Navigating the Green Tightrope: Carbon Offsets, Decarbonization, and Risk

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Abstract

Carbon offsets have become increasingly a controversial way of addressing GHG emissions in a bid to reduce climate change. Proponents argue that the use of offsets and the development of voluntary carbon markets for these offsets represents a critical tool in addressing climate change. Critics suggest that they represent a distraction and an ineffective tool. In this paper, we investigate if offset reliance is a substitute or a complement to decarbonization, whether risk measures reflect a firm's reliance on offsets, and the factors that explain variation in offset prices. This study aims to inform investors, policymakers and businesses about the prospects and risks underlying the reliance on carbon offsets for decarbonization.

Keywords: Carbon Offsets, Carbon Markets, Decarbonization, Risk, Climate Change.

JEL Codes: G11, G12, G15

Key Takeaways:

1. We find that in years with higher decarbonization rates organizations rely more on offsets.
2. We also find that organizations with higher emissions rely less on offsets, suggesting that organizations that have "more room" to reduce emissions would use fewer offsets.
3. We find little evidence that market-based or analyst-derived measures of risk reflect the inherent risk in different decarbonization and offset reliance strategies.
4. Our model explains two-third of the variation in carbon offset prices.

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Introduction

An organization's carbon footprint has emerged as a key risk consideration in recent years. Customers might show preference for products with lower carbon emissions, governments might tax carbon emissions or exclude high emission products from tax incentives and subsidies, investors might give better access to finance to companies with lower carbon emissions, employees might prefer to work for organizations with lower carbon emissions, and social activists might damage the reputation and brand of companies with high carbon emissions. Carbon emissions, therefore, could represent a liability for an organization giving rise to an expectation that the organization will incur future expenses to mitigate those emissions.

In turn, organizations could reach their own internal targets to "net zero" or "carbon neutrality" by making investments that lead to reductions in carbon emissions over time (decarbonization), purchasing carbon offsets, or a combination of both. In this paper, we seek to understand if offset reliance is a substitute or a complement to decarbonization, for organizations that report sufficient data to quantify those activities, and whether risk measures reflect a firm's reliance on offsets. Moreover, we provide insights into the quality of carbon offsets, analyzing the factors that explain variation in their prices.

What are Carbon Offsets?

The idea of carbon offsets gained formal recognition and momentum with the Kyoto Protocol, an international treaty adopted in 1997. The Kyoto Protocol established legally binding obligations for developed countries to reduce their greenhouse gas emissions. It introduced market-based mechanisms, such as the Clean Development Mechanism (CDM), which allowed countries with emission-reduction commitments to invest in emission reduction projects in developing countries to earn carbon credits. These carbon credits could then be used to meet a portion of their obligations under the treaty. This framework laid the groundwork for the concept of carbon offsets by recognizing that reducing greenhouse gas emissions in one part of the globe contributes to the global effort against climate change, irrespective of where the reduction takes place.

Carbon offsets are developed and sold by a variety of entities, including specialized carbon offset providers and sometimes by the projects themselves. These projects include reforestation and afforestation efforts, renewable energy projects, methane capture from landfills, and sales of clean cooking equipment. Each project generates carbon credits, with one credit typically equivalent to the reduction of one tonne of CO_2 or its equivalent in other greenhouse gases, such as methane.

Firms purchase carbon offsets for several reasons, including to comply with regulatory requirements or to meet internal targets for reducing greenhouse gas emissions. In the first case, the regulated markets are created through national, regional, or international regulatory frameworks and are often tied to legally binding emission reduction targets, such as those established by the Kyoto Protocol or local emissions trading schemes. In the second case, the voluntary market operates outside of these regulatory frameworks, where entities voluntarily choose to offset their emissions.

Therefore, carbon offsets represent a significant mechanism in the global effort to combat climate change by reducing greenhouse gas emissions. At their core, carbon offsets are a form of trade. When an individual or a company buys a carbon offset, they are essentially funding projects that reduce emissions of greenhouse gases somewhere else in the world to balance out their own emissions.

Literature Review

Empirical research studies on the mechanics of voluntary carbon markets (VCM) are well documented, with a report from SIX Swiss Exchange outlining a variety of frictions such as lack of liquidity, fragmentation and very little standardization in these markets. Given the infancy of these markets and lack of structured offset data, studies connected to decarbonization using offsets continue to be limited. Donofrio and Procton (2023), report an optimism in market participants about a high integrity-focused rebound of the VCM in the near term, while Conte and Kotchen (2009) study the factors that contribute to the price of these offsets. Procton et al. (2024) further report a reduction in overall volume in their latest report on outlook and trends in the VCM.

Decarbonization versus Carbon Offset Reliance

Ex ante, it is unclear whether offset reliance is positively or negatively related to an organization's decarbonization rate. A complementary relation between the two would emerge if companies, committed to sustainability, might use offsets as a complementary tool to bridge gaps in their direct emission reduction efforts. The use of offsets, in this case, is part of a broader, more aggressive approach to environmental stewardship, suggesting a positive correlation.[2] Companies that actively reduce their carbon footprint might also invest more in carbon offsets to enhance their green branding. For example, Apple has invested both in decarbonizing its operations and in buying carbon offsets, leading to the launch of a campaign that the Apple Watch is carbon neutral.[3] The simultaneous reduction in direct emissions and investment in offsets could be a strategic move to bolster a company's reputation as an environmental leader, thereby showing a positive relationship. Moreover, firms successfully reducing their carbon footprint may have more resources and expertise to invest in high-quality carbon offsets. These companies might be more efficient in their operations and better positioned to identify and finance effective offsetting projects, leading to a positive correlation between decarbonization rate and reliance on offsets.

On the other hand, the two efforts might be substitutes if firms that prioritize emission reductions view offsets as a less favorable approach or if companies with significant investments in reducing their carbon footprint might allocate fewer resources to carbon offsets due to budget constraints. The two concepts could emerge as substitutes also if organizations that invest little to decarbonize purchase larger amounts of offsets to mask their lack of decarbonization activities.

Using data from Bloomberg and MSCI, we measure for a small number of organizations that report their use of carbon offsets, the extent to which they rely on carbon offsets and their decarbonization rate. **Exhibit 1** summarizes the sample selection process. We consider the period between 2016 and 2022 for our analysis as we find better coverage of the offset data by Bloomberg post 2016. To obtain a robust analysis of a firm's decarbonization progress with its reliance on offsets, we focus on firms with a multi-year decarbonization and offset reliance, filtering out firms with offset data present only for a single year during this period. Finally, we only consider firms

[2] Gao, F. and Souza, G.C., 2022. Carbon offsetting with eco-conscious consumers. *Management Science*, *68*(11), pp.7879-7897.

[3] Apple unveils its first carbon neutral products, September 12, 2023.

with available data across all years in the analysis on Scope 1 carbon emissions to be able to calculate decarbonization rates across multiple years. As a result of this selection process, out of the 4,753 unique firms present in the MSCI ACWI Index, we are left with 180 firms with non-missing carbon emissions and Bloomberg offset data.

Exhibit 1: Sample Selection

Screening Criteria	Number of Firms: Missing Offsets: Dropped	Number of Firms: Missing Offsets: Assumed 0
Offset Data – Bloomberg & MSCI ACWI	274	2,958
# Unique Firms 2010 – 2016	56	1,398
# Unique Firms 2016 – 2022	269	2,847
Firms in Analysis Period	269	2,847
Remove Missing Data		
Less: Only 1 year of Offset Data	72	403
Less: Missing Emissions Data	17	591
Final number available for analysis	180	1,853

We estimate ordinary least square (OLS) models to understand the relationship between the two actions. **Exhibit 2** presents the estimated association between decarbonization rate and offset reliance cumulatively over the years of the analysis. Therefore, each firm enters the model once and the estimation is performed purely across firms. We include either GICS industry or sector fixed effects to account for variation across industries or sectors. We report estimates including sector fixed effects instead of industry because of the small number of firms in the sample, since within each industry there are only a few firms included in the sample therefore yielding a low power test. We report results both for the sample with available offset data and for a sample that assumes that firms with no available data on offsets have zero offsets. Panel A shows results based on Scope 1 and 2 emissions for both decarbonization rate and offset reliance and

Panel B also includes Scope 3 emissions in the calculation of the decarbonization rate and offset reliance denominator. Finally, we show results for decarbonization rate based on absolute emissions or emission intensity (emissions divided by firm revenues). Decarbonization rate and offset reliance are measured as:

Multi-year Decarbonization rate = $\left(\frac{carbon\ measure_{\ t}}{carbon\ measure_{\ t_0}}\right)^{\frac{1}{\Delta t}} - 1$

Single-year Decarbonization rate = $\left(\frac{carbon\ measure_{\ t}}{carbon\ measure_{\ t-1}}\right) - 1$

Offset Reliance = $\frac{carbon\ \ offsets}{absolute\ emissions}$

where:

$carbon\ measure$: Absolute Emissions or Intensity for a given emission scope.

t : Given year

$t\ - 1$: Previous year

t_0: First year when the carbon data is reported in the analysis period

Δt: Number of years between t and t_0

$carbon\ offsets$: Sum of offsets in metric tonnes of CO_2 used in a given period.

$absolute\ emissions$: Sum of Carbon Emissions in a given period for a given emission scope.

To remove outlier influence on our models, we first winsorize absolute emissions within a GICS sector before computing emission intensity. Our analysis focuses on Scope 1 and 2 and Scope 1, 2 and 3 decarbonization rates. Scope 3 emissions measure the companies' supply chain and downstream emissions and are thus hard to estimate and quantify.[4] Furthermore, our analysis period coincides with pandemic years, where decarbonization increased with lockdowns (2020) and then subsequently went down once the restrictions were lifted (2021). To account for spikes in the decarbonization rate caused by these issues, we only consider firms with decarbonization rate between -50% and 50%. To handle outliers in the carbon offset datasets we also cap the offset reliance to 100%, for firms using more offsets in a year than their absolute emissions. Our estimates in **Exhibit 2** suggest that in the cross-section, firms with higher decarbonization rates use more

[4] Cheema-Fox, A., LaPerla, B.R., Serafeim, G., Turkington, D. and Wang, H., 2021. Decarbonizing everything. *Financial Analysts Journal*, 77(3), pp.93-108.

offsets.[5] **Exhibit 3** shows estimates from a panel dataset where each observation is a firm-year. Given the panel data structure, we always include year fixed effects and either industry or firm fixed effects. We find similar results, documenting a negative coefficient on decarbonization rate and offset reliance, implying that firms that decarbonize more also use more offsets. Moreover, when we include firm fixed effects, we still find that in years with higher decarbonization rates organizations rely more on offsets, suggesting that organizations increase their investments in both activities in a given year. We also find that organizations with higher emissions rely less on offsets, suggesting that organizations that have "more room" to reduce emissions would use fewer offsets.

Exhibit 2 Panel A: Association between Cumulative Decarbonization Rate and Offset Reliance (Scope 1&2)

Variables	**Offset Reliance**							
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Decarbonization – Absolute Emissions	-0.464	-0.417	-0.062	-0.074*	-	-	-	-
Decarbonization - Emission Intensity	-	-	-	-	-0.504	-0.603*	-0.092**	-0.115***
Ln (Start Year Carbon Measure)	-0.070**	-1.091***	0.000	-0.068**	-0.073*	-0.218***	-0.018***	-0.043***
Industry Effects	Yes	No	Yes	No	Yes	No	Yes	No
Sector Effects	No	Yes	No	Yes	No	Yes	No	Yes
Adjusted R-squared	31.90%	19.40%	6.30%	3.60%	29.60%	17.50%	8.50%	5.40%
N	138	138	1440	1440	133	133	1297	1280
Emission Scope	1_2	1_2	1_2	1_2	1_2	1_2	1_2	1_2
Missing Offsets	Drop	Drop	Assumed 0	Assumed 0	Drop	Drop	Assumed 0	Assumed 0

* p<.1, ** p<.05, ***p<.01

[5] A negative decarbonization rate indicates carbon reduction. Therefore, a negative coefficient on decarbonization suggests that firms with higher, or more negative, decarbonization rates use more carbon offsets.

Exhibit 2 Panel B: Association between Cumulative Decarbonization Rate and Offset Reliance (Scope 1,2&3)

Variables	Offset Reliance							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Decarbonization – Absolute Emissions	-0.623**	-0.384**	-0.021	-0.021	-	-	-	-
Decarbonization - Emission Intensity	-	-	-	-	-0.372	-0.253	-0.041	-0.051**
Ln (Start Year Carbon Measure)	-0.064***	-0.657***	-0.001	-0.030	-0.103***	-0.098***	-0.008***	-0.056***
Industry Effects	Yes	No	Yes	No	Yes	No	Yes	No
Sector Effects	No	Yes	No	Yes	No	Yes	No	Yes
Adjusted R-squared	2.6%	12.1%	1.0%	3.6%	2.4%	10.5%	1.5%	8.3%
N	108	108	871	871	105	105	795	795
Emission Scope	1_2_3	1_2_3	1_2_3	1_2_3	1_2_3	1_2_3	1_2_3	1_2_3
Missing Offsets	Drop	Drop	Assumed 0	Assumed 0	Drop	Drop	Assumed 0	Assumed 0

* p<.1, ** p<.05, ***p<.01

Exhibit 3 Panel A: Association between Annual Decarbonization Rate and Offset Reliance (Scope 1&2)

Variables	Offset Reliance							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Decarbonization – Absolute Emissions	-0.143**	-0.133***	-0.015**	-0.019***	-	-	-	-
Decarbonization - Emission Intensity	-	-	-	-	-0.271***	-0.133**	-0.038***	-0.029***
Ln (Start Year Carbon Measure)	-0.122***	-0.046*	-0.012***	-0.027***	-0.062***	-0.014	0.001	-0.023***
Industry Fixed Effects	Yes	No	Yes	No	Yes	No	Yes	No
Sector Fixed Effects	No	Yes	No	Yes	No	Yes	No	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	40.4%	81.1%	8.6%	53.8%	37.9%	81.6%	7.3%	52.9%
N	938	938	12661	12661	964	964	13356	13356
Missing Offsets	Drop	Drop	Assumed 0	Assumed 0	Drop	Drop	Assumed 0	Assumed 0

* p<.1, ** p<.05, ***p<.01

Exhibit 3 Panel B: Association between Annual Decarbonization Rate and Offset Reliance (Scope 1,2&3)

Variables	Offset Reliance							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Decarbonization – Absolute Emissions	-0.082	-0.098***	-0.007	-0.010**	-	-	-	-
Decarbonization - Emission Intensity	-	-	-	-	-0.223***	-0.204***	-0.032***	-0.031***
Ln (Start Year Carbon Measure)	-0.081***	-0.042***	-0.007***	-0.010***	-0.048***	-0.031***	-0.001	-0.010***
Industry Fixed Effects	Yes	No	Yes	No	Yes	No	Yes	No
Sector Fixed Effects	No	Yes	No	Yes	No	Yes	No	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	34.2%	85.3%	5.2%	53.2%	33.3%	86.0%	4.6%	50.8%
N	728	728	7560	7560	747	747	7962	7962
Missing Offsets	Drop	Drop	Assumed 0	Assumed 0	Drop	Drop	Assumed 0	Assumed 0

* p<.1, ** p<.05, ***p<.01

Risk, Decarbonization, and Offsets

Understanding the nature of the relationship between decarbonization and offsetting activities is important because if an organization relies heavily on offsets without investing to decarbonize, it could expose the company and its investors to significant risks. First, reliance on offsets might lead an organization to miss opportunities for efficiency and improving operating performance. Second, a reliance on offsets requires continuous expenditures for the purchase of the offsets, which could grow over time if emissions grow, the price of the offsets grows or, even worse for the organization, both grow. As the expenditures grow, the organization might be forced to buy cheaper offsets, exposing itself to low quality offsets and accusations of greenwashing. Third and relatedly, reliance on offsets without decarbonization could expose the organization to reputational risk if stakeholders view the company's reliance on carbon offsets as merely "buying its way out" of environmental responsibility. Such a perception could lead to negative publicity, affecting brand value.

While our analysis suggests that, on average, organizations pursue offsets in the context of their decarbonization activities, this does not mean that there are no organizations that might rely on offsets without decarbonization activities. To understand whether market participants assign higher levels of risk to such strategies, we analyze whether risk measures are higher for firms pursuing such strategies. Specifically, we analyze the relationship between decarbonization, offset reliance, and risk using stock return volatility,[6] equity carbon beta,[7] and carbon risk ratings.[8]

By splitting our universe into high and low groups using medians within a given year and GICS industry or sector, we classify firms into four groups:

1. Low Decarbonization – Low Offset Reliance
2. Low Decarbonization – High Offset Reliance
3. High Decarbonization – Low Offset Reliance
4. High Decarbonization – High Offset Reliance

High decarbonization corresponds to lower than median decarbonization rate (since higher decarbonization rate is more negative). High offset reliance corresponds to higher than median offset reliance.

In **Exhibit 4**, we find little evidence that these measures of risk reflect the inherent risk in different decarbonization and offset reliance strategies. Specifically, we find no consistent differences across the four groups for any of the risk measures.

[6] Measured as annualized standard deviation of weekly stock returns.
[7] Measured as the regression coefficient of weekly returns of carbon risk portfolios regressed on weekly returns of EU ETS prices.
[8] Measured as regression coefficient of carbon risk dummies on MSCI IVA ratings for Climate Change Theme, Carbon Emission Exposure and Carbon Emission Management.

Exhibit 4

Panel A: Risk based on Carbon Emissions & Offset Reliance within a year-GICS Industry

Variables	**Annualized USD Return Volatility**			
Constant	0.773***	1.338***	0.695***	1.138***
Low Decarbonization - High Offset Reliance	-0.016	-0.005	-0.012	-0.011
High Decarbonization - Low Offset Reliance	0	0.002	-0.004	0
High Decarbonization - High Offset Reliance	-0.021**	-0.018	-0.016	-0.014
ln(Market Cap)	-0.025***	-0.049***	-0.019***	-0.039***
Industry Effects	Yes	No	Yes	No
Firm Fixed Effects	No	Yes	No	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Adjusted R-squared	71.90%	85.00%	72.10%	84.10%
N	607	607	528	528
Emission Scope	1_2	1_2	1_2_3	1_2_3
Missing Offsets	Drop	Drop	Drop	Drop

* p<.1, ** p<.05, ***p<.01

Panel B: Risk based on Carbon Intensity & Offset Reliance within a year-GICS Industry

Variables	**Annualized USD Return Volatility**			
Constant	0.697***	1.371***	0.646***	1.073***
Low Decarbonization - High Offset Reliance	0.007	-0.002	0.016	0.007
High Decarbonization - Low Offset Reliance	0.013	0.006	0.014	0.011
High Decarbonization - High Offset Reliance	0.01	0.001	0.01	0.006
ln(Market Cap)	-0.020***	-0.051***	-0.018***	-0.037***
Industry Effects	Yes	No	Yes	No
Firm Fixed Effects	No	Yes	No	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Adjusted R-squared	69.80%	83.50%	70.80%	85.00%
N	595	595	517	517
Emission Scope	1_2	1_2	1_2_3	1_2_3
Missing Offsets	Drop	Drop	Drop	Drop

* p<.1, ** p<.05, ***p<.01

Panel C: Risk based on Portfolios formed by Carbon Intensity & Offset Reliance within a year-GICS Sector[9]

Variables	EU ETS Carbon Beta			
Low Decarbonization - Low Offset Reliance	-0.0018	-0.0024	0.0049	0.0198
Low Decarbonization - High Offset Reliance	0.0075	0.0056	0.0046	0.0071
High Decarbonization - Low Offset Reliance	0.0082	-0.0056	0.0058	0.0066
High Decarbonization - High Offset Reliance	-0.0047	-0.0019	0.0038	0.0013
Emission Scope	1_2	1_2_3	1_2	1_2_3
Carbon Measure Used	Emissions	Emissions	Intensity	Intensity

* p<.1, ** p<.05, ***p<.01

Panel D: Risk based on Portfolios formed by Carbon Intensity & Offset Reliance within a year-GICS Industry[9]

Variables	EU ETS Carbon Beta			
Low Decarbonization - Low Offset Reliance	-0.0066	-0.0185	0.004	0.0231
Low Decarbonization - High Offset Reliance	-0.008	0.0014	0.0027	0.0261
High Decarbonization - Low Offset Reliance	-0.0063	-0.0034	-0.0055	0.0044
High Decarbonization - High Offset Reliance	0.0059	0.0199	0.0096	0.0148
Emission Scope	1_2	1_2_3	1_2	1_2_3
Carbon Measure Used	Emissions	Emissions	Intensity	Intensity

* p<.1, ** p<.05, ***p<.01

[9] Portfolios are formed by weighting the stocks within each carbon risk group by their free float market cap. The weekly gross local returns of these portfolios are then regressed against the weekly returns of EU ETS and weekly gross local returns of MSCI ACWI index.

Panel E: Risk based on Carbon Emissions & Offset Reliance within a year-GICS Industry

Variables	Climate Change Theme Score				Carbon Emission Exposure Score				Carbon Emission Mgmt. Score			
Constant	-0.634	6.386**	0.244	12.404***	2.249***	1.870*	2.535***	-0.334	1.281	8.383***	2.662***	5.643*
Low Decarbonization - High Offset Reliance	0.116	0.102	0.187	0.137	0.008	-0.031	-0.043	0.085*	0.041	0.131	-0.127	-0.164
High Decarbonization - Low Offset Reliance	-0.176	0.033	0.023	0.039	0.028	0.019	0.011	0.087*	0.238*	0.161	-0.076	-0.231*
High Decarbonization - High Offset Reliance	0.292	0.156	0.628**	0.1	-0.018	-0.052	-0.022	0.103*	0.313**	0.158	0.072	-0.129
ln(Market Cap)	0.382***	0.041	0.342***	-0.224	0.014	0.019	0.002	0.109**	0.184***	-0.145	0.128***	-0.005
Industry Effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Firm Fixed Effects	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	59.70%	90.10%	56.90%	89.60%	95.70%	98.40%	94.10%	98.80%	19.70%	62.80%	17.20%	54.50%
N	604	604	527	527	604	604	527	527	614	614	539	539
Emission Scope	1_2	1_2	1_2_3	1_2_3	1_2	1_2	1_2_3	1_2_3	1_2	1_2	1_2_3	1_2_3
Missing Offsets	Drop	Drop	Drop	Drop	Drop	Drop	Drop	Drop	Drop	Drop	Drop	Drop

* p<.1, ** p<.05, ***p<.01

Panel F: Risk based on Carbon Intensity & Offset Reliance within a year-GICS Industry

Variables	Climate Change Theme Score				Carbon Emission Exposure Score				Carbon Emission Mgmt. Score			
Constant	2.331**	6.882**	2.382*	11.859***	1.653***	1.592	2.281***	-0.627	1.316*	7.086***	2.923***	4.539
Low Decarbonization - High Offset Reliance	0.266	0.055	0.363*	0.164	0.083	-0.015	-0.086	-0.019	0.223*	0.125	0.161	0.136
High Decarbonization - Low Offset Reliance	-0.074	0.014	0.305	0.142	0.117**	0.035	-0.086	-0.049	0.141	0.055	0.213	0.065
High Decarbonization - High Offset Reliance	0.313	0.075	0.451*	-0.024	0.059	-0.043	-0.124	-0.064	0.234*	0.068	0.225	0.097
ln(Market Cap)	0.253***	0.025	0.242***	-0.2	0.035**	0.026	0.015	0.128**	0.185***	-0.084	0.110***	0.036
Industry Effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Firm Fixed Effects	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	55.00%	88.40%	53.50%	87.70%	95.20%	98.00%	95.30%	98.90%	17.80%	65.10%	12.70%	50.20%
N	594	594	516	516	594	594	594	516	604	604	526	526
Emission Scope	1_2	1_2	1_2_3	1_2_3	1_2	1_2	1_2_3	1_2_3	1_2	1_2	1_2_3	1_2_3
Missing Offsets	Drop	Drop	Drop	Drop	Drop	Drop	Drop	Drop	Drop	Drop	Drop	Drop

* p<.1, ** p<.05, ***p<.01

Carbon Offset Quality

To ensure the effectiveness of carbon offsets in contributing to the fight against climate change, several principles for quality offsets have been established. These principles are crucial for maintaining the integrity of the carbon offset market.

- *Real*: The emission reductions resulting from the offset project must actually occur and be quantifiable with a high degree of certainty. This means that the project's outcomes are not based on hypothetical scenarios but are tangible and can be measured accurately.
- *Additional*: Additionality is a key principle that requires the emission reductions achieved by the offset project to be over and above what would have occurred in the absence of the project. This ensures that the project contributes to net additional emission reductions and is not just a business-as-usual scenario.
- *Permanent*: The greenhouse gas reductions achieved should be long-lasting and not reversible. For example, a reforestation project should ensure that the trees will not be cut down in the future, releasing the stored carbon back into the atmosphere.
- *Verifiable*: The emission reductions must be verifiable by a third-party entity to ensure that they are accurately measured and reported. This independent verification adds credibility to the offsets and ensures transparency.
- *No Leakage*: The project should assess and mitigate against "leakage," which occurs when emission reductions in one area lead to an increase in emissions elsewhere. For instance, protecting a forest in one region shouldn't cause deforestation to simply move to another region.

Despite these principles, the carbon offset market has faced several concerns and criticisms. Key among these concerns are:

- *Questionable Additionality*: Some projects have been criticized for lacking additionality, meaning they would have proceeded even without the revenue from carbon offsets. This challenges the genuine impact of such offsets on additional emission reductions.
- *Double Counting*: There's the risk of both the buyer and the seller of the offset claiming the same emission reduction, which can undermine the integrity of national and global climate goals.

- *Temporary Storage of Carbon*: Projects like reforestation can be at risk from wildfires, diseases, or deforestation, leading to the release of stored carbon back into the atmosphere, thus negating the benefits of the offsets.
- *Social and Environmental Impacts*: Some offset projects have been criticized for their social and environmental impacts, including displacing local communities or failing to deliver the promised environmental benefits.

To address these concerns, there has been a push for stronger standards, greater transparency, and more rigorous verification processes in the carbon offset market. The development of international standards and certifications, such as those provided by the Verified Carbon Standard (VCS) and the Gold Standard, aims to ensure that carbon offsets meet high quality and integrity criteria. Additionally, there is a growing emphasis on choosing projects that not only reduce greenhouse gases but also provide social, economic, and environmental co-benefits to local communities, thereby ensuring a more holistic approach to offsetting emissions.

These attributes are analyzed by market participants who then determine the price of the carbon offset. All else equal, it should be that in the presence of well-informed counterparties, higher quality carbon offsets should be trading at higher prices. Unfortunately, there is very little price transparency around carbon offsets as most transactions are bilateral. To provide some evidence on the quality of offsets we analyze the factors that can explain variation in carbon offset prices. Past studies have provided insights into the factors associated with carbon offset prices using the limited data available.[10] We use Bloomberg's Project-Level Carbon Offset Prices and Volumes dataset for Offset Prices and The Berkeley Carbon Trading Project[11] for project level characteristics in our analysis. Bloomberg reports prices from New Stone Americas, a boutique commodity brokerage firm dealing with voluntary carbon offsets. The price data contains 2022 and 2023 bid, offer and transaction prices[12] (expressed in USD/tCO2e) for different vintages and individual carbon offset projects. The Berkeley dataset is a research outreach program which

[10] Conte, M.N. and Kotchen, M.J., 2010. Explaining the price of voluntary carbon offsets. *Climate Change Economics*, 1(02), pp.93-111.

[11] https://gspp.berkeley.edu/research-and-impact/centers/cepp/projects/berkeley-carbon-trading-project

[12] Prices are captured using the following order – 1. Transaction Price 2. Midpoint of Bid-Ask Spread 3. Bid or Ask if only one is available.

compiles project level characteristics from four different carbon registries: VCS, ACR, CAR and Gold Standard.

After combining the two datasets we take the latest price per transaction year and control for transaction year effects in our regressions. We exclude records which are marked as inactive by carbon registries. We also eliminate records for a project and vintage during which no credits were issued or retired. **Exhibit 5** shows the sample selection process.

Exhibit 5: Offset Price – Sample Selection

	Number of Records
Screening Criteria	Offsets – Price:
Price Records (Latest Transaction Per Year) in Bloomberg Data	696
Remove Missing/Ineligible Data	
Less: Records Missing in Registry Data	126
Less: Records with ineligible Registry Status	28
Less: Records with Credits Issued/Retired in Vintage = 0	119
Final number available for analysis	423

Exhibit 6 shows the results of models where the dependent variable is carbon offset price and explanatory variables include carbon offset characteristics. The omitted category for carbon offset type is impermanent removal, for scope is agriculture, for registry is ACR, and for region is the Caribbean. Overall, the models explain a significant percentage of the variation in carbon offset prices. Adjusted R-squared reaches 65% suggesting that these variables explain almost two thirds of the variation in carbon offset prices.

Projects with more issued and remaining offsets have lower prices. Offsets of projects that issue fewer offset are scarcer, leading to higher prices. Higher percentages of remaining offsets signal lower demand and therefore lower prices. A 50% increase in offsets remaining is associated with $0.5 lower prices. Younger projects command higher prices consistent with buyers viewing older projects as lower quality. We fail to find evidence that project developer expertise, length of project and the average ETS price are associated with prices.

We document that carbon reduction credits have lower prices than removal offset. The removal offsets in the sample do not exhibit likely high permanence and as a result they are classified as impermanent removal. Nevertheless, removal offsets tend to be thought of as higher quality since they are viewed as more additional than reduction offsets. Removal offsets command a premium of about $1.4-2.6 compared to reduction credits.

In terms of scope type, forestry and land offsets and household and community offsets (e.g. clean cooking) command the highest prices. The price premium for those is equal to ~$4-6. Both exhibit high social and environmental co-benefits potentially explaining their higher prices. Offsets for chemical processes and renewable energy command the lowest prices, potentially reflecting buyers' skepticism of their additionality.

In terms of regions, we observe a clear "home bias." Given that most buyers are companies in developed markets, we observe higher prices for European and North American offsets. The premium for European and North American offsets is ~$6 and $5 respectively. The one exception to this phenomenon is credits from Sub-Saharan Africa that command a premium of ~$3. This could be attributed to the high social co-benefits of those offsets given income levels in the region. When we include region indicator variables in the models, we observe that the registry of the offset does not make any difference.

Exhibit 6: Relationship between carbon offset prices and characteristics

Variables	Predicted Sign	1	2	3	4	5
Constant		-	-	-	-	-
Log(Total Credits Issued)	-	0.278***	0.340***	-0.188**	-0.149	-0.222**
% Total Credits Remaining	-	-1.433**	-1.455**	-1.178**	-0.783	-1.080**
# Unique Projects by Provider	+	0.062***	0.080***	0.017	0.025	0.007
Vintage	+	0.589***	0.624***	0.590***	0.522***	0.463***
Length of Project	-		-0.030	0.042	0.060	-0.022
Avg ETS Price	+/-	-0.009***	-0.008**	-0.003	-0.003	-0.004
Reduction / Removal_Mixed	-		-0.585	-0.872	-2.273**	-2.383***
Reduction / Removal_Reduction	-		-4.670***	-1.242*	-1.404**	-1.333**
Scope_Agriculture						
Scope_Chemical Processes	+/-			1.026	-2.266	-2.048
Scope_Forestry & Land Use	+			6.130***	5.662***	5.943***
Scope_Household & Community	+			5.177***	4.853***	4.220**
Scope_Industrial & Commercial	+/-			1.493	1.195	1.260
Scope_Renewable Energy	-			0.871	0.536	0.480
Scope_Waste Management	+/-			3.113*	3.018*	1.911
Registry / ARB_ACR						
Registry / ARB_CAR	+/-				1.098	1.259
Registry / ARB_GOLD	+/-				-2.637***	1.384
Registry / ARB_VCS	+/-				-3.079***	0.929
Region_Carribean						
Region_Central America	+/-					1.659
Region_East Asia	+/-					1.119
Region_Europe	+/-					6.293***
Region_Middle East	+/-					1.461
Region_North America	+/-					5.072***
Region_Oceania	+/-					-1.113
Region_South America	+/-					1.440
Region_South Asia	+/-					1.123
Region_South East Asia	+/-					1.620
Region_Sub Saharan Africa	+/-					2.720**

Transaction Year Fixed Effects		Yes	Yes	Yes	Yes	Yes
R-squared Adj.		18.60%	29.10%	58.10%	59.10%	64.80%
N		423	423	423	423	423

Conclusion

Data on corporate purchases of carbon offsets is remarkably scarce hindering a systematic analysis of how companies use carbon offsets. We use the limited available data to study the relation between reliance on carbon offsets and decarbonization rates and document a complementary relation. Moreover, we analyze various risk measures and find little evidence that reliance on offsets is reflected in those measures. Finally, we document the factors that are related to carbon offset prices to provide evidence on the types of offsets that buyers exhibit higher willingness to pay.

Glossary

Total Credits Issued: The total number of credits issued by the registry from the start of the project.

Total Credits Retired: The total number of credits retired or canceled from the start of project. Credits are marked as retired once an owner notifies the registry that credits are being used towards a compliance or voluntary emissions target. Once this happens, the credits can no longer be sold to another buyer.

% Total Credits Remaining: Percentage of **t**otal credits still remaining out of the total credits issued from the start of the project.

 # Unique Projects by Provider: Number of Unique Carbon Credit Projects developed by Project Developer in the registry.

Vintage : The year in which emissions were avoided, reduced, or sequestered and carbon credits subsequently verified and made available for issuance.

Length of Project : Total number of years passed from the start of the project.

Avg ETS Price : Average Price of the EU ETS during a vintage year.

Reduction / Removal : Each project type is categorized as: Reductions, Impermanent removals, or Mixed. Reductions are projects types that reduce the amount of emissions entering the atmosphere. Removals are project types that primarily draw carbon out of the atmosphere. Mixed are project types that can generate both emissions reductions and carbon removals

Scope[13]: Each project falls under a scope or project category described below:

- **Agriculture:** Projects involved in reducing/capturing emissions from agricultural activities such as compost production, improved irrigation management, manure methane digesters etc.
- **Chemical Processes:** Projects involved in reducing or reusing high potency gases from manufacturing or chemical processes such as advanced refrigerants, N_2O destruction, Ozone depletion recovery etc.
- **Forestry & Land Use:** Projects involved in afforestation/reforestation activities, improved forest management, REDD+ (Reducing Emissions from Deforestation and Forest Degradation) etc.
- **Household & Community:** Projects involved in energy efficiency efforts within household and community such as biodigesters, clean water, cookstoves etc.
- **Industrial & Commercial:** Projects involved in energy efficiency efforts within commercial spaces and industrial production processes such as Aluminum smelters, carbon absorbing concrete, fuel switching etc.
- **Renewable Energy:** Projects involved in generating renewable energy such as biomass, geothermal, hydropower, solar etc.
- **Waste Management:** Projects involved in reducing emissions through advanced waste management such as composting, fuel generation through landfill methane, waste diversion and incineration etc.

[13] For more details refer: https://gspp.berkeley.edu/assets/uploads/page/VROD-ScopesTypes-v9.pdf

Registry/ARB : The project registry that issues and tracks offset credits. There are 4 registries used in the analysis, described below along with the carbon markets for projects tracked by these registries

ACR : American Carbon Registry (North American carbon markets)

CAR : Climate Action Reserve (Global carbon markets)

GOLD : Gold Standard (Global carbon markets)

VCS : Verified Carbon Standard (Global carbon markets)

Region: Geographic regions where the carbon credit project is being carried out.

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Disclosures