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Leakage from climate policies and border tax adjustment: lessons from a geographic model of the cement industry

Abstract

We present a spatial international trade model, GEO, which computes transportation costs by not treating markets as dimensionless points and explicitly represents capacity shortages and investment decisions in new production capacities. We link it to CEMSIM, a partial equilibrium model of the world cement industry developed by the IPTS. We assume that the Kyoto Protocol Annex B countries (except the USA and Australia), create a CO_2 tax at 15 euros per tonne. This policy entails significant emissions reductions (around 20%) in these countries. A significant leakage occurs, with an emissions increase in the rest of the world of around 20% of the emissions reduction in Annex B-USA&Australia. We thus run two scenarios combining a CO_2 tax with border-tax adjustments (BTA). With the more ambitious BTA tested, not only is there no leakage, but emissions in the rest of the world decrease slightly. However, compared to business-as-usual, non-Annex B price-competitiveness and production decrease a little and these countries loose some market shares, so they could attack this system as distorting competition in favour of Annex B countries. A less ambitious BTA is thus tested, which cannot be criticised on this ground and prevents almost all leakage. The only drawback of both BTA policies is that the cement price in Annex BUSA& Australia increases a little more than without BTA, further impacting the cement consumers in these countries.

Keywords

Cement, leakage, spillover, climate change mitigation, Kyoto Protocol, border-tax adjustment, international trade, transportation cost

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Introduction[2]

A recurrent concern raised by industry against climate policies is the fear of competitive distortions, industrial relocations and carbon leakage in case of asymmetric constraint. The recent entry into force of the Kyoto Protocol is unlikely to reduce these concerns since the developed countries that have ratified it only account for 35% of world energy-related CO_2 emissions (Enerdata, 2005, p. 9).

Intuition suggests that these sectors may be affected by strong carbon asymmetric constraints. But to this intuition can be opposed the fact that the carbon-intensive sectors are typically weakly exposed to international competition. International trade of cement for example accounts for less than 7% of the world consumption, mostly because of the existence of significant transportation costs and of capacity shortages.

What makes difficult to assess both the magnitude and the determinant of carbon leakage is the fact that the current representation of international trade is dominated by the well-known Armington specification, or similar functional forms. This specification assumes that products are differentiated by their place of production. For example the chemicals produced by different countries are not perfect substitutes. In applied models, this tool is used in such a way that it merges all the grounds for imperfect substitution – heterogeneity of the products throughout the world, national preferences, transportation costs – in the Armington substitution elasticity, or a parameter with an equivalent meaning, which is either econometrically calibrated, what is difficult[3], or just guesstimated.

Our intuition is that, even though the use of the Armington specification is probably the best compromise for most sectors, especially aggregated ones, progress can be made through an alternative approach for the sectors dealing whit relatively homogeneous products whose trade is not much affected by national preferences, and where transportation costs and capacity constraints are central to explain international trade patterns. Many GHG-intensive sectors fit with these characteristics.

Such an alternative must have three objectives. First, it has to represent satisfactorily transportation costs, notably by not treating markets as dimensionless points. Second, it must take explicitly into account capacity shortages. Third, investment decisions in new production capacities have to be modelled realistically.

We developed a spatial international trade model, GEO, that:

- drops the imperfect substitution assumption among goods produced in different places;

- makes explicit the transportation costs, for both road and sea transportation, utilising a spatial representation of the world including 15 500 consuming “areas”,
- represents the competition among producers in every consumption area, taking into account their differentiated marginal production costs, transportation costs and capacity shortages by assuming that producers subjected to such a constraint deliver their production in the most profitable areas
- justifies investment decisions by explicitly representing the producers expectation of which amount of product can be sold and where.

We applied this model to cement for three reasons. First, the characteristics of the cement sector particularly suit to the use of GEO. Second, this sector is an important greenhouse gas emitter: it accounts for around 5% of global anthropogenic CO_2 emissions (IEA, 1999). Third, it is potentially one of the most impacted by a climate policy: among twelve UE 15 industry sectors, non-metallic minerals – mostly cement – have the second direct CO_2 emission/turnover ratio (Quirion and Hourcade, 2004)[4]. Cement manufacturers thus claim that an ambitious climate policy would impose an additional burden that may jeopardise their competitiveness and induce carbon leakage (e.g., British Cement Association, 2004).

To represent the cement industry, we use a modified version of CEMSIM, a recursive

[2] The present analysis has benefited from a deep collaboration with the Institute for Prospective Technological Studies (IPTS – Joint Research Centre – European Commission). Our analysis is partly based on the world cement model CEMSIM developed by L. Szabo, I. Hidalgo, J. C. Ciscar, A. Soria and P. Russ, from the IPTS. We thank them and the IPTS for the explanations on the model, for the free access to a world cement industry database compatible with the model structure and for having hosted one of us at the IPTS for two months. We also thank F. Le Gallo (INSEE) for providing data on international cement trade and J.C. Hourcade and F. Gusforf as well as the participants at the CIRED seminar for useful comments.

[3] Standard methods are likely to underestimate this coefficient (Erkel and Mirza, 2002). For example, if an exporting country increases the quality of its products vis-à-vis its competitors (in other words if its non-price competitiveness is improved), it will typically increase both its export level and its price. If econometric estimations are not able to control this quality effect, they will wrongly find a positive correlation between the export price and quantity exported (or at least the observed correlation will be "less negative" than if quality was taken into account). As a consequence, export elasticities (i.e., the decrease in exports following an increase in export price) will be underestimated, and Armington elasticities as well. However alternative econometric methods do not lead to robust results (Erkel and Mirza, 2002).

bottom-up model built by the IPTS team (see Szabo et al., 2003 and 2006). GEO and CEMSIM are integrated, allowing us to build a business-as-usual scenario until 2030 and three climate policy scenarios.

A CO_2 tax at 15 euros per tonne, which is equivalent to auctioned emission allowances with the same price, in the Kyoto Protocol Annex B countries that have ratified it (thereafter referred to as "the Annex B-R") turns out to entail significant emissions reductions in these countries. However, an important carbon leakage occurs.

The same policy with border-tax adjustments (BTA), i.e., a rebate on cement exports and a taxation of imported cement in Annex B-R, is simulated. Two BTAs are tested. In the first one, exported production is completely exempted from the climate policy and imports of cement from the rest of the world are taxed in accordance with the CO_2 intensity of the cement production in the exporting country. In the second BTA scenario, exports benefit from a rebate corresponding only to the least CO_2-intensive technology available at a large scale, and imports are taxed to the same level. Such a system is proposed by Ismer and Neuhoff (2004) who argue that it is compatible with the WTO rules, contrary to the first one we test. In the two BTA scenarios, the carbon leakage decreases. It is even replaced by a slight spillover in the first one. However, in both cases, the cement price in Annex B-R increases more than without BTA, further impacting the cement consumers in these countries.

The article is organised as follows: we first describe the GEO-CEMSIM model (section 1), then the business-as-usual simulation (2), the policy simulations without (3) and with (4) the border-tax adjustment, and section 5 concludes.

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[4] Only electricity generation has a higher ratio, but this sector is largely sheltered from international competition by transmission losses.

1. The GEO-CEMSIM model

1.1 GEO

In GEO, the world is modelled as an ensemble of cement consumption "areas" on the one hand and producing countries on the other hand[5]. An area is characterized by its geographical position on the globe. The areas used are the 1°x 1° squares defined in the EDGAR database (RIVM, 2001), but we subdivided squares with a high population and dropped squares where the population is negligible (figure 1). Because of the computation constraints, we assume that the totality of the market of a given area is taken by the producers of only one country which, given that we have 15.500 areas, is an acceptable approximation, at least in a first step.

Figure 1: Areas of GEO

A producing country is first characterized by its variable production cost, its production capacity and the intensity of the competition among its domestic producers. We assume that a Cournot oligopoly competition takes place among producers of the same country, since it is well known that the cement market is far from pure competition (Johnson and Parkman, 1983). A country is also characterized by its harbours able to trade cement. There are 1.600 such sea harbours in the world, according to the Lloyd's list (2004). 7.500 border posts, that we label "land harbours", are defined every 25 km on land borders, in order to allow us for modelling land trade.

GEO then calculates the minimum transportation cost from every producing country to every area, using road national transportation costs and international sea transportation costs. A fixed and a variable transportation cost are distinguished for each transportation mode.

We assume that a producing country is ready to sell its production in an area at any price bigger than the sum of its variable cost and the transportation cost to this area, subject to a capacity constraint. When the latter is binding, a producing country sells its production in the most profitable areas. Of course, the set of "most profitable areas" depends on other producing countries' behaviour, hence the need for an adequate algorithm to determine simultaneously what supplier takes each area. The cement price a firm applies in an area is limited by a double competition pressure:

- international competition from the other producing countries (Bertrand competition), and;
- national competition pressure from firms of the same producing country (Cournot competition). The number of firms in the Cournot model is calibrated to match the price/cost margin in the calibration year (1997), and assumed identical thereafter.

In every area, the cement supplier thus applies a profit margin[6] which is the minimum between the profit margin defined by the international competition and the profit margin defined by the national oligopolistic competition. Using the variable cost and capacity constraint of every country as well as the minimum transportation cost between every producing country and every consuming area, GEO gives for every area the cement price and where it comes from. At the country level, it gives the production and the average cement price (which is the weighted sum of the prices in the areas of this country).

Every country has a capacity constraint, which is not fixed but may be relaxed every year by investing in new capacities. In GEO, a country builds new capacities for the market of a given area if it expects not only to sell its new production there but also to cover its fixed construction cost, despite the competition of the existing and future capacities of the others.

In order not to mislead the reader of our quantitative results, it is useful to place here two caveats. First, we model no inertia in trade, whereas in the real world, for a cement manufacturer, exporting in a new market takes some time, notably to develop a distribution network. Second, the assumption of Bertrand competition among producers of different countries seems too harsh since there is some oligopolistic behaviour among them. However, it is the best compromise we found to date between modelling constraints and realism. As a consequence, real-world changes are likely to be smoother and less intense than modelled.

1.2. CEMSIM

An inverted U-shape curve of “intensity of use” relates the evolution of cement consumption to the per capita GDP. As in the original CEMSIM IPTS model, the demand curve for cement is assumed isoelastic, with a price-elasticity of 0.2, a value close to that estimated by La Cour and Mollgaard (2002, cited and used by IEA, 2004).

CEMSIM pays particular attention to fuel and technology dynamics. Seven technologies are included, characterized by energy, material and labour consumptions, an investment cost and a set of retrofitting options. We modified the original CEMSIM model to introduce more flexibility in the content of clinker, the carbon intensive intermediary product, in cement and in the choice of non primary fuels, following discussions with French cement industrials.

We stress that the quantification of some technical flexibility (clinker ratio, retrofitting, and fuel choice) is very difficult, so our quantitative results should be taken with some care.

The main exogenous variables of CEMSIM are GDP, population, electricity and primary fuel prices, all taken from the POLES model developed by LEPII-EPE. Primary fuel prices are higher under business-as-usual than under mitigation policies, since in POLES these policies reduce fuel demand, thus world fuel prices. Prices of other fuels (waste and wood fuels,

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[5] Areas, grouped together, form consuming countries. In GEO we have the same 47 consuming and producing countries.

petroleum coke) are calibrated.

We use 1998 and 1997 data on consumption, production capacity, energy demand (CEMBUREAU, 1999, 2002) and cement bilateral trade (OECD series C) to calibrate the GEO-CEMSIM model, which is then recursively run with a yearly step.

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[6] We define profit margin as the ratio (cement price – variable production cost – transportation cost) / (variable production cost + transportation cost).

2. World cement industry in the “business-as-usual” scenario

The business-as-usual scenario (BaU) is a necessary preliminary step to assess the impacts of a carbon mitigation policy. Moreover it provides interesting insights.

To present the results, we aggregate the 47 producing regions of our model to form 12 regions:

1. **Europe** : EU25, Bulgaria, Romania and the rest of western Europe,
2. **R&U**: Russia and the Ukraine,
3. **Japan**,
4. **Canada**,
5. **The USA**,
6. **RJAN**: Rest of Japan, Australia and New Zealand (Mostly Australia and New-Zealand),
7. **TRR**: Turkey, Rest of the CIS and Rest of Central and Eastern Europe,
8. **LAM**: Latin America,
9. **India**,
10. **China**,
11. **RoA**: Rest of Asia,
12. **A&ME**: Africa and Middle-East.

The first four regions have ratified the Kyoto Protocol and will implement climate policies in the next sections[7]. We label them the Annex B-R countries.

2.1. Increasing share of the developing countries in the world growing consumption

At the world level, cement consumption is estimated to increase from 1630 Mt in 2000 to 2900 Mt in 2030, corresponding to an annual 2% growth rate.

0
100
200
300
400
500
600
700
800
900
1000
Europe
R&U
Japan
Canadax10
US
A
RJANx10
TRR
LAM
India
China
RoA
A&ME
Mt of cement
2000
2010

2020
2030

Figure 2: Consumption in BaU

At the regional level, the evolution of cement consumption is highly dependent on the inverted U-shape hypothesis for the consumption path. The model predicts a high growth in developing regions. China and R&U peak around 2020 whereas the consumption in India, TRR, A&ME, LAM and RoA is still growing in 2030. On the contrary, no developed region sees its consumption growing after 2020. Whereas these regions represented 24% of the world consumption in 2000, they are projected to represent only 13% in 2030.

2.2. Importance of the "domestic excess capacities" and decrease in the cement trade flows

A feature of cement international trade is that, according to our model and as in the real world until now according to industry experts, very few capacities are built in order to export. Almost all the cement traded come from "domestic excess capacities". The domestic excess capacities are the capacities built for the domestic market but that are not fully used for it. For example such capacities exist in countries with growing demand because its producers anticipate this growth by over-sizing their new plants. The higher is the growth of the consumption in a country, the higher is the amount of domestic excess capacities of its producers.

Whereas very few export capacities are built, some countries see their exports limited by their capacity. Had they bigger domestic excess capacities, they would export more. Why don't they build export capacities? Because the expected gains of such capacities would not be sufficient to cover their investment cost.

According to our model, another feature of international trade is that its intensity drops between 2002 and 2004 from 7 to 4% of the world production, because of the exogenous increase in sea transportation costs between these two time periods. This increase, observed in reality, is due to the scarcity of transport capacities which originates in their intensive use to supply Chinese economical growth. Despite the stabilisation of the sea transportation costs after 2004, the intensity of international trade keeps on decreasing until 2030 in our model. This is mostly due to the fact that, after 2010, the growth of the consumption slows down in many countries. Therefore, their amounts of domestic excess capacities drop, and so does their ability to export.

In a few cases, cement trade is due to a lack of production capacities in the importing country (e.g., the Netherlands around 2000). But it is generally driven by differences in production costs and, as we have just seen, may be limited by capacity shortages.

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[7] Unfortunately, since New Zealand is merged with Australia in our set of 47 producing countries, we have to assume that it does not implement the Kyoto Protocol although it has ratified this agreement.

Import
Mt of cement
Export
Mt of cement
0
5
10
15
20
25
Europe R&U Japan Canada USA RJAN TRR LAM India China RoA A&ME
2000
2010
2020

2030
25
20
15
10
5
0

Figure 3: Exports and Imports in BaU

Concerning the Annex B-R countries, we observe that European imports drop after the increase in sea transportation costs and come mostly from TRR, A&ME and LAM. Such a drop occurs in Canada which only keeps on importing cement from the USA. R&U imports some cement during all the simulation, from Europe, TRR, RoA and China, whereas Japan does not.

After the increase in sea transportation costs, exports of European, Japanese and R&U producers drop. Then, European exports focus on the nearest countries. Utilising mostly the road to export cement to the USA, its main client, Canadian exports are not so much impacted by this increase.

For most of the countries, cement trade is marginal, the ratio (Export-Import)/Production being very rarely higher than 10% in absolute value. Therefore, in general, the national production almost equals the national consumption.

2.3. “CO_2 emission / production” relative decoupling

CO_2 emissions are projected to grow by 55% from 1320 MtCO_2 in 2000 to 2035 in 2030 corresponding to a 1.5% average annual growth rate. The relative decoupling with the consumption, which grows in average by 2% per year, is mostly due to the decrease in the fuel consumption per ton of cement, thanks to the use of more efficient machines.

0
100
200
300
400
500
600
700
800
Europe
R&U
Japan
Canadax10
USA
RJANx10
TRR
LAM
India
China
RoA
A&ME
Mt CO2
2000
2010
2020
2030

Figure 6: Carbon emissions in BaU

Unsurprisingly, the spatial distribution of emissions is roughly correlated with the increase in production. Share of China in world emissions decreases through time but it remains the largest CO_2 emitter with more than 30% of the world emissions in 2030. The share of developed countries drops from 22% to 12% of world emissions in 2030.

3. “Climate policy without border-tax adjustment” scenario ("No BTA")

3.1. Definition of No BTA

In this scenario, we assume that Annex B-R countries implement a CO_2 tax or a CO_2 Emission Trading Scheme[8] with auctioned allowances, without revenue recycling (thereafter: "the climate policy"). For 2008-2012, we rely on the estimation of the POLES model, assuming that Russia and the Ukraine use their market power to rise the international CO_2 price, up to 15 euros per tonne (Szabo and al., 2003). We assume that this price is sustained until the end of the simulation period and that no non-Annex B-R country takes on emission targets until 2030. We assume no Clean Development Mechanism.

This climate policy can not be considered as the most likely outcome of the climate negotiations but has the advantage of simplicity as a benchmark for comparative analysis.

3.2. Technological changes triggered by the carbon value

The carbon value triggers different mechanisms in CEMSIM-GEO: reduction of cement demand due to the increase in production costs and in prices; substitution between clinker and added materials in cement composition; substitution between high and low carbon fuels (from coal, oil and petroleum coke to gas, waste and wood fuels); retrofitting of carbon intensive technologies to low carbon technologies; changes in technological choices for new plants.

Compared with BaU, variable production costs in Annex B-R countries increase in average by 10 € per tonne of cement (+30%) from 2008 on.

[8] We stress that in the EU ETS, allowances are not auctioned but given for free, and the quantity distributed is influenced by their decisions. In particular, a firm closing an installation will generally stop received allowances and conversely, free allowances are distributed for new installations [Schleich and Betz, 2005]. As a consequence, the competitiveness impact of the EU ETS and its impact on emissions will be much lower than that of the policy we simulate, for a given CO_2 price.

Regarding the non-Annex B-R countries, they generally benefit from lower production costs thanks to the decrease in Annex B-R demand for carbon-intensive fuels, and therefore in prices.

3.3. Significant impacts of the climate policy on trade flows and no building of export capacities

-4
-3
-2
-1
0
1
2
3
4
Europe
R&U
Japan
Canada
USA
RJAN
TRR
LAM
India
China
RoA
A&ME
Mt of cement
2000
2010
2020
2030

Figure 7: No BTA: change in Exports compared to BaU

Consequently, the climate policy has significant impacts on cement trade. Compared with

BaU, Europe, Canada and Japan stop to export. Inversely R&U, which proves to be less impacted than European countries as we will see below, increases its exports to Europe.

-6
-4
-2
0
2
4
6
8
Europe
R&U
Japan
Canada
USA
RJAN
TRR
LAM
India
China
RoA
A&ME
Mt of cement
2000
2010
2020
2030

Figure 7: No BTA: change in Imports compared to BaU

Compared with BaU, Canada increases its imports from 19 to 26% of its consumption in 2010[9], R&U increases from 3 to 10% and Europe from 1 to 4%. Japan, as in BaU, does not import cement: the carbon constraint is not strong enough to outweigh its costcompetitiveness observed in BaU.

One interesting point is that only few capacities are built in non-Annex B-R to export in Annex B-R, despite the higher production cost of the latter. Exports keep on coming from domestic excess capacities, although the exports of some non-Annex B-R countries are not limited by transport costs but by capacity shortages. This traduces the fact that the rise in Annex B-R production costs is not high enough to outweigh not only the transportation costs but also the investment costs.

3.4. Significant drop in the production of Annex B-R

The growth in variable production costs highly impacts the industry of Annex B-R countries for two reasons: fall in domestic consumption (3% in average in 2010, 4% after) and lower market shares in the world cement market. Finally, the production of the Annex B-R countries drops in average by 7.5% in 2010, 2020 and 2030.

-50
-40
-30
-20
-10
0
10
Europe
R&U
Japan
Canada
USA
RJAN
TRR
LAM
India

---

[9] Figure for 2020 and 2030 are presented in Demailly & Quirion (2005).

China
RoA
A&ME
%
2000
2010
2020
2030

Figure 8: No BTA: Production compared to BaU

3.5. Significant drop in CO_2 emissions from Annex B-R and important carbon leakage

Emissions per tonne of cement in Annex B-R countries decrease with the implementation of the climate policy: from -12% in 2010 to -15% in 2030. The magnitude of this drop is roughly the same in all Annex B-R countries, R&U excepted which turns out to have more technical flexibility.

Cumulated with the fall in production, this decarbonisation leads to a decrease in carbon emissions of Annex B-R ranging from 18% in 2010 up to 22% in 2030.

-50
-40
-30
-20
-10
0
10
Europe
R&U
Japan
Canada
USA
RJAN
TRR
LAM
India
China
RoA
A&ME
%
2000
2010
2020
2030

Figure 9: No BTA: CO2 emissions compared to BaU

Part of these reductions is compensated by emissions increase in non-Annex B-R countries. These countries are less carbon efficient than Annex B-R countries and the gap increases with the implementation of the climate policy[10].

The resulting leakage rate (emissions increase in countries outside the Annex B-R divided by the emissions decrease in Annex B-R countries) equals 25% in 2010, 13% in 2020 and 16% in 2030[11]. All in all, world emissions decrease by around 2% in 2010, 2020 and 2030

4. “Climate policy with border-tax adjustments” scenarios

4.1 Definition of the two BTA scenarios

One way of preventing carbon leakage and limiting the effects on competitiveness of a fragmented climate regime is to impose border-tax adjustments (BTA): tax exemption of GHG-intensive products and materials exported to non-Annex B-R countries; border tax on the importation of these products and materials from outside Annex B-R.

Using analytical models, several authors have demonstrated the rationale for BTA for dealing with international pollutions: Markusen (1975), Hoel (1996) and Maestad (1998). In particular, Hoel (1996) showed that BTA are a better response to pollution leakage than the usually applied differentiation of the tax level between the exposed and the sheltered sector.

More recently, Mathiesen and Mæstad (2002), with a partial equilibrium world model of the steel industry, and Majocchi and Missaglia (2001), with a general equilibrium model, quantified the impact of BTA. It turned out that BTA prove to be efficient to prevent adverse impact on the domestic industry of a carbon constraint.

We first assess below this system in the “Complete BTA” scenario, but its compatibility with the WTO/GATT is controversial; see Hoerner (1998) for an early discussion and Ismer and Neuhoff (2004) for an up-to-date synthesis. The latter two authors conclude that to be WTOcompatible,
the BTA should be set "at the level of additional costs incurred for procurement
of CO_2 emission permits during production of processed materials using the best available technology". This is why without pushing this juridical discussion further, we provide an application of the BTA proposed by Ismer and Neuhoff in the "WTO BTA" scenario. We take as best available technology the dry rotary kiln with pre-heater and pre-calciner fuelled by natural gas[12].

In the rest of this section, we address two questions: do the two BTA scenarios effectively prevent CO_2 leakage, and could non-Annex B-R countries attack these systems on the ground that they suffer too much of them?

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[10] We notice that Chinese and Indian emissions decrease and that RJAN’s emissions increase, marginally, although these countries are not impacted directly by the ETS (they do not increase or decrease their imports or their exports compared to BaU). It is due to the fact that their consumption levels are indirectly impacted by the changes in the competition pressure they face.

[11] This is not the place to explain in detail the ups and down of the leakage rate. Suffice it to say that part of the decarbonisation is due to a more important use of waste recycling or a higher utilisation of efficient technologies; after 2020, prices of the waste recycling increase whereas the potentials of efficiency improvements are saturated.

[12] An even less CO2 intensive solution is to burn waste and wood fuels instead of gas, but since we assume that this solution may not be generalised because of the limited availability of these fuels, we did not retain it as "the best available technology".

4.2. Differentiated impacts on cost-competitiveness

Thereafter, we present the results of the two BTA scenarios in comparison with BaU. For simplicity sake, we present the results for Annex B-R and non-Annex B-R countries in aggregate, and for 2010 only. We insist on the differences of the impacts inside and outside Annex B-R markets.

Annex B markets

0
5
10
15
20
25
30
35
40
45
50
Annex B Non Annex B
euro per tonne of cement
BaU
No BTA
Complete BTA
WTO BTA

Figure 10: Variable production in 2010 on Annex B markets

Under *Complete BTA*, Annex B-R variable production cost in Annex B markets increases in average by 10.5€ per tonne of cement in 2010. It increases in average by 12.5€ for the non-Annex B countries. Thus, competition terms on Annex B markets are modified in favour of Annex B countries, which are in general more carbon efficient than the others. Indeed, not only do they use more energy efficient technologies and less carbon intensive fuels already in BaU, but the climate policy also leads them to reduce their CO_2 emissions per tonne of cement (especially by decreasing their clinker rates), while non-Annex B countries do not. Therefore the Complete BTA system tends to improve the cost-competitiveness of Annex B countries in their territory.

Under *WTO BTA*, the “after tax production cost” of non-Annex B-R countries in Annex B-R markets is the one of the less carbon intensive technology. Their variable production cost increases in average by 10€ in 2010. Therefore, the BTA WTO system results into a slight degradation of the cost-competitiveness of Annex B-R countries on their territory.

Non-Annex B markets

14

0
5
10
15
20
25
30
35
40
45
50
Annex B Non Annex B
euro per tonne of cement
BaU
No BTA
Complete BTA
BTA WTO

Figure 11: Variable production cost in 2010 on non-Annex B markets

On the markets outside Annex B-R, the *Complete BTA* still impacts variable production costs:

- Countries implementing the climate policy speed the retrofitting of their plants toward efficient technologies.
- In the other direction, their average fuel costs increase (in general). This is due to the higher utilisation of low C fuels that are, most of the time, more expensive.

Finally, we observe that most of the Annex B-R countries increase their cost-competitiveness on the markets outside their territory in 2010 (-0.4€ in average). However these gains only last a few years after the implementation of the system.

Under *the WTO BTA*, the cost-competitiveness of Annex B-R countries on the non-Annex BR markets suffers a bit since the technologies less efficient than the Best Available Technology are partially taxed. Their variable production cost increases, in average by 1.5€ in 2010.

4.3. Increase in Annex B-R net exports

0
2
4
6
8
10
12
14
Import Annex B / Export Non
Annex B
Export Annex B / Import Non

Annex B
Mt of cement
BaU
No BTA
Complete BTA
WTO BTA

Figure 12: Imports and Exports in 2010

Annex B markets

In the *Complete BTA* scenario, as we have just seen, most Annex B-R countries increase their cost-competitiveness inside their territory. Therefore non-Annex B-R countries loose some market shares, paving the way to a possible qualification of this system as protectionist. Annex B-R countries decrease their imports not only because of the increase in their competitiveness but also because the cement price increase makes their consumption drop. Under the *WTO BTA* scenario, Annex B-R countries import more cement from non-Annex BR countries than in BaU, since their cost-competitiveness is a little bit reduced. This system is thus not protectionist vis-à-vis non-Annex B countries.

Non-Annex B markets

In the *Complete BTA* scenario, but also, to a smaller extent, in the *WTO BTA* scenario, Annex B-R countries increase their exports to non-Annex B-R. In the latter case, this is due to the increase in capacities available for exports, following the drop in consumption in these countries, which more than compensates the small decrease in cost-competitiveness. In the *Complete BTA* case, this is also due to the temporary increase in their cost-competitiveness. To sum up on the impact of BTA on trade and competitiveness, the *Complete BTA* scenario could be qualified as protectionist because, although it treats domestic and foreign producers in a similar way (they pay the same cost per ton of CO_2), it gives a competitive advantage to Annex B-R producers, who use cleaner production techniques. On the contrary, in the *WTO BTA* scenario, Annex B-R countries suffer from a slightly higher cost increase than their competitors, which causes a small increase in their imports. However, as is apparent from the figure above, their exports rise by a larger extent, despite this relative variable cost increase, because some of their production capacities become available for exports. Therefore, should the *WTO BTA* policy be considered as distorting competition in favour of Annex B-R countries? This seems highly dubious since this increase in net exports originates only in the drop in domestic consumption, and would occur also following a macroeconomic recession, for example.

4.4. Higher consumption drop but lower production drop with BTA than without

-30
-25
-20
-15
-10
-5
0
5
10
15
20
Annex B Non Annex B World
Mt of cement
No BTA
Complete BTA
WTO BTA

Figure 13: Production in 2010 compared to BaU

In the two BTA scenarios, domestic prices increase in Annex B-R countries more than without BTA: +21% compared with BaU in 2010 without BTA, +27 with Complete BTA and + 26% with WTO BTA. Consequently, consumption in Annex B drops more significantly: in average by 4% in 2010, vs. 3% in the No BTA scenario.

From the total production point of view, this drop is, in both scenarios, more than halved by the gains on the international market: Production in Annex B-R decreases by 2% in 2010 under the *Complete BTA*, by 3% in 2010 under the *WTO BTA*, instead of 7.5% in No BTA.

It is worth noting that under *WTO BTA*, total production actually rises a little in non-Annex BR countries, which further reduces the rationale for attacking this scenario as distorting competition to the detriment of these countries. Indeed, average cement prices in these countries tend to decrease under the higher pressure of the Annex B-R, leading to the increase in their consumption. This rise offsets the increase in their net imports.

4.5. BTA: efficient reduction of the carbon leakage

-50
-40
-30
-20
-10
0
10
20
Annex B Non Annex B World
Mt of cement
No BTA
Complete BTA
BTA WTO

Figure 14: CO_2 emission in 2010 compared to BaU

Under *Complete BTA*, Annex B-R emissions decrease by around 13% in 2010 compared to BaU, less than under No BTA. In the same time, non-Annex B-R emissions also decrease, because of a little decrease in their production, although very slightly. The spillover rate (abatement in non-Annex B-R / abatement in Annex B-R) is 6%. Finally, world emissions decrease by 2%, a little more than under No BTA.

Under the *WTO BTA*, Annex B-R emissions decrease compared to BaU, a little more than under *Complete BTA*, whereas emissions from non-Annex B-R increase a little. The slight spillover observed in the *Complete BTA* is replaced by a slight leakage: around 4% in 2010. The reduction in world emissions is a little lower than under the *Complete BTA*.

5. Conclusions

Some of the messages delivered by our model are straightforward, for example the fact that a CO2 tax or auctioned allowances without revenue recycling at a price of 15€ per tonne of CO2 in the Annex B-R cement industry leads to a significant carbon leakage (+20%) through the international trade channel, despite the importance the transportation costs of this product and the capacity shortages. Even though this result does not justify the withdrawal of nonglobal climate policies (Baron, forthcoming) since about 80% of the abatement in Annex B-R remains, this indicates that these policies should take seriously into consideration the risks of leakage and that the tools able to tackle this issue should be further studied.

Other insights are related to the comparison between the border-tax adjustments systems tested. The Complete BTA system prevents efficiently carbon leakage and even leads to a slight positive spillover for Annex B-R countries. However, it could lead to WTO conflicts since it can be accused to be unduly protectionist. The WTO BTA system, which is designed to be WTO-compatible, avoids such a risk. It constitutes a less efficient hedging against carbon leakage but realizes a very acceptable environmental achievement: +4% instead of 20% without BTA. This moderate environmental loss suggests that this system should be accepted because the environmental efficiency of the Complete BTA may be proved to be illusory for political reasons. Note that, in both cases, the impact of the BTA systems on cement prices above the carbon constrained scenario without BTA is significant: about +5%; this is the price to pay by cement consumers to secure a higher environmental efficiency of the climate policy and to protect employment.

Beyond the comparison of these two types of BTA, we hopefully demonstrated that our approach help disentangling the mechanisms at stake in carbon leakage, which are merged with other issues in the Armington specification, namely the transportation costs, the capacity shortages and the investment dynamics to expand capacities. One robust conclusion is that under the previous carbon constrained scenario, even without BTA, there is no incentive to create to a large extent, in unconstrained countries, new capacities especially devoted to export. Indeed, the rise in production costs of constrained countries is not high enough to outweigh not only the transportation costs but also the investment costs. Therefore, exports keep on coming from capacities built for domestic consumption which are not fully used.

But all the analyses above have been conducted assuming a scenario in which international transport remains non-affected by the carbon constraint. Obviously such a constraint, rising costs of transportation, would shelter constrained countries from international competition without taking the form of an explicit tool like BTA. Our next step will be then to scrutinize at what level such a carbon price on international transport would start to offset the impact of an asymmetric constraint.

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