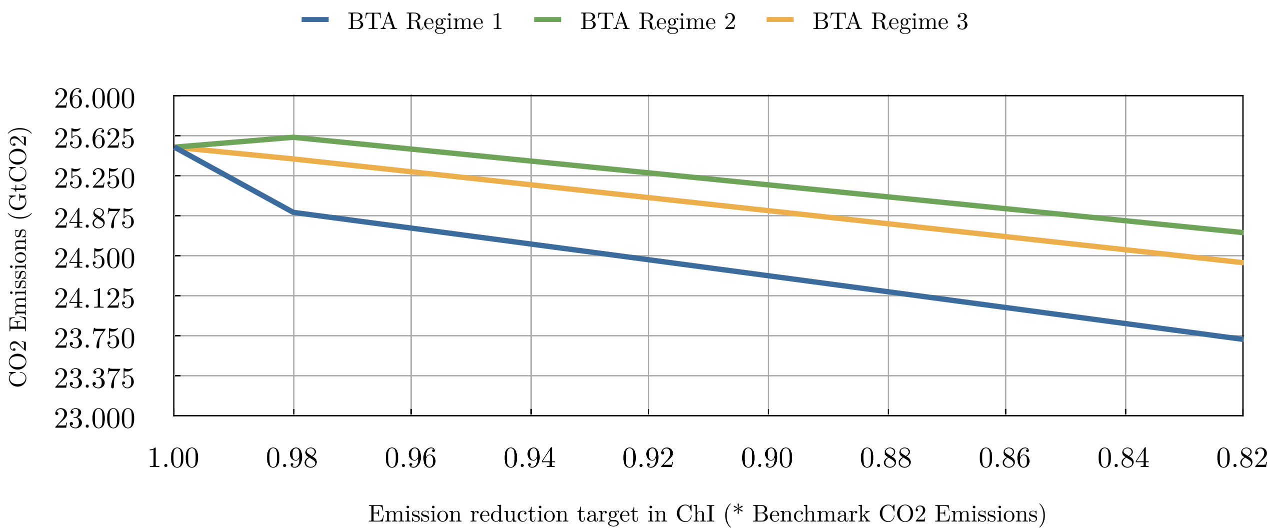

Figure 3: The development of the global CO_2 emissions over various levels of emission reductions $\underline{E}_{\mathrm{ChI}}$ ($\underline{E}_{\mathrm{ChI}}$ * Benchmark CO_2 emissions). *See also Table 3 in the appendix for the underlying numerical calculations.*

Figure 3 again shows the difference between BTA regime 2 on the one hand and BTA regimes 1 and 3 on the other hand. The latter two regimes show that global emissions are monotonically reduced with the strictness of the target set in ChI, while BTA regime 2 shows an initial increase of emissions from its benchmark value of 25.52 $GtCO_2$ to a maximum of 25.61 $GtCO_2$ at $\underline{E}_{\mathrm{ChI}} = 0.98$, after which it decreases nearly linearly down like the other two regimes.

An explanation for this effect is included in the definition of the BTA Regime 2. There are two effects that counteract each other. The aforementioned leakage effect causes an increase in emissions in the rest of the world while the border tax adjustement effect does the opposite. Figure 3 indicates that for emission reductions in ChI up to 2%, the leakage effect will dominate the border tax adjustment effect.

At the solution of the game, where ANX chooses BTA regime 2 and ChI decides for an emission target $\underline{E}_{\mathrm{ChI}} = 0.92$, global emissions turn out to be 25.28 $GtCO_2$, a reduction of 25.52-25.28=0.24 $GtCO_2$. Clearly, Figure 3 shows that, at this target, the other regimes offer results that are more positive towards the environment itself then the economically more efficient BTA Regime 2. This is obviously due to the increase in emissions under BTA regime 2 at an initially low target where the leakage effect dominates the border tax adjustment effect.

5. Conclusions

Mitigating the consequences of climate change on the economy is a global effort. In order for it to be successful, all countries need to participate. Just before the United States left the Kyoto Protocol agreements, it was urging for a significant role of the fast developing countries such as China and India in the international effort on climate change mitigation. Clearly any serious effort to reduce the effects of climate change cannot do without the participation of the countries whose economies are growing rapidly, soon to become one of the leading contributors to global emissions. Among these countries, China and India however see these requirements as a severe limitation on their growth towards a role inside the developed world.

The developed countries however are seeing their efforts nullified by this attitude of the fast developing countries. Many of them are discussing so-called border tax adjustments to goods imported from China and India in an effort to use this as a threat. To abstain from these adjustments, China and India are expected to come up with a significant emission reduction goal to participate on an emission permit trading market.

While Alexeeva-Talebi, Löschel, and Mennel (2008) give a description of the issues around border tax adjustments and emission permit trading, this paper takes a more strategic view of the issue. We describe a game between two players, one representing the developed world and one representing the emerging economies, here China and India, while the rest of the world takes up the role of an outsider whose welfare is significantly affected by the outome of the game. The developed world chooses its welfare maximizing option from three possible border tax adjustment regimes to implement on its imports and exports set by China and India (and on the rest of the world), given the emission reduction target chosen by China and India. These emerging economies choose their welfare maximizing emission reduction target, given the BTA regime chosen by the developed world. Within the PACE computable general equilibrium model, we compute an equilibrium to this game, where the developed countries chooses the most cost-effective border tax adjustment regime and China and India decide to set an emission reduction target of 8% of their benchmark emissions.

With respect to the outside player, the rest of the world, we distinguish two effects that may oppose each other with respect to its consequences on welfare and global emissions. The leakage effect describes the increase in emissions from the rest of the world due to the substitution of the game players' energy-intensive goods to the goods in the rest of the world. The border tax adjustment effect describes the decrease in emissions in the rest of the world due to the price increase on the goods imported from the rest of the world in the game players' economies. The cost effective border tax adjustment regime shows an initial domination of the leakage effect over the border tax adjustment effect for emission targets less than 2% in China and India, which causes it to be the worst case for the rest of the world and the environment.

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Appendix: The Underlying Numerical Results

$\underline{E}_{ChI}$	**BTA Regime 1**	**BTA Regime 2**	**BTA Regime 3**
1.00	8.01	7.27	8.18
0.98	8.54	7.72	8.72
0.96	9.09	8.18	9.27
0.94	9.65	8.64	9.85
0.92	10.24	9.12	10.44
0.90	10.85	9.60	11.06
0.88	11.48	10.10	11.70
0.86	12.15	10.61	12.37
0.84	12.84	11.13	13.08
0.82	13.57	11.66	13.82

Table 1: CO_2 permit price (in Euro per tonne CO_2) development according to emission reduction level $\underline{E}_{ChI}$ ($\underline{E}_{ChI}$ * Benchmark CO_2 emissions) in ChI. *See also Figure 1.*

r	$\underline{E}_{\mathrm{ChI}}$	BTA Regime 1	BTA Regime 2	BTA Regime 3
ANX	1.00	4.8780	46.2902	-21.2409
	0.98	3.7564	49.5844	-23.5784
	0.96	2.3190	52.9761	-26.2275
	0.94	0.5178	56.4680	-29.2375
	0.92	-1.7034	60.0628	-32.6658
	0.90	-4.4108	63.7635	-36.5796
	0.88	-7.6832	67.5732	-41.0585
	0.86	-11.6150	71.4952	-46.1973
	0.84	-16.3203	75.5329	-52.1103
	0.82	-21.9393	79.6900	-58.9367
ChI	1.00	16.6267	13.6523	18.9633
	0.98	16.8951	13.7915	19.2396
	0.96	17.0963	13.8645	19.4404
	0.94	17.2290	13.8697	19.5645
	0.92	17.2915	13.8053	19.6104
	0.90	17.2819	13.6696	19.5765
	0.88	17.1985	13.4604	19.4609
	0.86	17.0388	13.1755	19.2615
	0.84	16.8007	12.8126	18.9760
	0.82	16.4816	12.3690	18.6021
RoW	1.00	9.3574	-6.2359	14.2348
	0.98	10.2106	-6.5105	14.8690
	0.96	11.1267	-6.7814	15.5336
	0.94	12.1129	-7.0489	16.2372
	0.92	13.1777	-7.3133	16.9897
	0.90	14.3307	-7.5751	17.8022
	0.88	15.5838	-7.8345	18.6876
	0.86	16.9508	-8.0919	19.6612
	0.84	18.4486	-8.3477	20.7407
	0.82	20.0976	-8.6023	21.9477

Table 2: The development of the HEV indicator including damages over various levels of emission reductions $\underline{E}_{\mathrm{ChI}}$ ($\underline{E}_{\mathrm{ChI}}$ * Benchmark CO_2 emissions). *See also Figure 2.*

$\underline{E}_{\text{ChI}}$	**BTA Regime 1**	**BTA Regime 2**	**BTA Regime 3**
1.00	25.5175	25.5175	25.5175
0.98	24.9062	25.6100	25.4071
0.96	24.7578	25.4987	25.2861
0.94	24.6094	25.3872	25.1649
0.92	24.4608	25.2757	25.0436
0.90	24.3120	25.1640	24.9221
0.88	24.1631	25.0523	24.8005
0.86	24.0139	24.9404	24.6786
0.84	23.8646	24.8284	24.5565
0.82	23.7150	24.7163	24.4342

Table 3: The development of the global CO_2 emissions over various levels of emission reductions $\underline{E}_{\text{ChI}}$ ($\underline{E}_{\text{ChI}}$ * Benchmark CO_2 emissions). *See also Figure 3.*