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The Evolving Role of Greenhouse Gas Emission Offsets in Combating Climate Change

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Abstract

As governments, firms, and universities advance ambitious greenhouse gas emission goals, the demand for emission offsets – projects that reduce or remove emissions relative to a counterfactual scenario – will increase. Reservations about an offset's additionality, permanence, double-counting, and leakage pose environmental, economic, and political challenges. We review the role of offsets in regulatory compliance, as an incentive for early action, and in implementing voluntary emission goals. The rules and institutions governing offsets drive large variations in prices and in the types of projects deployed to reduce or remove emissions across offset programs. A lack of carbon price convergence and potential information asymmetries may contribute to limited price discovery and market segmentation. Taking into account the financial properties of offsets, an array of financial and technological innovations could enhance offsets' environmental integrity and promote liquid offset markets. Unresolved questions about the future of policy will influence the evolution of voluntary offsets markets.

Keywords: climate change, certified emission reductions, offsets, cap-and-trade, corporate social responsibility

JEL Codes: Q54, Q52, Q58, H23

The Evolving Role of Greenhouse Gas Emission Offsets in Combating Climate Change

In recent years, governments, major corporations, and universities have issued ambitious greenhouse gas emission pledges. For example, the European Union (2021) has enshrined a net-zero emissions goal by 2050 into law, Microsoft has established a carbon-*negative* goal by 2030, and Harvard University aims to be fossil fuel-neutral by 2026 (EU 2021, Smith 2020, Harvard University 2018). In each case, attaining these goals will require the use of emission *offsets* – emission reductions outside of a government's jurisdiction or the footprint of a company or a university. These emission offsets could make up for the difficult-to-eliminate residual emissions created by the entity in question. If these offsets at least equal the residual emissions for that entity, then it will have met its net-zero goal.

Emission offsets represent an estimated reduction of greenhouse gas emissions relative to a counterfactual. A project, such as the construction of a wind farm, may be evaluated for emissions reduction relative to a no-project counterfactual baseline. For example, if the project developer demonstrates that a coal-fired power plant would have been constructed otherwise, then the emission offsets associated with the wind farm would reflect the avoided carbon dioxide (CO_2) emissions from burning coal at that counterfactual power plant. Likewise, sequestration efforts, such as tree-planting projects, may be evaluated for their net impact removing CO_2 from the atmosphere and storing it in biomass. The offsets for sequestration efforts would then rely on an analysis to show how the tree planting alters the overall carbon equation and the estimated incremental afforestation would then be translated into tons of CO_2 stored biologically.

Emission offsets may serve as one strategy for firms to comply with government regulations, including emission cap-and-trade programs. They may also serve as a strategy for a business or university through its own initiative to demonstrate progress in attaining a voluntary emission goal. In either the regulatory or the voluntary context, the economic and environmental characteristics of offsets will depend on key institutional and policy design details, as in any environmental market. Such design details will influence the evolution of the market for offsets, as they affect both the supply and demand for emission offsets, as well as the prospects for financial innovation to improve the liquidity and efficiency of such markets.

The promise of emission offsets as a mitigation strategy is that it can promote cost-effective emission abatement and broaden the scope of participation in decarbonization activities. The buyers of emission offsets have an economic incentive to do so when the costs of reducing emissions through offset projects are lower than what the buyer can achieve through its own investments and actions. Encouraging the supply of emission offsets from otherwise unregulated or difficult-to-regulate sectors, such as forestry and agriculture, or from developing countries with nascent climate policy regimes, creates opportunities for learning how to reduce or remove emissions that could promote more ambitious efforts over time.

Several challenges, however, characterize the estimation of, and market for, emission offsets. Voluntary offsets could represent a form of greenwashing or green indulgences, allowing a business to appear like it is taking action to address climate change, but with little material benefit to the environment (Dalsgaard 2022). An offsets project could deliver "paper tons" – estimated emission reductions sold to another party – that result in "hot air" – an increase in emissions because the project would have happened anyway and it enables the party acquiring the offsets to continue its emissions. Uncertainty about the environmental integrity of offsets, resulting in potential buyers lacking sufficient information to discern low-quality from high-quality offset projects, could cause the market to unravel or fail to grow. Such questions have prompted an array of potential policy fixes, but these increased transaction costs may have a chilling effect on the offsets market.

To better understand the economic, environmental, financial, and policy implications for the use of offsets in mitigating greenhouse gas emissions, we turn next to the lessons from the use of emission offsets as a regulatory compliance strategy. We then focus on the growing voluntary market for offsets and examine key market drivers. The evolving regulatory institutions and emerging voluntary institutions governing offsets set the foundation for an assessment of the challenges in estimating offsets and demonstrating environmental benefits. In particular, we examine the threats to environmental integrity associated with offsets projects, drawing from policy experience with offsets markets and ex post evaluations of their environmental performance. We explore opportunities for financial and technological innovation to enhance the integrity and robustness of offsets markets. We conclude with a discussion of the policy implications of a growing voluntary offsets market.

Offsets as a Regulatory Compliance Strategy

Emission offsets emerged as a way to reduce regulatory compliance burdens by providing more cost-effective options for attaining environmental goals. For example, consider the implementation of national ambient air quality standards under the U.S. Clean Air Act. After setting a standard, the Environmental Protection Agency designates "non-attainment areas" that fail to meet the standard, and the law initially precluded firms from building new, emitting facilities in such areas. Amendments to the Clean Air Act in 1977 enabled firms to construct new facilities if they offset these new sources' emissions by cutting emissions at existing nearby sources (Hahn 1989; Schmalensee and Stavins 2019; Shapiro and Walker 2020). Such emission offset transactions typically require regulator certification and approval of "permanent" emission reductions, where the offset seller often meets the permanence standard by demonstrating the adoption of long-lived pollution control equipment.

Such a compliance option has the potential to deliver environmental, economic, and political benefits. By requiring, in some non-attainment areas, firms to finance emission cuts at nearby facilities that are greater than the new facility's expected emissions, such transactions could reduce net emissions in that area and facilitate progress toward attaining the air quality standard. Enabling a firm to seek out lower-cost emission reduction opportunities improves the cost-effectiveness of complying with the air quality regulations and most of these local offsets markets realized marginal benefits in excess of marginal costs (Shapiro and Walker 2020). Permitting such implementation flexibility can facilitate the political durability of air quality policy (Carlson and Burtraw 2019).

The fundamental challenge with offsets lies in demonstrating that the emission-reduction project would not have happened otherwise (Hahn 1989). The environmental benefits depend on the "additionality" of the activity; that is, evidence must be produced demonstrating that the investment and associated emission reductions are marginal and hence are the result of the offsets transaction. Failure to demonstrate "additional" emission reductions could produce "paper tons," defined as emission reductions recorded in a transaction that do not reduce net emissions in practice (Butler 1984, Dudek and Palmisano 1988). In an effort to address the potential for paper tons to undermine the environmental integrity of offsets and trading, environmental regulators developed project-specific review and verification methods, which have also increased the transaction costs associated with offset trading.

Nonetheless, these early Clean Air Act experiences informed policy experimentation in various forms of emissions trading, including the development of offsets programs to address greenhouse gas emissions. The 1992 United Nations (U.N.) Framework Convention on Climate Change established non-binding emission goals for developed countries and a voluntary offsets program, often referred to as "joint implementation." Under joint implementation, one country could invest in an emission-reducing project in another country. Such project-based transactions could evolve into an informal emissions trading market, since neither party to these transactions were subject to emission caps. A decision at the 1995 U.N. climate talks prevented a national government from investing in a joint implementation project in another country and using the estimated emissions reductions as a means to show progress toward its voluntary goal to limit emissions to 1990 levels by 2000. As a result, only a few developed countries invested in pilot projects of joint implementation to prove the concept, but these efforts resulted in limited emission-reduction activities. These early, modest efforts set the stage for expanding the role of offsets in subsequent international negotiations (Wiener 1998).

The 1997 Kyoto Protocol established the first, legally-binding emission targets for industrialized nations and enabled these countries to employ an array of market-based approaches – including emissions trading, joint implementation among industrialized nations with emission targets, and the Clean Development Mechanism (CDM) in developing counties – as a part of their implementation and compliance strategies. The CDM institutionalized a process where an emission-reduction project in a developing country could be registered, evaluated, and issued credits – offsets, referred to as Certified Emission Reductions (CERs) – that could be sold to a developed country for its use in demonstrating compliance with its Kyoto targets (Lecocq and Ambrosi 2007; Gillenwater and Seres 2011).

Like the possibility of paper tons under Clean Air Act project-based trading, CDM projects raise questions of additionality. If a project in a developing country that would have happened anyway receives emission reduction credits that offset efforts to cut emissions elsewhere, then this could result in “tropical hot air” – a net increase in emissions originating from developing countries (Meyers 1999, Philibert 2000). The CDM Executive Board, created under the Kyoto Protocol, developed rules to govern this new offset market and attempt to minimize such tropical hot air. These market rules covered project eligibility criteria; processes and methods for estimating emission reductions and monitoring projects on emission-related outcomes; registration and evaluation of specific CDM projects; issuance of offsets that may be sold by registered projects; and certification of independent project auditors. With an objective of demonstrating environmental integrity, CDM offsets provided a low-cost way for developed countries to satisfy their Kyoto targets. A robust CDM offsets market with buyers spread among the developed world could also enable greater global cost-effectiveness by indirectly linking country-specific mitigation programs via the offsets market: if developed country A bought CDM offsets and developed country B bought CDM offsets, then a liquid offsets market could result in carbon price convergence among countries A and B (Jaffe et al. 2009).

Since the CDM would require project-specific verification, the transaction costs were expected to result in less emission abatement than would be expected under a cap-and-trade program. Moreover, the CDM eligibility rules precluded some forms of emission abatement, such as building new nuclear power plants or sector- or economy-wide policies, such as a carbon tax or tradable performance standard. Early analyses of the Kyoto Protocol assumed that developing countries could reduce emissions under the CDM at 15-20 percent of what energy-economic models estimate under an efficient economy-wide carbon price (The White House 1998; Weyant and Hill 1999). To put this "20 percent haircut" assumption in context, consider a thought experiment in which we take the average *realized* carbon price in the European Union Emissions Trading System (EU ETS) between 2008 and 2012 – the primary market destination for CDM offsets during the Kyoto Protocol's first commitment period – and simulate what the U.S. government's modeling analysis would have estimated for China's emission reductions under the Clean Development Mechanism. With average EU ETS allowances of about €14/tCO_2, China would have been expected to produce more than 300 MMTCO_2 of offsets per year via the CDM. In practice, China produced certified emission reduction offsets of a little less than half this amount – about 135 MMTCO_2 per year – during the 2008 to 2012 period.[1] China's CDM certified emission reductions represented a little less than 10 percent of the reductions that would have been expected from an economy-wide carbon price of €14/tCO_2. While this gap between potential and realized reductions may reflect excessively optimistic assumptions about emissions abatement in China in late-1990s energy-economic models, the institutional details, selective eligibility of emission-

[1] The Subcommittee on Energy and Power (1998) includes several hundred pages – including spreadsheets of modeling results – on the Clinton Administration's economic analysis of the Kyoto Protocol, which serves as the basis for this simulation.

reduction activities, and associated transaction costs of the CDM likely precluded emission reductions that would otherwise be economic under lower-transaction cost policies.

While the Kyoto Protocol allowed national governments to buy and use CDM offsets to demonstrate compliance with their emission targets, the largest driver of demand for such offsets came from European firms covered under the EU's cap-and-trade program. The EU ETS allowed firms to acquire and submit CDM credits in lieu of ETS emission allowances to demonstrate their compliance. Doing so effectively converted the offsets into a commodity on par with allowances, which enhanced demand among firms for offsets and improved market liquidity. Indeed, CERs traded at prices fairly consistent with, but at a modest discount to, ETS emission allowances through 2011 (Ellerman et al. 2016).

The resulting revenues for CDM projects in developing countries delivered on one of the promises of market-based approaches highlighted in the 1997 Kyoto negotiations by their advocates: these projects could provide economic benefits to these countries with low costs of reducing emissions (Aldy 2004). The resulting demand catalyzed substantial growth in the offsets market: in 2012, developing countries' projects generated 350 million metric tons of credits (Figure 1). For the post-2012 period, the EU set qualitative and quantitative limits on the use of CDM credits, reflecting concerns about the environmental integrity of CDM projects. For example, the EU prohibited the use of CERs from projects that destroyed industrial gases, such as HFC-23 and nitrous oxide, because of the likelihood that these did not deliver additional emission reductions. The EU also began to limit CDM credits from country of origin – allowing post-2012 credits only from projects registered in least developed countries – and set maximum limits on the use of CDM credits for compliance purposes by emission sources covered by the ETS (European Commission n.d.). These restrictions depressed demand for CDM credits, and offsets issued through the CDM declined more than 80 percent between 2012 and 2020.

Building on the experience with offsets under the CDM, several sub-national and sector-specific carbon pricing policies have integrated offsets into their design. For example, California and the Regional Greenhouse Gas Initiative (RGGI) cap-and-trade programs have included offsets as a compliance strategy for covered firms, although only businesses operating in the California market have taken advantage of this opportunity to date. The California system, like the EU ETS between 2008 and 2012, effectively treats offset credits as fully fungible with allowances for compliance purposes. In contrast, RGGI allows offsets to enter the market only if allowance prices exceed a pre-specified level. Thus, the RGGI program's offset provision operates as a "safety valve" or cost containment mechanism to prevent unexpectedly high prices. Offsets in this program are available for compliance only in high-allowance price states of the world, whereas there are no such limitations on offsets used in the California market.

In 2016, the member countries of the International Civil Aviation Organization agreed on the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), which established the goal of "carbon-neutral growth" in emissions in the international aviation sector starting in 2020. After an initial voluntary compliance period, the goal becomes mandatory after 2027 (Larsson et al. 2019). Given the challenges of large-scale commercialization of low-carbon aviation fuels, emission offsets from beyond the aviation sector will play a critical role in whether countries' international aviation sector can sustain carbon-neutrality. CORSIA could represent the single largest policy driver for demand for emission offsets – on the order of 100 to 250 $MMTCO_2$ per year – between 2021 and 2035 (Warnecke et al. 2019).

Market Drivers for Voluntary Supply and Demand of Offsets

In the 1990s and 2000s, voluntary efforts to reduce emissions often reflected expectations about, or at least the possibility of, future regulatory policy and the signals from policymakers that firstmovers would receive credit for early action. For example, President Clinton called for legislation to "reward companies that take early, voluntary action to reduce greenhouse gases" in his 1999 State of the Union address. Some firms registered emission reductions through a Department of Energy voluntary greenhouse gas reduction registry (General Accountability Office 2008; Department of Energy 2011), while others began to participate in a voluntary emission reduction market organized through the Chicago Climate Exchange. The California Global Warming Solutions Act of 2006, which launched the state's CO_2 cap-and-trade program, required regulators to provide "appropriate credit for early voluntary reductions"[2] that enabled emission offsets dating back to 2004 to be used for compliance purposes starting nearly a decade later. The American Clean Energy and Security Act of 2009, which would have created an economy-wide CO_2 cap-and-trade program, included provisions to allocate emission allowances in exchange for offset credits to firms that could demonstrate that they undertook early action to reduce their emissions.[3] After the failure of federal cap-and-trade legislation in 2010, private firms reformulated their expectations of policy-driven offsets demand.

The demand for offsets shifted to universities and firms that sought to demonstrate progress on their own voluntary emission goals. Colleges and universities have adopted emission targets in response to support from students, faculty, and donors, as part of broader experimentation by academic institutions to address climate change (Barron et al. 2021). Likewise, some firms have adopted ambitious emission goals in response to investor, consumer, and employee pressures, as well as the leadership of managers (Lyon and Maxwell 2008; MSCI n.d.). Consumer demand for emission offsets – such as for airline travel – also emerged as a driver for emission reductions (Segerstedt and Grote 2016).

[2] §38562(b)(3) of Assembly Bill 32, State of California, September 27, 2006: http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0001-0050/ab_32_bill_20060927_chaptered.pdf.
[3] §795, Exchange for early action offset credits, HR 2454, 111th Congress: https://www.govinfo.gov/content/pkg/BILLS-111hr2454eh/pdf/BILLS-111hr2454eh.pdf.

The supply of offsets has grown with the spillover from regulated markets. The developers of offset-eligible projects under cap-and-trade programs and the CDM have likewise generated emission offsets for the voluntary market. The institutional development for third-party verification and independent audits in these public programs have facilitated the emergence of firms and trained workers who can likewise assess the environmental integrity of voluntary offset projects. The active engagement of civil society with the business community in crafting standards for what is effectively self-regulation in the voluntary carbon market replicates conventional regulatory standard development. For example, the Integrity Council for the Voluntary Carbon Market (ICVCM)– governed by a board consisting of representatives from environmental NGOs, sustainable finance, academia, indigenous peoples, and other stakeholders – published a 2022 draft assessment framework on which it solicited comment for a 60-day period, akin to what a regulatory agency may do for a proposed rulemaking.[4]

The evolution of remote sensing has enabled the growth in nature-based solutions, which rely on estimated carbon sequestration from satellite imagery of biomass (Lubowksi and Rose 2020). As a result, the voluntary offsets market grew to about 200 $MMTCO_2$ in volume in 2020, just shy of the 210 $MMTCO_2$ annual volume of the CDM during the Kyoto Protocol's first commitment period, and jumped to nearly 300 $MMTCO_2$ in 2021 (Figure 1; Forest Trends' Ecosystem Marketplace 2021b, 2021c).

The variation in the composition of offset projects among voluntary markets, the CDM, and the California cap-and-trade offsets program provides some suggestive evidence of the impacts of different market drivers and institutional designs. The CDM verified more than half of its offsets volume in projects that reduced emissions of methane, nitrous oxide, and hydrofluorocarbons. Clean energy projects – such as installation of wind and solar power – represented a much smaller fraction of offsets, and the CDM did not issue any offsets for biological sequestration (carbon removal) projects, such as

[4] Refer to the public consultation at https://icvcm.org/public-consultation/ (last accessed August 19, 2022).

afforestation and reforestation (Figure 2, Panel A). In contrast, forest projects that capture CO_2 and store it in woody biomass represent more than four-fifths of offsets in the California offset registry (Figure 2, Panel B). About half of the remaining California offsets reflect projects that reduce (or destroy) ozone-depleting substances that also warm the atmosphere. There are no California offset projects that reduce emissions through renewable energy projects. In sharp contrast, renewable energy represents more than half of the voluntary offsets market in 2020 (Figure 2, Panel C). Nearly one-third of the offsets in the voluntary market reflect forestry projects. The types of projects eligible for offsets under various programs differ considerably, as evidenced by the absence of reforestation in the CDM, but its dominance in California's offsets registry, and – conversely – the absence of renewable energy in the California registry, but its dominance in the voluntary market. Determining project eligibility, and how that intersects with emerging climate policies that may mandate, subsidize, or otherwise result in the deployment of various emission-reduction technologies and activities, will play a critical role in the growth in offsets over time.

An array of private sector forecasts for the voluntary offsets market have been published in recent years. For example, the Taskforce on Scaling Voluntary Carbon Markets (2021) projected that the value of the voluntary offsets market could increase by an order of magnitude over this decade, reaching about $50 billion per year in 2030. Bloomberg New Energy Finance (2022) published three offset market scenarios, with a 2030 annual market value of $190 billion for the most bullish scenario. To put this in context, the value of the EU ETS allowance market in 2020 was about €210 billion (Refinitiv 2021). In short, the future of voluntary emission offsets is uncertain, but potentially quite significant as a means to finance decarbonization efforts.

Comparing the Environmental Risks of Offsets to Other Policy Instruments

The potential growth in offsets markets will depend, in large part, on the environmental integrity of offsets projects. If offsets do not appear to result in meaningful emission reductions or removals, then the advocates for rapid decarbonization – investors in publicly-traded firms; students, alumni, and faculty of universities; the public and key stakeholders weighing in on public policy – may oppose their use in voluntary and regulatory compliance strategies. The inability to demonstrate environmental integrity would weaken the business and financial case for investment in offsets.

To put the environmental consequences of offsets in context, consider how offsets compare with other policy instruments, such as those that subsidize specific types of low- and zero-emitting investments and those that more generally price emissions. An offset project produces a stream of emission reductions and associated offset revenues over time similar to production subsidies, such as the U.S. production tax credit and other jurisdictions' feed-in tariffs for renewable power. Clean energy subsidies, like public subsidies more generally, often suffer from a targeting challenge: making a subsidy available for an observed investment or output rewards both projects that would have happened anyway (inframarginal projects) as well as those projects that proceed as a direct result of the subsidy (marginal projects). Large fractions of inframarginal claimants can reduce the cost-effectiveness of clean energy subsidies (e.g., Houde and Aldy 2017) – the government makes payments to claimants for projects and investments they would have undertaken regardless – but such poor targeting would not increase emissions. In contrast, an offsets program with a substantial degree of inframarginal projects could engender a net increase in emissions; the buyers of the offset credits from the projects would not undertake emission mitigation within its own footprint or finance an alternative project that would have been marginal (additional). As a result, granting credits for non-additional or inframarginal projects could crowd out marginal offsets projects.

An offset project generates offsets that can be used on par with emission allowances in some emission trading programs. This is similar to a voluntary opt-in to a cap-and-trade program, such as how

Phase II generating units could opt into Phase I regulation under the U.S. sulfur dioxide (SO_2) cap-and-trade program in the 1990s (Montero 1999). Adverse selection can characterize such opt-in: sources with low or zero-cost of emission reductions (i.e., inframarginal emission-reduction projects) could opt into the market and sell allowances (in the past SO_2 market case) or offsets (in the current CO_2 cap-and-trade program context). In either case, the emission cap effectively grows by either the allowances allocated to the firms opting in or the offsets supplied by each offsets project. The environmental risk that opt-in sources may receive allowances in excess of their emissions under the SO_2 market – and hence increase overall SO_2 emissions – was limited by the five-year window for Phase I. Unless an offsets project expects to be covered by future regulation, there is not an analogous time limitation on this risk for offsets.

By considering offsets as fungible with allowances, the buyer of the offsets bears no environmental risk. The instrument has the same compliance properties as allowances and each offset conveys the holder with the right to emit one ton of CO_2 under a cap-and-trade program. In contrast, if the buyer bears liability for emissions outcomes of an offset project, then the offset has properties more akin to a bond, in which the returns are a function of the environmental integrity of the project. For example, if a firm acquires offsets from a forest preservation project, and then the protected land burns in a wildfire releasing much of the stored carbon that generated the offsets, is the buying firm liable for the environmental damage?

Does the emerging voluntary offsets market resemble a fungible, homogenous allowance-like market or more resemble a variable-quality bond market? Recent evidence reveals significant price heterogeneity in the offsets market. Prices for offset projects in Asia are about one-tenth of the prices in Oceania, and offset project prices in Europe are double those in Latin America and Africa (Figure 3, Panel A). Average offset prices by verification standard – the rules determining the quantity of offsets for a given project – likewise vary by an order of magnitude (Figure 3, Panel B). And on the demand side of the market, the average price for offsets paid by buyers differs by a factor of four across major sectors of the economy (Figure 3, Panel C). In 2020, CORSIA-eligible offsets averaged nearly $5/tCO_2$, with a spread between minimum and maximum prices of nearly $50/tCO_2$ (Forest Trends' Ecosystem Marketplace 2021a). Such price dispersion could, in theory, reflect search costs, although the availability of such information (e.g., a free report available online, Forest Trends' Ecosystem Marketplace 2021) suggests relatively low search costs. The variation in prices across verification standards illustrates the importance of the rules and protocols for project evaluation: what counts as an emission offset in one standard may not in another. To be fair, some standards differ in the types of projects they focus on, and the differences in costs among project types could explain some of this variation. And the correlation among some project types and geographies may also explain some of the variation in prices across countries. The absence of price convergence among buyers, however, signals differences in the rules that individual companies employ to identify appropriate offsets for their acquisition. These price data are consistent with a segmented market in which some firms purchase offsets with lower environmental integrity or greater environmental uncertainty than others. The heterogeneity in prices may also reflect fundamental differences among corporate decision-makers in terms of the effective reserve prices they are willing to pay for offsets in implementing their voluntary emission goals.

Challenges in Evaluating Emission Impacts of Offsets'

While conceptually appealing as a low-cost way to reduce emissions, implementing offsets in practice raises a number of challenging issues (Aldy and Stavins 2012). What would have happened without the project –the counterfactual scenario – may be challenging to illustrate and impossible to guarantee. The potential for offsets projects to undermine environmental integrity of regulatory and voluntary schemes has motivated considerable effort among regulators, civil society, and the private sector to develop rules to evaluate the emission reductions and removals of offset projects. Demonstrating that a project delivers emission benefits, however, is daunting given that the comparison must be made relative to an unobserved counterfactual scenario. In contrast to a carbon tax, cap-and-trade program, or emission performance standard in which compliance reflects monitored and measured emissions, offsets reflect estimated emission reductions or removals. Consider a number of potential threats to the environmental integrity of offsets, which can then inform the development of rules – private and regulatory – that could enable a more liquid, high-integrity offsets market.

First, systematic biases in estimating baseline counterfactual scenarios could result in excessive estimates of emission reductions. For example, voluntary projects to reduce deforestation and forest degradation in the Brazilian Amazon employed ex ante baselines with higher rates of deforestation than evident through ex post, quasi-experimental estimation of deforestation (West et al. 2020). A key factor in this analysis, which we return to below, is the failure to account for national public policies that may affect the baseline activity that characterizes the potential for emission reductions and removals by offset projects.

A recent analysis of CDM wind farm projects in India found that more than half of the certified projects – representing 52 percent of the tons of issued offsets – were "blatantly inframarginal projects" (Calel et al. 2022). They found that these CDM-qualifying projects had more profitable characteristics along each of a number of project dimensions than non-CDM projects that came online in the same state and year. Since the CDM offsets do not appear to be necessary for these projects to have moved forward, the estimated emissions offsets are not likely to be additional to what would have happened anyway.

Related to this, offsets may create incentives for firms to manipulate the baseline. Recall from Figure 2 that, on a CO_2-equivalent basis, one-quarter of CDM credits over 2008 to 2020 reflected reductions in hydrofluorocarbons (HFCs). In the early implementation of the CDM, Chinese manufacturers built excess capacity for producing a specific HFC because they found it financially advantageous to then shut down this capacity in order to generate CDM credits (Wara 2007). In effect, the revenues of HFC-based CDM offsets induced firms to inflate their baselines by expanding HFC capacity that they would then, in turn, destroy to generate emission reductions, on paper at least.

Understanding whether a project would have occurred in the absence of financing through offsets requires an assessment of the underlying finances of a project. The challenge lies in the fact that many offsets projects, especially in the energy sector, are associated with an activity with private market value. Building a wind farm may displace carbon-intensive power generation, and in doing so it produces both electricity and emission offsets. Installing a more efficient industrial boiler could reduce emissions and enhance the value of energy services at a manufacturing plant. There may be some exceptions; for example, a carbon capture and storage project does not deliver an ancillary (or primary) revenue source other than through the emission-reduction activity. If such a project, however, receives substantial subsidies from other policies (e.g, the Section 45Q tax credit in the United States [Jones and Sherlock 2021]), there may still be a question of whether the firm would have undertaken the investment in the absence of the offsets revenue stream.

Second, the design of offsets rules could induce adverse selection into the market and the resulting crediting errors can undermine environmental integrity. Common practice to estimate emission reduction potential in improved forest management (IFM) projects requires forest data to be aggregated across species and geographies. Designating regions that lack sufficient homogeneity of tree type can cause the average regional value of a metric ton of CO_2 per acre to not accurately reflect the average benefit derived from IFM projects in that region. In other words, IFM projects around low carbon density forests are receiving credit for high carbon density forests that share the same region. For example, Badgley et al (2022) estimate crediting errors in California’s forest offset program have resulted in the over-crediting of 29 percent of offsets issued for compliance purposes in the California cap-and-trade market. In effect, the rules for California forestry offsets facilitate adverse selection: by employing regional averages for estimating biological sequestration, landowners can select the low-density parcels in their forests with specific below-average sequestration for participation in the offsets program. Efforts to reduce the administrative burden and transaction costs for offsets, in this context, have undermined the environmental integrity of the program. This represents about 30 $MMTCO_2$, valued at more than $400 million.

Third, considerable attention has focused on the risk of double-counting emission reductions from offset projects. Much of the concern is due to the lack of standardization of offset registries and incomplete disclosure on the use of emission offsets. For example, if the construction of a facility or the implementation of a project enables compliance with that jurisdiction's regulations or policies, then such project would not be in a position to also produce emission offsets. A wind farm could generate and sell renewable electricity credits under a renewable portfolio standard, thus enabling a utility to comply with the policy. If it also sold emission offsets as a function of its power generation, this would represent a form of double-counting.

Fourth, emission offsetting investments could have general equilibrium impacts that undermine the environmental integrity of any given project. Securing one forest parcel for biological sequestration may increase the rents for clearing another forest parcel, and thus reduce some of the net environmental benefit of the offset project (Monge et al. 2016). Building a wind farm to displace a coal-fired power plant may reduce demand for coal, and thus improve the economics of another firm to build or maintain a coal-fired power plant that they might not have done otherwise. This represents a form of emission leakage from the offsets market, and it could become substantial to the extent that the voluntary offsets market grows faster than public regulatory schemes that cover the emission sources that supply offsets.

Likewise, using offsets to subsidize the deployment of new energy projects, such as wind and solar farms, may undermine incentives for conservation and energy efficiency. By increasing the supply of electricity, without penalizing or regulating existing fossil energy sources, offsets could lower energy prices in markets relative to a no-offset counterfactual. This could counter some of the offsets projects' emission reduction benefits. For example, Calvin et al (2015) employ a global energy-economic model to show that clean energy offset projects satisfying project-specific additionality criteria could deliver less than one ton of global emission reduction for every two tons of credit because of such energy system impacts.

Fifth, the environmental benefit from the offset – especially in the case of afforestation and reduced deforestation activities – may depend not only on investment today, but the preservation of the biomass for decades into the future (permanence). A forest fire or future decision to clear the land effectively eliminates the stream of offsets estimated in the interim. Indeed, with growing wildfire risk in various parts of the world due to a changing climate, a good-faith effort to remove carbon from the atmosphere through forest protection could be undermined by forest fires.

These causes of environmental risks in emission offsets can prompt – and in many cases have prompted – rules and policies to reduce these risks.[5] Ex ante project assessment and verification protocols can address, to some extent, baseline bias and baseline manipulation risk. Such protocols may also serve as the basis for ex post audits of projects to ensure that they satisfy the standards established in verification protocols. While verification and auditing may be sufficient to demonstrate compliance with these standards, experience indicates that they do not eliminate the possibility that offsets deliver less than their verified emission reductions.

[5] For recent examples, refer to the REDD+ Environmental Excellence Standard developed by the Architecture for REDD+ Transactions at https://www.artredd.org/trees/, which has been employed to assess proposals to the LEAF Coalition, a public-private partnership financing reduced deforestation. Also refer to the Core Carbon Principles developed by the ICVCM at https://icvcm.org/public-consultation/, (websites last accessed August 19, 2022).

Recent efforts in ex post performance evaluation, which include empirical estimation of the counterfactual based on real-world experience, could inform further institutionalization of program evaluation techniques to confirm the environmental value of offsets projects. Establishing public protocols for conducting performance evaluations and committing to undertake them at the outset of a project could ensure the credibility of evaluations and provide an opportunity for public and expert feedback on evaluation methods. Such efforts could draw from the emerging literature and policy practice in program evaluation and retrospective review of regulations (Aldy 2014, 2022).

Leakage risk, whether it reflects general equilibrium market incentives or the lack of permanence of nature-based solutions, suggests the potential value in risk-management instruments. The next section turns to how financial innovation could influence the evolution of the voluntary offsets market to enable environmental integrity and accelerated decarbonization.

Building a Robust Offsets Market

Financial innovation can emerge in ways to enhance the liquidity, integrity, and robustness of emission offsets markets. As a starting point, it's important to address the fundamental financial characteristics of an offset. Is an emission offset similar to a commodity, like emission allowances under cap-and-trade programs, or more like a bond? In effect, does the buyer bear any liability for the environmental integrity of the offset project?

Recent private sector proposals and initial public policy efforts illustrate the various ways of addressing these questions. For example, the Taskforce on Scaling Voluntary Carbon Markets (TSVCM) (2021), spearheaded by Mark Carney, former Governor of the Bank of England, and Bill Winters, Chief Executive Officer of Standard Chartered, included more than 50 members representing various supply, demand, financing, and related market infrastructure of the voluntary offsets market. The TSVCM recommended standardized futures and spot benchmark contracts to facilitate a liquid market in offsets. Such benchmark contracts would be analogous to standardized futures contracts for crude oil, such as the CME NYMEX crude oil futures contract, which specifies the volume (1,000 barrels), grade (West Texas Intermediate), delivery location (Cushing, OK), pricing (U.S. dollars per barrel), and timing (month of contract). Such standardized contracts for emission offsets would effectively commodify offsets and could deliver two benefits: enable price discovery that can reduce price dispersion in the market and provide quality screening of offsets. The recent work of the ICVCM has focused on establishing a high environmental-quality, standardized benchmark that could serve as the basis for futures and spot contracts.

CBL, a market-maker in energy and environmental financial products, established the Global Emissions Offset (GEO) spot contract, and CME Group offers a futures contract based on the GEO standard (CBL 2021, CME 2021). The GEO spot contract specifies the volume (one metric ton of carbon reduced), quality as determined by one of three verification protocols (American Carbon Registry, Climate Action Reserve, and Verified Carbon Standard), pricing (U.S. dollars per metric ton), and delivery and timing (immediate via electronic registry account). The GEO contract is designed to satisfy the requirements of the CORSIA program under the International Civil Aviation Organization. Buyers of GEO contracts could use them to demonstrate compliance with CORSIA requirements or to represent progress toward their own voluntary emission goals.

Despite recent financial product development, there exist several limitations to structuring offsets as commodities. First, commodities markets require a high degree of liquidity to function in a robust manner and facilitate price discovery. Ongoing debate about the role of carbon offsets in corporate net-zero pledges, as well as the future form and ambition of climate change policies, cast a shadow of uncertainty on long-run private demand for offsets.

Second, benchmark contracts need to dominate market share in order to be effective. A key underlying assumption in commodifying offsets is that there exists a uniformity (or near uniformity) of firm preference toward high-quality offsets (that would meet the benchmark contract standards). If market segmentation emerges – with a cohort of firms opting for low-environmental quality, low-cost offsets (which can often trade at $1-2 per metric ton of CO_2) and another cohort opting for higher-quality, higher-cost offsets, there would be difficulty in establishing a benchmark contract with sufficient market demand. As illustrated in Figure 3, the absence of price convergence among regions, verification standards, and buyers, may provide some evidence of early market segmentation.

Third, the heterogeneity of carbon offset project types may complicate standardization and pose challenges to implementing feasible and environmentally adequate quality screening criteria. For example, removing CO_2 from the atmosphere through industrial direct air capture and storing it in a deep geological formation may be measurable and likely considered permanent. CO_2 removal through nature-based solutions may be more uncertain – requiring estimation models based on remote sensing data – and subject to greater questions about long-term permanence. And a CO_2-avoidance project, such as building a wind farm instead of a presumed counterfactual coal-fired power plant, likewise relies on estimation and key assumptions about the counterfactual and emission leakage. The variation in prices by project types may reflect differences in costs of avoiding or removing CO_2, but they may also reflect differences in environmental certainty, additionality, and integrity (Figure 4). How to compare a metric ton of CO_2 under each of these three projects through verification protocols will play a key role in determining the potential to commodify offsets project outcomes through spot and futures contracts.

In contrast, securitizing offsets into bonds would condition investor coupon payments on the emission outcome of the carbon-offsetting project. Under such an instrument, if a project does not deliver the stated emissions reduction, avoidance, or removal, the bond buyer would bear the liability, and thus be exposed to contractual risk. This would be analogous to social impact bonds (Liebman

2011). Rating agencies could evaluate specific projects, or a portfolio of projects reflected in a bond, and provide information on likely environmental outcomes.[6] Groom and Venmans (2022) present a method for calculating the social value of offsets that accounts for permanence and additionality concerns. Such quantifications could inform bond pricing as well as offset project insurance pricing.

The April 2022 proposal on climate-related disclosure by the Securities and Exchange Commission indicates that publicly traded companies covered by disclosure requirements would need to identify the financial risks associated with nature-based offsets that may need to be written off or replaced in the event of a wildfire or other factors reducing their emission-removal benefit. This differs from many allowance trading markets that have been fairly liquid (e.g., the EU ETS, U.S. SO_2 cap-and-trade program) because of the implicit seller liability characterizing transactions. The experience from policy-created markets illustrates some pitfalls with a buyer liability approach.

For example, the Environmental Protection Agency (EPA) implemented the Renewable Fuel Standard (RFS2) through a system of tradable credits (referred to as RINs). Biorefineries generate RINs as a function of the production volume and carbon intensity of their biofuels. In turn, refineries, blenders, and importers are required to purchase these RINs to satisfy their renewable volume obligations set under the regulation. The RIN program initially imposed liability for acquiring fraudulently created RINs on the buyers with renewable volume obligations. After several cases of fraud emerged, RIN market liquidity fell as the buyers had to undertake additional diligence to assess the quality and validity of any given set of RINs. Eventually, the EPA implemented a Quality Assurance Program that verifies RINs and effectively eliminates the buyer liability standard for any buyer that acquired the QAP-audited RINs (Aldy 2019).

[6] For example, the firm BeZero provides risk ratings on offsets used in voluntary carbon markets in a manner analogous to conventional credit rating agencies (refer to https://bezerocarbon.com/ratings/, last accessed August 19, 2022).

The California cap-and-trade program allows regulated firms to use emission offsets for compliance, some of which are subject to a buyer liability standard. The results of this approach appear to be mixed to date. Initially, some offset project developers expressed reservations about the buyer liability scheme because of the uncertainty it would introduce to a new market. Advocates of offset buyer liability have emphasized the low rate of offset invalidation – about 0.3 percent over the first seven years of the program – and large volume of offset generation – about 5 $MMTCO_2$ per year under the portion of the offsets program subject to buyer liability – as evidence of a liquid, high-environmental integrity market (Roedner Sutter 2020). It is difficult, however, to square this low rate of invalidation of 0.3 percent with the 29 percent estimated over-crediting, described above, for California's forestry offsets programs (Badgley et al. 2022). This discrepancy could reflect the fact that the conditions that would trigger a liability for a buyer may be a small sub-set of the factors contributing to less-than-expected emission reductions or removals by projects.

The emergence of various verification protocols highlights the importance of producing information in offsets markets to enable buyers to discern low-quality from high-quality offset projects. To signal the quality of offsets and improve the liquidity of offsets markets, a variety of financial instruments could be deployed. For example, bonding and insurance could reduce the uncertainty associated with and enhance the risk management of threats to the permanence of nature-based offsets projects. If the global voluntary offsets market grows to at least $50 billion by 2030, then an associated insurance market could be worth at least $1.3 billion globally (Carr et al. 2021; Figure 5). Existing insurable physical risks emanating from natural disasters and causes could be synthesized with adjacent market-specific risks in the crop and timber fields. Howden and energy risk company Parhelion also developed an offset invalidation insurance product, which covers the replacement cost for offsets under California's cap-and-trade scheme. Finally, to address leakage, a new insurance instrument could be required through government regulation of offsets markets, established as a condition for third-party verification, or encouraged by investors and other key stakeholders for adoption by firms voluntarily buying offsets. This insurance instrument could pay out, in the form of additional emission reduction projects, in the event that an ex post leakage from offsets projects is identified. Such an approach would likely require monitoring and evaluation methods to ascertain the scope of the emissions loss that could occur through threats to permanence or leakage.

Creating securities backed by portfolios of offsets projects could reduce the risk buyers face of project-specific environmental failures and maximize material impact through diversification of project types (Climate-Related Market Risk Subcommittee 2020). Such instruments could also lower the cost of financing the supply of offsets. Enabling the trading of derivative products could enhance price discovery in offsets markets that could facilitate greater investment in high-integrity offsets projects. Derivatives markets already exist in regulated environments: the Intercontinental Exchange provides a platform for transacting futures and options for carbon offsets associated with the EU ETS, California's cap-and-trade program, and the UK's emissions trading scheme (ISDA 2021). Swaps are also commonly employed (ISDA 2021).

Technological advancements can also improve the transparency and evaluation of offset quality and facilitate greater market efficiency. For nature-based solutions, carbon removal and storage quantities are derived by examining total biomass, which must be estimated based on the size and density of forests. Satellite imagery and LIDAR, in conjunction with machine learning, can improve the monitoring and attestation of many offset projects.

The variation in reporting among project developers and verification protocols can undermine transparency in the voluntary offsets market, and the lack of uniformity may increase the likelihood of double-counting of offset credits. To mitigate double-counting risk, blockchain technology could play a role in monitoring and tracking offset transactions. A blockchain system has information recorded in a distributed ledger and is thus decentralized. Given the near impossibility to hack into or modify the distributed ledger, using blockchain for carbon credit tracking can buttress the informational veracity of offsets. Additionally, carbon credits can be tokenized on a blockchain, and the resulting non-fungible token (NFT) can be transacted with a guaranteed uniqueness and verification.

Realizing the potential for financial market and technological innovation in emission offsets will require the development of rules and standards for evaluating offset projects' financial and environmental risks. Remarkable experimentation has emerged over the past decade, with various rules and guidelines governing third-party verification protocols, spot and futures contracts, regulatory approval of offsets, and firm-specific offset acquisition processes. Enhancing transparency and convergence on common standards would enable greater liquidity and enhance the environmental integrity of offsets markets. This has implications for reporting and disclosure on projects, the parameters of a standard derivatives contract, and the potential role of financial regulatory oversight.

Policy Implications of Growing Voluntary Offsets Markets

The growth in voluntary offsets markets reflects, in part, the gap between governmental goals and government mitigation policies. Many of the universities and businesses driving the offsets markets are doing so as part of their "Paris-aligned" emission goals. These represent more ambitious implementation than that of virtually any government participating in the Paris Agreement. When and how government policies catch up with governments' ambitious emission goals will have important implications for the voluntary offsets markets. We close by teeing up questions about the potential interactions among and co-evolution of voluntary offsets markets and climate change policies.

First, would a growing voluntary offsets market create a larger business constituency in support of a national carbon pricing policy? The political economy of carbon pricing has long been challenging. Engaging more and more businesses in decarbonization, including through the supply and acquisition of offsets, may enable broader business community support for national emission mitigation policy. Moreover, the price per ton for an offset – to the extent that convergence in offset prices emerges in voluntary markets – could serve as a focal price to inform the setting of a carbon tax or in designing regulatory approaches, such as a clean electricity standard or a cap-and-trade program, which could include carbon price cost containment mechanisms (e.g., Aldy 2012). New climate policy that recognizes offset project investment with "credit for early action," as considered in past U.S. legislative proposals, could secure support from some incumbents in voluntary carbon markets. In contrast, these voluntary efforts could simply lock-in offset markets and deter the development of national climate policies.

Second, how does the evolution of public policy influence offset project eligibility and the counterfactual used to estimate offsets? Consider the case of a wind farm in a jurisdiction without any renewable power regulations or other related policies, that generates emission offsets relative to a counterfactual coal-fired power plant. An array of potential policies could reduce the estimated emissions offsets from this project, from standards that would phase out coal-fired power plants, to renewable power mandates, to subsidies and tax credits for wind farm output. The possibility that future policies and regulations could reduce the offset revenues of clean energy projects may have a chilling effect on offsets investment. For firms that are already incumbents as suppliers of offsets to the voluntary market, this may inform how they would engage on and influence – and potentially oppose – future climate change regulation and policy discussed under the previous question. In the event that future regulatory policies include offsets as a compliance strategy, the ongoing efforts of civil society and the business community to establish standards and verification processes could inform the design of regulatory standards for offsets projects. This may reflect policy innovations at the state level (e.g., California), national level, and international level, such as the agreement at the 2021 Glasgow climate talks on a successor to the CDM and rules for cross-border trading of emission reduction efforts (UNFCCC 2021).

Third, how could climate-related disclosure regulations influence the evolution of the voluntary offsets market? Disclosure requirements could create incentives for greater transparency in the standards for verifying and auditing emission offsets, and potentially establish a common, minimum standard for environmental integrity. Such requirements may also clarify emissions accounting rules, such as for emissions beyond the boundary of the firm (e.g., scope 3 emissions in a firm's supply chain), to reduce the prospect for double-counting. Transparency about a firm's use of internal carbon pricing in the acquisition of emission offsets may also send more information to potential offset suppliers and enhance market liquidity.

Fourth, how could innovation in the data and methods for ex post evaluation of offsets projects and programs inform the assessment of environmental integrity and the development of risk management instruments in the financial sector? With greater precision in monitoring and measurement data enabling broader application of causal inference statistical tools, more rigorous program evaluation methods could estimate the emission impact in practice of offset projects and overall offset programs. This rigorous evidence could inform instruments premised on buyer liability, the pricing of insurance policies, or the accounting of progress toward net-zero and other emission goals.

Finally, given recent political interest in carbon border adjustments, could an importer reduce its carbon tariff obligations through offsets? Under a carbon border adjustment mechanism, a covered imported good would need to pay a tariff as a function of its carbon intensity. Emission offsets could enable the producer of the good to claim that its emissions are lower than estimated for that class of good. Alternatively, the producer could argue that it acquired offsets at a carbon price that would be on par with the price that producers in the importing market face, thus ensuring the level playing field and lack of potential emissions leakage that would justify the carbon border adjustment mechanism. In either case, the producer would face lower or zero tariffs, so long as the importer's regulatory agency recognizes the offsets. Allowing such an exemption or modification to the carbon tariff could enable the carbon border adjustment mechanism to spur the offsets market in under-regulated jurisdictions around the world. Doing so may, as noted in the first point, then create positive policy feedbacks for more ambitious decarbonization policies in those exporting countries.

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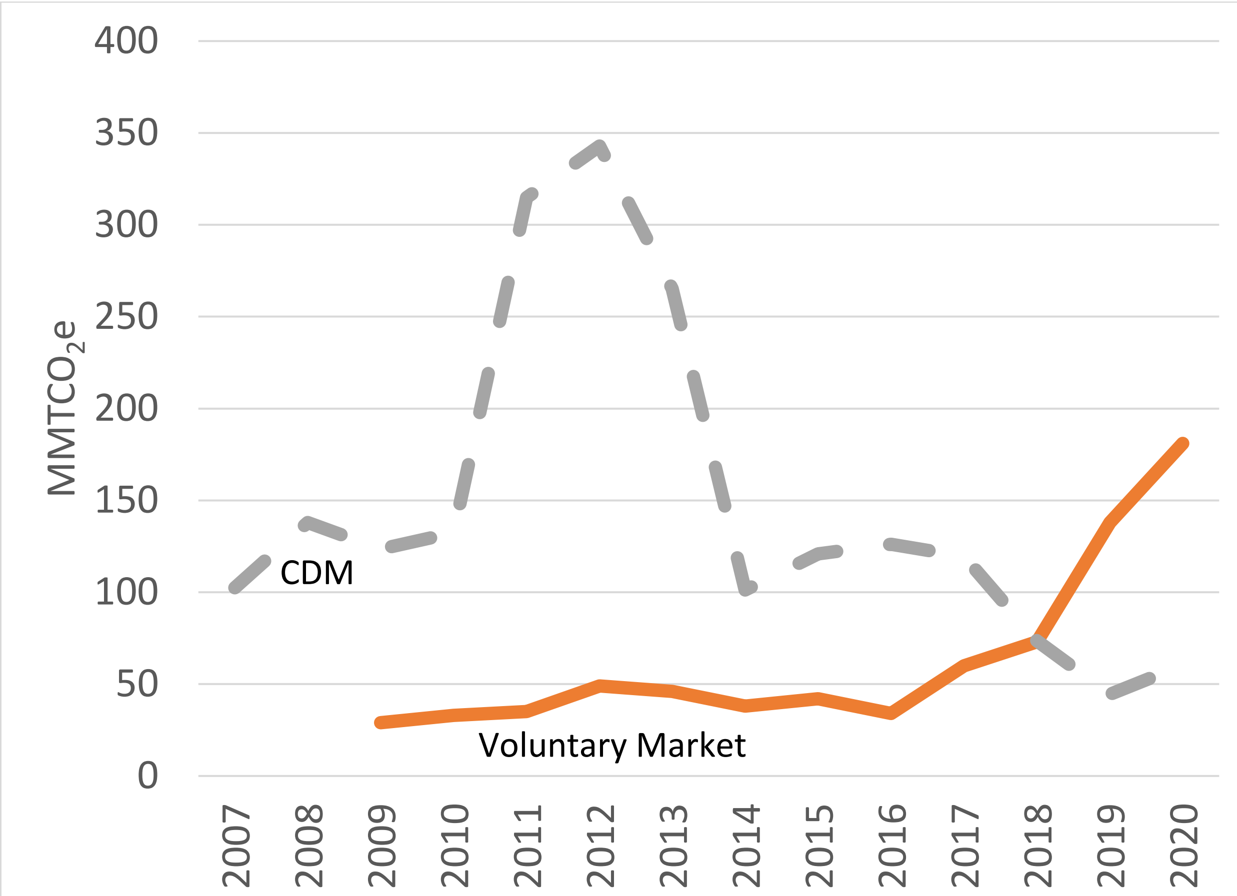
FIGURES

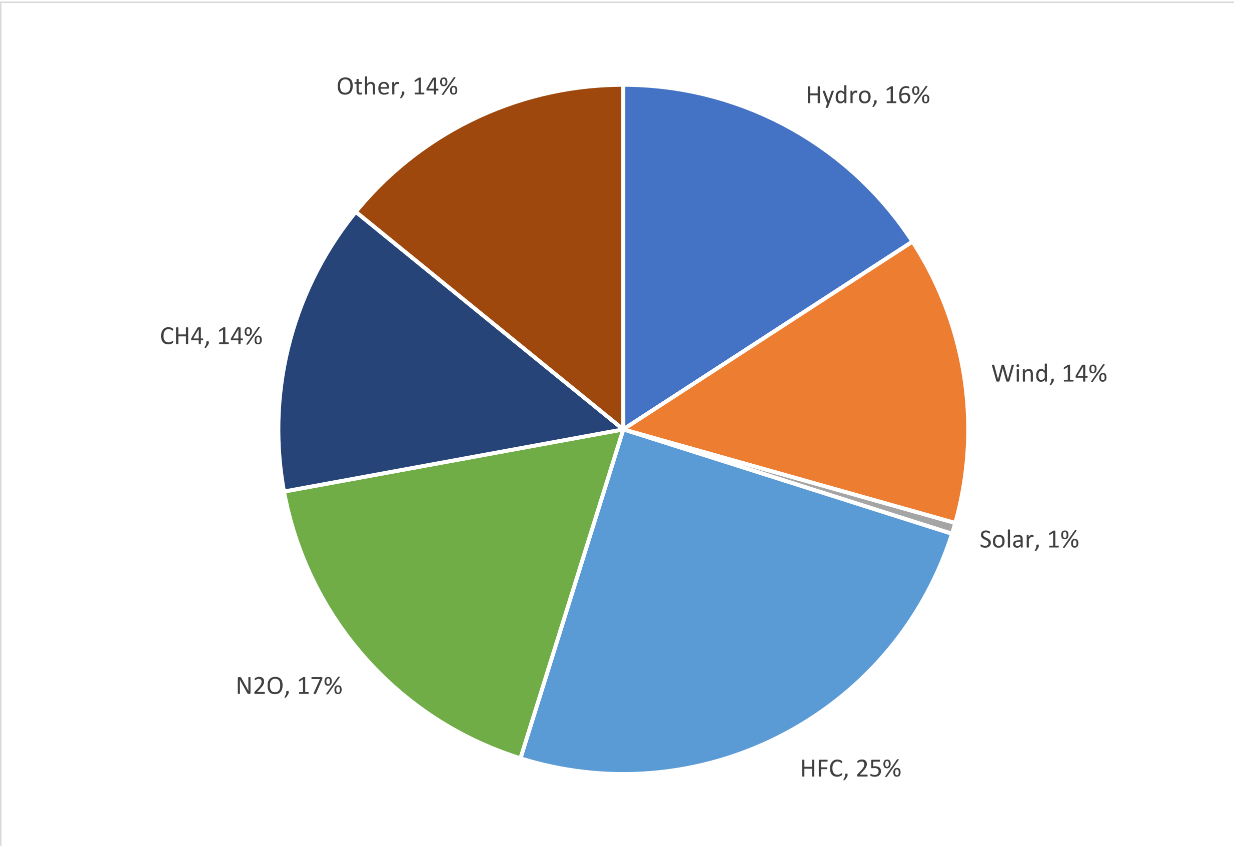
Figure 1. CDM and Voluntary Market Offset Volumes, million metric tons of CO_2-equivalent, 2007-2020



Sources: TSVCM (2021) and UNFCCC Clean Development Mechanism database, available at: https://cdm.unfccc.int/Statistics/Public/files/202202/cerstypenum.xls, last accessed April 7, 2022.

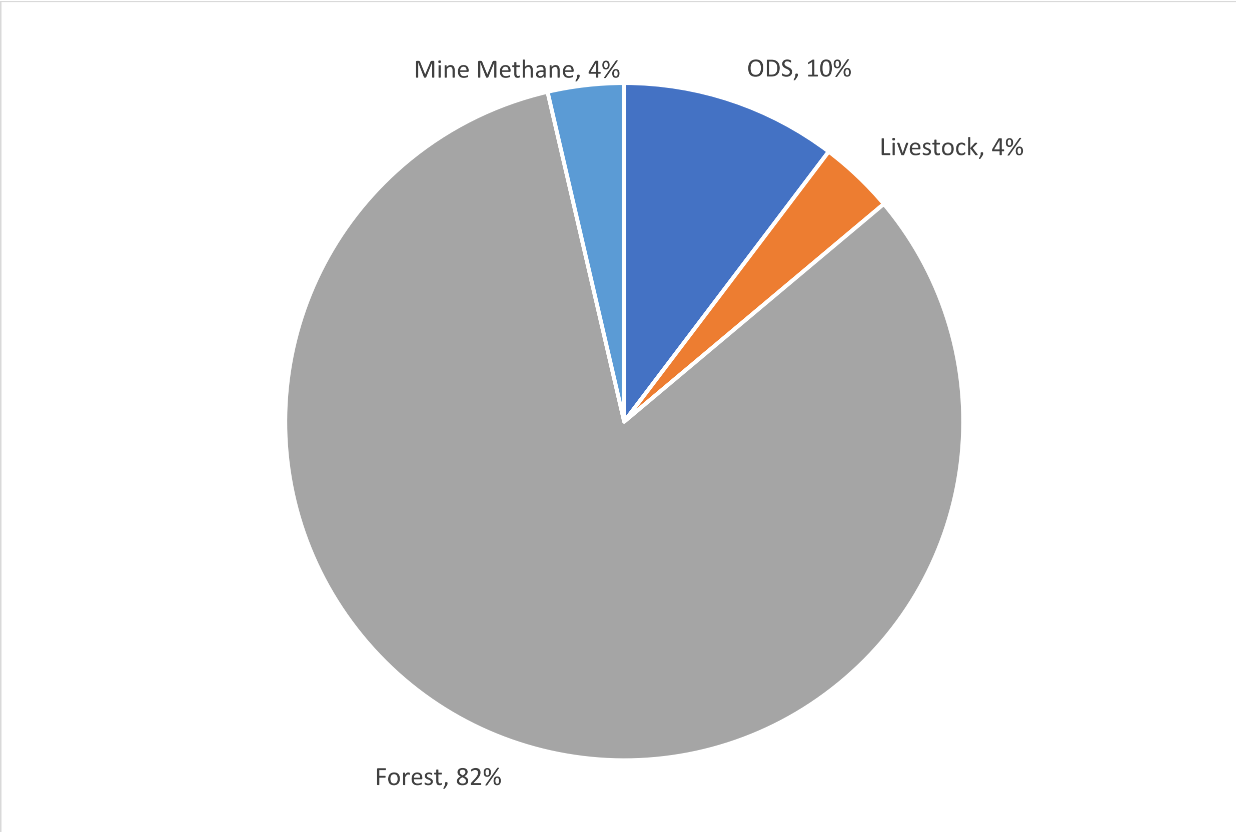
Figure 2. Distribution of Offsets by Project Type, Clean Development Mechanism (top), California Offsets Registry (middle), Voluntary Market Registries (bottom)

Panel A. Clean Development Mechanism 2008-2020



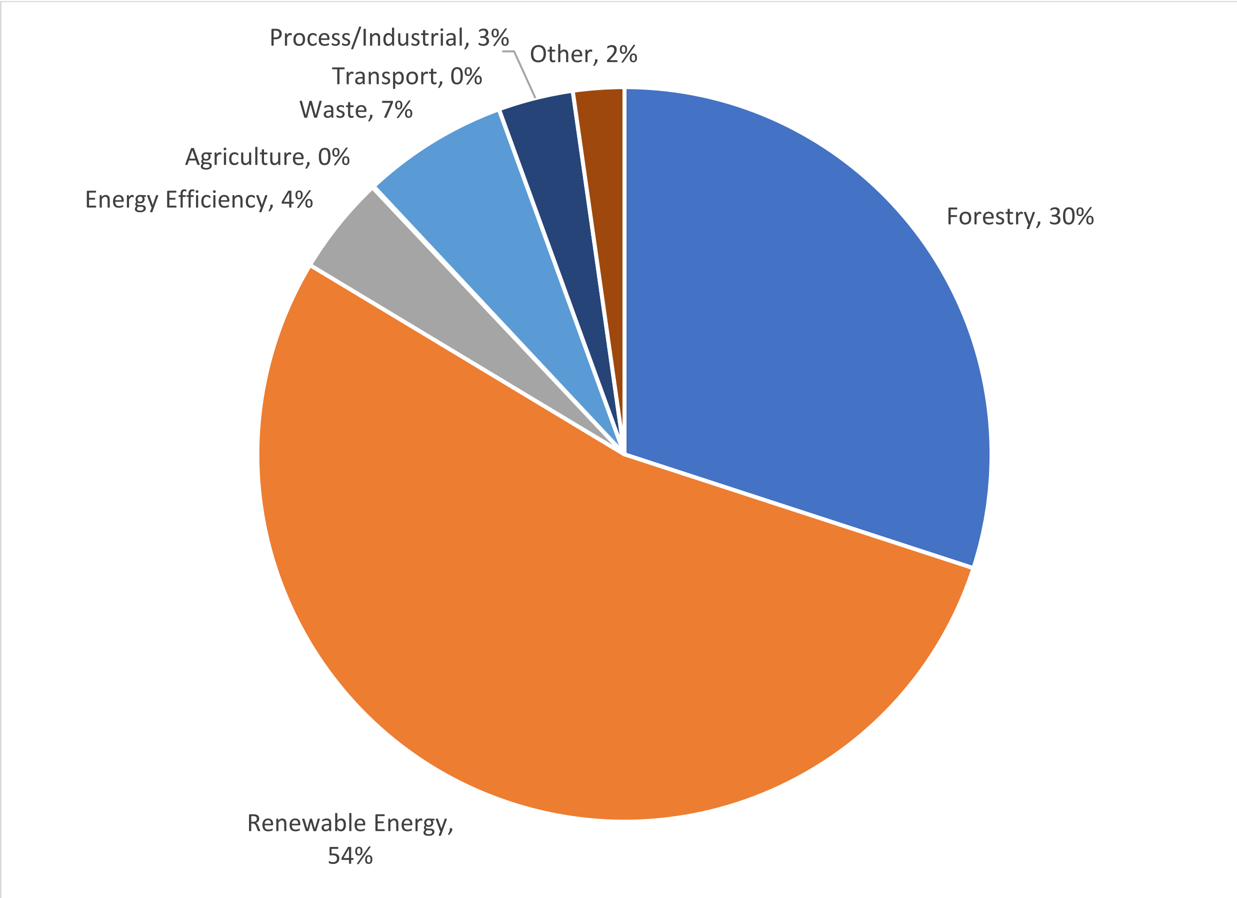
Notes: The CDM did not issue certified emission reduction offsets to biomass projects.
Source: UNFCCC Clean Development Mechanism database, available at: https://cdm.unfccc.int/Statistics/Public/files/202202/cerstypenum.xls, last accessed April 7, 2022.

Panel B. California Offsets Registry, 2008-2020



Notes: The California program recognizes urban forest and rice cultivation projects for emission offsets, but has not issued offset credits for these categories.
Source: California Registry of offset credits issued by the California Air Resources Board, available at URL: https://ww3.arb.ca.gov/cc/capandtrade/offsets/issuance/arboc_issuance.xlsx, last accessed April 7, 2022.

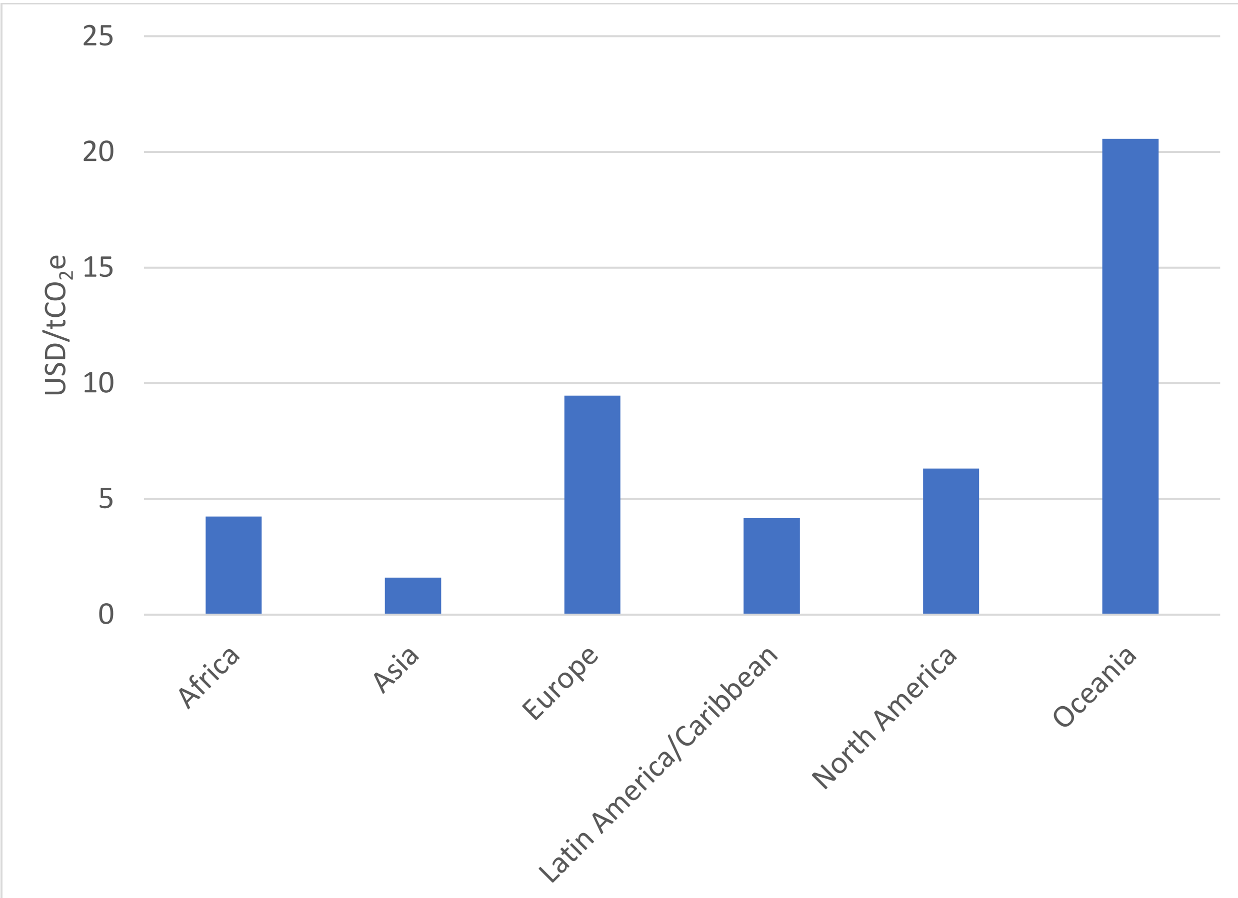
Panel C. Voluntary Market Registries, 2020



Source: Forest Trends' Ecosystem Marketplace 2021b.

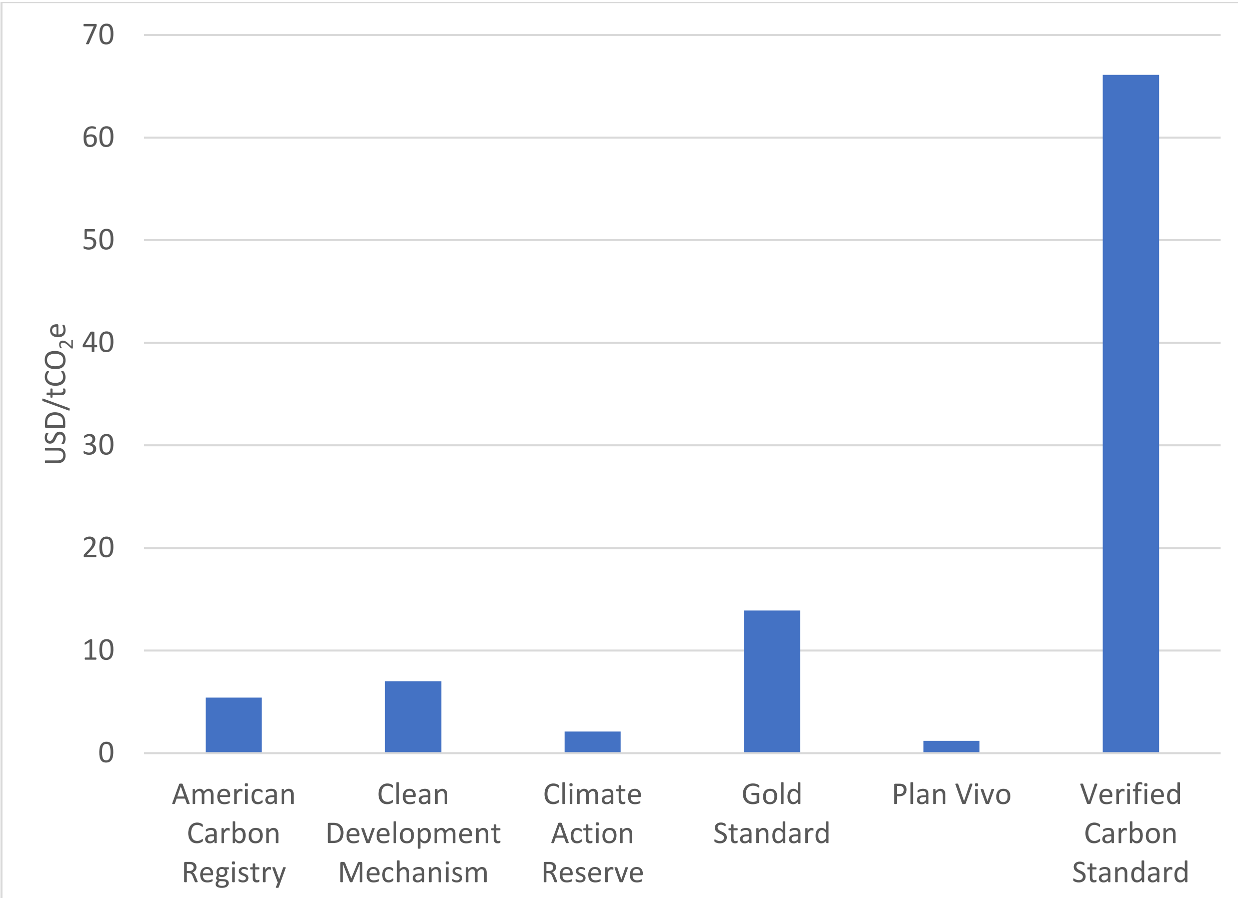
Figure 3. Variation in Offset Prices by Source Region, Verification Standard, and Buying Sector, 2020

Panel A. Offset Prices by Region, 2020



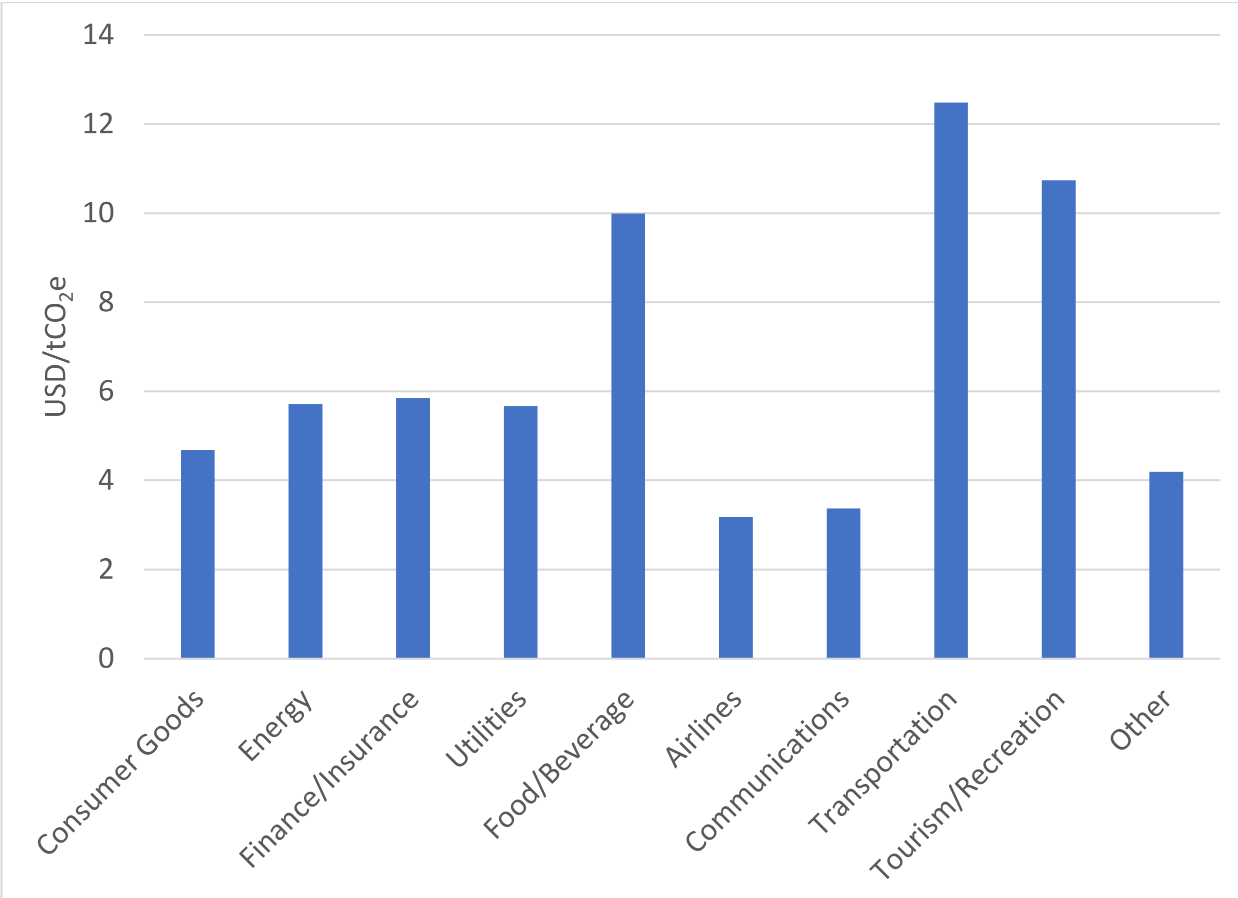
Source: Forest Trends' Ecosystem Marketplace 2021b.

Panel B. Offset Prices by Verification Standard, 2020



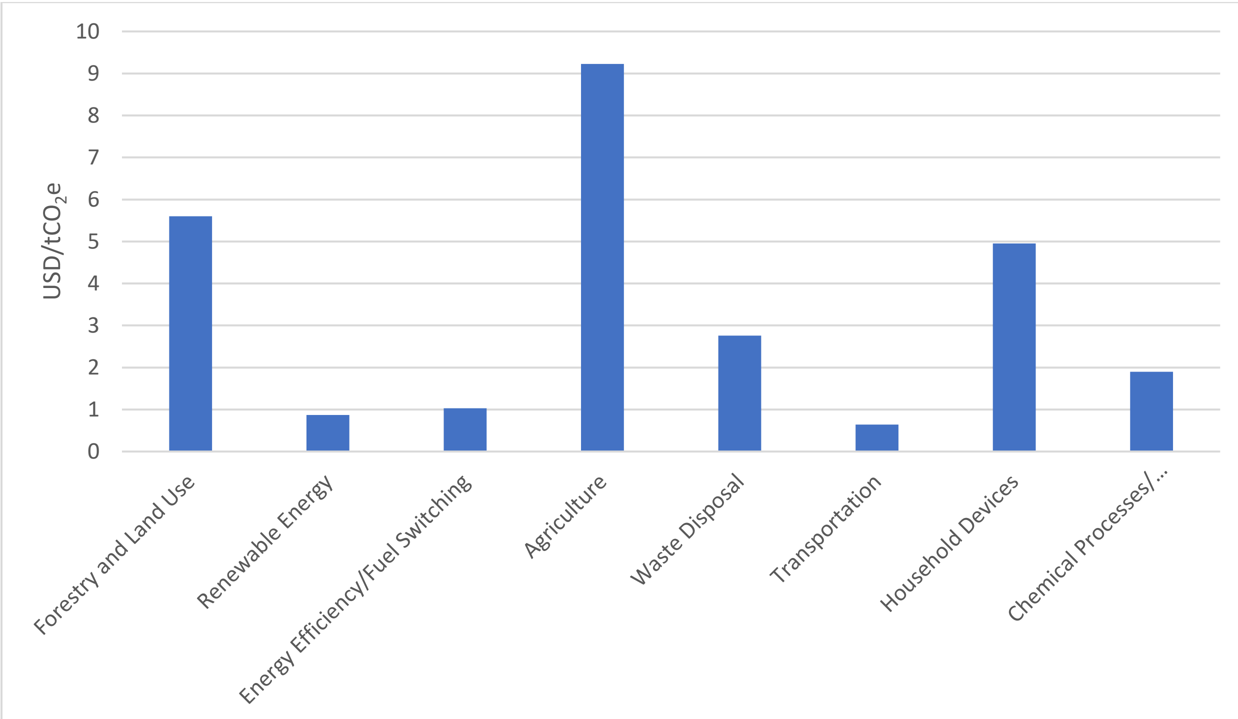
Source: Forest Trends' Ecosystem Marketplace 2021b.

Panel C. Offset Prices by Buyer Sector, 2020



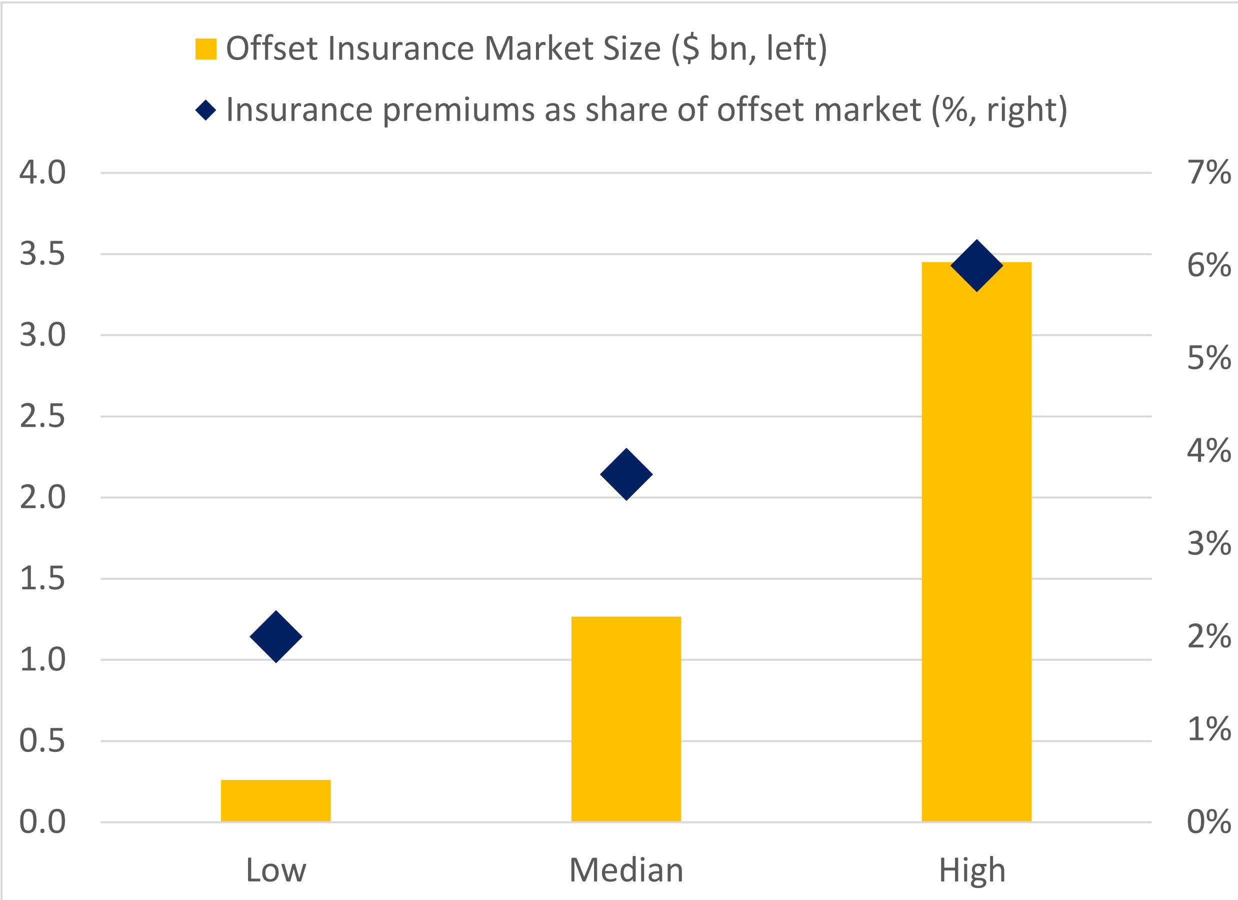
Source: Forest Trends' Ecosystem Marketplace 2021b.

Figure 4. Variation in Offset Prices by Project Type, 2020



Source: Forest Trends' Ecosystem Marketplace 2021b.

Figure 5. Projections of the Voluntary Carbon-linked Insurance Market in 2030



Source: Carr et al. 2021.

Notes: The low, median, and high scenarios reflect variation in assumptions of overall offset market size, share of market covered by insurance, and premiums as a share of nominal offset values. The 2030 offset market is assumed to range from $13 - $50 billion, with insurance penetration rates ranging from 20 to 30 percent, and average premiums ranging from 10 to 20 percent of offset value.