DRIVERS OF DEMAND FOR CARBON OFFSETS: A COMPREHENSIVE ASSESSMENT OF IMPERFECT SUBSTITUTES

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ABSTRACT

The efficient design and behavior of market-based approaches to public policy are of growing importance to scholars and policymakers, particularly in light of the concern for global climate change. This paper provides the first comprehensive assessment of the drivers of demand for carbon offsets in transferable property rights markets (cap and trade programs). Carbon allowances (permits or credits) and carbon offsets, despite being perfect substitutes statutorily, behave more like imperfect substitutes. The demand for carbon offsets is heavily influenced by key structural policies in the design and implementation of offsets provisions as well as extra-statutory drivers of demand. These policies influence the degree to which transaction costs, regulatory uncertainty and risk feature into market decisions of firms.

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JEL Classifications: *Q58, Q54, Q48*

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1. Introduction

Contemporary Coasian transferable property rights markets (cap and trade programs) have provided policymakers with a cost-effective approach to public goods management and the mitigation of negative pollution externalities. Their efficiency gains stem from the fact that heterogeneous firms can choose their own cost-minimizing compliance approach from among abatement and purchasing or trading pollution rights (e.g., permits, allowances, or credits) (Tietenberg, 2006; Tietenberg and Lewis, 2012). Most recently these markets have been applied to the mitigation of climate change, in which an additional policy instrument has been introduced in the form of carbon offsets. Offsets are a type of emissions credit generated by emissions-reducing projects, and serve as a cost-reducing alternative compliance instrument for covered firms.

Because regulated firms are statutorily permitted to use both allowances and offsets as equivalent compliance instruments in carbon markets, economic theory would suggest that these instruments behave as substitutes. However, carbon offsets are consistently discounted relative to allowances by a magnitude exceeding 60 percent. And, in one key regional trading market, the Regional Greenhouse Gas Initiative (RGGI), no offset projects have been registered since the market's inception in 2008.

This paper seeks to explain why carbon allowances and offsets behave as imperfect substitutes despite the fact that they are perfectly substitutable statutorily. This paper advances the theory of market-based policy tools by providing a comprehensive assessment of the drivers of demand for carbon offsets. Both scholars and policymakers are seeking to understand the fundamental dynamics inherent to market-based policy approaches, particularly when there is such a substantial divergence between theory and practice.

2. Imperfect Substitutes of Offsets in the ETS

The use of offsets in the European Union Emissions Trading System (ETS), the world's largest carbon market and the world's largest source of offset demand, provides an illustrative case of imperfect substitution between these policy instruments. The European Commission (EC), the regulator of the ETS, relies upon United Nations-appointed bodies to regulate the suppliers of the two types of international offsets, Certified Emissions Reductions (CERs) and Emission Reductions Units (ERUs). In January, 2011, the EC enacted a ban (beginning in 2013) on surrendering "grey CERs," a type of CER generated from the destruction of the gases HFC-23 or N2O (EC, 2011a). This ban was put in place for two reasons. First, due to low production costs

(IPCC/TEAP, 2005) and perverse incentives in producing grey CERs (Lambert, 2011), the market was flooded with cheap grey CERs that depressed the market price of offsets. Second, the EC wanted the "advanced developing" countries that produced grey CERs (primarily China and India) to finance these projects themselves (EC, 2011b; EC, 2013a).

The substitutability between allowances and CERs as permitted by the EC created a system of perverse incentives for suppliers of grey CERs. Perverse incentives emerged because suppliers could earn substantial profits from selling grey CERs in addition to the profits suppliers earned from selling their primary product. For example, HFC-23 is a byproduct in the production of HFC-22, a refrigerant.[1] Suppliers of HFC-23 offsets actually earned more from selling grey CERs than from selling HFC-22 (Wara, 2008). Suppliers were therefore incentivized to heavily overproduce HFC-22 for the purpose of creating and subsequently destroying HFC-23.

Supply and demand data for grey CERs shows a clear link, motivated by this perverse incentive, between production of grey CERs and demand from ETS firms. From 2008-2010, grey CERs comprised 75 percent of all offsets surrendered by ETS firms, representing 62 percent of the total quantity of grey CERs issued (Point Carbon, 2012; UNFCCC, 2013). Supply and demand for grey CERs increased dramatically in 2011 and 2012 to maximize respective profits before the ban took effect in 2013 (see Fig. 1).[2]

[1] HFC-23 offsets will be discussed specifically, because twice as many CERs were issued for HFC-23 destruction than for N_2O destruction, which also has a similar production process. The perverse incentives in the production of both HFC-23 and N_2O CERs stem from the extremely high 100-year CO_2-equivalent Global Warming Potential (GWP) of these gases. HFC-23's GWP is 11,700, meaning that each ton of HFC-23 that is destroyed can result in the issuance of 11,700 CERs.

[2] Note that ETS firms could not surrender offsets until Phase II began in 2008. Phase I, the "trial period" of the ETS, ran from 2005-2007.

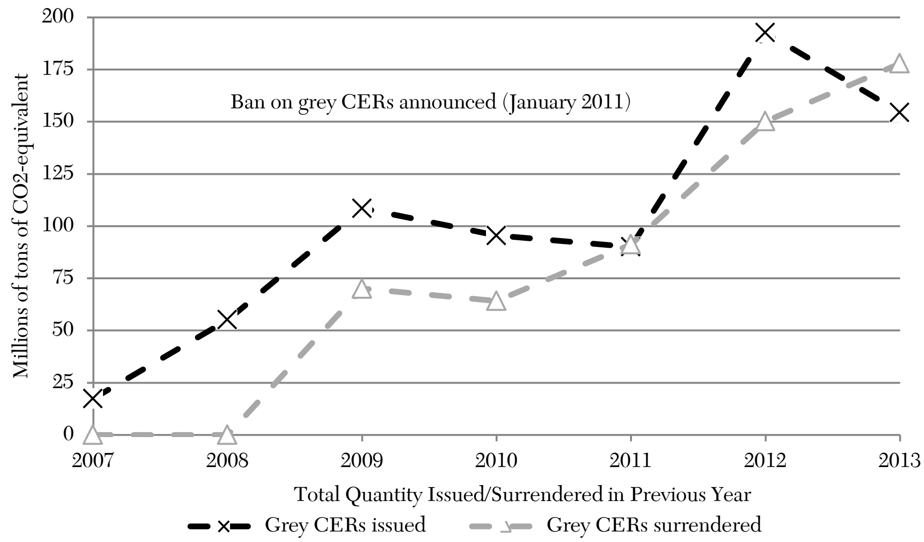

FIGURE 1. ANNUAL QUANTITY OF GREY CERS ISSUED IN THE CDM AND SURRENDERED IN THE ETS
Sources: *CDM Executive Board, European Commission, and Point Carbon*

The substantial increase in supply of CERs and ERUs[3] led to a glut of offsets on the market at the same time that allowance (EUA) price decreased in correspondence with the recent economic downturn. CER/ERU price (averaged CER and ERU price) declined even further than EUA price, widening the price spread between EUA price and CER/ERU price. In response to the large price spread, the quantity of offsets surrendered increased by 84.9 percent in 2011 and increased again in 2012 by 98.6 percent (see Fig. 2). The existence of such a price spread provides some evidence that the two instruments behave as imperfect substitutes. That is, prices for perfectly substitutable instruments should more or less correspond. The change in magnitude of the price spread, from €1.79 in 2010, to €2.98 in 2011, and to €4.42 in 2012, also suggests that the substitutability of offsets for allowances has also changed over time.

[3] Supply of ERUs increased by 377% in 2011 and quadrupled again in 2012, with the quantity of ERUs surrendered concurrently tripling in each year. This increase was due in part to expected usage restrictions on ERUs, though restrictions eventually enacted in 2013 were relatively minor (EC, 2013b). 97% of ERUs have been issued with the host country (mainly Russia and Ukraine) acting as the regulator, leading to a lack of transparency and an incentive to issue low-quality offsets (Carbon Market Watch, 2013).

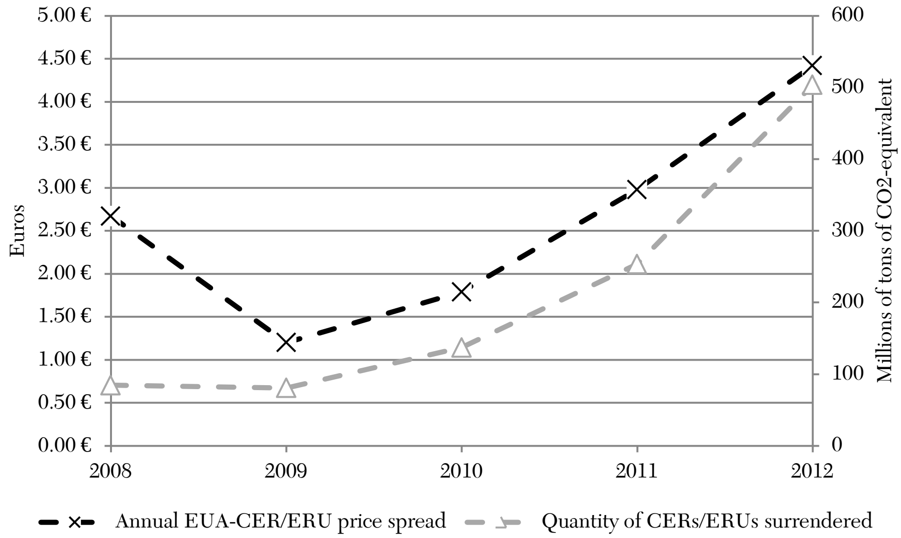

FIGURE 2. PRICE SPREAD AND OFFSET DEMAND IN PHASE II OF THE ETS
Sources: *European Commission and BlueNext*

No analysis to date has provided a comprehensive assessment of the drivers of demand for substitute tradeable property rights. Scholars have provided several econometric analyses of EUA price drivers in the ETS (Mansanet-Bataller, Pardo and Valor, 2006; Alberola, Chevallier and Chèze, 2008a; Benz and Trück, 2009; Hinterman, 2010; Creti, Jouvet and Mignon, 2012), and of offset price drivers in the ETS (Mansanet-Bataller et al., 2011; Nazifi, 2013), but nearly all are limited in explanatory power due to the heavy interdependence (i.e. collinearity) among drivers and endogeneity.

We draw upon economic theory, insights from the literature, market data and the regulatory frameworks of the world's major carbon markets to detail how procedural costs in the generation of offsets (Sect. 3), key institutional factors (Sect. 4), and extra-statutory factors (Sect. 5) affect the demand for carbon offsets. Table 1 provides the expected effect of each of these factors. Finally, the results of this paper offer theoretical and practical lessons that enable carbon emissions trading programs to more effectively accomplish their central goal: incentivizing a socially-efficient compliance strategy among firms.

TABLE 1

DRIVERS OF OFFSET DEMAND

Driver	*Definition*	*Impact on offset demand*	*Section*
Price Spread	Difference between allowance price and offset price	Effect on demand varies; positive spreads will tend to increase offset demand and negative spreads will tend to decrease offset demand	2
Procedural Costs	Costs incurred in the generation of offsets, including transaction costs, monitoring, reporting, and verification costs, and other costs related to the approval process	Decreases demand; disproportionately disincentivizes use of offsets by small-scale firms	3
Offset Limit	A cap on the quantity of offsets a firm can surrender (usually annual)	Decreases demand; cap can reduce utilization of offsets as compliance instruments	4.1
Banking	A flexibility mechanism that allows firms to hedge against differences in compliance cost across time by utilizing instruments from time t in time t+n	Effect on demand varies; if the rate of expected future abatement cost increases exceeds the discount rate, firms will bank, shifting demand for offsets forward in time	4.2
Ex Post Invalidation Risk	Risk that offsets that have already been issued will be invalidated by the regulator	Decreases demand; to the extent that risk premium can be passed through to the offset buyer, any additional risk premium will increase offset cost and decrease offset demand relative to alternative compliance instruments	4.3
Reversal Risk	Risk that sequestered CO_2 will be released into the atmosphere, reversing emissions reductions	Decreases demand; varies with program liability provisions	4.4
Regulatory Uncertainty	Uncertainty stemming from potential for administrative rule changes in program design and compliance requirements	Effect on demand varies; covered firms or other investors may avoid offset projects with an uncertain future	4.5
Economic Growth	Carbon emissions and economic growth are positively correlated	Increases demand; positive output changes increase system-wide demand for compliance instruments heterogeneously in relation to an economy's carbon intensity and specific sectors of growth	5.1
Fuel Price	Market price of input fuel utilized in energy production by covered firms	Effect on demand varies; increase in the price of high-carbon fuels relative to low-carbon fuels decreases emissions and need for compliance instruments as firms respond to price incentive	5.2
Energy Efficiency	The energy services obtained per unit of energy inputs	Decreases demand; energy efficiency gains reduce demand for compliance instruments	5.3
Weather	Weather conditions influence both supply and demand for energy	Effect on demand varies; whereas weather conducive to hydro production decreases demand for compliance instruments, extreme weather conditions can inflate demand for compliance instruments	5.4

3. Procedural Costs in the CDM Process

Key to understanding the market dynamics inherent to carbon markets is an understanding of the institutional structure of the United Nations' Clean Development Mechanism (CDM), the largest source of offsets globally and the mechanism through which CERs are generated. In order to ensure offset quality criteria such as *additionality*, the requirement that emissions reductions achieved by the offset project are additional to a baseline scenario, the CDM Executive Board has instituted a rigorous and lengthy process that issues CERs to only 52 percent of projects and takes an average of two years and four months (Cormier and Bellassen, 2012). The procedural costs incurred through the lengthy process by which CERs are generated incur significant transaction costs and other costs on suppliers of offsets, causing suppliers to increase the price of offsets, and diminishing the market demand for offsets.

Procedural costs, if exceedingly large, can constitute inefficiencies of engaging in an economic transaction that results in a Pareto inefficient outcome that can negatively affect both project developers and participating firms. Procedural costs include typical transaction costs such as search and information costs and negotiation costs (Williamson, 1975), monitoring, reporting and verification (MRV) costs (Stavins, 1995; Jaraite, Convery and Di Maria, 2010), "approval costs," which are the fees and taxes paid to the CDM Executive Board, lawyers, debt and equity investors, and the host country's local and federal government (Carbon Retirement, 2009), and finally the costs of investing in a project that may or may not fail at each successive stage in the approval and operation process (Cormier and Bellassen, 2012). Procedural costs imposed on offsets that are not imposed on other compliance instruments widen the demand disparity and impose inefficiencies on the program. Understanding the procedural costs that arise at each stage of the CDM process informs the degree to which these costs impact demand for CERs from covered firms, and provides a more general understanding of how the offset project approval process contributes to offsets being treated as imperfect substitutes for allowances.

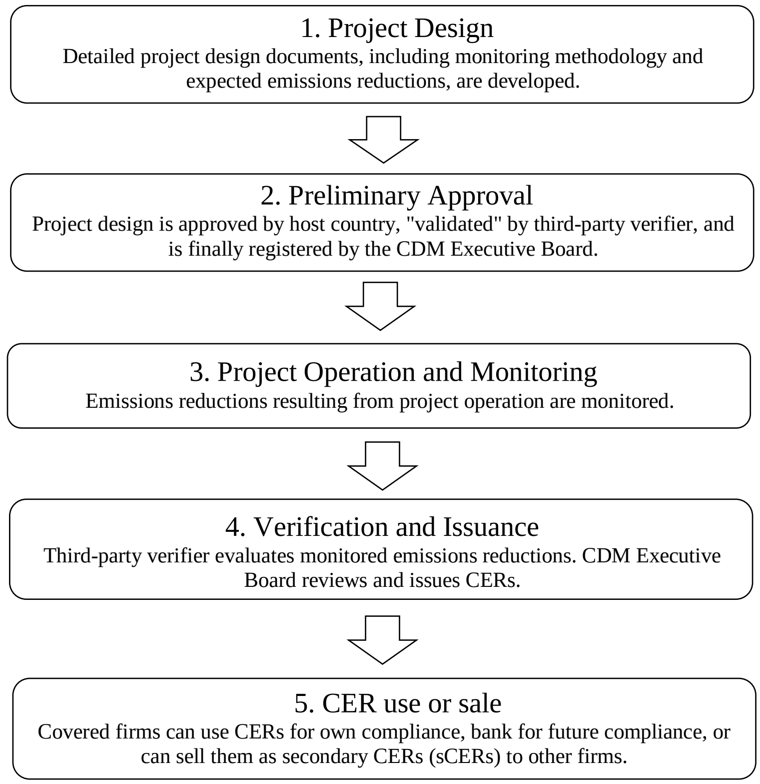

FIGURE 3. THE CDM PROCESS

The first stage of the CDM process is project design. A detailed plan must be developed by the project developer that includes the quantity of emissions reductions (and corresponding quantity of CERs) expected to result from the project. Procedural costs are specifically incurred by the project developer when, within this detailed plan, the methodology to measure a baseline emissions scenario and monitor emissions reductions is developed (UNFCCC, 2006). If an existing methodology for that project type does not presently exist, then the project developer must incur the cost of developing and obtaining approval for a new methodology.

Next, in the preliminary approval stage, the project design must be approved by the host country and by a third-party verifier. The project developer pays taxes and fees to these parties and incurs approval risk, the risk that the project will be rejected and/or significantly delayed. The third-party verifier's initial review of project design, known as validation, takes approximately one year and is the riskiest sub-stage in the CDM process, with 33 percent of total projects being rejected (Cormier and Bellassen, 2012). Following validation, the project is reviewed and registered with the CDM Executive Board. If the project is registered, the project developer pays a fee of $.1 per ton of expected CO_2-equivalent emissions reductions for the first 15,000 tons and $.2 per ton for "any amount in excess of 15,000 tons" (UNFCCC, 2006, p. 99).

After being registered, the offset project begins operating and generating emissions reductions. MRV costs are incurred by the project developer through monitoring the quantity of emissions reductions generated by the project. Delivery risk, the risk that the quantity of emissions reductions achieved will differ from expectations outlined in the project design documentation, is also incurred at this stage.

In the fourth stage, which occurs each year, the project developer incurs further MRV costs when it pays a third-party verifier to conduct an *ex post* evaluation of the emissions reductions monitored by the project developer. This *ex post* evaluation constitutes an average of 4 percent of final CER price (Carbon Retirement, 2009). Finally, the CDM Executive Board reviews the *ex post* evaluation and issues CERs to the project developer. The project developer pays the CDM Executive Board an issuance fee for each CER issued (same cost-structure as the registration fee).[4] The CDM Executive Board deducts 2 percent of the total CERs issued, using the proceeds to fund climate change adaptation in developing countries. At this stage, the project developer again faces approval risk and the potential for long delays from the third-party verifier and from the CDM Executive Board. The project developer also faces regulatory uncertainty risk, arising from the uncertainty that the project type, geographic location, or methodology used in the project will continue in future years to be accepted by the CDM Executive Board and the regulators for covered firms (e.g., the EC ban on grey CERs).

In the final stage, covered firms purchase CERs from the project developer.[5] Covered firms incur search costs when choosing an offset project from many potential alternatives, and incur negotiation costs. Long-term contracts that fix a CER price before CERs have been issued (i.e. "pre-issuance") expose covered firms and project developers to price risk, the risk that market price at the time CERs are issued will differ from the contract price. For example, the recent collapse of sCER price has caused some firms that signed such contracts to attempt to renegotiate with project developers, or to simply renege on their obligation to purchase the credits (Point Carbon, 2013). Furthermore, contracts negotiated pre-issuance, as in any capital

[4] For the first year of issuance, project developers deduct this fee from the registration fee so that project developers do not have to pay the same fee twice in the same year.

[5] Note that most offset projects have other sources of revenue besides the revenue from selling offsets. For example, renewable energy projects sell electricity and suppliers that destroy HFC-23 to generate grey CERs also sell HFC-22 as a refrigerant.

investment, expose covered firms to delivery risk, which is not incurred through acquisition of statutorily-substitutable compliance instruments.

The covered firm can surrender CERs for compliance or bank them for future use. If the covered firm negotiated pre-issuance, it can also choose to sell the CERs to other firms, usually through a brokerage, at a premium that includes the procedural costs the firm incurred by contracting pre-issuance. There is no mechanism in the ETS for *ex post* invalidation of CERs (unlike in the Western Climate Initiative), so sCERs are essentially riskless (Michaelowa, 2012).

Many of these procedural costs can be minimized by larger firms, disincentivizing smaller firms from purchasing offsets (Trotignon, 2012). Smaller-scale firms that do purchase offsets, however, tend to purchase proportionally larger quantities. Over time, procedural costs should decrease as maturation increases the number of firms trading offsets (Tietenberg, 2006), the approval process becomes more uniform, and regulatory uncertainty risk decreases (Woerdman, 2004; Jaraite and Kažukauskas, 2012). We now turn to providing a theoretical treatment of factors impacting offset demand after offsets have been issued, beginning with regulatory design features.

4. Institutional Drivers of Demand

Much of the divergence in demand between compliance instruments can be attributed to the structural design of the trading market. The structural design includes the institutional parameters of the market as imposed by the regulator. These design features inherently impact the incentives of firms, and as a result impact the demand for both instruments. The degree to which a design feature applies to only one instrument and not the other, or alternatively, influences the demand for one instrument over another, further impacts the substitutability between the instruments.

4.1 Offset Limits

Offset limits consist of a categorical restriction on the quantity of offsets firms can surrender for compliance. These limits are a prime program-related design parameter that directly impacts the substitutability of offsets and allowances, as the limit only applies to offsets. The offset limit is usually an *ex ante* cap relative to emissions allowances (see Table 2 for a comparison among extant programs).[6] The theoretical purpose of setting quantitative limits on offsets is to balance the potential for compliance cost reduction with the regulator's desired level of abatement by covered firms. Without a quantitative offset limit and with a large supply of inexpensive offsets (relative to allowance price and abatement cost), the quantity of abatement undertaken by covered firms can decrease as the oversupply of compliance instruments drives down the market price. In the RGGI and in California's program, the offset limit was calculated to satisfy the pre-condition of "supplementarity"; that at least 50 percent of emissions reductions resulting from the declining cap are achieved by covered firms (Langrock and Sterk, 2004; RGGI, 2006).[7]

TABLE 2
OFFSET LIMITS AS A PERCENTAGE OF TOTAL EMISSIONS IN MAJOR CARBON EMISSIONS TRADING PROGRAMS

Covered Region	*Percentage Limit*	*Compliance Period*
ETS (European Union)	13.4%[8]	Annual
RGGI (Northeastern US)	3.3%	3 Years
California	8%	3 Years

[6] In New Zealand's Emissions Trading Scheme, covered firms may meet up to 100% of their compliance obligations with credits from the CDM. Among other problems in the program's design, unlimited offset usage has contributed to a near-zero allowance price (Newell, Pizer and Raimi, 2013). Tokyo's Cap-and-Trade Program also does not have an offset limit (Tokyo Bureau of Environment, 2012).

[7] The offset limit in California was initially set at 49% of emissions reductions, but was changed to 8% of total surrendered compliance instruments (Mulkern, 2011). If the offset limit had remained at 49% of emissions reductions, the limit as a percentage of total emissions would have been about 4% (CARB, 2009).

[8] Each EU member state sets their own offset limit (e.g. Estonia's limit is 0% and Germany's is 20%). The 13.4% limit represents an average of these limits, weighted by each member state's annual emissions.

A binding quantitative offset limit constrains the ability of covered firms to optimize across compliance periods (inter-temporally) as they make demand decisions between allowances, offsets, and abatement. For example, if a firm determines that it is more profitable to take a long position in offsets because of a recent price spike in the allowance market, that firm's long position would be circumscribed by the offset limit. Even when it is more profitable for that firm to purchase additional offsets, the firm is restrained from doing so because of the offset limit. Demand for offsets beyond that limit would be met by alternative compliance options (i.e., abatement or allowances). This likewise translates into increased demand for allowances, which further exacerbates the price spread. However, an offset limit that allows firms to exceed their annual cap in certain years, as long as the limit is not exceeded over the entire compliance period, increases temporal flexibility. For example, the 13.4 percent offset limit in the ETS is calculated across 2008-2020, which allowed offsets to constitute 27.3 percent of compliance instruments surrendered in 2012 and contributed to the problems discussed in Sect. 2. A quantitative offset limit also reduces liquidity in trading offsets between covered firms, because firms that hold sufficient offsets to meet their quantitative limit for that compliance period will not demand further offsets.

Without corresponding qualitative restrictions, quantitative limits can have a negative impact on offset quality because purely profit-maximizing firms purchase the least-expensive (lowest-quality or least additional) offsets first (Wara and Victor, 2008; Bushnell, 2010). Discounting, one policy alternative to an offset limit that issues a quantity of offsets that is proportionately smaller than the emissions reductions achieved by the offset project, can lead to a similar result, because reducing revenue to offset projects renders the offset projects most dependent on offset revenue (i.e. the most additional projects) less viable compared to offset projects less dependent on offset revenue (Kollmuss and Lazarus, 2011).

To address the concern of low-quality offsets, regulators enact qualitative restrictions in conjunction with a quantitative limit to promote offset quality and to pursue other policy objectives. These qualitative restrictions are enacted in addition to the rigorous approval process described in Sect. 3, contributing to the regulatory uncertainty risk described in that section. Qualitative restrictions are typically placed on project type, size, location of project origination, and on methodologies for measuring baseline emissions and for monitoring emissions reductions. Qualitative restrictions influence supply of offsets and vary by program according to the regulator's policy goals.

4.2 Banking

While a quantitative offset limit reduces liquidity and the ability of firms to inter-temporally optimize, allowing firms to bank increases both price stability of compliance instruments and temporal flexibility, significantly reducing compliance costs (Tietenberg, 2006). Banking is a flexibility mechanism that allows firms to inter-temporally adjust to differences in compliance cost. This hedging is an explicit forward hedge, whereas a backward hedge, referred to as "borrowing," is not allowed in most cap and trade programs. Banking allows both allowances and offsets to be surrendered or traded to other firms in any forward compliance year in addition to the current compliance year.

Ceteris paribus, the declining cap combined with economic growth increases future abatement costs because, in the future, covered firms will have to implement more costly abatement technologies to comply with a more stringent cap (Stevens and Rose, 2002). When expected future abatement cost is increasing at a rate greater than the discount rate, firms demand greater quantities of allowances and offsets in the short run. Banking enables firms to respond to this short run demand by purchasing compliance instruments early on for use toward future compliance, leading to a greater than optimal quantity of emissions reductions in the early years of a program and increased aggregate emissions in the program's later years (Burtraw and Mansur, 1999; Chan et al., 2012). If expectations are accurate, then firms that bank reduce long-run compliance costs by surrendering banked compliance instruments in lieu of purchasing compliance instruments at the higher future market price or incurring comparatively higher abatement costs (Chevallier, 2012).

4.3 Ex Post *Invalidation Risk and Liability Provisions*

Carbon emissions trading programs vary widely in statutory design pertaining to mechanisms that allow for *ex post* invalidation of issued offsets and provisions that assign liability to replace invalidated offsets. The presence or lack of these provisions fundamentally alters offset demand. When an *ex post* invalidation mechanism is incorporated into a program, the regulator can invalidate offsets if emissions reductions from the offset project are found to be overstated, non-additional, double counted, or if the project has violated an environmental, health, or safety regulation (Erickson et al., 2013). Even if a specific project is not found to be in violation of these criteria, the regulator, in California's program for example, can choose to invalidate all offsets issued from a certain project type (CARB, 2013a). Programs with an *ex post* invalidation mechanism must also incorporate a liability provision specifying the party liable to replace invalidated offsets with valid offsets or allowances.

Regulators can assign liability to the buyer (the firm that surrendered or is holding invalidated offsets), producer, "system," or some combination of these parties.

While the general impact of a liability provision is to decrease offset demand relative to other compliance instruments as covered firms account for *ex post* invalidation risk, programs vary widely in their liability provisions, as do the strategies available to the potentially-liable party. 1) In a program with buyer liability, firms large enough and capable of measuring *ex post* invalidation risk can discount offsets according to the risk of *ex post* invalidation, shift the burden of liability to a private insurance company by purchasing insurance, and/or bank extra offsets to act as a hedge against *ex post* invalidation risk (Morris and Fell, 2012). These strategies either decrease the value of offsets or incur a premium on offsets. 2) In a program with seller liability, producers can charge a risk premium for their offsets to account for the risk of *ex post* invalidation, purchase private insurance, and/or bank extra offsets to act as a buffer. These strategies increase the price at which offset producers are willing to sell their offsets, reducing quantity of offsets demanded. 3) In a program with system liability, the regulator can claim a percentage of all offsets for a buffer account, can hold the host country or region liable to replace invalidated offsets, and/or can also incorporate private insurance into the program. 4) Finally, liability can be shared between the buyer, seller, and/or system, with the degree of responsibility for each party varying upon the manner and reason for the *ex post* invalidation (Murray et al., 2012).

The carbon emissions trading programs in California and Quebec, which will formally link in 2014 under the Western Climate Initiative (WCI), are the only programs to include an *ex post* invalidation mechanism for non-forestry offsets (Kachi, Taenzler and Sterk, 2012; Michaelowa, 2012). California's program implements buyer liability, while Quebec claims 4 percent of total offsets issued for a buffer pool that is used to replace invalidated offsets as needed.[9] Buyer liability in California is intended to ensure that covered firms only purchase high-quality offsets, and will affect offset demand in the program accordingly. If covered firms wish to shift liability to another party, two strategies are available to date. First, one private insurance company announced in 2013 that it will offer insurance against the risk of *ex post* invalidation (Climate Action Reserve, 2013). Secondly, covered firms can shift liability to the seller by purchasing "golden" offsets, in which sellers agree to accept liability for invalidated offsets. The difference between the price of

[9] Quebec chose to claim a relatively low percentage of credits because its three allowed project types, destruction of Ozone Depleting Substances, Livestock Methane Destruction, and Small Landfill Gas, have low invalidation risk and no risk of reversal.

golden offsets and offsets that retain buyer liability represents the risk premium that offset suppliers charge to accept liability. This difference has historically varied between 15-25 percent (Evolution Markets, 2012; Climate Connect, 2013).

The lack of an *ex post* invalidation mechanism in the ETS left the EC unable to remove grey CERs and low-quality ERUs from the market. If such a mechanism had existed and was employed by the EC, many of the problems detailed in Sect. 2, such as the suppressing effect on allowance and offset price, could have been alleviated. The *ex post* liability mechanisms incorporated into California's and Quebec's programs will leave regulators with an additional tool to prevent a similar scenario from occurring, but will also reduce offset demand due to the risk of *ex post* invalidation.

4.4 Reversal Risk in Forestry Projects

Offsets from land-use, land-use change, and forestry projects (LULUCF) are discounted further by covered firms because of reversal risk: the risk that emissions reductions achieved by an offset project will be unintentionally reversed by fires and other naturally-occurring events, from management and financial failure of the project, or from institutional changes that cause the project to stop operating. While a ton of HFC-23 can be destroyed with no chance of the resulting emissions reductions re-entering the atmosphere, a LULUCF project would need to continue to operate indefinitely in order to ensure equivalent permanence.

In order for regulators to issue permanent, statutorily substitutable offsets for LULUCF activities satisfying offset quality criteria (e.g. additionality, permanence, etc.), regulators also implement specific liability provisions that account for this reversal risk. The RGGI, California, and several voluntary offset programs issue permanent offsets for LULUCF activities (mainly forestry), and use buffer accounts to replace offsets that are lost to unintentional reversals (Mignone et al., 2009; California EPA, 2010; California EPA, 2011; Murray et al., 2012). Regulators can give suppliers an incentive to take measures that reduce reversal risk by tying the percentage of offsets claimed to a project-specific risk evaluation (California EPA, 2010).[10]

[10] This risk evaluation is calculated according to the risk of financial failure, management risks (e.g. overharvesting), social risk (e.g. change in government policies), and natural disturbance risk (e.g. wildfire risk). Projects that have a Qualified Conservation Easement, are publicly owned, and/or have received fuel treatments (thinning and targeted burning of forest to reduce risk of fire) can decrease the percentage of credits that are placed in the Forest Buffer Account. The percentage of credits taken for the Forest Buffer Account ranges from 11-21% (California EPA, 2010).

To recover the value of the offsets claimed for the buffer account, project developers may increase the price of offsets, decreasing quantity demanded. However, for covered firms in California, the benefit of shifting from buyer liability (for non-forestry offsets) to system liability will increase demand for forestry offsets if the price premium charged by the seller of forestry offsets is less than the *ex post* invalidation risk discount applied to non-forestry offsets and less than the cost of liability-shifting strategies discussed in the previous section.

A second approach to LULUCF offsets is to issue temporary credits that must be replaced by the buyer after a period of time. Though the two types of temporary offsets the CDM issues for afforestation and reforestation activities (UNFCCC, 2006) are not valid compliance instruments in any of the major carbon emissions trading programs, demand for temporary offsets would be expected to be low unless the discount rate is greater than the expected increase in price of permanent offsets and in abatement cost (Dutschke and Schlamadinger, 2003). Hybrid approaches, such as "renting" offsets or incrementally issuing permanent offsets, have also been developed that remove reversal risk, but have not been incorporated into any of the major carbon emissions trading programs (Marland, Fruit and Sedjo, 2001; Sohngen and Mendelson, 2003; Mignone et al., 2009).

4.5 Regulatory Uncertainty

Offset demand from utilities is especially relevant because the power sector often constitutes the largest emitting sector covered under carbon emissions trading programs. Whereas all covered firms must ensure that they meet the standards of an emissions program, utilities are also required to continually assess the degree to which their compliance strategies will be permissible under a state regulatory commission. Despite the fact that many electricity markets have undergone restructuring, this restructuring has mainly taken place in the wholesale markets (e.g., the sale of generation to retailers). The retail market, however, remains very much a product of traditional price and cost regulation. The retail market refers to the sale of electricity from public utilities to households and businesses. State public service/regulatory commissions review the appropriateness of the market actions taken by utilities, and permit changes in regulated rates paid by businesses and households, on the basis of costs incurred both in the wholesale market and in utility-owned generation.

In deregulated markets, as a positive price on carbon incentivizes abatement and a shift in production away from carbon-intensive fuels, the costs of both abatement and this production shift will be first incurred by wholesale markets. As these costs are passed through to power retailers (public utilities), retailers will pass those costs through to the consumer (e.g., businesses and households). Should a utility's request to pass through additional cost be considered "imprudent," its shareholders may be on the hook for those costs and unable to recoup those costs in the rate base. This naturally creates market uncertainty regarding the range of options that are considered most permissible by a state's regulatory commission.

At the same time, the planning horizon for retrofits and abatement spending on the part of utilities can be quite time-intensive. That is, certain fuel switching activities and their accompanying transmission siting and construction can require a planning horizon of up to three decades. In that time, the temperament and political disposition of the regulatory commission, which determines which actions are in fact permissible, can change dramatically.

Whereas firms operating in deregulated markets only are free to pursue a broad range of cost-minimizing strategies including purchasing offsets and fuel switching, firms subject to regulatory approval may not have the same range of options available to them. In these markets, costs for compliance may be limited by a subset of available strategies favored by state regulators (Averch and Johnson, 1962; Arimura, 2002). For example, it is not clear that a public utilities commission would be likely to allow utilities to invest in offset projects before offsets have been issued, even if doing so would reduce long-run compliance costs. This is because offset projects are not generally issued offset credits for several years. The nature of regulatory policy plays a key role in capital acquisition of the largest firms in this key sector, and thus regulatory influences are key drivers of offset demand.

5. Extra-Statutory Drivers

While Sect. 4 focused on drivers within the context of policy design, the demand for offsets can similarly be influenced by conditions exogenous to the offset market. While there exist many exogenous factors that influence offset demand, we have chosen to focus on four key drivers.

5.1 Economic Growth

The relationship between economic growth and offset demand is clear, in that, *ceteris paribus*, economic growth is heavily correlated with energy consumption, increasing demand for carbon-based inputs and thus compliance instruments (Alberola, Chevallier and Chèze, 2008b). However, two complexities define this linkage. First, covered sectors are defined by heterogeneous levels of output in relation to aggregate economic growth. Secondly and most importantly, changes in output have a heterogeneous effect on offset demand from each covered sector depending on the carbon intensity of each sector's production process. In other words, economic growth may or may not occur equally in carbon-intense sectors as it does in less carbon-intense sectors. As economic growth heterogeneously affects sectors that vary widely in carbon intensity of production process, demand for compliance instruments also varies widely. Disaggregating ETS compliance and production data into sectors allows for an examination of the link between economic growth, emissions, and offset demand. Despite the perverse incentives that existed in the second phase of the ETS (Sect. 2), both emissions and offset demand from each sector were highly correlated with each sector's level of economic output. The cement sector had the highest correlations between YOY emissions and output change (*rho*=.999), and YOY offset demand and output change (*rho*=.997) because this sector is the most carbon-intensive sector in the ETS (van der Zee et al., 2009). In the ETS as a whole, changes in economic output were highly correlated with corresponding changes in emissions and quantity of offsets surrendered.

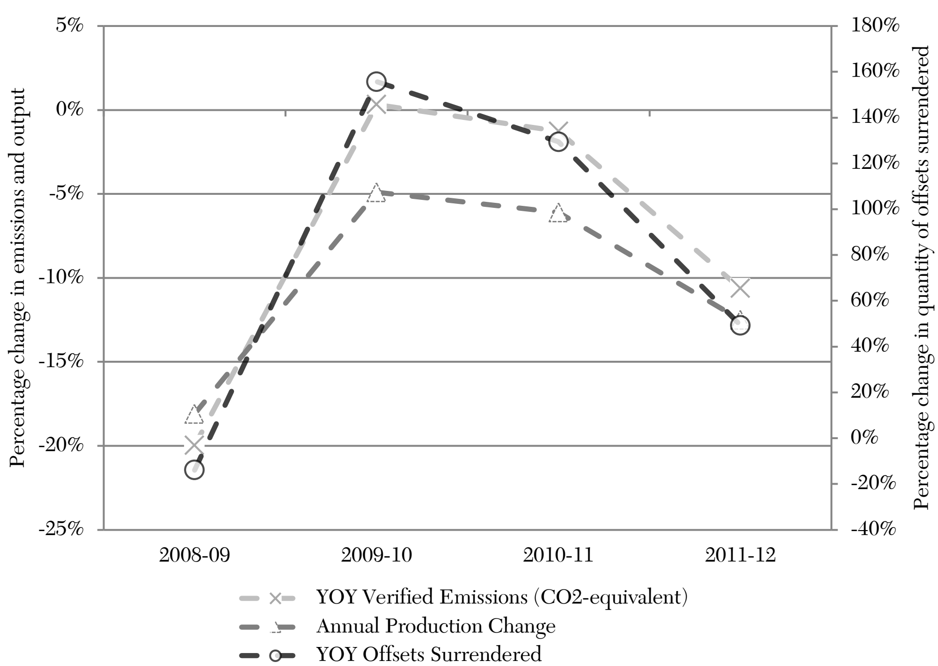

FIGURE 4. EMISSIONS, OUTPUT, AND OFFSET DEMAND FOR THE CEMENT SECTOR
Sources: Data available from the European Commission and Eurostat

While the high correlation of output with offset demand provides evidence that offsets were used as substitutes for allowances in Phase II (2008-2012), a sectoral comparison based upon a 9-sector aggregation scheme of ETS covered firms reveals significant heterogeneity in marginal offset use, which was calculated by dividing annual sectoral output by each sector's relative offset use (quantity of offsets surrendered divided by total emissions). Explanations for this heterogeneity include the emission intensity of each sector's production process, the degree of each sector's familiarity with trading offsets (Trotignon, 2012), the number of firms in a sector, and the difference between quantity of emissions and quantity of freely allocated allowances. Sectors with fewer firms are subject to greater variance in marginal offset use, and sectors that are allocated more allowances than their emissions have a decreased need for additional compliance instruments.

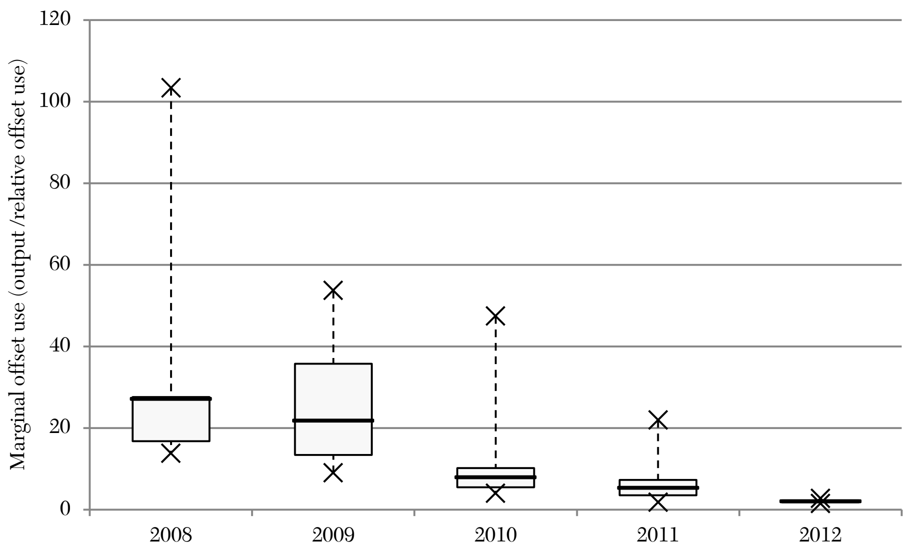

FIGURE 5. BOXPLOT OF SECTORAL MARGINAL OFFSET USE IN THE ETS

Note: Data available from European Commission and Eurostat

Gini coefficients are calculated for each year to measure heterogeneity of marginal offset use. The Gini coefficient was very low in 2012 because relative offset use doubled[11] for all sectors as covered firms took advantage of near-zero CER and ERU prices. While marginal offset use declined each year as each sector increased relative offset use, significant heterogeneity remained: the Gini coefficient was 38.51 in 2008, 32.29 in 2009, 41.56 in 2010, and 37.07 in 2011.[12] Heterogeneity in marginal offset use provides additional qualitative evidence that offsets have been utilized as imperfect substitutes for allowances. If offsets were perfect substitutes for allowances, their proportional use would be close to equivalent across sectors.

5.2 Fuel Price

The extent to which a positive carbon price alters the marginal cost of one input fuel over another depends inherently on the relative base marginal cost of those inputs (e.g., excluding a carbon price). Because of this dynamic, analyses of the demand for carbon offsets should inherently consider the dynamics associated with the relative prices of fuels utilized by firms within the market. They should also consider the relative portfolio of fuels available within the regional market of those firms. Considering both of these dynamics, a number of *ceteris paribus* hypotheses can be easily provided, as given in Table 3. In resource rich regions where all fuel inputs are readily available, an increase in the price of a high-carbon fuel relative to a low-carbon fuel should signal a decrease in the demand for carbon offsets. And alternatively, an increase in the price of low-carbon fuels relative to high-carbon fuels should signal an increase in the demand for carbon offsets. In regions where the production portfolios vary in their resource mix, a variety of alternatives may ensue.

[11] Relative offset use for all sectors (weighed by verified emissions) increased by 130 percent. However, this average masks significant heterogeneity. The pig iron or steel sector was the only sector to decrease relative offset use in 2012, from 59.1 percent in 2011 to 52.6 percent in 2012. The metal ore roasting or sintering sector increased relative offset use by 1,146 percent, from 4.8 percent in 2011 to 59.4 percent in 2012. The Gini coefficient in 2012 was 11.

[12] Even with marginal offset use from the metal ore roasting or sintering sector, an outlier due to its small size (27 firms) and high allocation ratio (63%), removed from the calculation of the Gini coefficient, there is still significant heterogeneity in the effect that output level has on offset demand from different covered sectors. In ascending order for the years 2008-2012, Gini coefficient is equal to 19.13, 29.49, 17.41, 24.68, and 11.86.

TABLE 3

FUEL PRICE CHANGE SCENARIOS

Regional Energy Portfolio	Fuel Price Change Scenario	
	Price of high-carbon fuel increases relative to low-carbon fuel	*Price of low-carbon fuel increases relative to high-carbon fuel*
Resource rich region (high-carbon fuels and low-carbon fuels are abundant)	Demand for offsets decreases (shifts to less carbon-intensive fuels)	* Demand for offsets increases (shifts to carbon-intensive fuels)
Resource poor region (high-carbon fuels and low-carbon fuels are less abundant)	Demand for offsets decreases (small shifts to less carbon-intensive fuels)	*Demand for offsets increases (small shifts to carbon-intensive fuels)
Carbon intensive region (high-carbon fuels are more abundant than low-carbon fuels)	*Demand for offsets decreases slightly (very small shifts to less carbon-intensive fuels)	*Demand for offsets increases (shifts to carbon-intensive fuels)
Less carbon-intensive region (high-carbon fuels are less abundant relative to low-carbon fuels)	Demand for offsets decreases (shifts to less carbon-intensive fuels)	*Demand for offsets increases slightly (very small shifts to carbon-intensive fuels)

* Indicates scenario in which a positive carbon price is most integral to achieving the social optimum

Where a region's energy portfolio is favorable to the production of high-carbon fuels, or where exogenous market forces signal a switch to higher-carbon forms of production, the success of a viable carbon price is integral to achieving the socially-optimal outcome. However, even under conditions in which the regional resource mix and the market for those fuels is favorable to decreased carbon intensity, an inherent paradox remains. That is, policymakers often assert that markets will somehow immediately respond to a positive carbon price by switching production away from carbon-intensive fuels. A firm's ability to respond to a positive carbon price is tied both to the market dynamics of the input fuel as well as the physical constraints inherent to a firm's production process (Delarue and D'haeseleer, 2007; Considine and Larson, 2012; Moeller, Balmann and Kataria, 2012). As such, "fuel switching" is not an inherently short run activity.

These physical constraints include a variety of market-specific exogenous conditions. Firms may be tied-in to a long-term contract for the supply of power. These contractual obligations are often incentivized in deregulated markets as a volatility-reducing mechanism. Firms may have already taken a long position in their current input fuel, or may be heavily invested in the current production technology. Convincing shareholders that are expecting a long-run return on investment from the current capital mix that they should consider switching production technologies in response to short or medium-term price dynamics may be difficult. Firms may also be locked in to a long-term fuel purchasing agreement. Similarly, firms that are part of a regional reliability market, or ISO, may hold contractual supply obligations, may be incurring payments for available capacity, or may be limited by ramping requirements or load following obligations inherent to the regional market, all of which may limit switching. And finally, regulatory distortions such as the incentivizing of locally-produced fuels, union preferences, and citing approvals, may also limit switching.

Given that typical carbon market designs include compliance horizons of 1 to 3 years, short run drivers of demand, and suitable instruments to respond to them, are particularly important to covered firms. Matching short run drivers of demand to short run compliance instruments is key to the vitality of carbon markets. Because fuel switching is less of a short run activity, firms will ultimately seek compliance instruments that can be similarly responsive in the short run. Under the context of a regional energy portfolio, because fuel price is a critical driver of the demand for compliance instruments, and because firms cannot respond to fuel price easily within the short run window of a typical compliance period, firms will tend to avoid investing in offset projects and will instead purchase allowances or sCERs.

5.3 Energy Efficiency

Changes in energy efficiency include any policy change or technological change that enables increases in output with fewer energy inputs. Efficiency improvements can be *autonomous*, which occurs when capital and equipment increase in their rate of efficiency across time with natural changes in production practices (e.g., refrigerators today use far less energy than in the 1970s) (Kaufmann, 2004). Efficiency improvements can also be *induced*, which occurs when direct investment by private or public means increases the rate of technological innovation (Newell, Jaffe and Stavins, 1998). Induced efficiency improvements can also include technology "forcing" standards or regulatory requirements, in which industry is forced by regulatory fiat to adopt more efficient capital, equipment or production processes that would not otherwise be incentivized by the market (Jaffe and Stavins, 1995).

Energy efficiency drives demand for offsets in a manner similar to aggregate economic growth, in that energy efficiency affects offset demand through influencing emissions levels. *Ceteris paribus,* energy efficiency improvements decrease demand for carbon offsets and allowances. A common policy design of carbon emissions trading programs is a requirement that revenue from the sale or auction of allowances (if the system does not allocate them freely, or "grandfather" them) at least partially be utilized to fund energy efficiency investments. When this auction or sales revenue is utilized for this purpose, which is referred to as "revenue recycling," it can serve to accelerate further the growth in technological innovation and have a negative effect on the demand for carbon offsets (Speck, 1999). At the same time, an increase in allowance demand due to economic growth can increase auction revenue recycled for energy efficiency improvements, accelerating the above trend.

The targeted use of auction or sales revenue for the purpose of energy efficiency investments varies widely across trading programs. All of the major trading markets include some form of revenue recycling requirement, with varying levels and sectoral targets. For example, Germany has allocated €1.4 billion in auction revenue in 2013 to fund climate initiatives primarily targeted to reduce emissions from the power sector, reducing future demand for compliance instruments from this sector (Esch, 2013).[13] Auction revenue from the RGGI may also be used to improve energy efficiency and expand renewable energy, prompting similar effects in the power sector (RGGI, 2005). California and Quebec allocate a greater percentage of funding than

[13] Germany auctioned 8.8% of allowances in Phase II, a higher percentage than any other member state (Ellerman, Convery and Perthuis, 2010). Member states receive 88% of revenue from auctions, of which at least 50% must be used to combat climate change in Europe or in other countries (European Commission, 2013c).

the ETS or the RGGI for emissions reductions in the transportation sector, especially affecting demand for compliance instruments from oil refineries (Finances Québec, 2012; CARB, 2013b). A wide range of energy efficiency measures can be implemented to reduce energy demand (Roberto and Dormady, 2013).

While increases in energy efficiency do decrease emissions and long-run demand for compliance instruments, a "rebound effect" can result as firms (and individuals) respond to efficiency increases by increasing consumption (Maggioni, 2008). That is, energy efficiency gains lower the marginal cost of production for firms, and as a result, total production increases. A classic example is the urban motorist, who after purchasing a more fuel efficient automobile can now afford to drive even further, and may consume more total fuel than with the prior automobile. Studies show that the rebound effect is between 10-30 percent, varying by economic sector (Greene, Kahn and Gibson, 1999; Berkhout, Muskens and Velthuijsen, 2000; Herring, 2006; Sorrell, 2007). While not sufficient to reverse the long-run reduction in emissions, a short-run increase in demand for compliance instruments from some covered firms is possible.

5.4 Weather

Fluctuations in weather can provide a significant year to year driver of demand for carbon offsets, particularly in regional energy markets influenced heavily by hydro and renewable resources. Some of the key variables of interest include variation in temperature, precipitation, wind, and cloud cover. Weather can inherently influence the demand for carbon compliance instruments on both the production and consumption side.

On the production side, climactic variations that necessitate short run increases in regional utilization of high-carbon fuels for electricity generation can influence the demand for carbon compliance instruments. On the consumption side, extreme temperatures (Mansanet-Bataller et al., 2006) and deviations from seasonal averages (Alberola, Chevallier and Chèze, 2008a) are found to be statistically significant allowance price drivers because of their impact on demand for heating or air conditioning. However, Alberola and Chevallier (2009) and Lutz, Pigorsch and Rotfuss (2013) do not find extreme temperature to be significant drivers. Level of precipitation (including snowpack) influences the availability of hydroelectric power, and in extreme cases, can reduce the amount of electricity available from nuclear energy if sufficient water is not readily available for cooling (Benz and Trück, 2009).

An interesting interaction between the drivers of demand for offsets is that between weather and forestry reversal risk (see Sect. 4.4). Level of precipitation can impact both regional hydrology and snowpack, which can play an integral role in the risk of fires. Depending upon the liability provisions of a program's trading system, this can similarly impact the demand for forestry offsets.

The State of California provides a salient example of these effects. In California, hydroelectric power is imported to municipalities from sources such as the Bonneville Power Authority in Oregon through long-term power procurement contracts. Hydroelectric power is the state's second-largest energy import by type (excluding coal imports). Annual fluctuations in precipitation directly impact the state's supply of this key energy import. During years of low hydro output, the state is forced to rely more heavily on gas generation. Low hydro in 2000 and 2001 also provided market manipulators such as Enron and AES Corp., with a highly inelastic demand for gas resources, and allowed producers operating within the RECLAIM cap and trade market to leverage energy-emissions market linkages to inflate both energy prices and the price of RECLAIM credits (Borenstein, Bushnell and Wolak, 2002). In 2012, below average precipitation decreased the amount of electricity generated from hydro by 36 percent (California Department of Water Resources, 2012). The decrease in available electricity from hydro increased emissions from substitute sources, as electricity generated from natural gas increased by 34 percent.

In deregulated electricity markets, generation units are dispatched in order of price and subject to reliability constraints, and only the most economically-efficient units produce. When low-cost hydro resources are limited from reduced rainfall or insufficient snowpack, higher marginal cost units are dispatched more frequently and average wholesale prices can increase dramatically (Hunt, 2002). Even in the event of a sufficiently high carbon price, wholesale markets will regularly dispatch high-carbon generation units when low-cost units have already been utilized. Regional generation portfolio's that rely heavily on energy sources that fluctuate with climatic changes will ultimately vary in demand for compliance instruments in response to these fluctuations. The impact on offset demand of climatic fluctuations will therefore depend on the degree to which offsets are substitutable for allowances.

6. Conclusion

Whereas scholars and practitioners of public policy have long considered market-based approaches to allocation problems of public goods and externalities to hold significant social benefits over more direct regulatory approaches, long established beliefs about market-based approaches may be worthy of revision in light of contemporary design applications of market-based policies.

The introduction of an alternative compliance instrument (allowances + offsets) into a Coasian transferable property rights market (cap and trade program) introduces a number of important public policy concerns. The degree to which these instruments are substitutable will ultimately impact the efficiency of the overall trading program, particularly when aggregate caps are based mainly upon allowances. Despite the fact that allowances and offsets are statutory substitutes in extant markets, they behave far more like imperfect substitutes. Relying upon economy theory, and the regulatory framework and program design of each of the world's major carbon emissions trading programs, this paper has provided a comprehensive theoretical treatment of the drivers of demand for carbon offsets to help explain why offsets and allowances are defined by imperfect substitution.

This paper began with a case analysis of exploitation in the European ETS offsets market for "grey" offsets. This case illustrates the degree to which program design considerations must be considered in any analysis of the demand for carbon offsets. In this case, lax program design and a supplemental industrial benefit led to a system in which offsets were over-produced, and in which the production of greenhouse gases was subsidized abroad.

This paper then provided an analysis of the procedural requirements of the UN's Clean Development Mechanism (CDM) which illuminates the significant procedural and transaction costs inherent in the production of a carbon offset. The production of carbon offsets is a heavily regulated and monitored process that is enshrouded with bureaucracy at all levels of governance. This imposes a significant cost on offsets that is not imposed on allowances. Whereas this paper provides a theoretical analysis, prior work that has attempted to explain the demand for carbon offsets quantitatively cannot account for the rigorous process inherent to producing carbon offsets in the international marketplace.

Additionally, the demand for carbon offsets is heavily influenced by the design of policy. Program design features heavily into the demand for offsets as it explicitly influences private firms' production decisions. This paper provided a comprehensive treatment of key program design features, including procedural requirements, limits, and liability provisions of the world's major carbon markets. Similarly, four major extra-statutory drivers of demand were detailed. These include the drivers of demand that are external to both the production of offsets as well as the policy design itself.

Despite challenges in the ETS from environmentally-dubious offsets, offsets remain a major component of current and proposed carbon emissions trading programs because their use by covered firms can serve to reduce compliance cost. Offset usage will therefore continue to shape the effectiveness of carbon emissions trading programs in inducing economically efficient abatement by covered firms. The theoretical treatment provided by this paper will better enable scholars, policymakers and regulators to carefully balance the benefits of compliance cost reduction with an appropriate quantity of abatement that maximizes social welfare.

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APPENDIX A
KEY MARKET DESIGN CRITERIA OF MAJOR CARBON EMISSIONS TRADING PROGRAMS

Program Name	Regional Greenhouse Gas Initiative Inc. (RGGI)	EU Emissions Trading System (ETS)	California Cap-And-Trade
Location	Northeast United States	Europe	California
Time Horizon	2008-2018	2005-2028	2012-2020
Covered Sectors	Electricity	Electricity, Industrial, and Transportation	Electricity and Industrial
Approximate Number of Installations/Facilities	650	12,000	600
Size of 2013 cap (mT CO2-equivalent)	165 (decreases to 91 in 2014)	2,004	160
Percentage of emissions covered by cap	25%	40%	35% from 2013-14, 85% from 2015-2020
Percentage of allowances auctioned	Approximately 90%	40% in 2013, 100% by 2027)	10% for 2013, increasing each year.
Compliance Period	3 Year	Annual	3 Year
Banking	Allowed	Allowed	Allowed
Borrowing	Not Allowed	Not Allowed	Not Allowed
Vintaging	Current and next compliance period vintage	Current compliance period vintage	Current and next compliance period vintage
Non-Compliance Penalty	3 times the number of shortage allowances must be purchased, plus state-specific penalties	1 times the number of shortage permits must be purchased, plus €100 per ton penalty	4 times the number of shortage permits must be purchased
Number of Offset projects	None	>5,000	500
Quantity of Offsets surrendered (mT CO2-e)	None	504 (2012)	N/A
Offset Limit	3.3%	13.4%	8%
Allowed Location for Offset Generation	Within RGGI states	Projects begun after 2012 must originate in Least Developed Countries	Within continental US
Types of Offsets Allowed	Capture or destroy CH_4, reduce SF_6, afforestation, energy efficiency, avoid CH_4 from agriculture	Most types of CERs and ERUs, with the exception of grey CERs.	Forest, urban forest, livestock, and ozone depleting substances (sectoral scope currently under regulatory revision).