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Article (Published version)
(Refereed)

Original citation:
Branger, Frédéric, Ponssard, Jean-Pierre, Sartor, Oliver and Sato, Misato (2015) *EU ETS, free allocations, and activity level thresholds: the devil lies in the details.* Journal of the Association of Environmental and Resource Economists, 2 (3). pp. 401-437. ISSN 2333-5955

DOI: 10.1086/682343

EU ETS, Free Allocations, and Activity Level Thresholds: The Devil Lies in the Details

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Abstract: It is well known that discontinuous jumps or thresholds in tax or subsidies are socially inefficient, because they create incentives to make strategic behavioral changes that lead to substantial increases in private benefits. This paper investigates these distortions in the context of the EU Emissions Trading Scheme, where activity level thresholds (ALTs) were introduced in Phase 3 to reduce the overallocation of free allowances to low-activity installations. Using installation-level data, we find evidence that cement producers indeed respond to such thresholds when confronted with low demand, by strategically adjusting output to obtain more free allocation. We estimate that in 2012, ALTs induced excess cement clinker production of 6.4 Mt (5% of total EU output), and in affected regions this further distorted trade patterns and reversed carbon intensity improvements. As intended, ALTs reduced free allocation by 4%; however, a linear scheme (output-based allocation) would have achieved a 32% reduction.

JEL Codes: D24, H23, L23, L61

Keywords: Activity level thresholds, Carbon trading, Cement, EU ETS, Free allowance allocations

STARTING FROM PHASE 3, the EU Emissions Trading System introduced a new rule that links the level of free allocation to the activity level of an installation—known as activity level thresholds (ALTs). While put in place with the intention to reduce excess free allocation to low-activity plants, the new rule creates incentives for

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Received October 16 2014; Accepted May 19 2015; Published online August 5, 2015.

JAERE, volume 2, number 3. 2333-5955/2015/0203-0003$10.00 http://dx.doi.org/10.1086/682343

installations to "game" output levels in order to maximize free allocation. This paper measures the distortionary effects resulting from ALTs, by exploiting the natural experiment of the introduction of the new rule in 2012, and discusses whether the disadvantages of ALTs outweigh the advantages.

The justification for using free allocations in emission trading schemes has evolved over time. Historically, in schemes such as the US acid rain program, it was introduced as a compensation mechanism for the owners of existing industrial assets for a change in the rules of the game (Ellerman et al. 2000). A lump sum transfer would be made to existing assets through a predetermined amount of annual free allocations for a given number of years. Such methods are termed "grandfathering," "historic," "lump sum," or "ex ante" allocation. New assets would not be allowed free allocations and thus would have to pay for all their permits on the market. As long as the free allocations are predetermined, all assets (old and new) would compete on the same playing field, the price of permits would provide the same opportunity cost for mitigating pollution, and in theory, the output price of the goods sold would incorporate the price signal for consumers.

More recently, free allocations have been explicitly used (or have been proposed to be used) as a way to strategically alleviate the risk of offshoring production and emissions (so-called carbon leakage) for Energy-Intensive and Trade-Exposed (EITE) sectors such as cement, chemicals, and steel. Economists generally agree that, in a world of unequal carbon prices, full auctioning together with some form of border leveling of prices would be the optimal approach to tackling leakage (Hepburn et al. 2006; Monjon and Quirion 2011). However, the required degree of international cooperation to achieve such a system has not yet been forthcoming. Thus, a number of papers suggest that, from an economic efficiency standpoint, free "output-based" allocation (OBA) would be a preferred third-best option (Fischer and Fox 2007; Quirion 2009; Fischer and Fox 2012; Meunier, Ponssard, and Quirion 2014). OBA reduces the effect of the carbon price on the output price, which reduces trade distortions, but also means that the final price does not fully reflect the carbon price, which reduces efficiency.

OBA has been implemented within the Californian emissions trading system (ETS) that began in 2012 (California Air Resources Board 2013). In contrast the EU ETS Phase 3 is unique in using a complex system. It combines an ex ante calculation of an allocation and subsequent lump-sum transfer based on historic output (and

ute to the Getting the Numbers Right (GNR) cement sector database, and numerous people from the cement industry. Jean-Pierre Ponssard gratefully acknowledges the financial support from the ANR/Investissements d'avenir (ANR-11-IDEX-0003-02). Misato Sato gratefully acknowledges financial support from European Community's Seventh Framework Programme under grant agreement no. 308481 (ENTRACTE), the Grantham Foundation, and the ESRC through the Centre for Climate Change Economics and Policy.

multiplied by an emissions intensity benchmark) with a possible ex post calculation and adjustment of this lump sum according to rules related to actual capacity and activity levels as defined in Decision 2011/278/EU (European Commission 2011).[1] Situations in which ex post adjustments occur include the arrival of new entrants into the market, plant capacity extension/reduction, plant closure, and partial cessation or re-commencement of activity at an existing plant. These latter rules are governed by the activity level thresholds.[2]

Qualitatively, ETS schemes with ALTs approximate OBA: the amount of free allocations will vary with the activity level, and the overallocation profits[3] associated with ex ante schemes will be reduced.[4] The advantage of ALT rules is that they allow for a fixed cap (in fact, a cap that will not exceed a predetermined amount for existing installations and the reserve for new entrants). One disadvantage is that they introduce an element of complexity in the scheme. Under these nonlinear rules, the lump-sum transfer of allowances to EITE sectors is reduced by 50%, 75%, or 100% if the annual level of production of the plant falls below 50%, 25%, or 10%, respectively, of the historical activity level (HAL) of production that is used to determine the ex ante allocation (European Commission 2011).

A second disadvantage is that the ALTs introduce distortions, which is the focus of this paper. A recent study on the EU ETS impacts on the cement sector during 2005–13 (Neuhoff et al. 2014) found preliminary evidence through data analysis and comprehensive interviews with industry executives that new ALTs introduced in 2013 provided cement installations the incentive to adjust output levels.[5] The rationale is as follows. Since the free allocation in year $t + 1$ is directly linked to output in year t, if output levels lie below the threshold levels, there may be an incentive to increase

1. Note that ex ante and ex post refer to whether the calculation of the freely allocated amount of allowances occurs prior to or following the production and emissions for which allowances are to be allocated.

2. New entrant provision and closing rules were already in place in Phases 1 and 2 of the EU ETS. A closure rule is also used in the Californian ETS.

3. Overallocation profits come from the allowances surplus automatically generated when the number of free allowances received is higher than emissions necessary to manufacture the amount of cement produced (Branger and Quirion 2015). Overallocation profits can be distinguished from windfall profits, which refer to the profits from free allocation where emitters additionally profit from passing on the marginal CO_2 opportunity cost to product prices, despite receiving the allowances for free. Overallocation profits can occur even in the absence of cost pass-through, if output fall short of historic levels.

4. Windfall and overallocation gains have been a persistent shortcoming of the use of ex ante free-allocation mechanism in the EU ETS (e.g., Sandbag Climate Campaign 2011; Laing et al. 2014; Sartor, Pallière, and Lecourt 2014).

5. Three coauthors of this paper participated in this study and in conducting interviews that were carried out.

output in year t to achieve the relevant threshold (.10, .25, .50) and receive higher free allocations in year $t + 1$. In this paper, such strategic adjustments of output motivated by ALTs are termed "gaming" behavior, in line with the management literature (e.g., Jensen 2003). Neuhoff et al. (2014) report that company executives consistently confirm in interviews that these practices indeed occur, where the regional cement market demand is insufficient to reach the minimum activity level. They identify three channels to marginally increase production in a plant that is producing below the threshold:

- Production shifting among local plants, that is, reducing the production at a plant that is well above the threshold to increase the production at the plant that is below; this generates some transport costs so that it can be too costly to be undertaken at a large scale.[6]
- Exports of clinker to other markets so as not to perturb the local market while increasing production; this generates some cost in terms of export price rebate, since these exports would not naturally occur.
- Increasing the clinker to cement ratio, that is, incorporate within limits more clinker in cement instead of using less costly cementitious additives such as slag or flying ashes; this directly generates some cost.

In this paper, we revisit the existence and the magnitude of the distortions and ask whether or not the installation outputs and trade flows in 2012 were affected by the free allocation policy change for year 2013. Our analysis is conducted in a unique context of low demand induced by a severe economic downturn. The construction of a counterfactual requires some assumptions, the most significant of which considers that consumption and price levels for cement are independent of the allocation scheme. This assumption is consistent with the observations made in Neuhoff et al. (2014). We discuss in detail how our results would be affected if we had adopted the more standard assumption in which grandfathering and output-based allocation would lead to different cement and price levels.

Empirical studies on the impact of ALTs or similar rules remain limited. Most of these studies have examined the distortive effects of combining ex ante allocations with ex post new entrant and plant closure provisions. Neuhoff, Keats, and Sato (2006), Ellerman (2008), and Pahle, Fan, and Schill (2011) compared the new entrant provision relative to auctioning. These papers argued that new entrant provisions distort via their impact on investment decisions in the electricity sector (essen-

6. McKinsey & Company (2008) estimate that transport costs for a tonne of clinker from Alexandria to Rotterdam are roughly €20/tonne, that inland shipping costs are approximately €3.5/tonne per 100 km, and that the inland road transport is about 8.6€/ton per 100 km.

tially by acting as a subsidy). Meunier et al. (2014) compared this same provision with an output-based scheme whenever firms face an uncertain demand in the EU cement sector. They showed that the entrant provision could induce excessive new investments while offering limited protection against leakage. Fowlie, Reguant, and Ryan (forthcoming), this time for the US cement sector, compare ex ante schemes with closure rules with an output-based scheme and show that the lifetime of old inefficient plants would be unduly extended with the former while temporarily reducing leakage. Only this last paper has discussed the impacts of the possible distortions associated with the (limited) addition of nonlinear ex post adjustments to ex ante allocation via the use of ALTs, such as introduced in the EU ETS Phase 3 (2013–20).

The findings in this paper could be potentially relevant to other EITEs with similar characteristics. Altogether, we argue that the benefits of implementing ALTs in terms of reduced overallocation profits will not necessarily outweigh the significant costs in the form of distortions. Hence it may be preferable to abandon ALTs for OBA for some sectors. We discuss some broader questions if such a change were adopted.

The paper is organized as follows. Section 1 discusses the EU ETS Phase 3 allocation rules, the predicted gaming behavior from thresholds and the alternative allocation rules. Section 2 describes our conceptual framework for evaluating the effects of ALTs, the methodology, data sources, and the key assumptions involved in our analysis. Section 3 presents the results. Section 4 concludes and discusses policy recommendations.

1. ETS FREE ALLOCATION RULES AND GAMING OF ALTS

1.1. The EU ETS Phase 3 Free Allocation Rules

In Phase 3 of the EU ETS, installations in sectors "deemed to be exposed to carbon leakage" are eligible to receive free allocation of emission allowances. The determination of the free allowances for each installation combines an ex ante calculation, based on the historic output for existing installations (known as the "historical activity level" or HAL)[7] or the initial capacity for new installations, with an ex post calculation based on the ongoing activity level of this installation as defined in Decision 2011/278/EU (European Commission 2011). The ex post calculation provides stepwise adjustments intended to reflect changes in market volumes. These adjustments follow complex procedures.

For existing installations, the precise relationship that determines the next-period allocation from ex ante and ex post values is summarized by equations (1) and (2)

7. The benchmarked product-related historical activity level (HAL) is defined as the maximum of the median annual historical production of the product in the installation (or subinstallation) concerned during either 2005–8 or 2009–10 (cf. Decision 2011/278/EU).

below. The amount of free allocations to an installation, i, at period $t + 1$, for an eligible product, p is denoted $A_{i,p,t+1}$.

$$A_{i,p,t+1} = CSCF_{t+1} \times B_p \times HAL_{i,p} \times ALCF_{t+1}\left(\frac{q_t}{HAL_{i,p}}\right). \tag{1}$$

In equation (1), $CSCF_{t+1}$ is the uniform cross-sectoral correction factor,[8] B_p is the benchmark for product p,[9] $HAL_{i,p}$ represents the historical activity level, and $ALCF$ is the activity level correction factor, which depends on the ratio $q_{i,p,t}/HAL_{i,p}$, $q_{i,p,t}$ being the output of the eligible product in year t. The ALCF defines a stepwise function for the thresholds. It is defined as:

$$ALCF_{t+1}\left(\frac{q_t}{HAL}\right) = \begin{cases} 1, & q_t \geq 0.5\,HAL \\ 0.5, & 0.25\,HAL \leq q_t < 0.5\,HAL \\ 0.25, & 0.10\,HAL \leq q_t < 0.25\,HAL \\ 0, & 0\;HAL \leq q_t < 0.10\,HAL \end{cases} \tag{2}$$

For new installations, the historic activity level is replaced by the capacity, to be precisely determined according to the rules.[10]

1.2. Gaming and Thresholds

In this paper, gaming behavior refers to artificially increasing production to attain thresholds, in order to obtain more allowances. Consider a plant for which the "business as usual" activity level for year 2012 would be at, say, 40% of its historic activity level. Increasing production up to 50% of its historic activity level allows for doubling the free allocation received. A rough calculation with a clinker plant illustrates the potential benefit of gaming. Suppose HAL refers to 1 Mt/year (millions of metric tons per year), and the business as usual is 0.4 Mt in 2012 so that the plant needs to increase production by 0.1 Mt to achieve the 50% threshold. At 8 €/t CO_2 in 2013 (average future price of December 2013 during year 2012), if the firm gets 100% of free allowances relative to HAL it is worth €5.8 million (0.9427 × 1Mt × 0.766 tCO_2/t × 8€/tCO_2, numbers being, respectively, CSCF, HAL, clinker benchmark, and carbon price); losing 50% allowances implies a loss of €2.9 million. Suppose the emission intensity is 0.8 t CO_2/t of clinker (slightly above the benchmark).

8. This is determined by comparing the sum of preliminary total annual amounts of emission allowances allocated free to installations (not electricity) for each year over the period 2013–20. In 2013 the CSCF is equal to 0.9427; then it declines at 1.74% per year.

9. Product benchmarks in general reflect the average performance of the 10% most efficient installations in the sector or subsector in the years 2007–8. The benchmarks are calculated for products rather than inputs Decision 2011/278/EU.

10. Guidance document no. 7 in European Commission (2011).

The increase in emissions is then equal to 0.080 t CO_2, which at 8 €/t CO_2 amounts to €0.64 million.

In the presence of activity level thresholds, the net benefit of gaming in terms of allocations is the difference between the increased free allocations and the certificates needed to cover the increased production (in our case €2.26 million = €2.9 million −€0.64 million). The net benefit depends on the price of CO_2, the benefit rising with the price. However, this artificial increase of production involves cost inefficiencies, which can be assumed to be an increasing function of the extra production, independent of the CO_2 price but dependent on the plant. These cost inefficiencies can up to a point cancel out the gains from increased free allocation. This is shown in figure 1, where gaming is undertaken only if the increased production to attain the threshold is less than ΔX_0. In our case, if the extra production of 0.1 ton of clinker does not involve cost inefficiencies of more than €2.53 million, gaming is profitable.

Evidence of strong responses to thresholds—where small changes in behaviors lead to large changes in outcomes—has been found in the recent literature. Sallee and Slemrod (2012) find evidence that the automakers respond to thresholds (or "notches") in the gas guzzler tax and to mandatory fuel economy labels by manipulating fuel economy ratings in order to qualify for more favorable treatment. The management control literature also finds that managers tend to react strongly to the existence of discontinuities. This is the case, for example, when bonuses depend on the achievement of a given level of sales for a sales manager, a given productivity

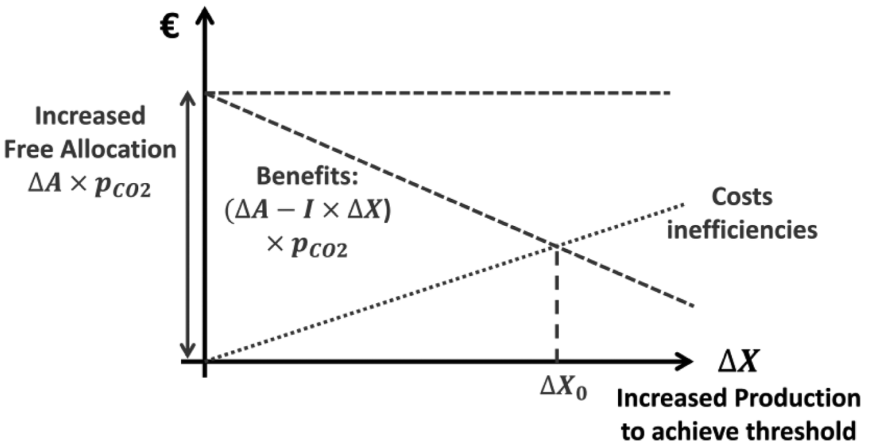

Figure 1. The value of gaming. The installation engages in gaming when $\Delta X < \Delta X_0$. I refers to the carbon intensity of the plant. Benefits are the increased free allocations minus increased emissions.

indicator for a plant manager, a given return on investment for a business manager, a given level of the total shareholder return for a CEO, etc. (Locke 2001). In a well-known article, Jensen (2003) points out that such “gaming” behavior is perfectly rational under threshold rules. He argues that these rules imply an agency cost that is largely underestimated and suggests that linear bonus schemes should be preferable.

1.3. Alternative Free Allocation Rules

The EU ETS Phase 3 rules can be compared with an ex ante allocation without ALTs or an output-based allocation scheme. Under OBA, the next period allocation is determined according to an equation similar to equation (1) (with $HAL_{i,p} \times ALCF(q_{i,p,t}/HAL_{i,p})$ replaced by $q_{i,p,t}$). The scheme therefore has no thresholds, and the historic activity level HAL is replaced by the previous year activity level q_t as allocations are altered on a continuous yearly production basis. In this paper, we will evaluate the impact of the ALTs by contrasting four scenarios, with their respective acronym:

- Ex ante free allocation with ALTs (Phase 3 allocation rules) and gaming (EXALTG),
- Ex ante free allocation with ALTs (Phase 3 allocation rules) without gaming (EXALTNG),
- Ex ante free allocation without ALTs (EX),
- Ex post output-based allocation (OBA).

Scenario EXALTG corresponds to what was observed in Phase 3. Scenario EXALTNG applies the same rules, but it is a hypothetical scenario where no gaming behavior is observed (every variable is identical as in EX, except the allocation, which follows a different rule). EXALTNG, EX, and OBA represent counterfactuals.

2. METHODOLOGY AND DATA

Since 2013 is the first year the threshold rule is in place, the 2012 activity level directly determines the allocation of allowances for 2013. The preliminary analysis in Neuhoff et al. (2014) provided evidence of distortions arising from the ALTs rule. The present study quantifies these distortions.

2.1. The Cement Sector

Our analysis focuses on the cement sector for three reasons.[11] First, it ranks amongst the highest in terms of carbon intensity per value added; thus the effects of free

11. For an overview of the European cement sector, see, e.g., Hourcade et al. (2007) and Boyer and Ponssard (2013).

allocation rules are magnified. The cement production process can be divided into two basic stages: production of clinker and the subsequent grinding and blending of clinker with other mineral components to produce cement. The first stage (clinker production) accounts for the bulk of carbon emissions in cement production. Allocation under the EU ETS is based on a benchmark on clinker.[12] The relevant output involved in the threshold rule is then the quantity of clinker produced. As an intermediate product, clinker is more traded among cement producers than the final product, cement.[13] However, cement is traded as well; hence, the analysis has to be done simultaneously for both products.

In terms of geographical segmentation the high cost of land transportation of cement (or clinker) suggests that regional cement consumption be sourced from local plants. Some imports or exports mostly take place through long haul sea transportation (rail or river transportations of cement are not well developed within Europe as opposed to, for instance, the United States). A relevant market is usually defined in reference to competition analysis. It allows for a precise definition of consumption, production facilities, and import and export flows. In the EU, these data can be collected at the member state (country) level, and a number of antitrust analyses are typically made at this level. In this paper, we shall consider that the member state provides a good level of segmentation for our analysis.[14]

Second, as the sector experienced a demand collapse in the order of 50% or more between 2007 and 2012 in several member states, the ALTs rules were likely to have been a relevant factor for operational decisions during the period studied. Indeed, we suspect that the most important differences between scenarios EX and EXALTG will occur in countries in which cement and clinker consumption in 2012 fell well short of the historical consumption level, and hence ALTs rules were relevant. For convenience our results obtained for each member state will be aggregated. The 26 EU ETS member states with ETS-participating clinker production plants will be

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12. It could have been based on a cement or a hybrid benchmark instead. The hybrid benchmark avoids the "clinker-cement paradox" (Quirion 2009). If the benchmarked product is cement, plants have an incentive to outsource clinker production. If it is clinker, the incentive to reduce the clinker-to-cement ratio is lost. In California, the benchmarked product is "adjusted clinker and mineral additives produced," which is equal to $Q_K(1 + r/R)$, where Q_K is the clinker produced, R is the clinker ratio, and r is the "mineral additives ratio" (limestone and gypsum consumed divided by cement produced). This system gives an incentive to use more mineral additives while preventing clinker outsourcing.

13. International traders do also play a role in this market. Yet in 2011 around 50% of world cement trading was undertaken by the top five global cement companies (see, e.g., financial analyst's report Jefferies [2012, 153]).

14. Some small countries are regrouped into larger entities which are coherent in terms of regional market (see the appendix, sec. C.1).

divided into two groups (see table 1).[15] The first group includes countries where the average domestic cement consumption in 2011–12 was less than 70% of 2007 levels.[16] We name this group "low demand" (LD) countries. Of the LD countries, we present some of the results separately for Greece and Spain, as these two member states were particularly affected by the downfall. The LD countries represented 51% of EU ETS cement emissions in 2008 and 40% in 2012. The remaining countries are classified as "moderate demand" (MD).

Third, the cement sector is characterized by relatively homogeneous products and production processes, unlike chemicals and steel, for example, with many product categories and differentiated impacts. This aspect does not make distortions due to ALTs more likely to occur but facilitates their quantifications. Indeed, allocation is determined with activity levels (q/HAL, in the cement sector, q being the quantity of clinker), but data on output are not publicly available at the installation level. However, data on emissions are available, thanks to the European Union Transactions Log (EUTL). Because of the very strong and direct relationship between production of clinker, a highly homogeneous product, and emissions, it is possible to infer production (activity) from emissions.[17]

2.2. Conceptual Framework and Main Assumptions

The quantification of distortions due to the thresholds necessitates the elaboration of counterfactual states of the world for 2012 (what would have happened had the threshold rule not been implemented, that is, under scenarios EX, OBA, or had it been implemented and had the firms not reacted strategically) for each relevant

15. Note that Iceland, Liechtenstein, and Malta have no listed clinker plants in the EUTL database, while data for Cypriote plants were not able to be exploited due to missing data.

16. The average of 2011 and 2012 was taken since both years are relevant to the analysis that follows here. The year 2007 is taken as the reference year since this was the year in which demand peaked in most EU member states prior to the economic crisis of 2008.

17. We use the observed ratio of publicly reported verified emissions (E) relative to the historical emissions level (HEL), to proxy the share of unobserved activity level relative to historical activity level (HAL), i.e., $E/HEL \approx q/HAL$. This approximation is possible because the emissions intensities of clinker production have changed only very marginally in the EU in recent years between 2005 and 2012 (GNR database; WBCSD 2014). At first sight, the approximation $E/HEL \approx q/HAL$ may turn problematic for precisely distinguishing between installations that are above or below thresholds (25% and 50% of q/HAL). However, as detailed in the appendix, sec. A.1, we ensure that installations are correctly identified using 2013 allocations data. This reveals whether or not the installation had seen its allocation reduced because of 2012 activity levels. Further, 2013 allocation data also allowed us to obtain clinker carbon intensity at the plant level and then to assess production through emissions (see the appendix, sec. A.2).

Table 1. Moderate- (MD) and Low Demand (LD) Countries in Terms of Cement Consumption in 2012 Relative to 2007 Levels

Low Demand (LD) Countries	Moderate Demand (MD) Countries
Ireland, Spain, Greece, Bulgaria, Hungary, Denmark, Portugal, Italy, Slovenia, and Baltic countries	Austria, Belgium, Czech Republic, Finland, France, Germany, Netherlands, Norway, Poland, Romania, Slovakia, Sweden, and United Kingdom

Note.—There are no clinker plants in Malta, Lichtenstein, and Iceland. Emissions data on two clinker plants of Cyprus are available from 2012 only; hence they cannot be used in this analysis.

market. A straightforward caveat is that our results are then very dependent on the counterfactuals, which is estimated by combining historical data of country- and plant-level characteristics using a panel data model. We conduct Monte Carlo analysis to assess confidence intervals and conduct a number of robustness tests to limit this caveat.

We consider a "state of the world" as consisting of:[18]

- Consumption and price of cement;
- Production of clinker and cement, distribution of this production among plants, clinker to cement ratio;
- Trade flows of cement and clinker.

We know the (actual) state of the world for EX in 2011 and for EXALTG in 2012 thanks to trade and emissions data, the close relationship between emissions and clinker production, and conservation principles. We need to construct counterfactuals for 2012 for OBA, EX, and EXATNG. There are two issues: the change in economic conditions from 2011 to 2012 (cement consumption fell by 13% at the EU level between 2011 and 2012) and the possible impacts of the allocation rules (we expect that ALTs led to an increase in the production of clinker to get a higher level of free allocation).

We now detail our main methodological assumptions. We start with the second issue: the role of the allocation rule.

Hypothesis H_1: The state of the world is identical for OBA, and EX/EXALTNG.[19]

18. The amount of free allocation received is then excluded from the "state of the world."

19. EX and EXALTNG have by definition the same state of the world and differ only by the allocation method.

We assume that firms take for granted that the ex ante free allocations have been obtained through a leakage argumentation so that they will not pass through the marginal cost of carbon to consumers. This implies that the only difference in the corresponding counterfactual scenarios refers to the amount of free allocations.

This assumption appears at odds with the economic literature (Demailly and Quirion 2006; Fischer and Fox 2007), which would clearly distinguish between ex ante free allocations and ex post OBA. Ex ante free allocations do not provide any protection against leakage because the marginal cost of production is not affected (as long as a plant operates ex ante free allocation only implies a lump-sum transfer). In contrast, with ex post OBA allocations, marginal cost is unchanged because free allocation is directly proportional to output; hence there are no competitive impacts with respect to imports. This is the usual argument in favor of OBA. Cement consumption and price would then differ depending on which of these two allocation methods are used.

H_1 is supported by a series of in-depth interviews with cement sector actors in the EU ETS (Neuhoff et al. 2014, 26). These interviews point out three reasons why in practice, no price change (cost pass-through) was observed in the cement sector so far. First, the ex ante free allocations were given out, precisely to mitigate carbon leakage. Thus firms perceived a risk of losing future free allocations if they passed through the cost of carbon and there was no leakage. Second, companies reported that long-term strategic considerations—such as maintaining market share and good client relationships—could partially balance the incentive to pass the carbon price. Third, they perceived the risk of drawing the attention of competition authorities due to abnormal profit levels, if the pass-through of the carbon cost led to large windfall profits.[20] It is important to note that these empirical observations have been made in a context of low carbon prices. We certainly do not claim that H_1 would prevail at all times.

Hypothesis H_2: The cement consumption and price for EXALTG is identical to the one of EX/EXALTNG.

Since the clinker production is likely to increase through gaming, the question is what happens to the excess production of the plants that game the scheme. This assumption says that this excess production affects the clinker plant distribution, the trade flows, and the clinker to cement ratio but not the consumption (quantity and price). From H_2 we shall derive the trade flows for the other scenarios through an economet-

20. The UK Competition Commission has argued that UK cement firms enjoyed abnormal profits even without passing through the cost of carbon: https://www.gov.uk/cma-cases/aggregates-cement-and-ready-mix-concrete-market-investigation.

ric analysis of the historical trends. The difference between this estimation with the observed trade flows for EXALTNG can be attributed to the introduction of ALT and the gaming.

Neuhoff et al. (2014) indeed identify the three above channels: reshuffling of production among plants (this may be quite easily done since many cement companies are multiplants), exports to non-EU countries, and increase in the clinker to cement ratio. The data support the extensive use of these three channels. This does not exclude that a small fraction of the excess production goes into the regional market. Our assumption is that this fraction can be neglected because of the oligopolistic nature of competition. Increasing the regional supply would most certainly depress the price substantially, and increasing a plant market share would most certainly induce strong reactions from competitors.

We now come back to the change in the economic conditions. We shall assume that the distribution of clinker production among plants remains proportional to the change in consumption with some corrections for coastal plants and plant capacity. Having estimated counterfactual production levels by installation,[21] we can estimate *the number of free allowances (EUA for EU Allowance, which is the official title pollution permits traded in the EU Emissions Trading Scheme) received* at the plant level under the various scenarios.[22]

The two hypotheses H_1 and H_2 allow us to construct a counterfactual plant activity common to the counterfactual scenarios (EX, EXALTNG, and OBA) in the absence of data or models to directly assess the effects of allocation methodologies on consumption and prices. We argue that the empirical evidence reported in Neuhoff et al. (2014) is persuasive and supports these assumptions. However, given the discrepancy with the literature, it is important to see how our results would stand if H_1 or H_2 were relaxed. This is done in section 3.7.

To convert the free allocation and emission effects into monetary value, we shall assume a CO_2 price at 7.95 €/t, which corresponds to the average future price (December 2013) during the year 2012.[23]

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21. As we perform a Monte Carlo analysis, there is not "one" counterfactual but 10,000. For simplicity, we will explain the reasoning as if there was just one (these different steps are simply repeated for each sample of counterfactual).

22. As an example, let us consider a plant, which is functioning at 50% E/HEL and receiving 1 million EUAs. Suppose that our econometric model finds that the counterfactual activity level of this plant is 40%. This plant would have received 0.4 million EUAs under OBA, 1 million EUAs under EX and EXALTG, 0.5 million EUAs under EXALTNG. In this short example, we see that gaming from 40% to 50% allows obtaining 0.5 MEUAs more allowances, but involves 0.11 Mt CO_2 of additional emissions, so that the net gain in terms of allowances is 0.39 MEUAs.

23. Data from ICE database (http://data.theice.com/MyAccount/Login.aspx).

Hypothesis H_3: The increased production due to gaming is sold at marginal cost (excluding emission cost) and has no impact on profits.

In practice, plants may actually sell their excess production at a higher or lower price, the important point being that the associated revenue be higher than the associated inefficiency costs (see sec. 1.2). The precise financial impact is bound to depend on circumstances specific to each plant which are unobservable. H_3 allows for an estimate of the financial impact.

In summary, for each scenario, we compute production, emissions, and allocation. The net allowances (allocations minus emissions) are compared for the scenarios EX, EXALTNG, EXALTG, and OBA. Comparing other scenarios to OBA gives an estimation of overallocation profits (in MEAUs or M€). The difference between EXALTG and EXALTNG gives the impact of gaming. Table 2 summarizes how allocations and production are obtained under each scenario, and table 3 lists the data sources.

Comparing counterfactual net exports to real net exports gives the parts of the excess clinker production which are destined for clinker exports and cement exports. Assuming no stockpiling, the remaining part is attributed to a change in the clinker ratio.

2.3. Estimation Strategy

Counterfactual values for clinker plant activity are predicted based on panel data estimations at the plant level. We use first differencing in order to control for country-level time invariant factors and the autoregressive nature of plant activity. The regression includes both country-level data (cement consumption, GDP) and plant-level characteristics, such as carbon intensity, size, and geographical location (coast) as detailed in section 2.2 and in the appendix, sec. C, available online. To assess the robustness of our results we use a semiparametric approach (Powell 1994) by specifically modeling the multiplicative error of our estimation. The counterfactual plant activity level is then not fixed but a random variable. We perform a Monte

Table 2. Scenarios

Scenarios	Allocations	Production
OBA	Proportional to activity (*HAL* × *ALCF* <-> *q* in eq. [1])	Counterfactual (explained in the appendix, sec. C.1)
EX	Independent of activity (*ALCF* = 1 in eq. [1])	Same as OBA
EXALTNG	Hybrid (eq. [1])	Same as OBA
EXALTG	Same as EXALTNG	Actual 2012 production

Table 3. Data Sources

Variable	Source
Emissions and *HEL*	European Union Transaction Log
Clinker net exports (NE_K)	Eurostat. International trade, EU trade since 1988 by HS2, 4, 6, and CN8 data are originally given by country pairs. Total net exports are recomputed. Product category: "Cement Clinker" (252310)
Cement net exports (NE_C)	Eurostat. Product category: Difference between "Cement, incl. cement clinkers" (2523) and "Cement Clinker" (252310)
Cement consumption (C_C)	(1) Cembureau (2013) for the main European countries (2) VDZ for Baltic countries and Norway (table C10).
Country GDP (GDP)	World Bank
Clinker production (Q_K)	EUTL-derived estimation (through estimated clinker carbon intensity and emissions; see the appendix, sec. A.1). Where there were data gaps, supplementary data were obtained from several sources, e.g.: • National cement association data when reliable and exploitable, i.e., Oficemen (2012) for Spain • VDZ for Germany (table A2) • Info Ciments (2013) for France • Getting the Numbers Right database (GNR) for available countries (UK, Italy, Poland, Czech Republic, Austria)

Carlo simulation with 10,000 samples and report the average and the 95% confidence interval.

3. RESULTS

3.1. Impact of ALTs on the Plant Distributions

Figures 2 and 3 display the distribution of plant activity levels for 2012 (EXALTG), the counterfactual production (EX, EXALTNG, OBA), and also the distribution in 2011 for comparison.[24] In LD countries, there is a marked jump (or "bunching") in installations operating around the 25% and 50% activity level thresholds in 2012, whereas the counterfactual distribution for these countries is not skewed at the

24. There is not "one" but 10,000 versions of the counterfactual. The distribution displayed here corresponds to the central scenario (with average activity level for each plant).

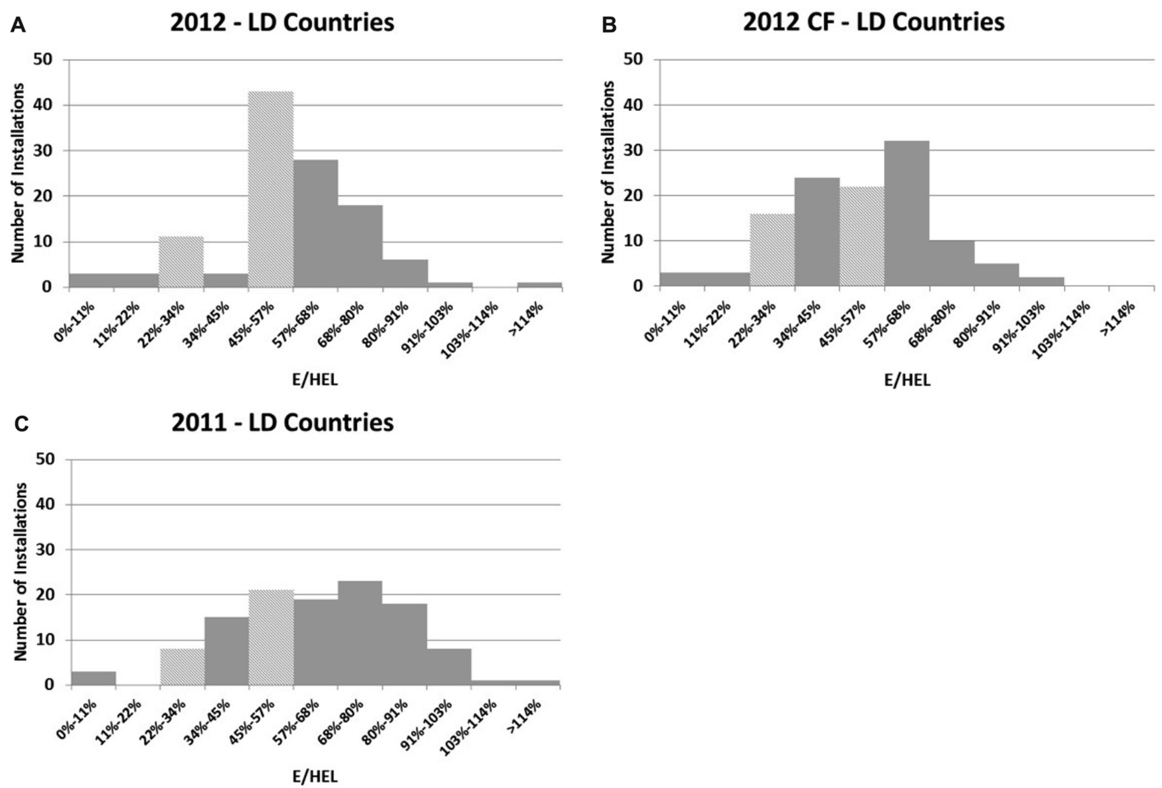

Figure 2. Distribution of installations according to their activity level (approximated by *E/HEL*) in 2012 (*A*), compared with 2012 counterfactual production (*B*) and 2011 observed production (*C*) in low demand countries. Light gray bars indicate categories just above thresholds. Using 2013 allocation data enables us to indirectly distinguish installations which were above or below thresholds (25% and 50% of *q/HAL*) in 2012 (see the appendix, sec. A.1, for more explanations).

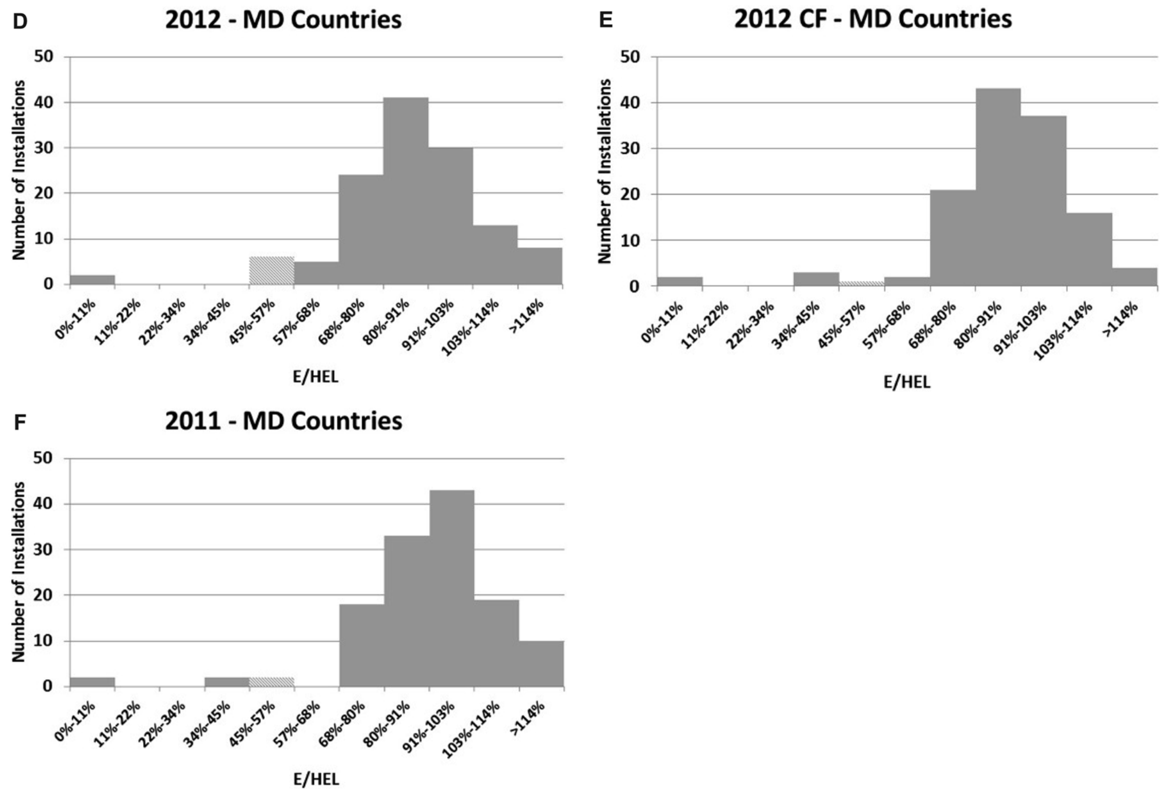

Figure 3. Distribution of installations according to their activity level (approximated by E/HEL) in 2012 (D), compared with 2012 counterfactual production (E) and 2011 observed production (F) in moderate demand countries. Light gray bars indicate categories just above thresholds. Using 2013 allocation data enables us to indirectly distinguish installations which were above or below thresholds (25% and 50% of q/HAL) in 2012 (see the appendix, sec. A.1, for more explanations).

thresholds. We find that in LD countries where 117 of the 246 cement installations are located, ALTs should have reduced free allocations in 50 of them, but due to gaming, only in 20 installations were they reduced in reality. Thus, in line with preliminary findings of Neuhoff et al. (2014), these results show clearly that cement companies have indeed altered plant production levels in response to ALTs rules. In MD countries, this response is noticeable but to a much less degree. The contrast between LD and MD shows the importance of the demand collapse in triggering this gaming behavior.

3.2. ALTs' Impacts on Clinker Production and Emissions

Table 4 gives the clinker production and the emissions for 2012 (EXALTG) and the counterfactual (EX, EXALTNG, OBA). The excess clinker production due to the introduction of thresholds rule is quantified. It represents an increase of 15% (+7.2 Mt) in LD countries, 28% (+3.5 Mt) for Spain, and 56% (+2.0 Mt) for Greece. These increases are extremely large, even if the total impact at the EU level is more modest (5%). The increase in the clinker production translates into increases in emissions. Altogether we estimate that an additional 5.8 Mt CO_2 (+5% of total EU cement emissions) have been emitted by EU cement firms as a consequence of the ALT-induced strategic behavior of cement companies.

3.3. Impact of Gaming on Plant Distribution on the Free Allowances

Table 5 gives the amount of EUAs that are allocated to cement installations under the four scenarios (EX, EXALTNG, EXALTG, OBA). If installations received 100% of their allowances regardless of their activity (i.e., the allocation under the EX scenario), then LD countries and MD countries would have received 74.5 and 70 million EUAs, respectively. OBA allocations would lower allocations to 36.1 and 62.2 million EUAs, respectively. The decrease in allocations is more significant for LD countries because the average activity is much lower.

As explained, the scenario EXALTNG can be seen as an imperfect approximation of the OBA rule (OBA represents a linear scheme with no thresholds). If there had been no gaming, it would have set the allocations at 55.1 and 68.1 million EUAs for LD and MD countries, respectively. Thus for the cement sector as a whole, ALTs reduced free allocation in 2012 by 6.4 MEUAs or 4% compared to the scenario without ALTs (EX). Had OBA been implemented instead, free allocation would have been further reduced considerably by 46 MEUAs (32% reduction compared to EX), which corresponds to 34% of the total cement sector free allocation in 2012. The effect for the MD countries is negligible, as most of the installations have an activity level superior to 50%. However, for LD countries the theoretical effect of the threshold rule as an approximation of the OBA rule would have been more significant: a 50% (i.e., (74.5 − 55.1)/(74.5 − 36.1)) reduction should have been obtained. With gaming (EXALTG), a reduction of only 16% prevails (i.e., (74.5 − 68.4)/(74.5 − 36.1)). For

Table 4. Production and Emissions for the Observed (EXALTG) and Counterfactual (EX, OBA, EXALTNG) Scenarios

	LD Countries	MD Countries	All Countries	Spain
Production (CF)				
in Mtons	47.2	80.2	127.4	12.4
	[45.2, 49.4]	[76.9, 83.7]	[123.6, 131.5]	[11.5, 13.5]
Production (observed)				
in Mtons	54.4	79.4	133.8	16.0
Increased production				
in Mtons	+7.2	−.8	+6.4	+3.5
	[5.0, 9.2]	[−4.2, 2.5]	[2.3, 10.2]	[2.5, 4.4]
	p = 1.00	p = .33	p = 1.00	p = 1.00
Increased emissions				
in Mtons CO_2	+6.4	−.6	+5.8	+3.1
	[4.5, 8.2]	[−3.6, 2.2]	[2.2, 9.1]	[2.2, 3.8]
	p = 1.00	p = .34	p = 1.00	p = 1.00

Note.—Reported values are the average of the 10,000 simulations and the 95% interval. p is the probability that the value is above zero. LD = low demand; MD = moderate demand.

Spain, the percentages would, respectively, be 61% and 20%; and for Greece, 73% and 24%. Further, we estimate the allowances gaming gain at 14.8 MEUAs, located almost exclusively in LD countries, and a net gaming gain (deducing extra emissions) of 9.0 MEUAs.

3.4. Financial Potential Gain Associated with Gaming

In the calculation of the potential gain we assume that the increased production is sold at marginal cost and so has no impact on profits. This gives an upper bound for the profits that could be achieved with gaming since it does not take into account the possible inefficiency costs: logistics cost for production shifting, extra sales expenditures and rebates for increased exports, opportunity cost for increasing the clinker to cement ratio. That there are inefficiency costs can be seen from the fact that not all plants achieved the 50% threshold, but some gaming was certainly worthwhile since a large proportion of plants did manage to exceed the threshold.

To convert the increase in free allowances and the increase in emission rights into monetary value, we need to assume a CO_2 price. It should be clear that the amount of profitable gaming depends on the CO_2 price. We shall come back to this point in our discussion of the results. Table 6 gives the potential profit associated with gaming for a CO_2 price at 7.95 €/t, which corresponds to the average future price

Table 5. Free Allowance Allocation Levels (MEUAs) for the Observed (EXALTG) and Counterfactual (EX, OBA, EXALTNG) Scenarios, the Allowances Gain from Gaming, and the Net Gain from Gaming

Allocations	LD Countries	MD Countries	All Countries	Spain	Greece
EX	74.5	70.0	144.5	23.6	8.7
EXALTNG	55.1	68.1	123.2	14.9	4.3
	[52.8, 57.3]	[67.2, 68.9]	[120.8, 125.6]	[13.5, 16.3]	[3.5, 5.1]
EXALTG (observed)	68.4	69.6	138.1	20.7	7.3
OBA	36.1	62.2	98.2	9.5	2.7
	[34.5, 37.7]	[59.6, 64.9]	[95.2, 101.5]	[8.7, 10.2]	[2.2, 3.2]
Allowances gaming gain	+13.3	+1.5	+14.8	+5.8	+3.0
	[11.1, 15.6]	[.7, 2.4]	[12.5, 17.3]	[4.4, 7.2]	[2.2, 3.8]
	p = 1.00	p = 1.00	p = 1.00	p = 1.00	p = 1.00
Net gaming gain (minus emissions)	+6.9	+2.1	+9.0	+2.8	+1.2
	[4.9, 9.0]	[−.5, 5.0]	[5.7, 12.5]	[1.7, 3.8]	[.6, 1.8]
	p = 1.00	p = .94	p = 1.00	p = 1.00	p = 1.00

Note.—Reported values are the average of the 10,000 simulations and the 95% interval. p is the probability that the value is above zero. LD = low demand; MD = moderate demand.

(December 2013) during the year 2012. Then it reflects more expected gains than actual gains, which may be lower or higher (the CO_2 price decreased the following year, but firms may have banked these extra allowances and the CO_2 price may rise in the future).

For LD countries, the potential gain of EX relative to OBA is estimated through the net increase of allowances, which is 74.5 − 36.0 Mt CO_2 and an EUA price 7.95 €/t, which makes €306 million. With the introduction of the threshold rule this increase would have been only €158 million had the firms not gamed the scheme. The reduction is coming from the reduced amount of free allocations due to the downfall in market demand. The gaming increases the amount of free allocations but increases emissions, bringing a potential gain at €213 million, which represents an increase of 35% (+€55 million) relative to €158 million. For Spain, the percentage increase is 44% (+€22 million) and for Greece it is 77% (+€10 million). These figures are substantial even though the carbon price was low at that time. This explains

Table 6. Quantification of the Monetary Value of Excess Free Allocations for the Various Scenarios

Millions of € Relative to OBA	LD Countries	MD Countries	All Countries	Spain	Greece
EX	306	62	368	113	48
	[292, 318]	[40, 83]	[342, 392]	[107, 119]	[44, 52]
EXALTNG	158	49	207	50	13
	[145, 170]	[27, 69]	[181, 231]	[44, 55]	[9, 16]
EXALTG	213	66	278	72	23
	[209, 216]	[65, 67]	[276, 281]	[69, 74]	[22, 24]

Note.—Reported values are the average of the 10,000 simulations and the 95% interval. LD = low demand; MD = moderate demand.

why firms undertake the various inefficiencies described earlier to capture part of this gain.

3.5. Where Does the Excess Clinker End Up? Indirect Evidence Revisited

This section revisits the indirect evidence of excess clinker production proposed by Neuhoff et al. (2014). As noted, three channels have been identified, production shifting, exports increase, and clinker ratio increase.

3.5.1. Production Shifting in Multiplant Companies

Cement company executives reported, in interviews, that subsequent to the introduction of ALTs, it was a frequent practice to arrange production levels across plants to ensure being above the threshold at as many units as possible (Neuhoff et al. 2014). We observe output behavior consistent with these statements in several cement companies which have a number of plants producing close to the thresholds. Table 7 presents four examples.[25] In each of these firms in 2012, production (within the same geographical country) simultaneously falls in one plant (which produced well above the threshold in 2011), and rises in another plant above the threshold (which was previously operating below the threshold).

3.5.2. Exports

Table 8 gives net exports of clinker and clinker embedded in cement from 2010 to 2012 for LD and MD countries. We observe a surge in clinker net exports in LD

25. We only display here groups of installations belonging to a country-company that are the most consistent with production shifting but avoid cherry-picking individual installations. For the four cases, all installations of a certain country-company are displayed.

Table 7. Evidence of Within-Firm-Country Production Shifting to Meet Thresholds

Country-Company	Installation	*E/HEL* 2011 (%)	*E/HEL* 2012 (%)
Greece-W	1	34	49
Greece-W	2	77	66
Greece-W	3	11	0
Spain-X	1	42	50
Spain-X	2	57	46
Spain-X	3	68	56
Hungary-Y	1	41	46
Hungary-Y	2	68	50
Portugal-Z	1	34	64
Portugal-Z	2	55	51
Portugal-Z	3	71	60

Note.—An appropriate use of 2013 allocation data enables us to indirectly distinguish installations that have been in 2012 above or below thresholds (25% and 50% of q/HAL). We find that whenever E/HEL is superior to 45% (respectively 22%), the corresponding installation is above the first (respectively second) activity level threshold (see the appendix, sec. A.1 for more explanations).

countries: 6.21 Mt in 2012, compared to 2.03 Mt and 1.94 Mt in 2010 and 2011, respectively. In contrast, MD countries remained small net importers of clinker and no significant shift was observed in their trade patterns. Further analysis revealed that these clinker exports in 2012 were destined mainly to countries in Latin America and Africa, including Brazil, Togo, Ghana, Cameroon, Côte d'Ivoire, and Mauritania and Nigeria.

Table 8. Clinker Net Exports in 2010, 2011, and 2012 in LD and MD Countries in Millions of Tonnes

	2010	2011	2012
LD countries:			
Clinker	2.03	1.94	6.21
Clinker in cement	5.49	4.58	6.37
MD countries:			
Clinker	−.93	−.74	−.71
Clinker in cement	2.24	2.46	2.02

Note.—Data are from Eurostat; we use a common clinker ratio of 75% to compute clinker embedded in cement. LD = low demand; MD = moderate demand.

Table 9. Clinker-to-Cement Ratio in Selected Areas (%)

Clinker Ratio	2010	2011	2012
MD countries	76	76	77
LD countries	74	72	74
Spain	79	76	82
Greece	76	71	75

Note.—Data from authors' analysis. LD = low demand; MD = moderate demand.

3.5.3. Clinker Ratio

Another way excess clinker production might materialize is in a higher clinker-to-cement ratio. That is, firms could use more clinker to produce the same ton of cement. The clinker ratio can be recomputed at the macro level (state of group of states) with the formula $R = Q_K - NE_K/(C_C + NE_C)$, where Q_K is the clinker production, NE_K and NE_C are net exports of clinker and cement, and C_C is the cement consumption (see the appendix, sec. B, for explanation and table 3 for data source). Table 9 shows the clinker ratio for the MD countries, LD countries, Spain, and Greece. There is some suggestion that the historically declining trend in the clinker-to-cement ratio reversed in 2012, notably in Spain and Greece. This is important because improvements in the clinker ratio have been the main driver of carbon abatement in the EU cement sector.

3.6. Decomposing the Channels for Clinker Disposal

In order to understand better the effects of the distortions that arise from ALTs, we attempt to decompose the excess clinker output into the main destinations to which they are channeled through: changes to clinker ratio of domestic cement and increase in exports (clinker or cement).[26] Although it is likely that there is some stockpiling, the lack of data makes it difficult to attribute excess production to this channel.

This decomposition requires that actual net export volumes of cement and clinker are compared to counterfactuals levels (see the appendix, sec. C.2, for the estimation method and data used). Assuming no stockpiling, we can attribute the remaining excess clinker output to clinker ratio increase. Table 10 gives the results. Figure 4 provides a graphical representation. For LD countries, net exports of clinker increased by 6.2 Mt while our counterfactual is 4.6 Mt (+1.6 Mt); the net export of cement increased by 8.5 Mt while the counterfactual is 6.1 Mt (+1.7 Mt

26. Production shifting in multiplant companies does not generate excess clinker output; hence, it is not quantitatively assessed.

Table 10. Real and Counterfactual Net Exports of Clinker and Cement (Mt)

Region	Total Increase Production Clinker	2012 Clinker Net Exports			2012 Cement Net Exports			Clinker Ratio	
		CF	Observed	Diff	CF	Observed	Diff*R	Effect	Relative (%)
All LD	7.2	4.6	6.2	+1.6	6.1	8.5	+1.7	3.9	+6
All MD	−.8	.4	−.7	−1.1	3.3	2.7	−.4	.7	+1
All	6.4	5.0	5.5	+.5	9.4	11.2	+1.3	4.6	+3
Spain	3.5	2.2	3.4	+1.2	2.2	2.6	+.3	2.0	+12
Greece	2.0	.5	1.8	+1.3	1.5	1.7	+.2	.5	+9

Note.—CF = conterfactual; LD = low demand; MD = moderate demand.

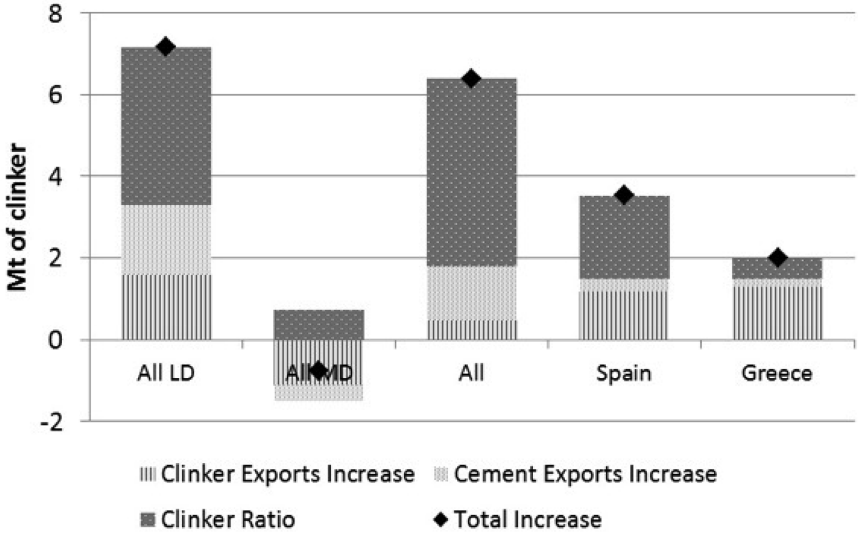

Figure 4. Routes of excess clinker production decomposition

of clinker embedded); this implies that 2.4 Mt of clinker went into the increased content of clinker in cement. This latter figure represents an increase of 6% relative to our counterfactual for the clinker to cement ratio as defined in the previous section. The values of clinker ratio effect are higher here than the estimates in section 3.5 suggesting that stockpiling of excess clinker output may be occurring, as well as increased clinker ratio of cement exports.

3.7. Robustness and Caveats

In this section we briefly discuss how our results would be affected if we were to relax hypotheses H_1, H_2, and H_3. Let us briefly recall these assumptions which may be seen as behavioral rules reflecting the anecdotal evidence.

Hypothesis H_1: The cement market (quantity and price) is identical for OBA, and EX/EXALTNG.

Hypothesis H_2: The cement market (quantity and price) for EXALTG is identical to the one of EX/EXALTNG.

Hypothesis H_3: The increased production due to gaming is sold at marginal cost (excluding emission cost) and so has no impact on profits.

We now detail the potential impact of adopting more standard hypotheses regarding profit-maximizing behavior. A change in the allocation rule will affect the cement market (quantity and price) and the trade flows (leakage). ALT rules need also to be analyzed in terms of profit maximizing. Qualitatively we certainly expect that going from EX to OBA would increase the domestic consumption, increase domestic production, decrease the output price, and reduce net imports. It would of course eliminate the lump-sum profits due to the ex ante free allocation rule. Going from EX to EXALTNG would only matter in terms of decreasing these lump-sum profits. Now going to EXALTG would partly reduce the revised differences between EX and OBA as regards the domestic consumption, the domestic production, the output price, and the trade flows. We can expect this because the reduction in domestic production would be partly offset by the excess production to achieve the thresholds at some plants, part of this excess production affecting the domestic market and the trade flows. We have neither the model nor the data to quantify how this change in hypotheses would quantitatively affect our results.

Fowlie et al. (forthcoming) provide some ideas on how this could be done. They analyze the impact of various allocation schemes in the context of the US cement industry. Their model incorporates two modeling features: short-term oligopolistic Cournot competition with endogenous capacity constraints and leakage (imports are introduced through a competitive fringe). The model is dynamic with incumbents and entrants, and allows for investment strategies. Firms maximize their discounted profits. The model is calibrated on a regional basis (US districts; areas roughly equivalent to EU member states) and then analyzed under various hypothetical scenarios.

Among other results, they point out differences between OBA, grandfathering (EX), and grandfathering with closure rule (a weak version of EXALTG in which free allocations are lost if the plant is closed). As expected, the cement market and the trade flows differ between OBA and grandfathering; the latter leads to lower domestic production and more leakage. The difference in profits depends on the level of the lump-sum transfer associated with free allocations. The novel part of their analysis (the standard economic literature on OBA reported in the introduction assumes a static framework) concerns the difference between grandfathering and grandfathering with a closure rule; the latter increases domestic production and reduces leakage, at least temporarily. The introduction of the closing rule induces some gaming (excess domestic production relative to EX), which is beneficial to the incumbents.

It would certainly be interesting to use a similar approach to quantify how our results would be affected if H_1, H_2, and H_3 were replaced by more standard economic assumptions based on explicit profit maximizing. This may be particularly important in a context of high carbon price since this may trigger more economic behavior than the one we assumed. Still our intuition is that the qualitative insights mentioned above would hold. This needs to be confirmed by further work.

4. CONCLUSIONS AND POLICY OPTIONS

An important change in the EU-ETS Phase 3 for EITE concerns the introduction of the activity level threshold rule (ALTs). The underlying rationale for its introduction is that it would reduce the overallocation profits in case of downfall in the demand: whenever the activity level of an installation falls below some threshold (50%, 25%, 10%) relative to its historic activity level used to allocate free allocations, the allocation would be reduced accordingly (50%, 75%, and 100%).

Our ex post analysis of the year 2012, the first year in which the threshold rule applies, focused on the cement sector, a sector in which approximately half the EU countries had experienced a significant downfall in consumption (LD countries). It provides a natural experiment to evaluate the consequences of this rule.

Our main conclusion is that while ALTs did reduce to some extent overallocation profits, they also created operational distortions that led to outcomes inconsistent with the low carbon transition of EU energy intensive industries. The reduction in overallocation profits is less than expected because of the gaming behavior of the industry to achieve the thresholds, during periods of low market demand. Thanks to the elaboration of a counterfactual, we have been able to quantify that after the introduction of ALTs: the potential overallocation profit with gaming is €278 million (2 €/t clinker) and €207 million without gaming, while it would have been €368 million in the absence of ALTs. The expected reduction in windfall profits due to the ALTs is 44%, while the actual reduction is 24%. The incentives are magnified in low demand countries, where profit with gaming is €213 million (3.9 €/t clinker) and €158 million without gaming, while it would have been €306 million without ALTs.

In the 2000s, top management attention to the issues of climate change emerged as an important dimension of corporate social responsibility, and a large number of companies got involved in proactive strategies to limit their own emissions (Arjaliès, Goubet, and Ponssard 2013). The EU ETS positively contributed to turn this strategy into operational practice by putting a price on carbon. The distortions reported in our study are particularly detrimental in this respect: if the threshold is not achieved in a given plant this encourages the firm to increase its production to obtain a lump-sum gain in free allowances. The cement industry has several ways to get rid of this excess production without incurring significant incremental costs on top of the induced emission costs. It can reshuffle the production load at close-by plants. It can increase the level of clinker in cement. It can also increase its exports to external markets. All of this is at the detriment of the global corporate strategy to pursue a low carbon transformation of the sector. Our study demonstrates that these effects are substantial.

Our results have been obtained in a context of a low carbon price, severe downfall in market demand, and large allocations of free allowances. However, a higher carbon price would make our results even more relevant; the higher the carbon price, the higher the incentive to achieve the thresholds.[27] Had we observed growth, the threshold rule may have been less relevant. Anecdotal evidence suggests that instead, the reserve for new entrants may have been a more important source of distortions (there would be an incentive to have an artificially high production level during the period used to fix the equivalent of HAL for new entrants).[28]

These considerations suggest that the activity level thresholds may need to be reconsidered for sectors such as cement for which carbon costs represent a significant share of production costs. This raises the question of what to put in their place instead. As mentioned in the introduction, economists generally agree that in the absence of global carbon prices, replacing free allocation with full auctioning and using border carbon adjustments offers the most efficient solution. This is because it helps in leveling the carbon costs between domestic and foreign producers while also allowing for carbon costs to be passed along the value chain to incentivize demand side abatement. Politically this solution has not yet gained serious traction. This is largely due to concerns that border leveling may be perceived as protectionism disguised as environmentalism and hence not conducive to building trust in international climate negotiations. However, the situation may change. If one looks forward to the post-2020 period, a larger number of nations are expected to have begun implementing carbon prices. More countries will face similar challenges related to designing appropriate anti-leakage measures that the EU now faces, and thus there may be more scope for cooperative approaches. Border leveling via international cooperation would, however, take time to negotiate and design. This raises the question as to the interim solution.

One option is to increase the number of activity level thresholds to reduce the incentive to game output. For example, a threshold at 50%, 60%, and 70% for cement may incentivize a larger number of installations to increase their clinker production to the next highest threshold. Since thresholds create an allocation system that falls between an ex ante and an ex post scheme, it would be much simpler to implement full output-based allocation for sectors like cement, where the risk of distortions arising is high, because carbon costs are high relative to production costs in the absence of free allocation. The analysis in this paper suggests that this option would

27. Taking an EUA price at 20 €/t, a simple extrapolation for LD countries would bring up the potential windfall profit to 236 × 20/9 = €524 million. However if we assume that all plants achieve the 50% threshold, a reasonable assumption for an EUA price at 20 €/t, it would go up to €583 million. The expected reduction remains at 42% but the actual one drops to 22%. Note, however, that a high carbon cost might endanger the validity of assumption H_1 and could possibly lead to a result in which EXALTG would be preferred to EX, but still worse than OBA.

28. Information from private conversation with industry representatives.

outperform both ex ante allocation with and without thresholds in terms of reducing distortions and overallocation profits.

However, a number of issues must be carefully considered before going in that direction. A central drawback of a move to OBA is that little can be expected in terms of carbon price pass-through to product prices and, hence, demand side substitution toward lower-carbon goods. For sectors where carbon costs are high as a share of production costs, such as cement, this would significantly limit the EU's potential to reduce emissions cost-effectively and to decarbonize these sectors. Unlike ex ante allocation, OBA implies the loss of an absolute cap for free allocations, and this may be a politically contentious point. Further, the implementation of OBA to selected sectors may also raise political difficulties. There are ongoing discussions on how to circumvent these issues. For example, the loss of demand side substitution incentives could perhaps be restored with a consumption charge on downstream products (Neuhoff et al. 2014). An output-based scheme with a hybrid benchmark was implemented in California in 2012. An ex post study on this implementation would be welcome to see if, again, the devil lies in the details.

APPENDIX

A. EUTL DATA COMPUTATIONS

A.1. Determination of the Activity Level Correction Factor ($ALCF_{2013}$) at the Plant Level

The key challenge is to correctly distinguish installations that are above or below thresholds (25% and 50% of q/HAL), despite the limitation that activity levels have to be approximated using emissions data (E/HEL). To do so, we exploit the observations from the 2013 allocation data, which revealed whether or not the installation had seen its allocation reduced because its 2012 activity level fell below a threshold. Allocations in 2013 are equal to (cf. eq. [1]):

$$A_{i,2013} = CSCF_{2013} \times I_B \times HAL_i \times ALCF_{i,2013},$$

where $CSCF_{2013}$ is the 2013 cross sectoral correction factor (0.9427), I_B the clinker carbon intensity benchmark (766 kg CO_2 per ton of clinker), and HAL_i the historical activity level of installation i (in tons of clinker). Transforming the previous equation, where both HAL_i and $ALCF_{i,2013}$ are unknown, we obtain:

$$\frac{CSCF_{2013} \times \frac{I_B}{I_A} \times HEL_i}{A_{i,2013}} = \frac{1}{ALCF_{i,2013}} \times \frac{I_{i,HAL}}{I_A}.$$

Noting that $I_{i,HAL} = HEL_i/HAL_i$ (corresponding approximately to the clinker carbon intensity for the HAL producing years), and I_A is the average clinker carbon intensity (863 kg CO_2 per ton of clinker, GNR, indicator 321) in 2008.

The ratio at the left part of the equation can be computed with available data. On the right part, we have $ALCF_{i,2013}$, which we want to find, and the ratio, $I_{i,HAL}/I_A$, which is unknown as well but bounded and likely to be close to 1. Indeed, $I_{i,HAL}$ varies in an extreme range from 720 kg CO_2 per ton of clinker to 1,300 kg CO_2 per ton of clinker (and for the very large majority of the plants from 780 to 950 kg CO_2 per ton of clinker), which translates into a ratio $I_{i,HAL}/I_A$ varying from 0.83 to 1.51 (and most likely from 0.90 to 1.10). Then, if the ratio is between 0.83 to 1.51 (respectively between 1.67 and 3.01, and between 2.64 and 4.80),[29] we infer that $ALCF_{i,2013} = 1$ (respectively 0.5 and 0.25).

This enabled catching out situations in which imperfections in the *E/HEL* measure as a proxy for the *q/HAL* would have led to a false conclusion about whether an installation was truly above or below its activity threshold in 2012. We found that the actual thresholds for the *E/HEL* measure that matched the 2013 allocation data were slightly lower in practice, at 22% and at 45%, rather than 25% and 50%. Discussion with industry experts revealed that there was a logical explanation for this systematic bias: clinker producers often have more than one kiln inside an installation that is treated as a single unit for free allocation purposes. When demand falls, it is common to concentrate production in the most efficient kiln(s). Thus emissions may fall by slightly more than overall clinker production, creating a slight downward bias in *E/HEL* as a measure of *q/HAL* in low demand countries. This bias could also be explained by the clinker carbon intensity improvement between HAL years and 2012 or to the fact that it is the responsibility of the company to report to the authorities if it is producing under the threshold.[30]

A.2. Determination of Clinker Carbon Intensity and Production at the Plant Level

Once the $ALCF_{i,2013}$ has been determined at the plant level *i* (see previous section), the plant clinker carbon intensity for HAL years, $I_{i,HAL}$, can then be obtained with the previous equation.

For 20 plants (out of 246), we found an unusual number (below 700 kg CO_2 per ton of clinker), possibly due to a capacity increase, and put instead a default value equal to I_A. We also set the default value I_A when $A_{i,2013} = 0$ (meaning $ALCF_{i,2013} = 0$ or plant closure), making the computation impossible (15 plants).

We then correct the first approximation of clinker carbon intensity so that weighted average clinker carbon intensity in big countries corresponds to GNR data in 2008 (818, 831, 832, 797, 847, 858, 849, and 842 kg CO_2 per ton of clinker for, respectively, Austria, Czech Republic, France, Germany, Italy, Poland, Spain, and

29. In our data there is actually a gap between 2.14 and 4.01, so no case of overlapping.

30. At least in France, re private conversation with a policy maker.

the United Kingdom).[31] Finally, we correct values of clinker carbon intensity in plants of other countries in the same way, as the European weighted average clinker carbon intensity (I_A).

Once clinker carbon intensity is estimated for each plant, clinker production can be obtained through emissions ($Q_{K,i,t}=E_{i,t} \times I_{i,HAL}$). We assume that clinker carbon intensity does not evolve over time.

B. MACRO DATA CONSISTENCY AT THE NATIONAL LEVEL

If we denote the six different variables:

- Q_K, clinker production,
- Q_C, total cement production,
- NE_K, clinker net exports,
- NE_C, cement net exports,
- C_C, cement consumption,
- R, clinker-to-cement ratio,

we have two equations translating the conservation of cement on the one hand and the conservation of clinker on the other hand (neglecting stockpiling):

$$Q_C = C_C + NE_C,$$

$$Q_K = R \times Q_C + NE_K.$$

These equations must be verified for each country every year (for real or counterfactual scenario).

In this paper for real data, Q_K, NE_K, NE_C, and C_C are obtained through different sources (see table 3), and Q_C and R are recomputed (we have $R = Q_K - NE_K/(C_C + NE_C)$).

C. COUNTERFACTUAL CLINKER PRODUCTION AND NET TRADE ESTIMATIONS

C.1. Plant-Level Clinker Production Estimation

We calculate counterfactual clinker production levels of a plant in 2012 and characterize output behavior of firms conditional on national and plant-level variables. As noted, the unobserved level activity of plant i in year t is approximated by the observed level of emissions $PlantActivity_{i,t} \approx E_{i,t}/HEL_i$, the activity level of plant i in year t (ratio of emissions divided by historic emissions level). As noted also, we

31. The weights are production, as multiplying plant emissions by this first approximation of clinker carbon intensity gives a first approximation of clinker production at the plant level ($\tilde{Q}_{K,i,2008}=I_{i,HAL} \times E_{i,2008}$).

assume that cement consumption is independent of allocation rules. Therefore, cement consumption would have been the same in 2012 had the ALTs rule not been implemented.

We use a multiplicative panel data model to estimate the following specification of clinker production level in plant i at time t to obtain parameters used to calculate counterfactual activity level in 2012:

$$\begin{aligned}\Delta \ln PlantActivity_{i,t} = \alpha_0 &+ \beta_1 \Delta \ln CementConsum_{c\ni i,t} + \beta_2 \Delta \ln GDP_{c\ni i,t} \\ &+ \gamma_1 \ln RelativeCO_2Intensity_i + \gamma_2 \ln RelativePlantSize_i \\ &+ \gamma_3 Coast_i + \varepsilon_{it}.\end{aligned}$$

In order to accommodate the autoregressive nature of plant activity, we define all country-level variables (source of the data is in table 3), including the dependent variable in first differenced terms. This allows us to difference out the time-invariant country-specific heterogeneity, using adjacent observations. The dependent variable is the (first differenced) natural log of the activity level of plant i in year t. Cement consumption and GDP are also expressed in first differenced natural log terms. In addition, we include time invariant plant-level variables: the relative average carbon intensity of a plant;[32] relative plant size;[33] and a dummy variable for coastal plants.[34] In order to minimize measurement errors that would bias the regression, we regroup some small countries into larger entities that are coherent in terms of regional market: Baltic countries, Benelux, Norway-Sweden, and Slovenia-Italy. As the Breush-Pagan test reveals the presence of heteroskedasticity, robust standard errors clustered at the country level are used.

Robust standard errors are in parentheses clustered at the country level. The dependent variable is the first differenced natural log of plant activity level. The sample includes 246 clinker-producing plants identified as operating between 2010 and 2012, across 26 EU member states, for the years 2008–11.

Table A1, column 1, shows the results for the period 2008–11 (postcrisis). Cement consumption has a statistically significant effect on clinker production, with

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32. The relative carbon intensity is defined as the natural log of carbon intensity at the plant level divided by the average carbon intensity in the country it is located ($RelativeCO_2 Intensity_i = \ln(I_{HAL,i}/\overline{I_{HAL,c\ni i}})\overline{I_{HAL,c\ni i}}i$), where $\overline{I_{HAL,c\ni i}}$ is the average carbon intensity of plants (in tons of CO_2 per ton of clinker) in the country where the plant i is located.

33. This is defined as the natural log of the historical activity level of the plant divided by the average historical activity level in the country it is located ($\ln RelativePlantSize_i = \ln(HAL_i/\overline{HAL_{c\ni i}})\overline{HAL_{c\ni i}}i$), where $\overline{HAL_{c\ni i}}$ is the average historical activity level (in Mt of clinker) in the country where the plant i is located.

34. The dummy $Coast_{it}$ is equal to 1 if the plant is located near the coast (less than 50 km; this was done thanks to the geolocalization of the plants in the EUTL data). It concerns 61 plants out of 246.

Table A1. Regression Results of Corrections at the Plant Level

	(1)
Log cement consumption	.819***
	(7.23)
Log GDP	.235
	(1.31)
Log relative carbon intensity	−.333***
	(3.05)
Log relative historical activity level	.013
	(1.10)
Coastal dummy	−.037***
	(2.90)
Constant	−.003
	(.34)
Observations	737
Plant-level fixed effects	No
R^2	.21

Note.—Robust standard errors in parentheses clustered at the country level. The dependent variable is the first differenced natural log of plant activity level. The sample includes 246 clinker-producing plants identified as operating between 2010 and 2012, across 26 EU member states, for the years 2008–11.

* $p < .1$.

** $p < .05$.

*** $p < .01$.

an estimated elasticity of 0.819 (hence, if the demand at the country level decreases by 10%, the production at the plant level decreases by 8.19%). GDP is not statistically significant, with an estimated elasticity of 0.235. The relative plant size is not significant. Conversely, the carbon intensity of the plant has a negative effect, suggesting that production is lower in the most carbon intensive plants. Finally, the parameter *Coastal* is statistically significant and also negative. Production in coastal plants is lower by 4% on average than in inland plants. We could also have expected the opposite (coastal plants producing more, e.g., their production declining less, in order to export). This could reflect a strategy of cement companies to diminish production in coastal plants in the long run.

As a robustness check, we also estimate a fixed effects model that includes plant-level fixed effects to control for time-invariant unobserved heterogeneity of clinker production behavior. Parameter estimates from the fixed effects regressions are similar, suggesting that the combination of country-level fixed effects (implemented by first differencing) and time-invariant plant-level variables do a good job at controlling for heterogeneity in our random effects estimation. A number of further robustness tests were conducted. For example, we additionally ran the same specification using the correlated random effects model (Wooldridge 2010) and also tested the influence of other obtainable variables to predict clinker output, including year dummies, lagged values, square terms. We found that the results were stable across the various estimators and specifications.

These parameters from column 1 are thus used to estimate counterfactual activity level. In order to give results robust to uncertainty, we use a semiparametric approach (Powell 1994) by specifically modeling the multiplicative error. The counterfactual plant activity level is then not fixed but is a random variable:

$$\begin{aligned} Plant\widetilde{Activity}_i^{CF-2012} = {} & PlantActivity_i^{2011} \times \exp(\hat{\alpha}_0) \\ & \times \left(\frac{CementConsum_{c\ni i,2012}}{CementConsum_{c\ni i,2011}}\right)^{\hat{\beta}_1} \times \left(\frac{GDP_{c\ni i,2012}}{GDP_{c\ni i,2011}}\right)^{\hat{\beta}_2} \\ & \times RelativeCO_2Intensity_i^{\hat{\gamma}_1} \times RelativePlantSize_i^{\hat{\gamma}_2} \\ & \times \exp(\hat{\gamma}_3 Coast_i) \times \exp(\tilde{\varepsilon}). \end{aligned}$$

Extending the smearing estimate of Duan (1983), we first fit the distribution of $\tilde{\varepsilon}$ with a kernel density estimation as in Horowitz and Markatou (1996), which gives us its piecewise linear cumulative distribution function. The latter allows us simulating $\tilde{\varepsilon}$ (which has a standard deviation of 14%) via inverse transform sampling. We perform a Monte Carlo simulation with 10,000 samples and report the average and the 95% confidence interval in tables 5 and 6.

C.2. Country-Level Net Exports of Clinker and Cement Estimation

Counterfactual net exports of clinker and cement for each country are necessary to assess the channels of clinker disposal. A comprehensive analysis was not possible given the available data, and instead we use a simple first differenced estimation to control for country-level fixed effects and include cement consumption as the main explanatory variable.[35] This enables us to essentially extrapolate historic net export trends, while accounting for the influence of annual variation in cement consumption. The parameters are obtained from the following regression using data for the years 2008–11 and 20 countries:

$$\begin{aligned} \Delta NE_{Kc,t} &= \lambda_0 + \lambda_1 \Delta CementConsum_{c,t} + \varepsilon_{c,t} \\ \Delta NE_{Cj,t} &= \mu_0 + \mu_1 \Delta CementConsum_{c,t} + \varepsilon_{c,t}. \end{aligned}$$

35. As suggested by the Hausman test (if *p*-values are low, fixed effects are preferred), we used a fixed effect model. As the modified Wald test reveals the presence of heteroskedasticity, we present robust standard errors.

For clinker net exports, the coefficient on λ_1 is −0.162 and this is significant at the 5% level. Hence on average, if cement consumption decreases by 1 Mt, clinker net exports increase by 0.16 Mt. The negative sign on λ_1 is in line with expectations. The fit is good for the clinker net exports (R^2 = 0.41). For net cement exports, the coefficient on the cement consumption term is 0.025 and is not statistically significant at conventional levels. Changes in cement consumption thus do not predict changes in cement net exports, and in this case the counterfactual is an extension of historic trends only. For a region *c*, we then compute counterfactual net exports as follows:

$$\Delta NE_{K,j}^{CF2012} = NE_{K,j}^{2011} + \lambda_1 \Delta CementConsm_{c,2012}$$

and counterfactual net exports of cement as:

$$\Delta NE_{C,j}^{CF2012} = NE_{C,j}^{2011} + \mu_1 \Delta CementConsm_{j,2012}.$$

It should be noted that the cement consumption was remarkably low in 2012. Because of the consumption/export relationship established by the econometric model, clinker net exports would have risen anyway in 2012 compared to 2011 had the threshold rule not be implemented.

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