ACCOUNTING FOR PERMIT PRICE DIFFERENTIALS IN THE EUROPEAN UNION EMISSIONS TRADING SYSTEM

by

Nathan Eric Braun

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APPROVAL

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Nathan Eric Braun

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Dr. Timothy Fitzgerald

Approved for the Department of Department of Agricultural Economics and Economics

Dr. Wendy Stock

Approved for The Graduate School

Dr. Carl A. Fox

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

ABSTRACT

Since 2005, industrial installations regulated by the European Union Emissions Trading Scheme (EU ETS) have been required to surrender a permit for every ton of CO_2 they emit. In addition to the standard EU ETS permit — the European Union Allowance (EUA) — installations are allowed to surrender limited numbers of offsets. Offsets currently trade at a discount relative to EUAs. While it is well known that an offset limit theoretically results in a permit price differential, the current offset limit is not binding in aggregate. This thesis reconciles this nonbinding offset limit with the EUA – offset price differential. It is shown how such a limit can cause a price differential by binding for individual installations even when it is not binding in aggregate. At the same time it is shown how, under certain circumstances, barriers to entry in the offset market result in two types of behavior: installations either use offsets up to what they believe is their cap or forego them entirely. This appears consistent with empirical EU ETS behavior. Results suggest navigating the regulatory process makes up a significant portion of these barriers to entry.

INTRODUCTION

Since 2005, industrial installations in the European Union have been regulated by the European Union Emissions Trading Scheme (EU ETS), a cap and trade program that requires them to surrender an emission permit for every ton of CO_2 they emit. In addition to the standard EU ETS permit — the European Union Allowance (EUA) — installations are allowed to surrender two types of offsets: Certified Emission Reductions (CERs) and Emission Reduction Units (ERUs). Though there are supply-side differences between CERs and ERUs, the two are essentially perfect substitutes from the perspective of EU ETS regulated installations, trade at nearly identical prices (Figure 1), and hereafter are simply referred to as offsets.

Installations are not restricted in their use of EUAs, however each is allowed no more than a certain number of total offsets. Previous literature has shown how such a restriction theoretically results in a differential between domestic marginal cost of abatement and offset prices (Ellerman & Decaux, 1998; Zhang, 1999). Initially this appears consistent with empirical price dynamics in the EU ETS: an offset limit exists, and both CERs and ERUs trade at a discount relative to EUAs (

Figure **2**). However the issue is complicated somewhat by the fact that this offset limit is not binding in aggregate. Through 2010, installations in the EU ETS as a whole have utilized just 26% of the offsets they are allowed. At least some installations are passing over offsets in favor of costlier EUAs.

This thesis reconciles the simultaneous EUA – offset price spread and nonbinding aggregate offset cap. It is shown how an offset limit causes a price differential — even when it is not binding in aggregate — by binding at the *installation* level. At the same time, it is proposed that installations face transaction costs that make it prohibitive for some to enter the offset market. Incorporating these transaction costs and modeling installation behavior results in testable predictions about *when* installations will use offsets. These appear consistent with empirical behavior. When installations do use offsets, the model predicts (under certain circumstances) that they will use as many as they can. This is also consistent with empirical installation behavior. This fundamental insight — that installations either use offsets up to what they believe is their cap or forego them entirely — is central to understanding just how a price differential can persist in the presence of an offset cap that is nonbinding in aggregate.

The results provide information about the nature of these transaction costs. First, they appear to consist of entry (as opposed to marginal) costs. Second, a significant portion of these entry costs appears to involve navigating the regulatory process. Installations also appear to be getting better at overcoming these obstacles over time.

Accounting for the simultaneous existence of the EUA – offset price differential and nonbinding cap is important for a few reasons. First, it implies that it is indeed the limit on offsets that is driving the price differential. While this basic result has already been theoretically established at the country level (Ellerman & Decaux, 1998; Zhang, 1999), recent papers addressing the EUA – offset differential (Nazifi, 2010; Mansanet-Bataller, Chevallier, Hervé-Mignucci, & Alberola, 2011) have advanced additional explanations, perhaps in part because the current EU ETS limit is not binding in aggregate.

More importantly, explaining the simultaneous price differential and nonbinding cap has important implications for efficiency. If installations in the EU are to meet their abatement goals at the lowest possible cost, reductions should be undertaken by those who can do so the cheapest. The current price differential suggests reducing greenhouse gases is less costly for ERU and CER projects than it is for regulated EU installations. Understanding what is preventing installations from taking complete advantage of this fact is the first step in realizing the savings from a more efficient reduction allocation.

Understanding its fundamental causes also helps predict the future of the price differential. Given recent trends in the offset market, the results here suggest the spread will narrow in the future. This has important implications for policymakers, regulated installations, and offset projects today.

This thesis is organized as follows: the next section (chapter 2) consists of an overview of the EU ETS. This necessarily involves discussing the Kyoto Protocol, as the EU ETS exists in order to implement the goals of the latter. Because carbon markets are created by regulators, any insights about prices require a working knowledge of tradable permit theory, and chapter 2 starts there. The model demonstrating how an EUA – offset price differential can occur when at least one installation faces a binding offset limit is given in chapter 3. The inclusion of transaction costs results in predictions about installations' offset behavior. These predictions are tested in chapter 5; the data used to do so is outlined in chapter 4. The results and their implications are discussed in chapter 6; chapter 7 concludes.

Figure 1. Historical CER and ERU prices. Source: BlueNext Exchange

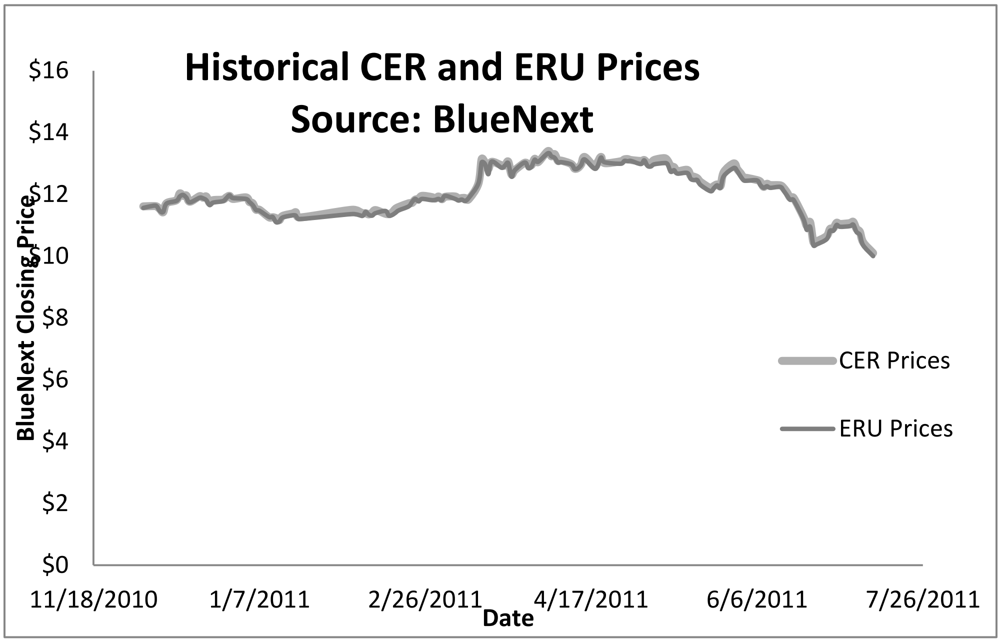
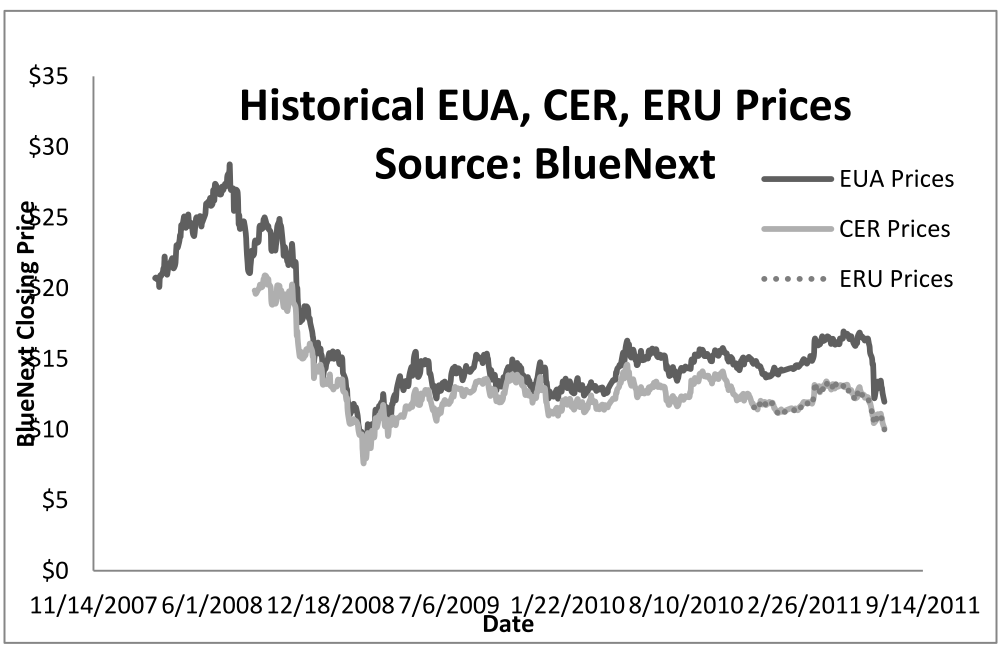


Figure 2. Historical EUA, CER, and ERU prices. Source: BlueNext Exchange



BACKGROUND: ECONOMICS AND INSTITUTIONAL DETAILS

Economics of Tradable Pollution Permit Schemes

Tradable pollution permit schemes are a fundamental component of modern environmental economics. Pollution may be *the* classic example of a negative economic externality — the costs of pollution are far less for the firm doing the polluting than they are to society. One way to correct this is through the price mechanism (Tietenberg, 1980); regulators could tax pollutants in an attempt to make the firms' marginal cost of polluting more reflective of the cost to society. Theoretically a tax of exactly the right size would perfectly correct for the externality and lead to an efficient outcome. Such taxes are rarely proposed, much less implemented. "In practice," says Dales (1968), "the decision [about how much pollution to allow] is made on a political rather than an economic calculus. Once there is a political demand for 'pollution control,' anti-pollution measures tend to be instituted incrementally until complaints about their cost outweigh complaints about pollution."

Dales believed it was unrealistic to expect economists to be able to determine the exact value of an externality and instead focused on a different question: how could regulators make sure any given level of pollution control would be met at least cost?

Dales' solution (1968) — also proposed by Crocker (1966) — is a tradable permit system. First, firms are required to surrender a permit for every unit of pollution they emit. Regulators decide how much pollution to allow, then sell a corresponding number of permits. If the number of permits is less than unrestricted emissions, permits will command a positive price. If firms can trade permits amongst themselves the cost of pollution reduction will be minimized.

Subsequent literature expands on the idea of tradable pollution permits. Although Dales suggested regulators initially sell permits to firms, Montgomery (1972) proves the lowest cost outcome is achieved regardless of whether regulators sell permits or give them away. This theoretical independence between method of permit allocation and lowest cost outcome is traditionally cited as one of the principle benefits to tradable pollution permit schemes (Tietenberg, 1980; Hahn, 1989). Stavins (1995) dampens this enthusiasm somewhat by pointing out there is no guarantee this result holds in the presence of transaction costs, particularly if these transaction costs are fixed and must be paid upon entering the market. In this case "trading will occur," according to Stavins, "if potential gains from trade exceed [the fixed cost]." Understanding such costs is paramount, as barriers to entry that cause some firms to forgo the market mean "the cost-effective allocation will not be achieved."

Beyond potential breakdowns in the presence of transaction costs, tradable pollution permit schemes have other theoretical drawbacks. First, there is no guarantee of absolute efficiency; that is — even when they work perfectly — tradable permits only minimize the cost of achieving a given standard. Whether this standard is the socially efficient one is a different question altogether (Tietenberg, 1980; Dales, 1968). In addition, because permits are tradable, they may end up concentrated in a relatively small area (e.g. an industrial sector). This could give rise to pollution "hot spots," where — although the regulated region as a whole meets emission standards — areas with concentrated permits experience emissions far above what they would have been under an alternative regulatory regime.

Much of the tradable permit literature discusses this latter issue and ways of dealing with it (Tietenberg, 1995; Shortle & Horan, 2002). But carbon and greenhouse gas emissions are uniformly mixed pollutants. This physical property means the location of emissions (and emission reductions) does not matter. A few firms in a very concentrated industrial area could emit vast quantities of CO_2, and — all else equal — nearby residents would not be any worse off from climate change than if the emissions instead came from somewhere around the world. Theoretically these firms might even pay someone else to reduce emissions rather than undergoing their own reductions. As long as these offsets meet two general criteria the net result is the same.

First, they must be additive. Additive reductions occur explicitly *because* the firm pays for them. The net result is decidedly not the same when a firm pays someone to make reductions that would have occurred anyway. Offsets must also be permanent. For example, CO_2 can be buried underground or temporarily sequestered in a tree, but these are not permanent reductions if the CO_2 eventually leaks or is rereleased into the atmosphere when the tree dies. Recent tradable CO_2 permit schemes have had to address both of these issues.

Early Tradable Pollution Permit Schemes

Tradable pollution permit theory dates from the late 1960's; actual implementation is just a bit younger. In the United States, permit markets have been instituted in a piecemeal fashion since the Clean Air Act. Initially, regulation went beyond the firm level, to the point where the EPA actually set emissions standards for each individual source of pollution (e.g. smokestack). After this proved costly for industry, the EPA allowed offsets within firms. This meant firms with multiple installations were allowed — under certain circumstances — to increase emissions at one installation as long as they reduced emissions at another source by the same amount (Tietenberg, 1980; Hahn, 1989). Eventually firms were allowed to trade with each other.

One of the first pollution control programs explicitly designed as a tradable permit scheme was implemented in 1981, when the state of Wisconsin set out to clean up the Fox River. Economists were initially optimistic about the program (O'Neil, 1983), and — after winning over skeptical firms and policymakers — kept an eager eye on the results, only to watch as member firms completed exactly one trade during the first six years of the program (Hahn, 1989). In retrospect, transaction costs to trading appear to have been prohibitively high (Novotny, 1986; Hahn, 1989). As this analysis indicates, this issue is still relevant for tradable permit schemes 30 years later.

The history of tradable permit schemes is not all failure. The SO_2 trading scheme created in the 1990's to deal with acid rain is generally considered a success (Stavins, 1998; Hepburn, 2007), and many empirical studies (Atkinson, 1983; Seskin, Anderson, & Reid, 1983; Krupnick, Oates, & Van De Verg, 1983; Foster & Hahn, 1995) conclude tradable permits are far cheaper than alternative regulatory regimens.

Because carbon dioxide and other greenhouse gases are uniformly mixed pollutants, they are particularly well-suited for permit schemes. It is no surprise that policymakers have been talking about a greenhouse gas emissions trading scheme almost as long as they have been talking about climate change itself (Hepburn, 2007). Voluntary carbon trades have been taking place since the late 1980's, though the Kyoto Protocol was the first major agreement to include a provision for carbon trading (Hepburn, 2007).

The Kyoto Protocol

Initially adopted in December 1997, the Kyoto Protocol requires certain industrial countries — referred to as "Annex I" countries because they are listed in Annex I of the Protocol — to reduce their greenhouse gas emissions, generally between 5% and 8% below 1990 levels by 2012. By design, the agreement includes no binding provision specifying just how these countries are to reduce their emissions. "In general," says Grubb (2003), "Countries were extremely resistant to anything that could intrude directly on national sovereignty over the choice of instruments adopted."

To help Annex I countries keep the costs of meeting their reductions under control, the Kyoto Protocol includes three "flexibility mechanisms." At the broadest level, Kyoto establishes an emissions trading scheme among nations. Annex I countries unable to meet their reduction obligations can purchase reductions from those that have reduced emissions below their targets. The permit for this world wide cap and trade scheme is the Assigned Amount Unit (AAU). Each Annex I country receives an allocation of AAUs corresponding to the number of equivalent CO_2 emissions it is allowed under the Protocol. AAUs are tradable, but only among governments (Grubb, 2003; Chadwick, 2006).

The second flexibility mechanism, Joint Implementation (JI), is outlined in Article 6 of the Protocol. It allows Annex I countries to meet their reduction obligations by investing (e.g. financing, providing technical expertise) in offset projects located in other Annex I countries. Because many offset projects are related to greenhouse gases other than carbon, part of this certification process involves converting noncarbon offsets into equivalent carbon units.

The offsets are known as Emission Reduction Units (ERUs). Unlike AAUs, private organizations are allowed to buy and sell ERUs.[1] "Essentially," Chadwick (2006) says, "JI projects transform a certain number of host country AAUs into an equivalent number of ERUs that are now transferable to other governments and private organizations."

Annex I countries are also allowed to buy reductions from offset projects in non-Annex I (i.e. undeveloped) countries. This third flexibility mechanism is facilitated by the Clean Development Mechanism (CDM), which certifies emission reduction projects and issues credits corresponding to the amount of CO_2 emissions sequestered. The final offsets each represent one ton of CO_2 emissions and are known as Certified Emission Reductions (CERs). Because they originate in countries that have no binding emission reduction obligations, it is important CERs actually represent additional reductions. As Chadwick (2006) cautions, "both project developers and the host country… have

[1] Although it is of no practical consequence to installations in the EU ETS, ERUs — unlike CERs — are subtracted from the project's host countries' stock of AAUs. This means the additionality of ERUs has no effect on the total number of reductions. Because every generated ERU results in the removal of an AAU, offsets that would have been undertaken even in the absence of Kyoto result in one less equivalent CO_2 emission.

incentives to overestimate business-as-usual emissions in order to maximize the number of marketable CERs that can come from a project."

This is a common concern among environmentalists (Sugiyama & Michaelowa, 2001; Voigt, 2007), and has resulted in a series of strict rules on who exactly is eligible to generate CERs. Project developers need to demonstrate that their offset project is *not* profitable without the sale of CERs. Offsets resulting from projects profitable on their own merits (without the sale of CERs) are not additional, and not eligible to receive CERs under CDM rules. At the same time, in order to make sense from the developer's perspective, the sale of CERs must *make* a project profitable. Otherwise the project will lose money even if it does generate CERs. In theory, every CER originates from a narrow band of offset projects in non-Annex I countries that are unprofitable on their own while being profitable with the sale of CERs (Chadwick, 2006).

Despite these criteria, more than 400 million CERs were produced as of 2009 according to Trotignon (2010), who estimates that this will increase to between 800 and 1,200 million by 2013. This far exceeds the number of projected ERUs, expected to be between 100 and 200 million.

In addition to requiring offsets be additive and permanent, Kyoto also specifies that they must be supplemental to domestic reductions, although it never defines exactly what this means. European countries in particular advocated for a concrete limit on the use of flexibility mechanisms (den Elzen & de Moor, 2002) to meet emission obligations. The final agreement, however, places no concrete limit on their overall use, merely specifying that shall "constitute a significant element" of reduction efforts by Annex I countries.

While permanence and additionally are necessary economic criterion, requiring offsets to supplement domestic action has little basis in economics. As long as offsets are additive and permanent, Annex I countries could theoretically offset *all* of their emission reduction obligations and the effect on climate change would be the same as if they were to reduce all of their emissions domestically.

Even with no concrete limits on flexibility mechanisms, compliance among ratifying Annex I countries has been mixed. Neither Canada (NRTEE, 2008), Japan (International Energy Agency, 2008), nor Norway (Statistics Norway, 2011) is on track to meet its Kyoto obligations, although Norway has said it plans to meet its obligations by investing in a reforesting project in China. Australia is on track to comply with Kyoto (Australian Department of Climate Change and Energy Efficiency, 2011), but its obligations — holding greenhouse gas emission growth to 8% above 1990 levels — are relatively relaxed compared to other nations. Other countries (e.g. Russia) have been able to meet their targets without actively seeking any reductions because economic activity has significantly declined since the 1990 base year.

Many countries *have* undergone significant reductions. Chief among these are members of the European Union, which, in order to comply with Kyoto, established the largest pollution permit market in history.

The EU ETS Phase I:

To meet their Kyoto obligations, members of the European Union established the European Union Emissions trading Scheme (EU ETS). The EU ETS covers some 11,500 installations that emitted over two billion metric tons of CO_2 annually prior to its implementation (Ellerman and Buchner 2007). The scheme is divided into distinct temporal phases: I (2005 – 2007), II (2008 – 2012) and III (2013 – 2020).

Individual installations covered by the scheme must surrender a permit for every ton of CO_2 they emit. The standard EU ETS permit is the European Union Allowance (EUA), each of which allows its owner to emit one ton of CO_2. Through the first two phases, EUAs have largely been given away in quantities determined by individual member states. These quantities are listed in each state's National Allocation Plan (NAP), which are subject to approval from the EU. Although the EU Commission did ultimately approve each country's NAP, the relatively decentralized allocation process did cause some tension among states over just exactly how many permits would be allowed (Ellerman & Buchner, 2007).

Policymakers designed the EU ETS so that installations in all sectors save power generation were to receive a free supply of business-as-usual allocation of EUAs in phase I. Regulators were not sure just how many EUAs this meant, mainly because they lacked specific installation level business-as-usual emission data (Ellerman & Buchner, 2007). As a result, states had to create their National Allocation Plans using less useful aggregate emission estimates. These aggregate models themselves were imperfect. While "there were a number of models that predicted national emissions, none captured the trading sector as defined in the [EU ETS]. Moreover, there were few sector-specific emission prediction models. Consequently, allocation often had to wait for improvements in modeling, which depended in turn on the availability of the appropriate data" (Ellerman & Buchner, 2007).

Because regulators recognized there was a significant chance of initial over- or under-allocation, phase I (2005 – 2007) was designated a trial period. This allowed for potential changes in phase II, the end of which corresponds with Kyoto's first compliance deadline in 2012. To prevent EUA misallocation from affecting future prices, installations were not allowed to bank or borrow EUAs into phase II. Despite the flexibility mechanism provisions in Kyoto, EUAs were effectively installations' only permit option in phase I.

Phase I opened in January 2005, with EUAs trading between €20 and €30 through the beginning of 2006. In April 2006, prices dropped dramatically — 54% in four days — after the EU revealed emissions were lower than expected (Grubb & Neuhoff, 2006; Montagnoli & de Vries, 2010; Hintermann, 2010; Alberola & Chevallier, 2009). As it turned out, not only were emissions lower than everyone had expected, they were lower than the *total* number of permits allocated in phase I. Because they were not allowed to be banked into phase II, phase I EUAs became essentially worthless by the end of 2007. At the same time, futures prices for phase II remained relatively steady.

This price break in April 2006 is the defining event in the Phase I EU ETS price literature; nearly all analysis finds prices behaved differently before and after (Alberola, Chevallier, & Chèze, 2008; Montagnoli & de Vries, 2010). Hintermann (2010) finds fuel prices (gas and coal), temperature, and availability of hydroelectric power all significantly explain carbon prices, but only after the crash. Before the crash only gas prices and hydropower had a significant effect on price. Mansanet-Bataller et al. (2007) arrive at similar conclusions. They also find EUA prices are significantly correlated with energy price expectations; Alberola et al. (2008) show prices react to unexpected weather events.

More recently, Alberola et al. (2008) investigate the relationship between aggregate industrial production and EUA price changes. They find production in the power and iron industries had a significant effect on EUA price changes in phase I. This is not a surprise, as the two sectors made up 77% of aggregate allocation in phase I. The authors found that the biggest price drivers for these two industries were quantity of production and whether the industries received enough initial EUAs to cover their emissions. A follow-up paper (Alberola, Chevallier, & Chèze, 2009) looks at this same relationship using data aggregated at the country and sector level. They find the production peaks of power producers in Germany have a particularly important effect on price.

Market design and structure also impact prices. At one point near the end of phase I the French government considered allowing installations to bank EUAs into phase II. Although the government ultimately reaffirmed the ban on banking, Alberola and Chevallier (2009) find that these official French communications had a significant effect on price in the latter half of phase I. In another example, EUA futures prices jumped in October 2006 after the EU ETS made it clear that the emission cap would be tightened considerably in phase II (Alberola & Chevallier, 2009).

The EU ETS: Phase II

Beyond the tightened cap, installations faced other changes in phase IIRecall 2012 is also the deadline for Kyoto ratifying countries to meet their emission reduction obligations. Kyoto explicitly allows for flexible mechanisms, and these are available to EU ETS installations in phase II.

The Kyoto Protocol includes no hard limits on the number of flexibility mechanisms allowed, specifying only that they should be "supplemental" to domestic action. It was up to the EU Commission to decide just how many offsets installations in the EU ETS would be allowed to use. Initially, the Commission delegated this responsibility to the national governments, instructing member states to include them in their National Allocation Plans. States were to keep in mind that these limits "shall be consistent with the relevant supplementary obligations under the Kyoto Protocol." Later the Commission thought better of this approach and decided to set each state's limit itself. Each state's flexibility mechanism limit was defined as a cap on the total number of CERs and ERUs, given by the *maximum* of the following:

1. 50% of 1990 emissions minus emissions allowed under Kyoto
2. 50% of emissions in 2004 minus emissions allowed under Kyoto
3. 50% of projected 2010 emissions minus emissions allowed under Kyoto
4. 10% of EUA allocation

This meant every state was allowed CERs and ERUs up to at least 10% of its EUA allocation. Although the formula allows the calculation of an actual, definitive number of total offsets allowed, the Commission left each state's flexibility mechanism limit as a percentage its total EUA allocation. Presumably they did this under the assumption that member states would simply pass onto individual installations these uniform percentages. That way it would be easy for any installation to calculate its CER and ERU limit — it would simply multiply the limit by its allocation. In reality this resulted in a few problems.

First, the Commission decided on this formula only *after* countries began submitting their phase II National Allocation Plans. In the meantime, three countries (Greece, Slovakia, and the United Kingdom) had already proposed offset limits below the 10% minimum. Others (Ireland, Sweden) had proposed caps that exceeded their limits according to the formula. The Commission promptly accepted the caps that were more stringent they could have been according to the formula (e.g. the United Kingdom's 9% limit) and sent the rest back for revisions. The Commission's timing appears haphazard in hindsight, although members continued to propose limits in violation of the rules even after the Commission released its formula. While eventually resolved, at least 16 member states initially proposed caps that were rejected by the Commission for violation of the formula.

Second, despite presenting the flexibility limits as a percentage of EUA allocation, the Commission never specified whether these percentages applied to *annual* EUA allocations — where no installation would be allowed to exceed the limit in any given year — or to the entire phase II allocation as a whole. States took a variety of approaches in the absence of such direction. About half of the countries effectively set a five year limit, allowing installations to use their entire 2008 – 2012 supply of offsets in any one year. Most of the others allow installations to roll over unused limits, but not borrow from future years' limits. A few countries apply the limit to each individual year (Trotignon, 2010).

Third, despite what the Commission may have initially intended, the limit given by the formula turned out to apply only in aggregate. Many individual governments set different standards among industries.[2] Because the Commission preferred to view limits as percentages of EUA allocation, this meant they had to multiply the individual industry specific caps by the relevant industry aggregated EUA allocations in order to determine whether the total limit for the country as a whole complied with the formula. Often it did not and NAPs had to be revised.

Eventually these issued were resolved, giving installations the option to surrender either ERUs or CERs in lieu of EUAs. CERs proved to be the more popular choice by far. In 2008 surrendered CERs outnumbered ERUs 81 million to 50 thousand. The number of ERUs surrendered has increased since then, to 21 million in 2010; although the number of CERs climbed to 130 million over the same period. Both CERs and ERUs are essentially the same from the perspective of installations in the EU ETS and trade at nearly identical prices

[2] For example Spain set a limit of 42% of EUA allocation for electricity producers and 7% of EUA allocation for other industries.

In contrast to EUAs, CERs and ERUs are *not* given away; installations must purchase them somewhere else. Installations may purchase them directly from offset providers, but many are first sold to brokers, where they are bundled and then sold to EU ETS members, either directly or through an exchange (e.g. BlueNext, ECX). Although the literature has traditionally made a distinction between the two, the cap applies to *all* offsets, no matter whether they are CERs or ERUs or whether they are bought directly from the offset provider or through a broker. As of July 2011 EUAs and offsets trade around €12 and €10 respectively (

Figure **2**).

EUA – Offset Price Spread Literature

Given the level of interest in other areas of the EU ETS, relatively little research has addressed the relationship between EUA and offset prices. Researchers have known as far back as 1998 that a quantitative offset limit would result in a theoretical domestic marginal abatement – offset price differential (Ellerman & Decaux, 1998; Zhang, 1999), although these papers model emission reductions at the country rather than individual firm level. This may partly explain why researchers continue to offer other explanations for the present EUA – offset price differential. Nazifi (2010) casts a broad net, attributing the spread to a combination of the offset cap, institutional uncertainty regarding rules about banking, and concerns about delivery risk of offsets. Mansanet-Bataller et al. (2011) dismiss arguments concerning delivery risk,[3] attributing the price

[3] It is true that primary offsets are inherently more risky than EUAs — they are often issued as projections, and sometimes projects fail or do not deliver as many credits as expected. And primary

differential to a combination of the cap and uncertainty about offsets' bankability. Neither paper reconciles the price spread with the fact that this offset cap is not binding in aggregate.

Mansanet-Bataller et al. (2011) conduct a technical analysis on EUA and CER[4] prices (separately) and find they can be significantly explained by similar factors, mainly natural gas and coal prices. They conduct a similar analysis on the EUA – CER price spread, this time regressing microstructure variables (e.g. permit volumes and prices) on the differences between prices. They find the EUA – CER price spread is positively correlated with trading volume. The authors speculate this is because firms are attempting to capitalize on a more advantageous arbitrage opportunity. They also find the EUA – CER price spread is negatively correlated with EUA prices; as the price of an EUA increases, the EUA – CER spread decreases.

Beyond Mansanet-Bataller et al.'s (2010) technical price analysis, Nazifi (2010) examines whether EUA and CER prices are converging over time and determines they are not (as of 2009). Conte and Kotchen (2009) look at the price of *voluntary* carbon offsets (i.e. those sold private organizations or individuals rather than regulated installations like those in the EU ETS). They find offsets certified as CERs trade at a premium. Chevallier (2011) looks at the statistical relationship between EUA and CER prices and finds they have become less correlated over time. In another paper Chevallier

CERs and ERUs do trade at a discount relative to EUAs. However, installations can bypass this risk in the form of *secondary* CERs and ERUs (Mansanet-Bataller, Chevallier, Hervé-Mignucci, & Alberola, 2011), which have already been issued by the CDM and JI. Though they involve no delivery risk — and as a result cost more than primary offsets — secondary CERs and ERUs still trade at a discount relative to EUAs.

[4] Literature on EUA and offset prices through the first half of phase II generally focuses on CERs. ERUs were not widely traded in the EU ETS until late 2010.

(2010) finds that the EUAs lead CERs in the price discovery process. Summarizing the state of the literature on the EUA – CER price gap, Gronwald et al. (2010) call the price spread “puzzling” and conclude, “the observed behavior of CER and EUA prices is still not understood sufficiently.”

The EU ETS: Phase III and Beyond

The EU Commission plans significant changes for phase III of the EU ETS, chief among them replacing National Allocation Plans with a single EU-wide cap. The cap tightens annually, with the number of EUAs allocated and auctioned declining by 1.74% each year. Total allocations will be 21 percent below 2005 emissions by 2020 (Skjaerseth & Wettestad, 2010).

Installations will continue to be able to surrender CERs and ERUs in phase III. Although the EU Commission has not decided on exact limits, the overall cap on flexible mechanisms will increase by about 21 to 36%, from 1,400 million tons in phase II to between 1,700 and 1,900 Mt in phase III. In addition installations will be allowed to bank any unused CER and ERU limits from phase II into phase III.

Phase III will make wider use of permit auctions. Installations in most industries will need to purchase a minimum of 20% of their allowances starting in 2013, and 70% by 2020. Installations in the power sector will generally need to purchase all of their allowances, while some 164 energy-intensive industries especially exposed to global competition are guaranteed free allowances from 2013 to 2020. Most (80%) of revenue from auctions will be distributed to member states based on their ETS emissions in phase

I. Ten percent will be redistributed to low per capita income states to invest in climate technology, while two percent goes to countries whose greenhouse gas emissions in 2005 were at least 20 percent below their Kyoto base year emissions (Skjaerseth & Wettestad, 2010).

The potential effect of the phase III changes on the future of the EUA – offset price differential is discussed in chapter 6.

THEORY AND MODEL

The model in this chapter shows how a binding offset cap for *some* installations results in an EUA – offset price spread. The model results in predictions both about *whether* an installation will use offsets as well as *how many* offsets it will use.

Notation is closely related to the model in Stavins (1995). Assume there are n installations regulated by the EU ETS. Denote installation i's prior, unregulated emissions and reductions as u_i and r_i respectively.

Define net EUA purchases as e_i and initial EUA allocations as $\bar{e}_i$. Net EUA purchases are negative if an installation sells EUAs. However no installation can sell more EUAs than it has available in any given period, so $-e_i \leq \bar{e}_i$. Define offset purchases as c_i. No installation is initially given offsets, which means $c_i \geq 0$ for all i.[5]

Under the terms of the EU ETS, each installation must hold at least as many permits, or EUAs allocated plus net EUAs purchased plus offsets purchased, as regulated emissions. Solving in terms of r_i: [6]

For all i: $$r_i \equiv u_i - \bar{e}_i - c_i - e_i \qquad 1$$

Unrestricted emissions u_i and EUA allocation $\bar{e}_i$ are exogenous, so the installation chooses an overall level of reductions by choosing e_i and c_i. For any given level of output, each installation's cost function is a convex function of emission

[5] Technically e_i and c_i represent permits purchased *and surrendered*. It is possible an installation might purchase EUAs or offsets and not surrender them into the registry. These are unobservable with current data, which includes only surrendered permits for each installation. More information will be available upon the release of transaction level data, which for phase II is scheduled to begin in 2013.

[6] This is technically an inequality with the absence of a banking term. When it is allowed to bank or borrow permits, a cost-minimizing installation will reduce emissions until discounted marginal abatement costs are equal in each period. Within each period, the first order conditions presented in equation 5 still hold.

reductions $C_i(r_i)$. It is assumed installations are producing on the increasing portion of $C_i(r_i)$, so that further emission reductions increase costs.

The total number of offsets installation i is allowed is defined as Ω_i. Transaction costs in entering the offset market are defined as $\Gamma_i(c_i)$, a piecewise linear function that is discontinuous and equal to zero at $c_i = 0$. After fixed costs of entry are paid, $\Gamma_i(c_i)$ is differentiable and positive for all $c_i > 0$.

With EUA and offset prices P_{EUA} and P_{OFF},[7] installation i's problem is to minimize its compliance costs subject to its offset constraint. The compliance cost function has three parts: overall abatement costs $C_i(r_i)$, the costs of permits $P_{OFF}c_i + P_{EUA}e_i$, and transaction costs to using offsets $\Gamma_i(c_i)$.

Minimize:

$$\min_{e_i,\, c_i} \left(C_i(r_i) + P_{OFF}c_i + P_{EUA}e_i + \Gamma_i(c_i)\right) \qquad 2$$

$$\text{s.t.} \qquad \Omega_i \geq c_i \geq 0$$

This results in a Lagrangian.

$$\mathcal{L} = C_i(r_i) + P_{OFF}c_i + P_{EUA}e_i + \Gamma_i(c_i) - \lambda_i(\Omega_i - c_i) - \mu_i c_i \qquad 3$$

Both an EUA and an offset have the same effect on reductions, which can be seen formally by taking the derivative of equation 1.

$$\frac{\partial r_i}{\partial e_i} = \frac{\partial r_i}{\partial c_i} = -1 \qquad 4$$

[7] Although there are technically two types of offsets (CERs and ERUs) available to installations, they are the perfect substitutes from the perspective of EU ETS installations and it is assumed they trade at equivalent prices (Figure 1).

Using the chain rule substituting -1 in for $\frac{\partial r_i}{\partial e_i}$ and $\frac{\partial r_i}{\partial c_i}$ using equation 4, the first order conditions for choice variables e_i and c_i are:

$$\mathcal{L}_{e_i} = -\frac{\partial C_i}{\partial r_i} + P_{EUA} = 0 \qquad 5.1$$

For all i:

$$\mathcal{L}_{c_i} = -\frac{\partial C_i}{\partial r_i} + P_{OFF} + \frac{\partial \Gamma_i}{\partial c_i} + \lambda_i - \mu_i = 0 \qquad 5.2$$

$$\Omega_i - c_i \geq 0, \lambda_i \geq 0, \lambda_i(\Omega_i - c_i) = 0 \qquad 5.3$$

$$c_i \geq 0, \mu_i \geq 0, \mu_i c_i = 0 \qquad 5.4$$

According to 5.1, installation i will reduce emissions until marginal abatement costs $\frac{\partial C_i}{\partial r_i}$ equal the price of a permit, P_{EUA}. Interpreting equation 5.2 requires considering three different scenarios. First, the cost of the very first offset may outweigh the benefits to the installation, which means $P_{OFF} + \frac{\partial \Gamma_i}{\partial c_i} + \lambda_i$ always lies above $-\frac{\partial C_i}{\partial r_i}$. Because the upper offset limit is not binding, $\lambda_i = 0$, which means $\mu_i > 0$ according to equation 5.2. [8]

In the second case an installation uses offsets, but not up to its cap. Here $0 < c_i^* < \Omega_i$, which means $\mu_i = \lambda_i = 0$. Substituting this into 5.2 and using equation 5.1:

$$P_{EUA} - P_{OFF} = \frac{\partial \Gamma_i}{\partial c_i}(c_i^*) \qquad 6$$

This implies a nonbinding cap $c_i^* < \Omega_i$ is consistent with a price differential only if there are marginal transaction costs to trading offsets at the optimum c_i^* equal to the price differential, i.e. if $\frac{\partial \Gamma_i}{\partial c_i}(c_i^*) = P_{EUA} - P_{OFF}$.

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[8] It is also possible $\mu_i = 0$ while $c_i^* = 0$ if the installation is just indifferent towards surrendering the first CER.

Finally, the installation may use offsets up to its cap, $c_i^* = \Omega_\mathrm{i}$. Then in 5.2 $\mu_i = 0$, $\lambda_\mathrm{i} > 0$,[9] and installation i will use offsets until marginal abatement costs $\frac{\partial c_i}{\partial r_i}$ equal the price plus marginal transaction costs $\frac{\partial \Gamma_i}{\partial c_i}(c_i^*)$ plus λ_i. Substituting P_{EUA} for $\frac{\partial c_i}{\partial r_i}$ using 5.1 gives:

For all i: $$\mathrm{P_{EUA}} - \mathrm{P_{OFF}} = \lambda_\mathrm{i} + \frac{\partial \Gamma_\mathrm{i}}{\partial \mathrm{c_i}}(\mathrm{c_i^*}) \qquad 7$$

Equation 7 shows that a binding offset cap, with $\lambda_i > 0$ for every installation that uses them, is equivalent to a positive price differential $P_{EUA} - P_{OFF}$ provided marginal transaction costs at the optimum $\frac{\partial \Gamma_i}{\partial c_i}(c_i^*)$ are less than $P_{EUA} - P_{OFF}$. The interpretation of λ_i as the shadow value of relaxing the offset constraint is straightforward. Holding output constant, assume an installation is allowed to use one more offset. In order to take advantage of the new cap, the installation will buy either a CER or ERU and sell an EUA. For the installation, the value of this maneuver is the difference in permit prices, $P_{EUA} - P_{OFF}$ minus the transaction cost.

In the first scenario an installation will not use any offsets, and c_i^* and Γ_i both equal zero. To differentiate from the other two cases, denote choice variables with an N when $c_i^* = 0$ and with a Y when $c_i^* > 0$. Using equation 1 then, $e_i^{*N} = u_i - r_i^{*N} - \bar{e}_i$ and $e_i^{*Y} = u_i - r_i^{*Y} - \bar{e}_i - c_i^{*Y}$. First order condition 5.1 applies in either case if the installation is to minimize costs, although the optimal number of reductions decreases.

[9] Unless the installation is *just* indifferent towards surrendering the Ω_ith offset.

Equilibrium offset and EUA prices change depending on whether a particular installation uses offsets or not — and must be denoted N and Y as well. The total costs of compliance with and without the use of offsets respectively:

$$C_i(r_i^{*Y}) + P_{OFF}^{Y} c_i^{*Y} + P_{EUA}^{Y}(u_i - r_i^{*Y} - \bar{e}_i - c_i^{*Y}) + \Gamma_i(c_i^{*Y}) \qquad 8$$

$$C_i(r_i^{*N}) + P_{EUA}^{N}(u_i - r_i^{*N} - \bar{e}_i) \qquad 9$$

Because the installation will choose the option that minimizes costs, it will choose to surrender offsets when equation 9 is larger than equation 8. This results in a complicated decision rule, portions of which are impossible to observe or even sign. Much of this complexity disappears by assuming individual installations do not influence prices. When installations have *no* market power[10] $P_{EUA} = P_{EUA}^{Y} = P_{EUA}^{N}$, $P_{OFF} = P_{OFF}^{Y} = P_{OFF}^{N}$, and $r_i^{*} = r_i^{*Y} = r_i^{*N}$ and an installation will use offsets when: [11]

<u>Hypothesis #1</u>

$$(P_{EUA} - P_{OFF})c_i^{Y*} > \Gamma_i(c_i^{Y*}) \qquad 10$$

According to this hypothesis a price-taking installation will use offsets when the benefits — the price differential times the number of offsets used — is greater than the entry and marginal costs of using offsets.

That c_i^{Y*} is unobservable for installations that do not use offsets still presents a problem for empirical predictions. However as long as marginal transaction costs to

[10] Price-taking installations appear to be a reasonable assumption; an installation level Herfindahl index for emissions is 0.0024.

[11] An installation that does affect prices will use offsets when: $C_i(r_i^{*N}) - C_i(r_i^{*Y}) + P_{EUA}^{N}(u_i - r_i^{*N} - \bar{e}_i) - P_{EUA}^{Y}(u_i - r_i^{*Y} - \bar{e}_i) + (P_{EUA}^{Y} - P_{OFF}^{Y})c_i^{Y*} > \Gamma_i(c_i^{Y*})$.

trading offsets $\frac{\partial \Gamma_i}{\partial c_i}(c_i^{Y*})$ are less than the price differential, c_i^{Y*} *is* known, even for installations that do not use offsets.

Hypothesis #2

If marginal transaction costs to trading offsets at c_i^{Y*} are lower than $P_{EUA} - P_{OFF}$, any installation that uses offsets will use as many as it is allowed, or Ω_i.

This can be seen formally by rearranging equation 7:

$$\lambda_i = P_{EUA} - P_{OFF} - \frac{\partial \Gamma_i}{\partial c_i}(c_i^*) \qquad \text{7a}$$

It follows that λ_i is positive as long as $P_{EUA} - P_{OFF} > \frac{\partial \Gamma_i}{\partial c_i}(c_i^{Y*})$. Meanwhile, substituting c_i^{Y*} in for c_i in first order condition 5.3:

$$\lambda_i(\Omega_i - c_i^{Y*}) = 0 \qquad \text{5.3a}$$

In order for 5.3a to hold when λ_i is positive, $c_i^{Y*} = \Omega_i$.

For installations at their cap, a change in Ω_i — as long as marginal transaction costs remain below the price differential — results in an equivalent change in c_i^{Y*}.[12]

Hypothesis #2 is derived assuming installations using offsets know what their limits are. When they do not, it implies installations will use offsets up to whatever they *believe* is their limit. One might expect estimating these perceived limits (and therefore determining whether installations are at them) would be impossible, however the

[12] For a change in Ω_i to result in Δc_i^{Y*} *less* than $\Delta\Omega_i$ (i.e. for marginal transaction costs to no longer be below the price differential), it is necessary $\frac{\partial \Gamma_i}{\partial c_i}(c_i^{Y}) > 0$, $\frac{\partial P_{EUA} - P_{OFF}}{\partial c_i} < 0$, or both.

institutional details of the EU ETS do hint at ways installations may *perceive* their offset limits even if they are not at them. More is described in the next chapter.

DATA

Offset Limits and CITL Data

Flexibility import limits are set by individual member states in their Phase II National Allocation Plans. The limits used in this dataset were obtained either directly from National Allocation Plans themselves or from Trotignon 2010 (details are in the Appendix). Per instruction from the Commission, limits are usually defined as a percentage of installation EUA allocation (Tables 1 and 2), although Sweden and Denmark have done their installations the favor of calculating the exact number of offsets allowed. The relevant allocation used in the limit calculation changes depending on the country (Trotignon, 2010).

Tables 1 and 2 list type and actual offset cap by country and industry along with the number of observations covered under each limit. The EU ETS initially covered some 11,500 installations, although this number has changed over time with entry and exit. In order to maintain a consistent comparison of installations over time, only installations active over all three years are included in the data. Some installations (e.g. those in Bulgaria and Cyprus) are missing enough data to be unsuitable for empirical analysis. Tables 1 and 2 also give the number of observations ultimately included in the rest of the data and results chapters.

Regulators allocate EUAs and enforce permit obligations and offset restrictions at the installation level. However, many installations within countries are operated by the same entity, either a corporation or individual. Henceforth, these multiple installation entities are denoted firms. [13] In the case of multiple installation firms, the level of decision-making is unclear. It is possible EU ETS decisions are made at the firm level and relayed to individual installations. Alternatively, installations within a larger firm may exhibit different behavior if installations have a great deal of autonomy. The possibility that the firm rather than the installation is the primary decisionmaker requires aggregating the usual installation level EU ETS data to the firm level.

Each EU ETS transaction is recorded in the Community Independent Transaction Log (CITL). Data used in this analysis comes from the most recent version the public CITL data release, released in May 2011 and current through 2010.[14] The CITL has data from the inception of the EU ETS, but because installations were not able to trade offsets until 2008, the relevant data spans 2008 – 2010.

The EU ETS covers ten different sectors and the data is presented by industry in Table 3. The vast majority of observations — about two thirds — are power plants. ceramics are the next largest sector, making up roughly 10% of all observations.

Summary statistics for installations and firms are given in Table 4. More than half of EU ETS members — 58% of installations and 55% of firms — face a five year offset cap. Nearly all other observations are located in a country with a cumulative offset limit; only 4% of installations (5% of firms) face an annual offset cap that resets every year. About 40% of firms and installations are located in countries where offset caps change by industry or installation, adding another degree of complexity as firms sort out

[13] A portion of these installations designated here as part of a larger firm are not actually owned by the same company, rather it appears they hired the same person to manage their account.
[14] Installation aggregated level CITL data in any year t is released in May of year $t+1$, while data concerning actual transactions (i.e. transfers in the registry) is released in year $t+5$.

the offset rules and regulations. Nearly a quarter of all firms have multiple installations, of these less than 200 own installations in multiple industries or facing different caps.

The CITL gives four annual permit variables for every installation in the EU ETS. These are: permits surrendered, verified emissions, offsets surrendered, and EUA allocation. Additional variables are calculated using these five standard variables, including net permits short — defined as verified emissions (minus any EUAs previously banked into the registry) minus EUA allocation. If allocation exceeds emissions, then the number of net permits short is negative and the installation is considered long.

Multiplying the caps given in Tables 1 and 2 by the relevant EUA allocation (entire Phase II, cumulative, or one year allocation) and — in 2009 and 2010 — subtracting offset use, gives the exact number of offsets available to any installation or firm at any point in time. Comparing this to the number of offsets actually *used* gives the number of offsets left on the table for each installation in any given year.

The four standard CITL variables, along with offset limits and offsets left on the table are summarized by year at the installation level in Table 5 and at the firm level in Table 6. Verified emissions among observations in this sample are highest in 2008, at more than 2 billion tons. Aggregate emissions declined to 1.8 billion tons in 2009 and 2010. As a result, the market went from being nearly 150 million permits short in 2008 to nearly 16 million permits long at the end of 2010. The number of offsets surrendered fell slightly from 2008 to 2009 — from 81 million to 80 million — before increasing to nearly 130 million in 2010.

Table 7 and Table 8 summarize installation and firm behavior in the market as a whole. Annual offset use indicates whether firms surrendered at least one offset in any particular year. Cumulative use indicates how many observations *ever* surrendered offsets. About 18% of installations used offsets in 2008; by 2010 this number increased to 41%. Most installations were allocated enough permits to cover their emissions. Only 31% of installations (27% of firms) were short permits in 2008; 26% (21%) in 2009; 27% (22%) in 2010.

Determining Whether Installations are at Their Offset Limits

To determine just how close installations came to using their offset limits, the percentage of limit that is utilized — the number of offsets surrendered divided by offset limit — was calculated for each installation in each year. The kernel density estimates calculated using a normal kernel density function and bandwidth that minimizes an approximate mean integrated square error are shown in Figure 3. The limit shown is the maximum number of offsets any installation is allowed at any point in time. Installations are exactly at their limits when this number is one. Figure 3 shows a clear bimodal distribution. In 2008, for example, percent limit utilized is centered around both the actual cap (i.e. 100% utilized) and one fifth of the cap (i.e. 20% utilized). This is because installations using 20% of their cap surrendered just enough offsets to meet their limit calculated using just 2008 allocation rather than the entire five year, phase II allocation that actually applied.

To correct for this, the portion of limit utilized is recalculated, this time using the limit *closest* to the actual number of offsets surrendered. The kernel density of this distribution is given in Figure 4. The distribution of utilized offset limits displayed in Figure 3 and Figure 4 shows installations that use offsets are clustered around their caps, however more precise descriptions will be helpful in understanding installation's offset behavior. One obstacle in doing this is that installations purchase offsets in different units. As a result, defining an installation "at its cap" only if it surrenders enough CERs and ERUs to be within one permit of its limit is likely too restrictive, while designating an installation at its limit if it uses offsets within some set number of its cap is rather arbitrary.

To get around this, an attempt is made here to determine just how installations purchase their CERs and ERUs — whether 1 at a time, in blocks of 100, etc. This block is referred to here as the *offset purchasing unit.* An installation is then designated as "at" a particular limit if it is within one offset purchasing unit without going over. Further details are described in the appendix. A market level summary of offset purchasing units is given in Table **9**.

Because offset limits are calculated as percentages of EUA allocations, they vary depending on which EUA allocation applies (which varies depending on country), or even by which allocation the installation *believes* applies. In 2010, for example, an installation might use enough offsets to be at its five year limit (2008 – 2012 allocation times cap), cumulative three year limit (2008 – 2010 allocation times cap), or just its 2010 limit (2010 allocation times cap). It is also possible that installations are deliberately pursuing a strategy that involves purchasing CERs and ERUs in amounts other than their correct five year, cumulative, or one year offset limits. Two such strategies are explicitly identified: purchasing just enough offset units to cover short emissions and purchasing just enough offsets to meet what the installation *believes* (incorrectly) is its cap. These perceived caps are calculated either using a wrong but plausible cap (e.g. an offset cap initially proposed in an NAP but rejected by the commission) or more commonly, the correct offset cap taken as a percentage of *emissions* rather than allocation.

Installations are assigned only one explicit rationale in using offsets per year. For example, it is assumed an installation that simultaneously uses exactly up to its cap *and* just covers its short emissions meant to be at its cap — not using CERs and ERUs to cover its emissions.

Table 10 summarizes installations' motives in using offsets over 2008 – 2010. The data is cumulative; at the end of 2009, 237 installations (10% of installations using offsets over 2008 – 2009) had surrendered just enough offsets to reach their 2008 cap. These installations surrendered offsets in 2008 and not 2009. Eighty seven of these 237 rejoined the market in 2010, and the number of installations just at their 2008 caps declined to 150. Another trend is that the number of installations at mistaken caps is declining, both absolutely and as a percentage of installations that use offsets. Meanwhile, both the absolute number and portion of installations using offsets at their five year cap is increasing.

A portion of installations are not within one purchasing unit of any significant benchmark. To shed more light on these installations, the kernel density estimate of percent offset limit utilized for installations is given in Figure 5. This figure shows *only* installations at no discernable cap in 2008. In order to determine whether these installation's CER and ERU behavior changes over time, the percent offset limit utilized was recalculated again for these same installations after 2009 and 2010. These installations have clearly moved towards their offset limits in 2009 and 2010 (Figure 6). This trend applies to the market as a whole: in *every* year, installations outside one offset purchasing block of any significant benchmark are nevertheless moving closer towards their offset limits over time (Figure 7).

Table 1. Offset caps among countries with five year limits. Most of these caps apply to all installations within a given country or industry, however some countries — i.e. Sweden and Denmark — set offset caps for each installation.

Countries with offset limit calculated as % of five year allocation					
Country	Cap	# Inst.	# Usable	# Firms	# Usable
Austria	10%	214	188	118	109
Belgium					
Walloon	4%	118	95	64	59
Flemish	7%	39	37	21	21
Flemish (power)	24%	141	121	96	87
Brussels	50%	5	4	2	2
multiple caps	-	-	-	14	14
Bulgaria	12.507%	132	0	102	0
Cyprus	10%	13	0	9	0
Czech Republic	10%	401	344	265	236
Denmark					
standard	6.5%	258	236	93	84
varies	11% - 29%	93	91	53	51
multiple caps	-	-	-	65	63
Estonia	0%	50	32	34	20
Finland	10%	603	381	170	150
France	13.5%	1,018	851	528	426
Germany	22%	1,688	1,512	947	870
Greece	9%	142	118	102	80
Ireland					
power and cement	11%	23	22	7	7
all others	5%	86	73	61	54
multiple caps	-	-	-	2	2
Luxembourg	10%	14	13	13	12
Netherlands	10%	397	317	275	219
Portugal	10%	223	155	192	130
Romania	10%	243	172	181	126
Slovakia	7%	188	148	144	112
Slovenia	15.761%	92	84	87	81
Sweden					
no CERs	0%	7	5		
varies	varies	171	145	92	83
multiple caps	-	-	-	42	34

Table 2. Offset caps among countries with cumulative and one year limits.

Countries with offset limit calculated as % of cumulative allocation

Country	Cap	# Inst.	# Usable	# Firms	# Usable
Italy					
steel	16.7%	6	6	1	2
thermoelectricity	19.3%	156	147	37	31
all others	7.5%	843	752	483	431
multiple caps	-	-	-	24	23
Norway	20%	119	71	75	61
Poland	10%	849	748	531	493
Spain					
public service electricity	42%	79	66	23	19
all others	7.9%	971	815	782	662
multiple caps	-	-	-	5	5
United Kingdom					
large electricity producers	9.3%	57	57	41	41
all others	8%	926	778	617	506
multiple caps	-	-	-	5	5

Countries with offset limit calculated as % of annual allocation

Country	Cap	# Inst.	# Usable	# Firms	# Usable
Hungary	10%	237	179	163	129
Latvia	10%	87	70	82	69
Lithuania	20%	101	84	79	64

Table 3. Installations and Firms by Sector.

Sector	# Inst	% Inst	# Firms	% Firms
Cement	492	6%	235	4%
Ceramic	822	9%	589	10%
Coke Oven	19	0%	10	0%
Electricity	6,044	68%	3,593	63%
Glass	379	4%	268	5%
Metal Ore	25	0%	17	0%
Oil	140	2%	84	1%
Other	99	1%	28	0%
Pulp	688	8%	522	9%
Steel	209	2%	141	2%
Multiple	-	-	180	3%

Table 4. Non Time Varying Market Summary Statics

	# Inst (n=8,917)	% Inst	# Firms (n=5,667)	% Firms
Face five year offset limit	5,144	58%	3,126	55%
Face cumulative offset limit	3,440	38%	2,279	40%
Face annual offset limit	333	4%	262	5%
In country with multiple offset caps	3,534	40%	2,362	42%
Nonstandard offset limit	510	6%	301	5%
offset limit given in # permits	477	5%	315	6%
Firms with multiple installations	-	-	1,317	23%
Multi-installation firms with mult. caps	-	-	144	3%
Multi-installation firms with mult. Industries	-	-	180	3%

Table 5. Installation Level Summary Statistics

							n=8,917
Variable	Year	Mean	Std Dev	Median	Max	Min	Total
EUA Allocation	2008	209,503	835,581	24,359	26,937,155	3	1,868,137,902
	2009	210,357	834,186	24,970	26,937,155	3	1,875,749,344
	2010	211,336	835,997	25,183	26,937,155	3	1,884,486,071
Verified Emissions	2008	225,496	1,011,196	19,830	30,862,792	1	2,010,744,849
	2009	199,825	923,003	17,796	29,473,072	1	1,781,840,264
	2010	203,752	949,200	18,516	29,659,590	1	1,816,859,618
Net Short	2008	15,993	414,550	-1,900	12,798,513	-10,810,776	142,606,947
	2009	-10,930	411,518	-3,846	11,400,173	-13,060,546	-97,462,366
	2010	-9,019	426,816	-3,103	13,164,029	-11,003,821	-80,420,430
Offsets Surrendered	2008	8,964	81,307	0	4,984,978	0	79,929,622
	2009	8,925	78,598	0	3,612,200	0	79,586,240
	2010	14,390	110,129	0	4,716,145	0	128,318,071
Offset Limit	2008	100,466	551,783	7,369	21,584,228	0	895,856,318
	2009	102,881	529,334	8,480	16,599,250	-98,952	917,387,829
	2010	105,282	522,393	8,971	16,477,126	-98,952	938,801,414
Offset Limit - Surrendered	2008	91,502	518,473	5,831	16,599,250	-181,250	815,926,696
	2009	93,956	503,959	6,804	16,477,126	-427,982	837,801,589
	2010	90,892	491,481	6,330	16,477,126	-235,222	810,483,343

Table 6. Firm Level Summary Statistics

Variable	Year	Mean	Std Dev	Median	Max	Min	n=5,667 Total
EUA Allocation	2008	329,652	1,830,094	27,786	53,769,722	3	1,868,137,902
	2009	330,995	1,812,257	28,345	54,088,115	3	1,875,749,344
	2010	332,537	1,810,903	28,709	54,108,578	3	1,884,486,071
Verified Emissions	2008	354,816	2,457,360	21,959	108,268,739	2	2,010,744,849
	2009	314,424	2,239,650	19,640	102,080,844	1	1,781,840,264
	2010	320,603	2,258,528	20,508	104,193,477	1	1,816,859,618
Net Short	2008	25,164	919,579	-2,689	54,499,017	-4,434,233	142,606,947
	2009	-17,198	826,066	-5,107	47,962,533	-9,427,806	-97,462,366
	2010	-14,191	859,421	-4,455	49,995,629	-8,419,186	-80,420,430
Offsets Surrendered	2008	14,104	153,015	0	7,817,150	0	79,929,622
	2009	14,044	142,900	0	5,456,914	0	79,586,240
	2010	22,643	180,657	0	6,478,840	0	128,318,071
Offset Limit	2008	158,083	1,265,017	7,819	59,637,511	0	895,856,318
	2009	161,882	1,255,407	9,156	59,637,511	-98,952	917,387,829
	2010	165,661	1,218,532	9,909	56,167,306	-98,952	938,801,414
Offset Limit - Surrendered	2008	143,979	1,226,936	6,381	59,637,511	-142,879	815,926,696
	2009	147,839	1,171,100	7,543	56,167,306	-427,982	837,801,589
	2010	143,018	1,136,005	7,078	53,157,248	-235,222	810,483,343

Table 7. Installation Level Time Varying Market Summary Statics

	2008		2009		2010	
Variable	# Inst	% Inst	# Inst	% Inst	# Inst	% Inst
Annual offset use	1,577	18%	1,753	20%	2,612	29%
Cumulative offset use	1,577	18%	2,435	27%	3,648	41%
At offset limit	529	6%	601	7%	739	8%
Net Short	2,747	31%	2,330	26%	2,414	27%

Table 8. Time Varying Market Summary Statistics

	2008		2009		2010	
Variable	# Firm	% Firm	# Firm	% Firm	# Firm	% Firm
Annual offset use	949	17%	1,146	20%	1,672	30%
Cumulative offset use	949	17%	1,514	27%	2,248	40%
At offset limit	388	7%	655	12%	826	15%
Net Short	1,511	27%	1,203	21%	1,228	22%

Table 9. Offset Purchasing Units Among Installations Using Offsets

	2008		2009		2010	
Offset Unit	# Inst	% Inst	# Inst	% Inst	# Inst	% Inst
1	960	61%	1,465	60%	2,190	60%
5	85	5%	138	6%	213	6%
10	139	9%	211	9%	307	8%
25	30	2%	30	1%	50	1%
50	23	1%	36	1%	71	2%
100	60	4%	123	5%	164	4%
500	31	2%	44	2%	65	2%
1,000	156	10%	273	11%	389	11%
10,000	62	4%	76	3%	139	4%
50,000	20	1%	23	1%	29	1%
100,000	11	1%	16	1%	31	1%

Table 10. Number of offsets used.

Installations using just enough offsets to:	2008		2009		2010	
	# Inst.	% Inst.	# Inst.	% Inst.	# Inst.	% Inst.
comply with cap that does not apply	18	1%	10	0%	9	0%
comply with cap calc. as % of permits	115	7%	33	1%	20	1%
comply with cap that does not apply calc. as % of permits	7	0%	3	0%	-	-
cover short allocation	14	1%	15	1%	21	1%
comply with 2008 cap	673	43%	237	10%	150	4%
comply with 2009 cap	-	-	183	8%	44	1%
comply with 2008 - 2009 cap	-	-	513	21%	122	3%
comply with 2008 - 2010 cap	-	-	-	-	485	13%
comply with 5 year cap	106	7%	207	9%	409	11%
not discernable	644	41%	1,234	51%	2,388	65%

Figure 3. Distribution of percent offsets used of actual offset limit among installations that surrendering offsets in any given year.

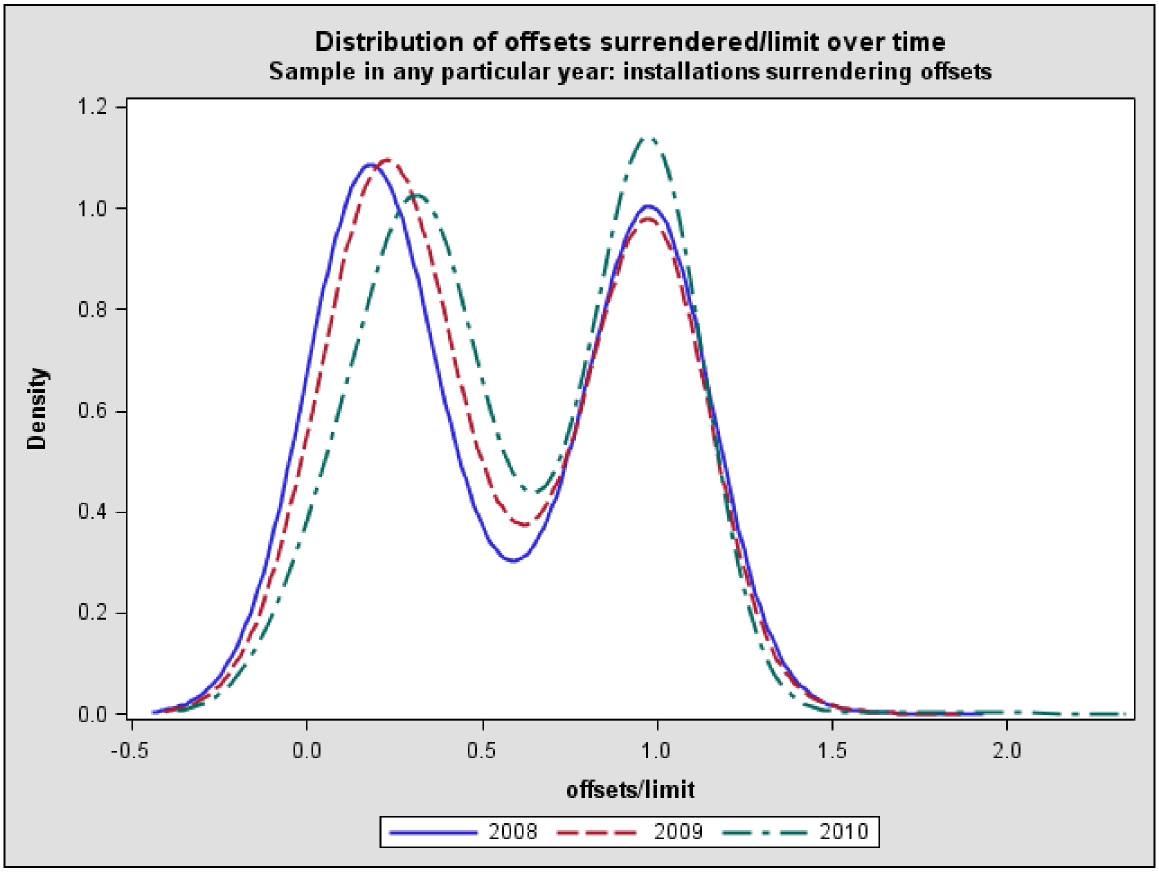


Figure 4. Distribution of percent offsets used of nearest limit among installations that have ever used offsets.

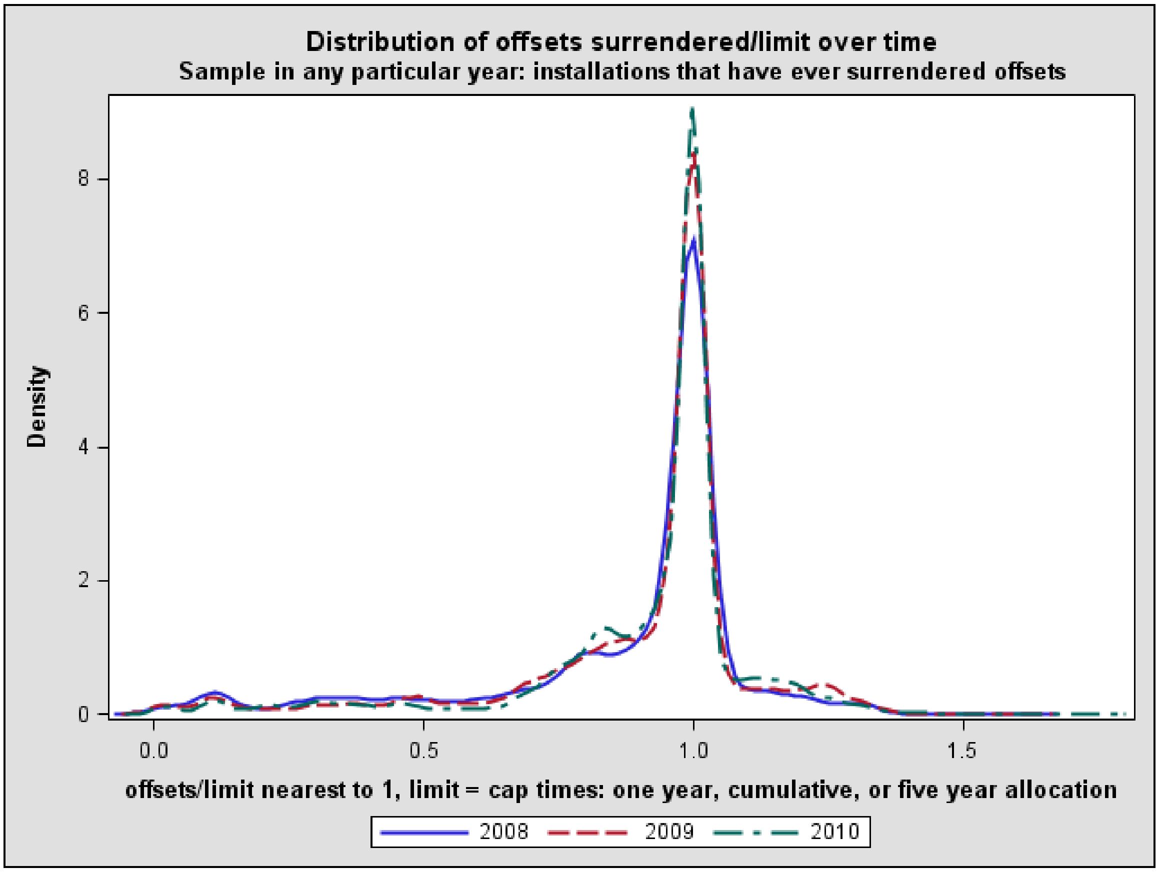


Figure 5. Distribution of percent offsets used of nearest limit among installations not within one offset purchasing block of any significant offset benchmark in 2008.

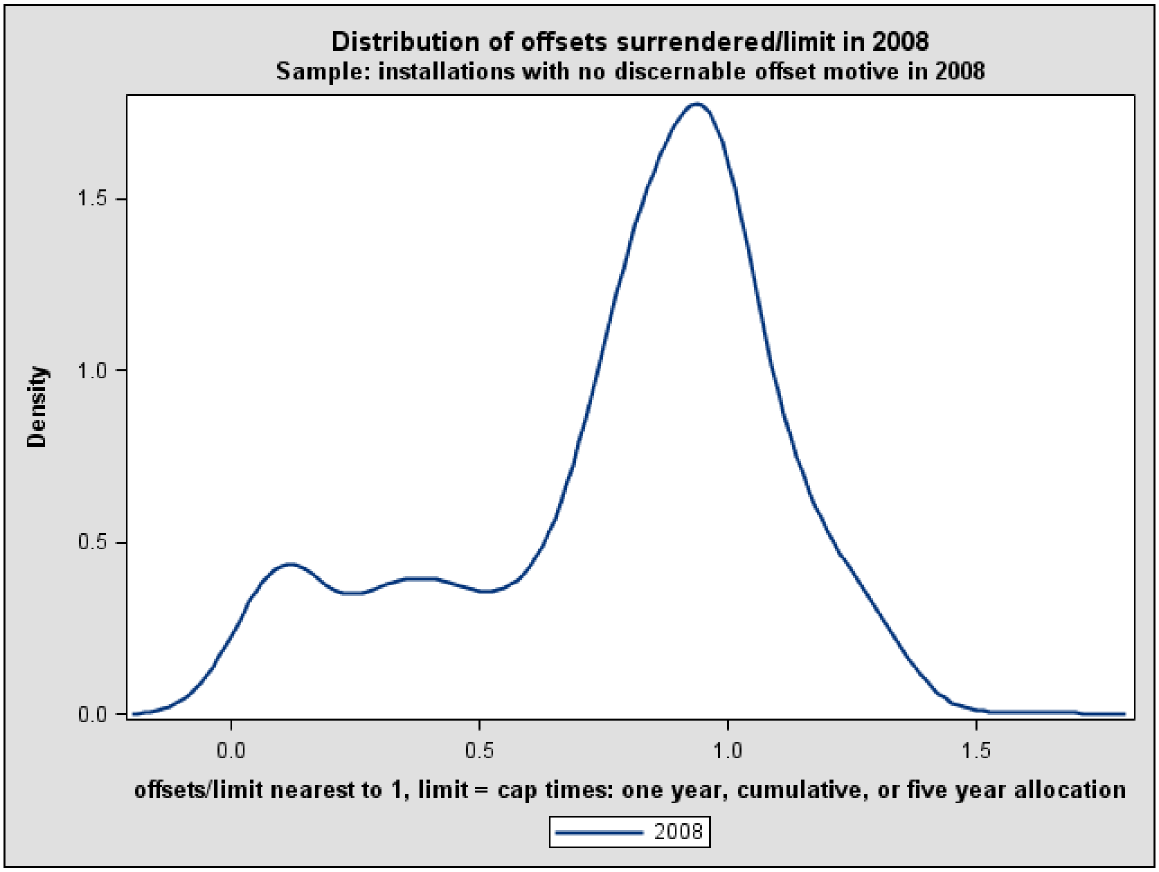


Figure 6. Distribution of percent offsets used of nearest limit over time among installations not within one offset purchasing block of any significant offset benchmark in 2008.

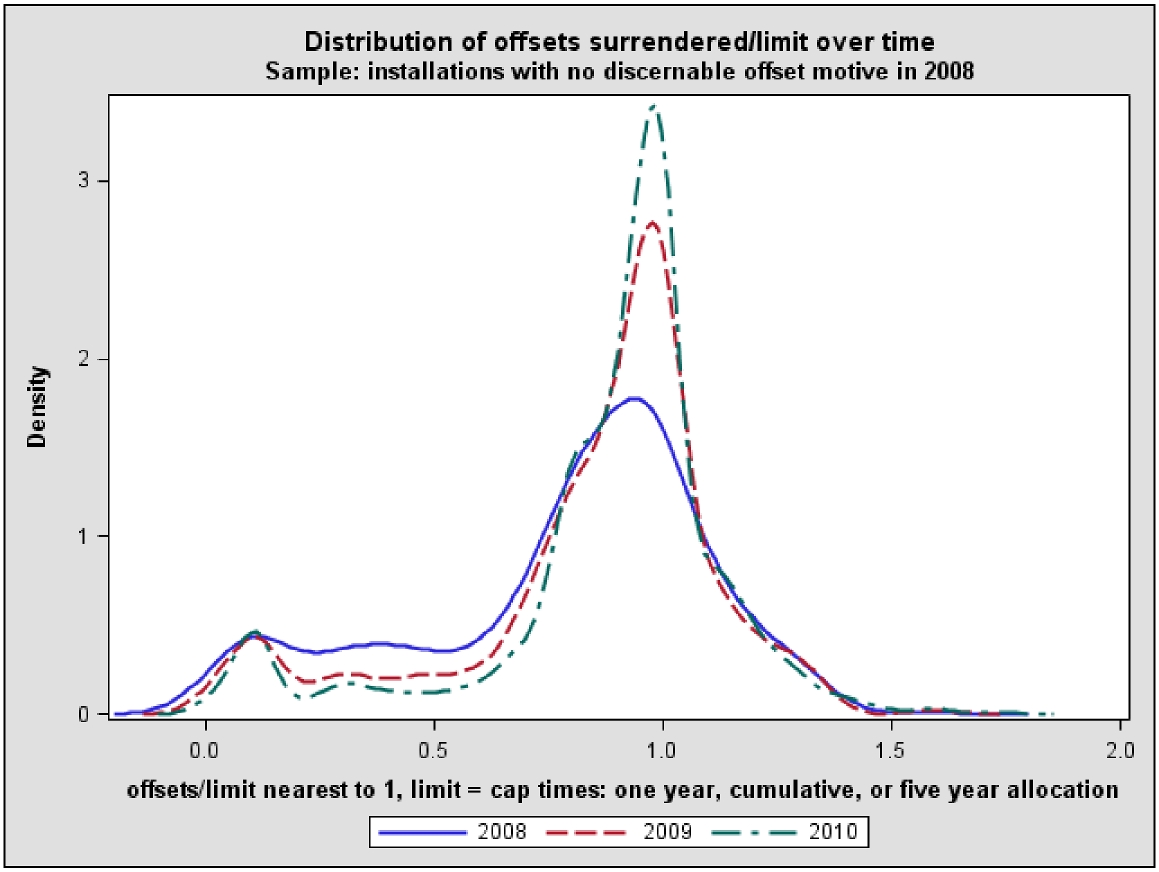


Figure 7. Distribution of percent offsets used of nearest limit among installations not within one offset purchasing block of any significant offset benchmark in any year.

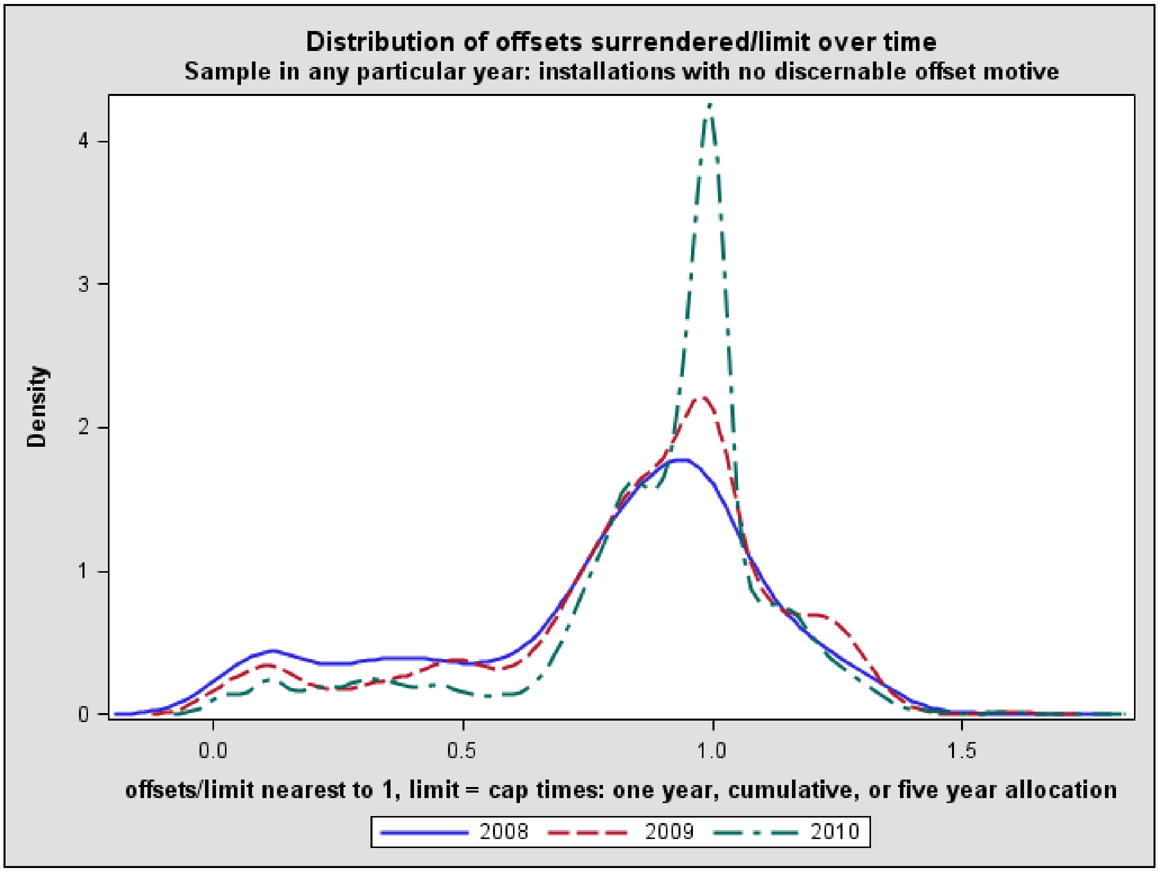
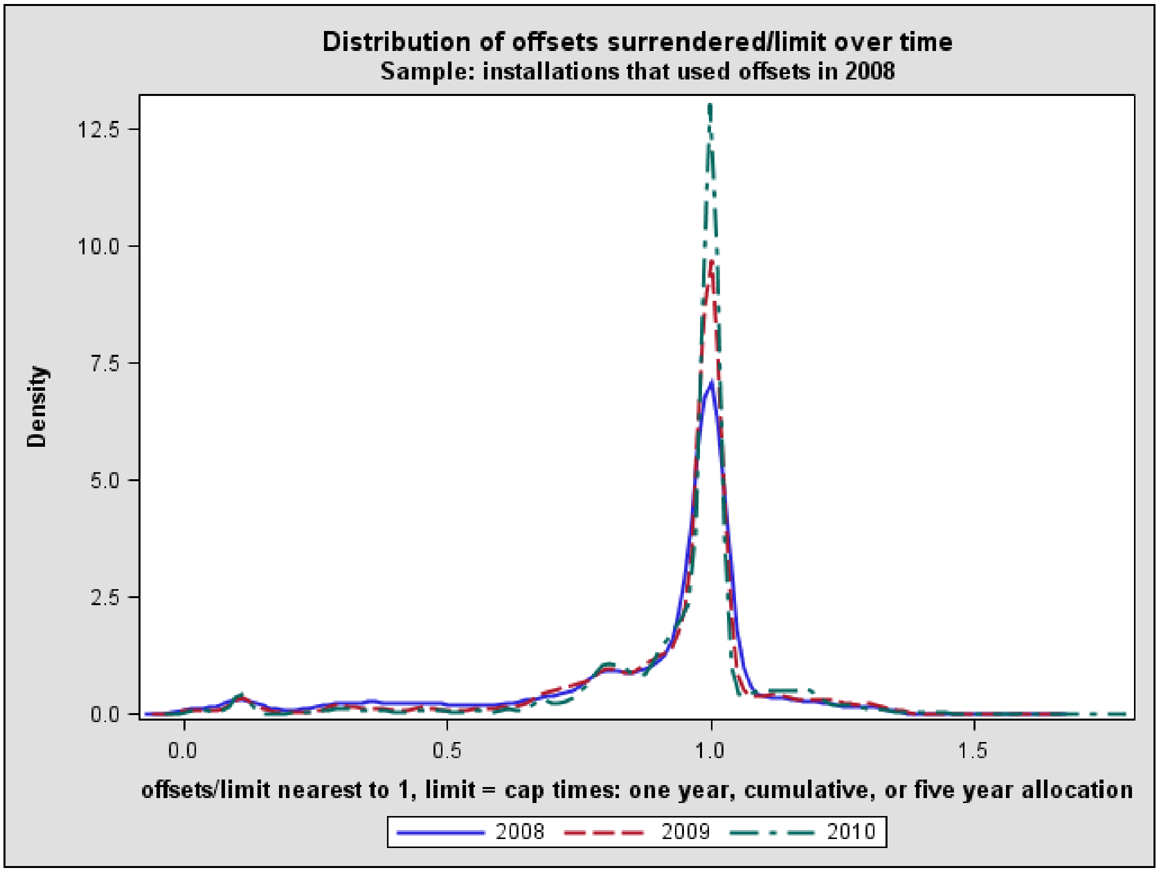


Figure 8. Distribution of percent offsets used of nearest limit among installations that used offsets in 2008.



EMPIRICAL SPECIFICATION AND RESULTS

Empirical specification

According to the model in chapter 3, installation i will use offsets when the net benefits are greater than zero (hypothesis 1).

$$y_i^* = (\mathrm{P_{EUA}} - \mathrm{P_{OFF}})\mathrm{c_i^{Y*}} - \Gamma_\mathrm{i}\left(\mathrm{c_i^{Y*}}\right) > 0 \qquad 11$$

The exact magnitude of y_i^* is unobservable. However whether $y_i^* > 0$ *is* observable by looking at the installation's offset decision. An indicator variable, y_i is coded 1 when $c_i > 0$ and 0 otherwise. Assume Γ_i is a random variable with conditional mean described by vectors of linear and exponential characteristics $\boldsymbol{x_i}$ and $\boldsymbol{z_i}$ with coefficients $\boldsymbol{\beta_x}$ and $\boldsymbol{\beta_z}$ respectively**.** Because it is impossible to observe variation in $P_{EUA} - P_{KFM}$, prices and other unobservable characteristics are assumed to enter an error term ε_i.

In final form, any installation will use offsets when:

$$\beta_c \ln \mathrm{c_i^*} - \beta_{x0} - \boldsymbol{\beta_z} \ln \mathbf{z_i} - \boldsymbol{\beta_x}\mathbf{x_i} - \varepsilon_\mathrm{i} > 0 \qquad 12$$

If ε_i is normally distributed with mean 0 and unit variance this specification can be estimated as a probit. Coefficients $\widehat{\boldsymbol{\beta}}$ are estimated by choosing values which maximize the joint likelihood function for all installations $i = 1$ through n.

In addition to deciding whether to use offsets, each installation also decides how many offsets it will leave on the table: $\Omega_i - c_i^*$. This is defined here by the following specification:

$$\Omega_i - c_i^* = \mathbf{s_i}^{\boldsymbol{\theta}_s} + e^{\theta_{w0}+\boldsymbol{\theta}_w\mathbf{w_i}+\tau_i} \quad 13$$

Taking the natural log of both sides, this becomes:

$$\ln(\Omega_i - c_i^*) = \boldsymbol{\theta}_s \ln(\mathbf{s_i}) + \theta_{w0} + \boldsymbol{\theta}_w \mathbf{w_i} + \tau_i \quad 14$$

If a portion of the unobservable characteristics in τ_i also enter ε_i, then the two error terms are correlated and coefficients $\boldsymbol{\theta}$ are biased and inconsistent. Here it is assumed that ε_i and τ_i are distributed bivariate normal:

$$\begin{bmatrix}\varepsilon_i \\ \tau_i\end{bmatrix} \sim N\left(\begin{bmatrix}0 \\ 0\end{bmatrix}, \begin{bmatrix}1 & \rho \\ \rho & \sigma^2\end{bmatrix}\right) \quad 15$$

The expected value of $ln(\Omega_i - c_i^*)$ given a firm uses offsets is:

$$E[\ln(\Omega_i - c_i^*)|y_i = 1] = \boldsymbol{\theta}_s \ln(\mathbf{s_i}) + \theta_{w0} + \boldsymbol{\theta}_w \mathbf{w_i} + E[\tau_i|y_i = 1] \quad 16$$

Using equation 12, $E[\tau_i|y_i = 1]$ becomes:

$$E[\tau_i|y_i = 1] = E\left[\tau_i|\varepsilon_i > -\beta_c \ln c_i^* + \boldsymbol{\beta}_z \ln \mathbf{z_i} + \beta_{x0} + \boldsymbol{\beta}_x \mathbf{x_i}\right] \quad 17$$

Or:

$$E[\tau_i|y_i = 1] = \rho\sigma_\tau \left[\frac{\phi\left(\beta_c \ln c_i^* - \boldsymbol{\beta}_z \ln \mathbf{z_i} - \beta_{x0} - \boldsymbol{\beta}_x \mathbf{x_i}\right)}{\Phi\left(\left(\beta_c \ln c_i^* - \boldsymbol{\beta}_z \ln \mathbf{z_i} - \beta_{x0} - \boldsymbol{\beta}_x \mathbf{x_i}\right)\right)}\right] \quad 18$$

where ϕ and Φ are the pdf and cdf of the standard normal distribution respectively. Conditional on *not* using offsets, the expected value of $ln(\Omega_i - c_i^*)$ is:

$$E[\ln(\Omega_i - c_i^*)|y_i = 0] = \boldsymbol{\theta}_s \ln(\mathbf{s_i}) + \theta_{w0} + \boldsymbol{\theta}_w \mathbf{w_i} + E[\tau_i|y_i = 1] \quad 19$$

and the conditional expectation of τ_i becomes:

$$E[\tau_i|y_i = 1] = \rho\sigma_\tau \left[\frac{-\phi\left(\beta_c \ln c_i^* - \boldsymbol{\beta}_z \ln \mathbf{z_i} - \beta_{x0} - \boldsymbol{\beta}_x \mathbf{x_i}\right)}{1 - \Phi\left(\left(\beta_c \ln c_i^* - \boldsymbol{\beta}_z \ln \mathbf{z_i} - \beta_{x0} - \boldsymbol{\beta}_x \mathbf{x_i}\right)\right)}\right] \quad 20$$

The bracketed terms in equations 18 and 20 are the inverse Mills ratio when $y_i = 1$ and $y_i = 0$ respectively. Including this term in the second stage regression allows estimation of equation 13 for the population as a whole (Heckman, 1979).

Although it necessarily involves making limiting assumptions, each year 2008 - 2010 is modeled independently, which implies decisions are made recursively. Hence the 2009 first stage equation includes variables describing offset use in 2008, while the 2010 equation includes variables from both 2008 and 2009.

Continuous right hand side variables in every first stage specification are logged total offsets allowed, verified emissions, and cumulative EUAs long (defined as zero if the installation is short). Right hand side dummy variables indicate whether the installation faces a nonstandard offset cap, is allocated net short, is part of a larger multi-installation firm, and whether another installation in that larger firm used offsets. Country fixed effects are included in all three specifications.

Results

Prior offset use (Table 11) makes installations significantly more likely to use offsets in the relevant years (2009 and 2010). At the same time — controlling for the previous decision about *whether* to use offsets — the more offsets surrendered previously the less likely any installation is to use offsets in any period. Installations are also much more likely to use offsets if they are part of a larger multi-installation firm with at least one other installation that used offsets. Likewise, an installation is less likely to use offsets if it is part of a larger firm whose other installations did not use offsets.

In every specification, an increase in offset limit makes installations more likely to use offsets. In 2008 and 2009, larger installations (as measured using verified emissions) were not significantly more or less likely to use offsets. By 2010 — controlling for previous offset use — larger firms were *less* likely to use offsets.

Although the benefits to arbitraging offsets are theoretically independent of a short or long allocation, short installations are empirically more likely to use offsets in 2009, with those short for the first time even *more* likely to use offsets (specification 2, stage 1). In addition, the longer an installation, the more likely it was to use offsets (specification 2, stage 1).

In 2008 installations in Hungary were more likely to offsets than any other country *ceteris paribus*, while installations in Greece were the least likely to use offsets. Details for every country over all three years are given in Table 13.

The independent variables for the second stage regressions include the log of total offset limit and verified emissions, as well as dummies for each installation indicating a net short allocation and whether the installation used offsets at certain points. Location-specific dummy variables indicate whether the installation is located in a country with a five year offset cap or a country (Denmark or Sweden) where offset limits are given in number of offsets rather than a percentage of allocation.

In all specifications, installations with higher offset limits left more offsets on the table. Installations with larger verified emissions were always closer to their offset caps (specifications 1 – 3, stage 1).

Net short installations left more offsets on the table in 2008 (specifications 1 , stage 2), while installations in Sweden and Denmark, where offset limits are given as actual numbers of offsets rather than percentages of EUA allocation, use more of their limits in every year but 2010.

Cross equation correlation between the two stages is significantly positive (0.1445 and 0.1084) in 2008 and 2009 and insignificant 2010. The coefficient on the inverse mills ratio, sigma, is always significantly positive. For the first two years of phase II at least, this indicates there is selection into this market and justifies the empirical strategy.

Table 11. First stage Heckman Results with P values given in parentheses. Coefficients denoted with one, two, or three stars denote significance at the 1%, 5%, and 10% level respectively

Installation Level	First Stage Heckman Decision: Whether to Use KFMs					
sample	all installations					n=8,917
	(1) 2008		(2) 2009		(3) 2010	
Variable: Used offsets	Coefficient	M.E.	Coefficient	M.E.	Coefficient	M.E.
intercept	-3.1203***		-2.8043***		-1.9063***	
	(<.0001)		(<.0001)		(<.0001)	
log total offsets allowed	0.1366***	0.0241	0.1486***	0.0272	0.1390***	0.0316
	(<.0001)		(<.0001)		(<.0001)	
log verified emissions	0.0317	0.0056	-0.0191	-0.0035	-0.0508***	-0.0115
	(0.2688)		(0.244)		(<.0001)	
dummy: nonstandard offset cap	-0.0595	-0.011	-0.2711***	-0.0497	-0.0029	-0.0007
	(0.5144)		(0.0028)		(0.9736)	
dummy: net short	0.2090	0.0369	0.1950**	0.0357	0.0772	0.0175
	(0.1414)		(0.0256)		(0.2940)	
dummy: first time net short			0.2125**	0.0389	-0.1431	-0.0325
			(0.0454)		(0.1239)	
log of cumulative EUAs long	0.0199	0.0035	0.0172**	0.0031	0.0091	0.0021
	(0.1968)		(0.0243)		(0.1674)	
dummy: installation part of a multi-installation firm	-0.8731***	-0.154	-0.8344***	-0.1529	-0.9623***	-0.2185
	(<.0001)		(<.0001)		(<.0001)	
dummy: another installation in same firm used offsets	2.2461***	0.3969	1.737***	0.3182	1.8424***	0.4182
	(<.0001)		(<.0001)		(<.0001)	
dummy: used offsets in 2008			2.8087***	0.5145	0.4952***	0.1124
			(<.0001)		(<.0001)	
dummy: used offsets in 2009					1.4694***	0.3336
					(<.0001)	
log previous offsets surrendered			-0.1691***	-0.031	-0.0297***	-0.0067
			(<.0001)		(0.0019)	
country fixed effects	yes		yes		yes	
Predicted # using offsets	1,076		1,198		2,130	
Actual # using offsets	1,577		1,753		2,612	
False Positive	316		332		544	
False Negative	817		887		1,026	
OVR Correct	7,784	87%	7,698	86%	7,347	82%

Table 12. Second stage Heckman Results with P values given in parentheses. Coefficients denoted with one, two, or three stars denote significance at the 1%, 5%, and 10% level respectively.

Installation Level	Second Stage Heckman Decision: Distance from Cap					
sample	all installations					n=8,917
	(1) 2008		(2) 2009		(3) 2010	
Variable: log of abs distance from cap	Coefficient	M.E.	Coefficient	M.E.	Coefficient	M.E.
intercept	-6.1714***		-5.3485***		-4.2934***	
	(<.0001)		(<.0001)		(<.0001)	
log total offsets allowed	2.1824***	0.386	1.4186***	0.2789	1.4744***	0.4319
	(<.0001)		(<.0001)		(<.0001)	
log verified emissions	-1.0254***	-0.181	-0.3298***	-0.0648	-0.4626***	-0.1355
	(<.0001)		(<.0001)		(<.0001)	
dummy: nonstandard offset cap	-1.3552***	-0.24	-0.5008	-0.0984	-0.0708	-0.0207
	(<.0001)		(0.1800)		(0.8032)	
dummy: net short	0.4758**	0.0841	0.2351	0.0462	0.0879	0.0258
	(0.0158)		(0.3173)		(0.5978)	
dummy: face five year offset limit	2.8885***	0.5108	2.5464***	0.5006	2.7874***	0.8165
	(<.0001)		(<.0001)		(<.0001)	
dummy: cap given in individual offsets	-1.474***	-0.261	-1.4757**	-0.2901	1.1020**	0.3228
	(0.0042)		(0.0131)		(0.0392)	
_Sigma	3.4039***		3.8865***		3.6120***	
	(<.0001)		(<.0001)		(<.0001)	
_Rho	0.1445***		0.1084***		-0.0624	
	(0.0015)		(0.0069)		(0.1147)	

Table 13. Fixed effects from first stage Heckman Results with P values are given in parentheses. Installations in Germany were omitted in each specification. Coefficients denoted with one, two, or three stars denote significance at the 1%, 5%, and 10% level respectively.

	(1) 2008			(2) 2009			(3) 2010		
Country	Rank	Estimate	P Value	Rank	Estimate	P Value	Rank	Estimate	P Value
Spain	10	0.3319***	(0.0038)	3	0.6339***	(<.0001)	2	0.3980***	(<.0001)
Lithuania	3	0.5989***	(0.0016)	1	0.8908***	(<.0001)	12	0.0703	(0.7058)
Czech Republic	4	0.5254***	(<.0001)	7	0.4050***	(<.0001)	6	0.2623***	(0.0053)
Poland	9	0.3642***	(0.0015)	5	0.6040***	(<.0001)	3	0.3883***	(<.0001)
Hungary	1	1.0979***	(<.0001)	2	0.7578***	(<.0001)	20	-0.1215	(0.3728)
Romania	23	-0.2507	(0.1457)	4	0.6228***	(<.0001)	1	0.4297***	(0.0003)
Italy	12	0.3255***	(0.0074)	8	0.3793***	(<.0001)	9	0.2238***	(0.0017)
Slovakia	2	0.6402***	(<.0001)	12	0.2562*	(0.0992)	16	-0.0102	(0.9402)
France	6	0.4813***	(<.0001)	17	0.0968	(0.2020)	8	0.2257***	(0.0007)
United Kingdom	5	0.5114***	(<.0001)	11	0.2931***	(0.0005)	15	-0.0082	(0.9129)
Norway	13	0.2791	(0.2142)	15	0.1241	(0.5796)	4	0.3828**	(0.0330)
Slovenia	18	0.1045	(0.5995)	6	0.4283**	(0.0166)	11	0.1078	(0.5170)
Denmark	7	0.4650***	(0.0004)	9	0.3507***	(0.0100)	23	-0.2225*	(0.0944)
Netherlands	14	0.2641**	(0.0152)	18	0.0294	(0.8072)	7	0.2457**	(0.0113)
Latvia	24	-0.3010	(0.3818)	14	0.1368	(0.6004)	5	0.3057	(0.1067)
Sweden	16	0.1935	(0.2471)	10	0.2935**	(0.0492)	18	-0.0702	(0.6494)
Austria	11	0.3258**	(0.0162)	13	0.2466*	(0.0771)	21	-0.1546	(0.2468)
Belgium	8	0.4307***	(0.0006)	21	-0.0324	(0.8086)	19	-0.1083	(0.3942)
Luxembourg	19	0.1035	(0.8155)	23	-0.2054	(0.6581)	10	0.2156	(0.5909)
Finland	20	0.0409	(0.7192)	22	-0.0696	(0.5344)	13	0.0540	(0.5647)
Germany	21	omitted	(.)	20	omitted		14	omitted	
Portugal	15	0.2607*	(0.0702)	19	0.0241	(0.8771)	24	-0.3544**	(0.0194)
Ireland	17	0.1767	(0.4349)	25	-0.5979**	(0.0490)	17	-0.0642	(0.7561)
Estonia	22	-0.1598	(0.9272)	16	0.0993	(0.9517)	25	-1.8281	(0.9091)
Greece	25	-0.6148	(0.0218)	24	-0.2334	(0.2871)	22	-0.1763	(0.2095)

DISCUSSION

Reconciling the Price Differential and Nonbinding Offset Limit

In order to take full advantage of the EUA – offset price differential, any particular installation must (a) first realize offsets are an option, (b) determine which offset cap applies, (c) understand *how* it applies (i.e. as a percentage of allocation), (d) understand whether it is a five year, cumulative or one year cap, and finally (e) complete the actual swap, purchasing offsets through a broker or from an offset provider and selling (or purchasing fewer) leftover EUAs. In real examples of the costs of acquiring information, installations fail at every observable point along way.

Short of asking them directly, it is impossible to judge how well companies understand the EU ETS. Many installations forgoing CERs and ERUs may not even be aware they are an option. By design, many installations — especially those outside the electricity sector — are given enough EUAs to conduct "business as usual." Since 2005, they have been allowed to emit CO_2 as usual, simply surrendering the same EUAs they were given. For many of these installations, the introduction of offsets in 2008 might have gone unnoticed.

Empirical evidence on the role of basic knowledge as an obstacle to using offsets is mixed. Factors increasing the likelihood that installations become aware of offsets *do* lead to a higher probability of actual use. For example, where it had a significant effect, a short allocation meant installations were more likely to use offsets (specification 2, stage 1) even though the theoretical benefits to arbitraging the EUA – offset price spread are independent of a net short or long allocation. Short installations cannot simply cover their emissions using their given EUAs. They must purchase permits from somewhere else, thus at minimum obtaining some basic knowledge of the trading process. These installations may be more apt to discover CERs or ERUs, and at least use them to cover their emission obligations even if they do not use their entire limit to fully arbitrage the spread outright. In 2009, being short for the first time made an installation even more likely to use offsets (specification 2, stage 1), as would be expected if initial discovery were an obstacle that short installations were more likely to overcome.

Likewise, the *longer* an installation — the more its EUA allocation exceeds emissions — the more it has to gain by spending time and resources developing a comprehensive trading strategy. In doing so, these installations may be more likely to discover offsets. If true, and if basic offset discovery is an obstacle, then these installations should be more likely to use CERs and ERUs. And indeed, longer installations are more likely to use offsets in 2009 (specification 2, stage 1).

While no installation that is completely ignorant of offsets will enter the market, other empirical results suggest the decision to use offsets is not wholly predicated on discovering they exist. Every installation with a positive cap can benefit from arbitraging offsets. If entry costs to trading offsets are entirely a matter of realizing they are an option, then every one of these installations that discovers offsets should be using them, no matter what the size of its offset limit. The decision to use offsets will not be correlated with the size of the gains from arbitrage.[15] But a positive correlation does exist. Holding everything else equal, installations with more to gain from arbitrage (i.e. installations with higher offset limits) are more likely to use offsets. This suggests more installations are aware of CERs and ERUs than those actually using them, and that there are further impediments to trading offsets than simply discovering they exist.

One of these impediments may be figuring out exactly which offset cap applies. Recall that caps often vary by industry within a given country; there is usually one cap that applies generally to most installations and another, usually higher cap that applies to specific industries (e.g. large electricity producers in the United Kingdom, steel plants in Italy). In 2009, installations set aside for such special treatment were actually *less* likely to use offsets (specification 2, stage 1). It appears the extra costs involved in determining which nonstandard cap applies are prohibitive for some installations and cause them to sit out the market altogether. In addition, a portion of installations that do use offsets surrender enough offsets to just meet either a cap that would have applied to them had it not been rejected by the EU, or a offset cap that applies to other industries in their country but not the installation itself (Table 10). Installations are getting more accurate over time; the number at these possible alternative caps has declined every year from 2008 to 2010, both in absolute terms and as a percentage of installations using offsets.

[15] This is not true if installations with higher limits were inherently somehow more likely to discover CERs and ERUs exist. Such a link between the size of benefits to using offsets and inherent knowledge is theoretically plausible. Perhaps some installations planning to use CERs and ERUs successfully lobbied for higher caps. Or else maybe offset suppliers or brokers actively peddle them to installations with higher limits and more to gain by using CERs and ERUs.

Even at the peak of confusion in 2008, relatively few installations were at altogether wrong caps. They seem to have had a more difficult time recognizing that Commission specified offset caps are to apply as a percentage of EUA *allocation* rather than total permits surrendered. About 7% of installations using offsets surrendered just enough offsets in 2008 to be at this miscalculated cap. This is in addition to the installations at the wrong offset cap altogether. A handful of installations went a step further, surrendering just enough offsets to be at a cap that did not apply to them, calculated as a percentage of emissions rather than allocation.

Even when installations recognize offset limits are calculated as a percentage of EUA allocation rather than verified emissions, there is still the question of which EUA allocation to use. For example, is an installation that decides to use offsets for the first time in 2010 allowed the cap times just its 2010 EUA allocation? Or is it the entire 2008 – 2012 allocation? Or maybe just a running 2008 – 2010 allocation? The right answer varies by country, and again, installations often surrender just enough offsets to meet a limit calculated using rules that do not actually apply to them. In 2010, for example, 253 installations surrendered just enough CERs and ERUs to meet their single year, 2010 cap (cap times EUA allocation in 2010). The problem is this limit actually only applied to 31 of them; the other 222 installations were allowed to calculate their limits using either their cumulative (2008 – 2010) or five year (2008 – 2012) allocation. Likewise, 128 of the 623 installations that surrendered enough offsets to just be at their three year cap in 2010 were actually allowed to calculate their limits using a five year allocation. This is common to every year and every type of cap.

The relatively high cost of acquiring information within the EU ETS contributes to the nonbinding aggregate offset cap in two ways. First, some installations may believe they are at their limits even though they are not. Less noticeably — but more important when it comes to the number of unused offsets — the costs of acquiring information cause many installations to forgo the market altogether. Much of the evidence that installations had trouble navigating the offset process comes from installations that *did* use offsets and presumably thought they were complying with the rules. For every installation like this many more may have chosen to sit the offset market out because of uncertainty about the rules.

From an outside perspective, it is often impossible to even guess where in the process installations decided against using offsets entirely. But the results in chapter 5 do indicate what makes an installation more likely to successfully navigate the entire process.

Early on in phase II, the size of an installation — as measured by verified emissions — has no significant effect on the likelihood of using offsets. By 2010, however, the larger an installation, the *less* likely it is to use offsets. Remember this 2010 specification controls for previous offset use. It is not hard to imagine large installations that had *still* not discovered offsets within the first two years of phase II being particularly inept and less likely than the average installation to use offsets for the first time in 2010. In addition, many installations — a little over half — are operated by some larger, multi-installation firm. These installations were much more likely to use offsets when another installation owned by the same firm also used offsets, implying that at least some decisions are made at the firm rather than the installation level.

Looking beyond individual installation characteristics, there are definite trends in offset use over time. More installations are using more CERs and ERUs over time. Because there is nothing to suggest actual *monetary* costs to entering the offset market have changed over time, these trends imply entry costs are in part a matter of acquiring information, and that installations are learning and overcoming these costs over time.

Once installations *do* use offsets, it is often possible to discern why they surrendered the number they did, even if they are not actually at their correct caps. Correcting for possible miscalculations, it appears about 58% of installations using CERs and ERUs in 2008 intended to be at their offset cap. An additional 1% used just enough offsets to cover their short emissions, an alternative strategy, which — although not the type of behavior predicted by the model — is at least observable. In 2008, that leaves some 650 installations (41% of those that used offsets) further than one offset purchasing unit away from any significant benchmark. These numbers climbed to 1,243 and 2,398 by the end of 2009 and 2010 respectively.

The bulk of these 650 installations are clustered around some offset cap in 2008, as shown by the kernel density distributions in Figure 5. These installations also appear to be learning over time. The same sample of installations appears to moving closer to their limits in 2009 and 2010 (Figure 6). The trend applies to most installations in the EU ETS. The kernel density estimates indicate installations at no discernable cap in any particular year are moving towards their limits over time (Figure 7). So even though nearly 2,400 installations are not within one offset purchasing unit of an exact limit in 2010, these installations were still closer to their limits than similar installations in both 2008 and 2009. It is difficult to determine just why these installations did not fully utilize their limits and purchase the exact, maximum number of offsets allowed, but it appears the majority of installations do not intend to leave significant numbers of offsets on the table.

Of course, many installations — even those with clearly identifiable strategies — do end up leaving significant numbers of offsets on the table. The second stage results in chapter 5 shed some light on the causes. The single largest predictor of how many offsets an installation leaves on the table is whether or not it faces a five year offset limit (specifications 1 – 3, phase II). The majority of installations facing five year caps appear to be under the impression the limit is calculated using a cumulative EUA allocation, and — while diligently surrendering offsets every year and moving closer to fulfilling their actual limit — are not technically using as many offsets as they could. This is not an issue for installations actually facing a cumulative cap, though they are not any better off than these installations who *believe* they face cumulative caps. A few installations make the reverse mistake, violating their cumulative caps by surrendering enough offsets to meet their entire five year limit.

Theoretically, differences in limit calculation rules will not affect the number of offsets left on the table at the end of 2012, when the cumulative offset limit and the five year offset limit are the same. However there are potential distributional consequences. It is not immediately apparent that there will be enough offsets available for every installation to meet its entire phase II offset limit, in which case the EUA – offset arbitrage opportunity is temporary, and installations not purchasing their entire five year limits risk missing out on substantial gains.

Beyond cap calculation rules, other factors significantly affect the number of offsets left on the table, including the size of installations' offset limits, as well as the size of the installation itself (verified emissions). The larger the offset limit, the more offsets an installation tends to leave on the table. This makes sense because these are population estimates. Sixty one percent of installations have never surrendered a single offset. The larger these installations' limits, the more offsets they are leaving on the table. Installations with more emissions are closer to their caps, likely because they have access to more and better resources, making it more likely they know their precise limits and exactly what is happening with the EU ETS.

Similar to stage one, the stage two Heckman results suggest the costs of acquiring the right information play a substantial role preventing installations from fully utilizing their caps. This also means installations should get better at arbitraging the EUA – offset spread over time, both as they gain experience in the market as well as observe the behavior of other installations (the CITL data is available publicly). Trends in offset use support this; installations *are* using more of their limits over time. The kernel density distribution of installations around their actual offset limits in Figure 3 shows the portion of installations using offsets and at their actual cap is at its highest in 2010.

When it comes to the predictions from the model in chapter 4, all that matters is that installations *believe* they are at their offset limits. Figure 8 suggests this is the case;

installations are clearly distributed around their limits when accounting for possible confusion about *which* allocation the percent limit applies to.

To reiterate, installations are more likely to use offsets as the benefits — price differential times offset limit — increase, or entry costs — e.g. factors that affect the costs of acquiring information — decrease. Thus EU ETS installation behavior is consistent with the model, and implies the EUA – offset price differential extends from the fact *some* installations *are* at their binding offset caps. That not all installations are is a result of barriers to entry.

Implications

First, the fact the EUA – offset price differential stems from structural, institutional details of the EU ETS (the offset cap) rather than some inherent difference in the quality of offsets (i.e. delivery risk or expectations about the future) implies welfare gains are available within the EU ETS. If EU installations are to meet their abatement requirements at the lowest possible cost, reductions should be undertaken by those who can do so the cheapest. It would be a mistake to conclude this is what is happening now, that the nonbinding aggregate cap suggests EU ETS installations and offset providers have reached some sort of interior equilibrium. Rather, the offset cap is binding for *some* installations, which is enough to cause the EUA – offset price differential. In short, offset restrictions really are restrictive.

The European Commission originally set limits on offsets because it wanted offset purchases in developing countries to supplement domestic action. But as long as these offsets are additive and permanent — and the Central Development Board certifies that they are — it does not matter whether installations reduce their own emissions or pay offset providers to do it for them. Assuming these offsets *do* meet the necessary theoretical economic qualifications, eliminating offset caps entirely would be welfare improving, although this is likely politically unfeasible. Even if offset limits are here to stay, transaction costs in the market make them more restrictive than they already are.

Lessening the impact of the restrictions in place benefits the EU ETS as a whole, not just those installations using offsets. The price of an EUA equals the cost of abatement at the margin; as the number of offsets approaches the aggregated institutional cap, this margin decreases and the price of an EUA drops market wide.

Regulators could address barriers to entry in the offset market without actually taking any costly measures to correct them. The stage two Heckman results suggest installations would leave significantly fewer offsets on the table if their limits were simply given in actual permit quantities rather than percentages of allocation.

Future of the EUA – Offset Spread

The use of CERs and ERUS has increased substantially from 2008 – 2010. There are reasons to suggest this trends will continue, especially because the primary barriers to offsets appear to be a matter of acquiring the right information. These should decrease in phase III when the Commission will replace individual member state National Allocation Plans with a uniform community-wide set of rules. In addition, most installations will be required to purchase at least some of their EUAs at auction, effectively increasing the number of net short installations and likely decreasing the costs of acquiring information about offsets.

Even in phase II, projections indicate the total aggregate EU ETS offset limit (1,400 million permits) likely exceeds the number of CERs (800 - 1,200 million) and ERUs (100 – 200 million) that will generated by 2013 (Trotignon 2010). And EU ETS installations are not the only source of demand for these offsets. With the compliance deadline approaching in 2012, other, non-EU ETS Annex I countries may require CERs and ERUs to meet their own Kyoto obligations.

The increase in demand for offsets relative to supply suggests the price spread will narrow before the end of phase II. It may even disappear completely, implying an equilibrium within the EU ETS and offset market. No longer would project developers be able to offset emissions more cheaply than EU ETS installations are able make reductions. This is a more efficient outcome from the perspective of policymakers and society as a whole. It implies installations would be better off completing the swap sooner rather than later.

CONCLUSION

The central aim of this thesis is to reconcile the EUA – offset price spread and nonbinding offset cap. Although some in the previous literature (Mansanet-Bataller, Chevallier, Hervé-Mignucci, & Alberola, 2011) have concluded the price spread must fundamentally extend at least in part from the import limit on offsets — no one has yet explained the mechanism by which a non-fully-binding cap on offsets results in an EUA – offset price differential.

The aggregated installation cost minimization model in chapter 3 starts here. First, installations are free to buy and sell EUAs as they wish, and standard permit theory dictates an equilibrium EUA price equal to each installation's marginal CO_2 abatement cost (equation 5.1). At the same time, each installation is restricted in the number of CERs and ERUs it can use. In equilibrium then, installations at their caps are willing to pay more at the margin than the cost of producing an offset. Quantity is fixed, demand exceeds supply, and observed offset prices lie below willingness to pay, equivalent to marginal abatement costs and the price of an EUA in equilibrium.

This straightforward progression — culminating formally in equation 7 — says an EUA - offset price differential is the natural result of a binding offset cap. The fact that this cap is *not* fully binding in aggregate is misleading; this result applies to individual installations rather than the market as a whole. If at least *some* of the installations in the EU ETS (even just one) are at their offset cap, equation 7 holds.

Three years into phase II, 925 installations (about 25% of installations that use CERs or ERUs) could be considered at their offset limits, including 500 (about 14% of installations that use offsets) *within one permit*. This explains the price spread. It does not explain why the cap is not binding for the other 75% of installations that use offsets, or why — though they present a risk-free arbitrage opportunity — nearly 5,300 installations (about 60% of the EU ETS) have yet to use even a single CER or ERU. The explanation given here is relatively straightforward: trading offsets involve transaction costs which make them prohibitive for some installations. If marginal costs of trading offsets at the limit are less than the price differential, the model predicts an installation that does use offsets will use as many as it believes it can use. This appears consistent with installation behavior (Figure 4).

Barriers to acquiring information appear to make up a large component of these entry costs. This is understandable. At least 16 *countries* initially proposed offset limits that were in violation of EU ETS rules. Empirical results show such widespread confusion was just as prevalent among installations that *did* use offsets; evidence suggests many installations were initially unaware CERs and ERUs were even an option.

Installations do appear to be learning over time. More installations surrendered offsets in 2010 than ever before. There is reason to believe these trends will continue for the rest of phase II and into phase III, perhaps to the point where aggregate EU ETS offset demand meets global supply. In that case EUA and offset prices should converge. Alternatively it may remain less expensive for EU ETS installations to purchase offsets rather than undergo reductions of their own. Although in that case a completely binding offset limit is unlikely — every one of the EU ETS's 11,500 installations would have to be exactly at its limit — the fact that installations are steadily overcoming these barriers over time suggests overall offset use will be substantially closer to the aggregate limit than it is today. Either way this suggests the current situation — the simultaneous EUA – offset price spread and widespread avoidance of offsets — is temporary.

This analysis results in possibilities for future research. One obvious extension is updating the results as data is released for the rest of phase II in 2011 and 2012 and in phase III through 2020. Another would be to include those installations that have entered and exited the EU ETS. These latter options simply involve running the same analysis with new data, but there is room for improvements in the model as well. One option would be to incorporate multiple periods, which would provide insight about optimal offset purchase timing for installations facing cumulative or five year caps.

It is shown here that the offset limit binds (whether cumulatively or for the entire period) for the installations that use offsets; the rest of the installations forego the market entirely. This means it should be possible to calculate a fairly accurate prediction about the number of offsets that will be used in the future. First, a portion of installations are at their five year limits and cannot surrender any more without violating the rules of the EU ETS. Second, it seems reasonable to assume installations that have met their cumulative 2008 – 2010 limit will continue to surrender offsets 2011 and 2012. The fact that installations appear to be learning over time suggests a portion of installations will discover their five year limit and surrender the rest of their offset limit in 2011. Likewise, a number of installations should discover and surrender offsets for the first time. Projecting future offsets surrendered then is largely a matter of estimating the portion installations in each of these latter two categories. In conjunction with an update to Trotignon's (2009) work forecasting CER and ERU supply, these numbers would allow substantial insight into the future of offset use in the EU ETS.

The EU ETS is the largest tradable pollution permit scheme to date, and the simultaneous permit – offset price differential and nonbinding offset cap is one of its more interesting aspects. The issue has important implications. Most installations could achieve significant cost savings, while policymakers have a decided interest in meeting the EU's climate change requirements at the lowest cost possible. In offering an explanation consistent with the empirical behavior of EU ETS installations, this thesis makes it easier to do both.

APPENDIX A

DATA DETAILS AND SOURCE

The contents of this dataset were obtained from the CITL, Phase II National Allocation Plans, Trotignon (2010) and the BlueNext exchange. It covers years 2008 – 2010.

Original CITL Variables

The following variables were obtained from the CITL:[16]

REG	country's registry
INSTALLATION	name of installation
REGNUM	installation registry id number
ID	reg + regnum
PERMIT	installation permit number
ACTIVITY	industry code
S_	surrendered permits (EUAs and CERs)
C_	CERs
R_	ERUs
V_	verified emissions

Other CITL variables, including:

accountHolder	
a08	2008 EUA allocation
a09	2009 EUA allocation
a10	2010 EUA allocation
a11	2011 EUA allocation
a12	2012 EUA allocation
id	reg + regnum

were obtained here: http://ec.europa.eu/environment/ets/nap.do?

The two previous sets were merged using the id variable. CERs and ERUs were combined into one variable. When the totals were not given (or when the total and one of

16 http://www.eea.europa.eu/data-and-maps/data/european-union-emissions-trading-scheme-eu-ets-data-from-citl-2

the years was not given) they were calculated, so that for every variable included the following suffixes (where relevant):

_08	2008 total
_09	2009 total
_10	2010 total
_11	2011 total (presently applies only to allocation)
_12	2012 total (presently applies only to allocation)
_2	2008 + 2009 total
_3	2008 + 2009 + 2010 total
_5	2008 + 2009 + 2010 + 2011 + 2012 total

These suffixes apply to the original CITL variables:

a	EUA allocation
v	Verified emissions
s	surrendered permits (includes CERs and ERUs)
c	CERs and ERUs

Using these, other variables were generated, including banked:

B08	permits banked into 2009; S08 - V08
B09	permits banked into 2010; S09 + B08 - V09
B10	permits banked into 2011; S10 + B09 - V09

and net short:

NS08	net permits short in 2008; V08 - A08
NS09	net permits short in JUST 2009; V09 - A09
NS10	net permits short in JUST 2010; V10 - A10
NS2	net permits short in 2009 including banked permits from 2008
NS3	net permits short in 2010 including banked permits from 2008 - 2009

Most of the variables above also have dummy variables, given with the prefix ‘*d*’ and suffix:

d_08	variable has positive value in 2008
d_09	variable has positive value in 2009
d_10	variable has positive value in 2010
d_2OR	variable has positive value in EITHER 2008 or 2009
d_3OR	variable has positive value in EITHER 2008 or 2009 or 2010
d_A	variable has positive value in all three years
d_08only	variable positive ONLY in 2008 (applies only to offsets)
d_09only	variable positive ONLY in 2009 (applies only to offsets)

These dummy variables were used to calculate "clean" variables as those having positive allocation, verified emissions and surrendered permits for every year 2008 – 2010.

dclean08	positive allocation, emissions, surrendered permits in 08; surrendered permits >= emissions in 08
dclean09	positive allocation, emissions, surrendered permits in 09; surrendered permits in 08-09 >= emissions in 08-09
dclean10	positive allocation, emissions, surrendered permits in 10; surrendered permits 08-10 >= emissions in 08-10
dcleanA	dclean08*dclean09*dclean10

Long and short variables were also constructed using the NS variables and dummy variables. Short is the same as net short, with long values given as zeros.

ST08	absolute value(NS08)*dNS08; gives 0 if installation was long
ST09	absolute value(NS09)*dNS09; gives 0 if installation was long
ST10	absolute value(NS10)*dNS08; gives 10 if installation was long
ST2	absolute value(NS2)*dNS2; gives 0 if installation was long
ST3	absolute value(NS3)*dNS3; gives 0 if installation was long

Long is excess EUA allocation (absolute value of net short) with short values given as zeros.

L08	absolute value(NS08)*(1 - dNS08); gives 0 if installation was long
L09	absolute value(NS09)*(1 - dNS09); gives 0 if installation was long

L10	absolute value(NS10)*(1 - dNS10); gives 10 if installation was long
L2	absolute value(NS2)*(1 - dNS2); gives 0 if installation was long
L3	absolute value(NS3)*(1 - dNS3); gives 0 if installation was long

Offset Limit Variables

CER caps were obtained from each countries NAP/Commission decision. Unless denoted otherwise with a footnote in the Offset Cap Documentation section, these documents are available from the EU.[17]

These caps were combined with allocation information to calculate the number of offsets allowed to each installation in various time periods (given by suffixes *08 – 10; 2, 3, 5*).

CL_ offset allowed in any period (A_*cap)

The above variable was combined with previous offset use to get more precise limits. The 2008 equivalents are omitted because they are equivalent to *CL08* and *CL5*.

CL09_2	offsets available to use in 2009 assuming a cumulative cap; CL2 - C08
CL09_5	offsets available to use in 2009 assuming a 5 year cap; C5 - C08
CL10_3	offsets available to use in 2010 assuming a cumulative cap; CL3 - C2
CL10_5	offsets available to use in 2010 assuming a 5 year cap; CL5 - C2

Finally, offset banking and borrowing rules are incorporated to these caps to get the actual number of offsets a firm has available at any point in time.

TCL08	CL5 for installations that can borrow, CL08 for everyone else
TCL09	CL09_5 for installations that can borrow, CL09_2 for those that can bank but not borrow, CL09 for those who can do neither
TCL10	CL10_5 for installations that can borrow, CL10_3 for those that can bank but not borrow, CL10 for those who can do neither

[17] http://ec.europa.eu/clima/documentation/ets/allocation_2008_en.htm

Country	Cap	Type	Source
Austria	10%	five year	AT Commission Decision page 9
Belgium		five year	
Walloon	4%	five year	Walloon NAP page 15 (translated)
Flemish	7%	five year	Flemish NAP page 25 (translated)
Flemish (electricity)	24%	five year	Flemish NAP page 25 (translated)
Brussels	50%	five year	Brussels NAP page 10 (translated)
Bulgaria	12.51%	five year	BG Commission Corrigendum Decision page 12
Cyprus	10%	five year	CY NAP page 33
Czech Republic	10%	five year	CZ NAP page 33 (translated)
Germany	22%	five year	DE Commission Decision pages 3-4
Denmark	multiple	five year	DK NAP
Estonia	0%	five year	Trotignon 2010
Spain	multiple	cumulative	ES revised NAP page 48610
Finland	10%	five year	FI Commission Decision page 14
France	13.50%	five year	FR NAP page 26 (translated)
United Kingdom	multiple	cumulative	GB NAP page 6
Greece	9%	five year	GR NAP page 29 (translated)
Hungary	10%	one year	HU NAP page 12 (translated)
Ireland	multiple	five year	IE NAP page 5, point 11; tables on page 55
Italy		cumulative	IT NAP table 7.1 (translated)
Lithuania	20%	one year	LT Commission Decision Amendment page 3
Luxembourg	10%	five year	LU NAP page 44 (translated)
Latvia	10%	one year	Trotignon 2010
Netherlands	10%	five year	NL Commission Decision page 15
Norway	20%	cumulative	Trotignon 2010
Poland	10%	cumulative	Trotignon 2010
Portugal	10%	five year	PT revised NAP page 3 (translated)
Romania	10%	five year	RO NAP page 16
Slovakia	7%	five year	SK NAP page 19 (translated)
Slovenia	15.76%	five year	SI Commission Decision page 5
Sweden	multiple	five year	personal communication with Swedish Energy Agency

Unused Offset Variables

*table_* is defined as the number of unused offsets (given by unused cap) for each installation each year.

table_ unused offsets each year; TCL_ - C_

In the variable above unused offsets is calculated using the actual cap (*TCL*). It is calculated using other limits in case installations are not aware they have the ability to bank and borrow offsets. In 2009, for example, a firm with a five year cap is allowed its five year allocation times cap (*A5*cap = CL5*) minus whatever offsets it used in 2008 (*CL5 – C08*). This limit (*CL09_5*) minus the number of offsets it uses in 2009 is *table09_5*.

table08_08	CL08 - C08
table08_5	CL5 - C08
table09_09	CL09 - C09
table09_2	CL09_2 - C09
table09_5	CL09_5 - C09
table10_10	CL10 - C10
table10_3	CL10_2 - C10
table10_5	CL10_5 - C10

Max Offset Block Variables

Part of the reason it is difficult to determine whether installations are actually at their offset caps is because installations purchase offsets in different units. For example, say an installation is allowed 16,543 offsets in 2008. Is it only at its cap if it buys 16,543 offsets? What if it does not want to deal with individual offsets and only purchases 16,540? Or 16,500, or even 15,000? Defining "at the cap" as only 16,543 is likely too restrictive. To take into account the fact firms may purchase offsets in discrete blocks, the following set of variables is calculated:

First, the discrete offset block is calculated for each installation. In 2008, this is done by figuring out the maximum number that divides evenly into C08 out of 1, 5, 10, 25, 50, 100, 500, 1000, 5000, 10000, 50000 and 100000. For an installation that used 30 offsets in 2008, for example, *maxblock08* = 10. With 11 or 16,543 offsets, *maxblock08* would be 1, with 60,000 it'd be 10,000. *maxblock08* is 0 if firms did not use any offsets in 2008.

Maximum block is calculated for each year. If the number of offsets = 0 in 2009 or 2010 maxblock takes on the value it had the previous year. So for an installation that uses 615 offsets in 2008 and 0 in 2009, *maxblock08* = 5 and *maxblock09* also equals 5.

At Offset Limit Variables

Any installation as at its offset limit if it within one maximum block without going over. For example, *maxblock08* = 10 for an installation using 30 offsets in 2008, and so as long as this installation's offset limit is somewhere between 30 – 39, it'd be considered at its offset cap. On the other hand, if this installation used 31 offsets, *maxblock08* = 1, and this installation would be considered at its cap only if the cap was 31 or 32.

It is also possible firms are using offsets only to cover their short emissions. In the same way, it is noted when installations use a *maxblock* of offsets just enough to cover its short emissions.

Each installation only one motive per year. So if an installation simultaneously used exactly up to its cap *and* just covered its net short emissions, it is denoted at its cap, not as using offsets to cover emissions.

In the same way, installations cannot be at multiple offset caps (e.g. any firm with only an EUA allocation in 2008 and not 2009 – 2012 could technically be at both its 2008 and 5 year caps in 2008). This generally is not a problem because this dataset does not include any observations with only one year allocations, however it occasionally becomes in issue when *maxblock* becomes very large relative to limits and allocation.

In each year, the cap locations take effect in the following order:

where08 =	5	at 5 year cap
	08	at 2008 cap
	-1	covering short emissions
	-2	at right cap calc as % of permits, not allocation
	-3	at altogether wrong cap
	-6	wrong cap calculated as % of permits, not allocation

where09 =	5	at 5 year cap
	2	at 2008 - 2009 cap
	09	at 2009 cap
	-1	covering short emissions
	-2	at right cap calc as % of permits, not allocation
	-3	at altogether wrong cap
	-6	wrong cap calculated as % of permits, not allocation

where10 =	5	at 5 year cap
	3	at 2008 - 2010 cap
	10	at 2010 cap
	-1	covering short emissions
	-2	at right cap calc as % of permits, not allocation
	-3	at altogether wrong cap
	-6	wrong cap calculated as % of permits, not allocation

So, if in installation was somehow within one *maxblock08* of both its 5 year and 2008 limit *and* just covered its short emissions, *where08* would equal 5, even though 5, 08 and -1 would also apply.

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