CARBON LEAKAGE FROM THE EU EMISSION TRADING SCHEME

A Comment on the Cement Sector

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Executive Summary

The EU-ETS post 2012 is likely to be implemented in a world of prolonged international differences in carbon prices. The unilateral increase of the CO_2 price for domestic producers in Europe may result in a loss of competitive advantage. The consequence may simply be the displacement of production and thereby increased emissions abroad, known as carbon leakage.

This note examines this issue for the cement sector. The investigation is based on two distinct models which emphasize two issues neglected so far. On the one hand, in the short term, exposure to import may be much higher than expected in coastal regions, relative to more inland zones. On the other hand, taking a long term perspective, an increase in the price of CO_2 may reduce the ratio of the capacity to the average demand in a number of EU States, because it will be more attractive to import when demand is high. Both effects are quantified using a relatively moderate assumption for the CO_2 price, 30 €/t, and 2007 as a reference for market and cost data.

The models have be run under the assumptions of full auctioning or, in the case of free allocations, that firms would take the CO_2 price as an opportunity cost. In the short term, the import level from non EU countries would increase from 13% to 25% in coastal regions, i.e. from 8% to 18% on average for the EU. The associated leakage rate would be 65%. The operating profit of EU cement firms, before tax and before free allocations, but after restructuring of the excess capacity, would decline in absolute terms (-39%) and in relative terms (-28%).

In the long term, the EU cement capacity would decline by 13%, 5% coming from the direct price impact on demand (pass-through + elasticity effect) and 8% coming from the change in relative competitiveness in EU versus non-EU cement production. At peak demand levels, imports may be as much as 24%.

This note concludes with some qualitative comments in light of recent events: what is now known of the forthcoming scheme (roughly similar to an output based scheme) and the severe world recession. It is argued that the recession will in fact induce a major restructuring of the European cement industry similar to the one that would have occurred with a pure full auctioning scheme without recession, as it was expected early 2008.

1 The EU-ETS and the cement sector

The EU ETS post 2012 will impact the trading sector in two ways: through the absolute level of emissions and through the allocation of the rights to emit. Regarding the second aspect, the details of the ETS post 2012 are not precisely known at this moment, the broad picture seems to give 100 % free allocation (cement being considered as an exposed sector) based on a benchmark declining over time. This is reminiscent of an output based allocation scheme.

For the simplicity of the economic analysis it will be assumed that the CO_2 price is given and that firms will take this input price as an opportunity cost whatever the free allocations they receive. The impact on the operational profit of the firms will be determined prior to the impact of the free allocation process. In the concluding section this assumption will be relaxed in view of recent events.

A sector is sensitive to carbon leakage under two conditions which determine profits and the passing through of carbon costs: (i) the impact of the CO_2 price is high relative to its value added (the value at stake), (ii) it is highly exposed to international trade (trade intensity). If both [what, if only one is relevant?– like value at stake in cement sector] conditions are satisfied the risk of carbon leakage from this sector is high so that imposing a CO_2 price in the EU will not have the desirable effect of reducing CO_2 emissions worldwide. The EU climate package takes into account these factors and has set threshold values for both indicators: if cost exceed 5% of gross value added (GVA) and if trade intensity exceeds 10%.
The value at stake in the cement sector is clearly high but its import intensity is low, if measured at the EU-27 level. Moreover, if measured at the EU level, the cement sector is quite concentrated. This suggests that EU firms could easily pass through the full cost of CO2 without much change in market shares and profits. Consequently the cement sector may be considered as insensitive. This judgment is reinforced by the fact that the cement industry is mature and not strategic for the global competitiveness of the EU[1].

However, there are important factors that structure competition in the cement sector. Though cement may be considered as a homogeneous commodity the prices vary considerably from one location to another. Three factors explain this major market imperfection:

- a high transportation cost relative to the ex-work cost with major differences regarding road, rail or sea transportation
- the regional differences between supply and demand, given that production is subject to strong capacity constraints
- the globalization of the industry worldwide [2] but with notable differences in concentration levels from one region to another.

The relevance of these factors for the price differences within the EU can be readily observed (see table 1). Regional supply/demand balances vary from one member state to the other: Spain has a high supply shortage (even higher, if measured at the level of clinker production) while Germany has a large excess capacity. The exposure to long-haul competition through marine transportation is reflected by the respective market shares of non-EU imports in each EU member state. Due to transport cost this pressure is higher in the coastal regions. The various spatial distributions of demand within each member state makes some EU countries more exposed than others. Moreover, concentration varies from one member state to the other, it also plays a role in the international exposure of a given

[1] See for instance section 3 pp 60-93, Climate Strategies Report 2008: Differentiation and Dynamics of EU ETS Industrial Competitiveness Impacts, 15 January 2008

[2] The top 5 cement firms account for approximately 20 % of worldwide production in 2007 (Sources: analysts'reports).

country. Strategic entry barriers such as vertical integration are probably lower in Italy or Spain than in France or UK.

On top , the fact that major cement firms typically operate a large number of plants allows to optimize their sourcing of production at any point in time depending on local supply and demand conditions. Their short term optimization depends on their available capacities in the various markets and on the relative production and freight costs. As such they have a competitive edge over smaller firms that are stuck in a given regional market. These smaller firms have to rely on traders. These traders may quickly react to a short term disequilibrium but they do not have the long term efficiency to sustain long haul trade flows.

Accordingly, the history of the trade flows in the cement industry consists of two phases:

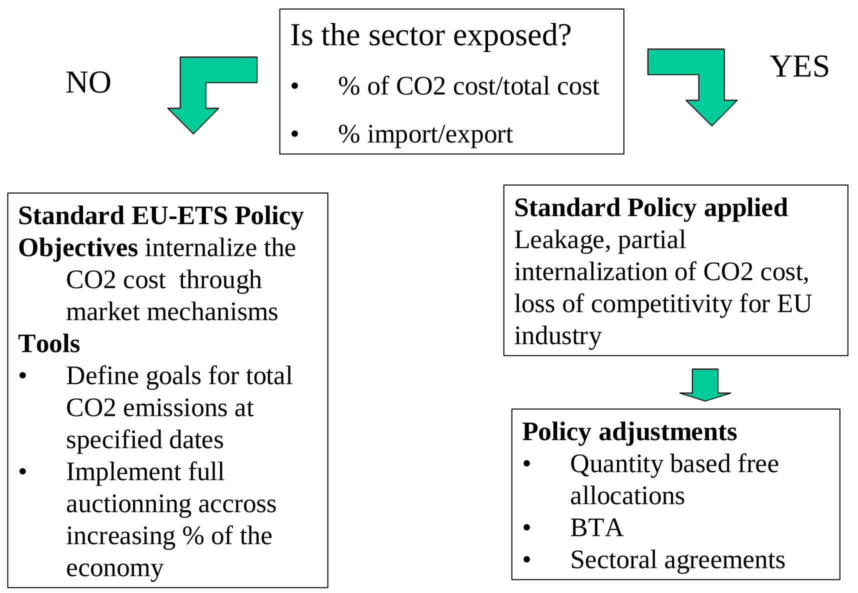
- Phases in which short term factors dominate after a shock in demand (such as in the recent years in Spain) or in cost (such as in the mid'80 with the development of maritime freight). Then import flows increase mainly through the pressure of traders. Eventually, with entry in grinding stations, this process leads to strong price pressure
- Phases in which long term factors dominate follow. Most of the imports at peak levels of demand are made through major cement players. A limit pricing strategy is implemented in order not to attract traders and imports are progressively reduced as the demand/supply ratio moves down.[3]

This process needs to be introduced in the reasoning on carbon leakage since it is the long term factors that determine the amount of investment in a given regional market, and finally at the EU level.[4]

This note suggests that, if these key factors are given due consideration, a different picture on the impact of the EU-ETS on the cement industry would emerge. The note provides a quantification of the impacts of these factors both on the short term and on the long term. The figures obtained would certainly incline to review the qualification of cement as not exposed. Discussions of appropriate adjustment policies are out of the scope of the paper.

[3] The US market is a good empirical illustration of such a stabilized situation. In that market new investment is concentrated in inland regions while in the coast plants are rather old and obsolete.

[4] The Climate Strategy Report op. cited does recognize that supply/demand conditions are a key factor to explain the long-haul trade flows. However it provides no rationale for investment decisions. Most models on carbon leakage existing in the literature ignore investment decisions. They are exclusively short term oriented. One notable exception is "*The competitiveness impact of of CO emissions reduction in the cement sector*", Demailly D; and PH. Quirion, Report to OECD Environment Directorate – Center for tax policy and administration, 16 November 2005. But investment decisions in the Demailly Quirion model are myopic and strictly based on consumption trends.



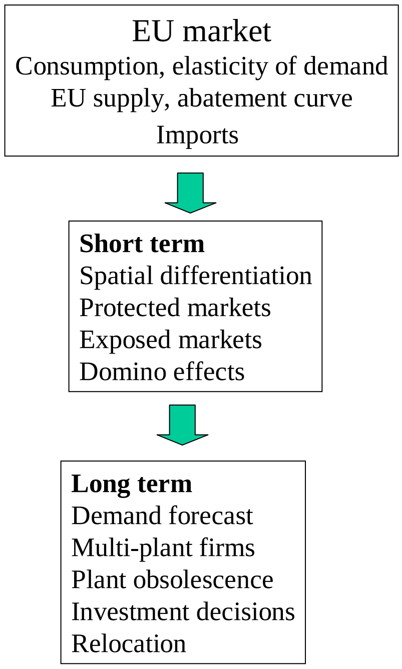
2 Scenario for the cement industry with a full auctioning trading scheme

The scenario covers the period 2013-2020. It evaluates the impact of full auctioning of CO2 allowances under the EU-ETS to the cement sector.

Qualitatively one may expect two impacts:

- In the short term (say 2013-2015) the auctioning of an increasing fraction of total allowances will generate an asymmetric shock on the input cost for EU plants. The competitiveness of coastal regions relative to imports would have been more affected than the one of inland regions. The pressure would have come mostly from independent firms outside of the EU and traders. However, domino effects between coastal and inland regions would have limited the ability of EU firms to pass through the CO2 cost to customers even in the inland regions. A quantitative assessment of this impact requires a detailed analysis in which geography matters.
- In the long term (say 2015-2020) one may expect that the major EU firms will get back a large share of the imports because of their multi-plant facilities in and outside the EU and because of their efficiency to sustain long-haul trade flows. A high CO2 price will nevertheless affect the optimal sourcing of the EU market in two ways. Firstly, for EU production to remain profitable total cost of producing cement in the EU must be lower than the total cost of imports, including freight. Secondly, even if this were the case in many EU regions, installed capacity in the EU may still decline, because a high CO2 price makes imports more attractive. A quantitative assessment requires an analysis of the links between relative costs, fluctuations of demand and optimal capacity.

Two different models are applied to discuss the short term and the long term impacts respectively. They are calibrated using 2007 as a reference year.



2.1 Short term analysis: the role of geography

The underlying economic model is presented in appendix 1.
The main data used in the current discussion is summarized below (see table 2):[5]

- Each of the 27 EU States is segmented geographically. This is captured through defining coastal regions (including border regions for Central Europe) and inland regions. Based on 2007 consumptions, the relative size of the coastal regions amounts to 63% in the EU. The import rates are respectively 13% and 0% for coastal and inland with an average of 8% for all EU (see table 1)
- The freight cost from importing zones such as MENA is higher for Northern Europe (30 €/t) than for Southern Europe (25 €/t)
- An inland freight cost from countries such as Ukraine and Russia to Central Europe is introduced (35 €/t)
- Local distribution cost and margin for imports are introduced (6 €/t)
- A FOB price is assumed for importing cement (40 €/t)
- For EU a variable cost (25 € per ton of production) and a fixed cost including sustaining capital expenses (25 € per ton of capacity) are uniformly assumed across all the 27 EU.

From this data a EU price for each region is inferred (see table 1) assuming that imports drive these prices. This assumption is preferred to using current prices because these prices result from local factors such as costs (while we assume a uniform production cost across all EU countries), concentration level of the industry, capacity constraints, which may not be recurrent. These prices should not be considered as the average prices observed in 2007. As can be seen in table 1, the prices reported by Eurostat vary from 55€/t to 102€/t from one region to another (and actual costs probably vary in the same proportion).
The EU operating profit before tax is then derived in absolute (4 438 M€) and relative (18 €/t) terms. This constitutes the reference scenario.
The impact of a full auctioning scenario is simulated using a CO_2 price of 30 €/t with a content of .7 ton of CO_2 per ton of cement.
The CO_2 scenario is constructed using two sets of key parameters directly obtained from the model:

[5] Sources of data are detailed in the tables.

- The different pass through rates in the coastal (55 %) and inland (75 %) regions.
- The different shares for imports in the coastal (25%) and inland (5 %) regions The results can be summarized as follows (table 3).
- The price would increase (17%) which will reduce the consumption of cement (-5%), assuming a price elasticity at -.27.
- The average pass through rate would be (62%), this provides an indication of the ability of the EU firms to transfer the cost increase to the customers.
- The imports rate would increase from 8% to 18% which emphasizing the loss of competitiveness of the EU firms.
- The leakage rate would be 65% (not including CO2 associated with transportation) which means that for 1 t of CO2 avoided in the EU, .65 t are emitted outside of the EU.
- The EU capacity, assuming no change in utilization rate, would decline by 45 Mt (or approximately 45 plants of 1 MT each) from 297 Mt to 255 Mt (-17%). 18 Mt of the total capacity reduction are due to reduced demand and 27 Mt due to increased imports.
- The EU profit, after restructuring of the excess capacity, would decline in absolute terms (-39%) and in relative terms (-28%), emphasizing again the loss of competitiveness of the EU firms.

Two sensitivity analysis are carried out, taking into account in each case that there would be changes both in the pass through rates and the import rates (see table 4). This gives shows the robustness of the model:

- relative to the emission rate: with .6 rather than .7 CO2/cim, the total CO2 emission is reduced from 5% to 4% and the leakage rate from 65% to 61%
- relative to the CO2 price: with 50€/t instead of 30€/t the total CO2 emission would increase from 5% to 7% and the leakage rate from 65% to 73%.

2.2 Long term analysis: the investment decisions

The underlying investment model is presented in appendix 3. It determines the optimal capacity to face a fluctuating demand given that two sources may be used:

- domestic plants which typically have low variable cost but limited capacity
- imports which typically have no capacity constraints but support a higher variable cost.

The optimization assumes that the EU market consists of a limited number of major cement companies operating plants in and outside the EU. In particular, it is assumed that they directly or indirectly control the imports into the EU.[6] Prices are constrained by limit pricing so as not to attract traders when the demand is high.
The variable cost of imports involve two components:

- the FOB price (40 €/t), interpreted as the economic transfer price that should be used by multinational firms, and as such somewhat higher than the marginal price that traders could obtain
- an average freight cost to the EU assumed to be 35€/t as an average between coastal and inland regions

A first additional assumption need be introduced concerning the investment cost in the EU. Assuming a set up cost of 150€/t for a brown field reconstruction, with a life duration of 30 years and a cost of capital at 6%, this gives approximately 9€/t. The variable cost (25€/t) is

[6] This is clearly a strong assumption, it allows an explicit calculation of the optimal capacity of a major cement company which may import. A model combining short and long term effects would be a useful extension, bringing the role of geography and the life time of plants into investment decisions.

assumed to be identical to the one used in short term model. For the fixed cost, it is estimated at a lower level based on scale economies in modern plants (13€/t).
A second additional assumption concerns the fluctuations of demand. Based on consumptions in the EU countries over the period 1970-2007, a fluctuation of 15% around a mean value can be estimated. This means that the long term capacity trend remains in line with the long term demand trend but that annual demand fluctuates in the range of –15% to +15% of its long term trend.
Using this set of data (new data is summarized in table 5) to calibrate the investment model a number of results prevail. Firstly, consider the question whether CO2 pricing would lead to a complete relocation of the cement industry. The full cost of production in the EU is

25 (var) + 13 (fixed) + 9 (inv) + (CO2) = 47 €/t

to be compared with

40 (FOB) + 35 (freight) = 75 €/t

As long as the CO2 cost remains lower than 28 €/t it remains profitable to produce in the EU. This is true with a CO2 price at 30€/t with an emission rate at 0.7 ton of CO2 per ton of cement. This is our base case.
However it would no longer be true with a freight cost at 25€/t, which means that it may no longer be worthwhile to invest in some coastal regions. A CO2 price at 50€/t would also endanger investment, even with an emission rate at 0.6, since the CO2 cost would then be 30€/t.
In the base case, a second impact prevails due to the best way to cope with the fluctuations of the demand. Intuitively, the higher the CO2 price the lower the capacity that should be invested in the EU since a high CO2 price makes importing more attractive. This impact may be easily overlooked. The model demonstrates that it is important.

The main results are the following (table 6):7

- The optimal capacity would be 281 Mt without CO2 pricing (the actual capacity as computed from table 2 is 297 Mt) but only 245 Mt (- 13%) with a CO2 price at 30€/t; the decline comes in part from the decline in demand because of the elasticity effect (-5%) and partly (- 8%) from the fact that importing is more profitable
- Note that the import rate depends on the actual demand, at peak level it increases from 13% to 24%,8 with an average increase over the cycle from 1% to 7%.
- The leakage rate also depends on the actual demand. In low demand member states there are no imports independently of the CO2 price and thus non leakage. In peak demand member states the demand that exceeds capacity is fully imported, the leakage rate is 100%; the average leakage rate over the cycle is 56%.
- The price change also depends on the actual demand, in member states with low demand the pass through is high since there are no imports (close to 80% with our calibration), in member states with peak demand the price depends only on the import limit price (independent of the CO2 price) so that the pass through rate is 0%; the average price increase over the cycle is 17% which corresponds to an average pass through rate of 57%.

[7] We construct a midyear reference using 2007 as a peak. The average consumption over the cycle would correspondingly be 15% lower than the one in 2007.
[8]This is assuming EU as a single market, which is an oversimplification. See footnote 7.

2.3 Summary of results

For convenience the following two tables provide a synthesis of the key data used and of the corresponding results in the short term and long term models.

Data	unit	short term	long term
CO2 price	€/t	30	30
t CO2 / t cim		70%	70%
cost var/t	€/t	25	25
fixed /t cap	€/t	25	13
invest/t	€/t	-	9
FOB price	€/t	40	40
Freigth to EU	€/t		35
marine S EU	€/t	25	
marine N EU	€/t	30	
land C EU	€/t	35	
local cost	€/t	6	
elasticity		27%	27%
demand fluctuation		-	15%

Synthesis	Reference	short term	long term	
			over the cycle	peak
CO2 price €/t	0	30	30	
consumption	266	-5%	-5%	0%
EU capacity	297	-17%	-13%	-13%
pass through		62%	57%	0%
import	8%	18%	7%	24%
leakage		65%	56%	100%

3 Scenario for the cement industry: full auctioning versus output based allocation

The full auctioning scenario as modelled in this note is expected to induce:

- in the short term: a strong competitive pressure from imports on the coastal markets and a domino effect from the coastal markets to the inland markets; the alternative from EU firms (in terms of their EU plant activity) would be either to accept a loss in market share or a decline in profit margins;
- in the long run, plants in the coastal markets would be closed while inland plants would adapt their capacity to meet a cyclical demand targeting a lower average capacity/demand ratio; altogether the EU cement capacity would be significantly reduced.

The first thought about an output based allocation is that, in theory, it should considerably reduce the competitive pressure at the expense of eliminating the price signal for downstream activities.
The second thought is that the difference with a full auctioning scenario is not that significant because of the severe world recession.

Indeed:

- the decline in demand creates an economic incentive for industrial restructuring (that need was already there in countries such as Germany); restructuring of plants, such as closing of small plants (or turning them into grinding stations) and increasing the production of others, is "facilitated" when the demand is objectively low;
- the relevance of putting into operations abatements in the industry is now clear and will be pursued actively by firms; these abatements will be easier to implement in large modern plants through specific investment; the benchmark will become tighter and tighter as plants with low performance are removed from production reinforcing this trend;
- these two elements are likely to generate a concentration of investments inland close to large markets (assuming availability of quarries), leaving the coastal markets to be served by clinker imports when demand will be back;
- in the short term, due to the world recession, there is plenty of excess capacity; in the long term, the cement markets in North Africa and Middle East are likely to grow at a substantial rate generating large excess capacity to serve the EU at low cost (given that a number of EU firms are operating in those countries).

Consequently, one should not expect a substantial difference in terms of industrial scenario, still a major difference concerns the level of profits of EU firms (as regards their EU operations). With full auctioning these profits would have been seriously eroded, putting pressure for industrial change, while output based allocation mitigates the financial pressure that comes from the economic recession it does not alleviate the need to restructure.
There is another difference about the two scenarios which concerns the price signal for downward activities. Clearly this price signal is almost totally eliminated with output based allocations. If one considers that the cement price represents approximately 4 to 5 % of the housing construction cost, it would seem that this impact is of the second order.

Appendix 1: Tables and graphs

Table 1: Prices, kiln capacity / consumption, concentration levels in some EU States

EU state	price €/t 2006	consumption 2006 Mt	consumption / capacity 2007	Non EU import % 2006	Number of competitors 2006	of which only grinding stations 2006
Italy	62	46	82%	9%	13	8
France	102	24	110%	6%	4	1
Germany	55	28	67%	0%	14	4
Spain	75	56	114%	20%	19	10
UK	90	14	104%	1%	4	1

(Sources: Prices, consumption, import data come from Eurostat. Capacity data and number of competitors come from industry interviews)

Table 2: Background data for cement in the EU 27 and adjusted prices

	2007			geographic split		Prices €/t	
Country	Consumption MT	cons / capa %	Import rate %	Coast	Inland	Coast	Inland
Austria	5,7	88%	3%		100%		87
Belgium	6,0	60%	6%	100%		76	
Bulgaria	4,4	100%	4%	25%	75%	76	82
Cyprus	2,3	87%	1%	100%		71	
Czech Republic	5,1	86%	0%		100%		87
Denmark	1,8	60%	4%	100%		76	
Estonia	0,6	77%	0%	100%		76	
Finland	1,9	95%	12%	100%		76	
France	25,0	110%	8%	65%	35%	71	77
Germany	28,8	67%	0%	15%	85%	76	82
Greece	11,2	72%	1%	100%		71	
Hungary	4,2	115%	1%		100%		87
Ireland	6,0	100%	10%	100%		76	0
Italy	45,4	82%	8%	75%	25%	71	77
Latvia	0,8	107%	3%	100%		76	
Lithuania	1,0	71%	22%	100%		76	
Luxembourg	0,6	33%	0%		100%		87
Malta	0,3	NA	0%	100%		71	
Netherlands	5,7	204%	0%	100%		76	
Poland	16,7	95%	0%	25%	75%	76	82
Portugal	7,7	70%	6%	100%		71	
Romania	9,9	95%	7%	25%	75%	76	82
Slovakia	2,7	67%	1%		100%		81
Slovenia	1,5	100%	6%	50%	50%	71	77
Spain	56,1	114%	23%	80%	20%	71	77
Sweden	2,3	79%	2%	100%		76	
United Kingdom	12,9	104%	2%	100%		76	

Demand, emission rate and cost data			
elasticity of demand	-0,27		€/t
		cost var/t	25
t CO2 / t cim	0,7	fixed /t cap	25
		FOB (MENA)	40
		Freight	
		marine S EU	25
		marine N EU	30
		land C EU	35
		local cost	6

(Sources: Consumption, segmentation between coastal and inland, import data are based on Eurostat. Emission rate, elasticity of demand, capacity and cost data are the author's estimate based on industry interviews and analysts reports. Prices in this table are constructed from the estimated FOB price and freight costs)

Table 3: Quantification of the role of geography

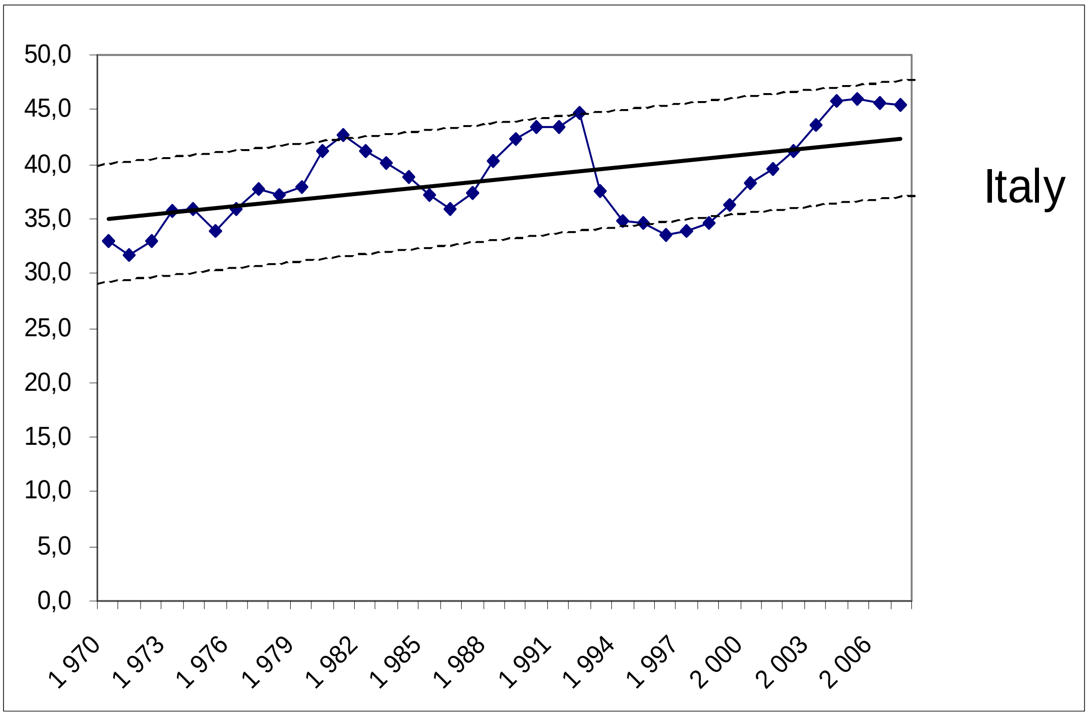
Short term (2013-2015)	Reference	Base Case	Change
consumption	**266**	254	-5%
o/w coastal	**63%**	63%	
o/w inland	**37%**	37%	
average price	**76**	89	17%
delta price coast/inland	**6**	10	
average pass through		62%	
import coast	**13%**	25%	
import inland	**0%**	5%	
import average	**8%**	18%	
capacity	**297**	255	-14%
utilization rate	**82%**	82%	
cost var/t	**25**	46	84%
fixed /t cap	**25**	25	
CO2			
EU cons	186	178	-5%
europe prod	171	146	-14%
RoW	16	31	102%
leakage		65%	
Profit EU			
oper margin /t	18	13	-28%
abs margin decline		-39%	

Table 4: Short term: Sensitivity analysis

	Reference	Base case		High CO2 price		Low emission rate		
CO2 price €/t	0	30		50		0	30	
t CO2 / t cim	0,7	0,7		0,7		0,6	0,6	
Pass through								
coastal		55%		55%			55%	
inland		75%		66%			77%	
import rates								
coastal	8%	25%		40%		8%	23%	
inland	0%	5%		15%		0%	3%	
CO2			change		change			change
EU cons Mt	186	178	-5%	173	-7%	160	153	-4%
europe prod Mt	171	146	-14%	119	-30%	146	130	-11%
RoW for EU Mt	16	31	102%	53	242%	13	23	75%
leakage %		65%		73%			61%	
Profit EU			change		change			change
oper profit €/t	18	13	-28%	7	-62%	18	14	-22%
Total operating profit M€	4 438	2 721	-39%	1 183	-73%	4 438	3 086	-30%

Table 5: Long term analysis: data

Demand, emission rate and cost data			
elasticity of demand	-0,27		€/t
		FOB (MENA)	40
demand fluctuations	15%	Freight	35
		cost var/t	25
t CO2 / t cim	0,7	fixed /t cap	13
		invest cost as 150€/t with 6% discount rate	9



(Sources: demand fluctuations are the author's estimate based on consumptions in each of the EU member States over 1970-2007, see Italy as an illustration; fixed costs correspond to scale economies in modern plants, which require 150 €/t investment cost annualized using a 6 % economic discount rate; the estimates for the fixed and investment cost are based on industry interviews)

Table 6: Long term analysis: results from the model

Long term	Over the business cycle			At peak levels		
	Reference mid cycle MT	with standard CO_2 policy MT	% changes	Reference 2007 coastal MT	with standard CO_2 policy	% changes
average consumption	226	215	-5%	266	266	0%
EU capacity	281	245	-13%	281	245	-13%
average EU production	224	199	-11%	231	201	-13%
average import	2	16	600%	35	65	83%
import %	1%	7%		13%	24%	
average price	69	81	17%	90	90	0%

Appendix 2: The spatial model
(taken and slightly adapted from Ponssard and Walker 2008)

The Cement Trade and Competition (CTC) model represents a stylised EU country with two distinct regions ('coastal' and 'inland') each with a homogeneous cement market exhibiting Cournot-Nash equilibrium. In the absence of CO2 costs, customers in the coastal region are served both by local and inland EU producers, as well as by non-EU producers. However, because of the land transportation barrier between the two regions, inland customers are initially served only by local and coastal producers. From this starting point, the model calculates how the pattern of trade, and the number of competitors active in each region, would change in response to rising EU ETS costs. We consider two types of competitive structure, namely:

- a base case where there is no overlap between the EU firms which operate inland and coastal plants; and
- a more general and more realistic case where each EU firm operates plants in both regions of the country, eventually under capacity constraints.

The model parameters are calibrated using empirical data on production and trade in Portland cement and its energy-intensive precursor (clinker) and they refer to a typical EU country where the coastal and inland regions have similar populations. The model can readily be adapted, however, to allow consideration of cases where the absolute level of market prices, or the proportion of the total market volume located in proximity to a seaport, differ from the European average.

Appendix 3: The investment model
(taken and slightly adapted from Meunier and Ponssard 2008)

The relationship between demand fluctuations and capacity decisions is a well-known topic in the economic literature. Usually, firms should select a higher capacity when the demand uncertainty increases. The reason is that profits are higher when demand is higher so that firms facing a capacity constraint, while the competitors do not, risk a major loss.
This is no longer true when firms trade. Then the relative level of import costs to domestic costs is crucial, i.e. the level of the CO2 price matters. The optimal domestic capacity may be significantly lower than the average demand so that firms rely much more on imports.
This "uncertainty effect" can be investigated in a simple economic model. A firm in a monopoly situation in the EU may either invest in the EU or import. There are two stages of decision making. The choice of capacity is made under uncertain demand conditions while production and import decisions are made once uncertainty is resolved. Three situations can arise relative to production and import: (i) the monopoly has excess capacity and produces the unconstrained monopoly output, (ii) the capacity is fully used, there are no imports, (iii) the capacity is fully used and additional production is imported.

The analysis is made assuming a linear long run average cost function (investment and production) and a linear demand function, which includes a random parameter uniformly distributed over a given range. The model is solved for various combinations of the parameters. It is extended to the case of Cournot competition between symmetric firms.

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