

EXPLAINING THE PRICE OF VOLUNTARY CARBON OFFSETS

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This paper identifies factors that explain the large variability in the price of voluntary carbon offsets. We estimate hedonic price functions using a variety of provider- and project-level characteristics as explanatory variables. We find that providers located in Europe sell offsets at prices that are approximately 30% higher than providers located in either North America or Australasia. Contrary to what one might expect, offset prices are generally higher, by roughly 20%, when projects are located in developing or least-developed nations. But this result does not hold for forestry-based projects. We find evidence that forestry-based offsets sell at lower prices, and the result is particularly strong when projects are located in developing or least-developed nations. Offsets that are certified under the Clean Development Mechanism or the Gold Standard, and therefore qualify for emission reductions under the Kyoto Protocol, sell at a premium of more than 30%; however, third-party certification from the Voluntary Carbon Standard, one of the popular certifiers, is associated with a price discount. Variables that have no effect on offset prices are the number of projects that a provider manages and a provider's status as for-profit or not-for-profit.

Keywords: Voluntary carbon offsets; hedonic price method.

1. Introduction

There is widespread agreement on the need to reduce greenhouse gas (GHG) emissions in order to mitigate the effects of global climate change, and attention is now focused on setting emission targets and designing policies to help achieve them. The unique and difficult challenges associated with the design and implementation of GHG policies are well-known and have given rise to a substantial academic literature (see, for example, [Aldy and Stavins, 2007](#)). Among the significant challenges that must be overcome are concerns about the high costs of compliance and distributional equity. In response to these concerns, nearly all GHG policies — regardless of whether they are implemented at the regional, national, or international level — allow offsets to count toward emission reductions. Moreover, while GHG policies struggle to address these issues, a substantial market for voluntary carbon offsets has developed to allow

emission-producing firms and individuals to reduce their carbon footprints even when not required by law.

Offsets are based on the idea that agents need not reduce their own emissions in order to reduce the amount of GHGs in the atmosphere; instead, they can pay someone else to reduce emissions and achieve the same effect on atmospheric concentrations. Agents prefer offsets, of course, if the payment required is less than their own abatement costs. Though often controversial for reasons that we discuss below, offsets work in principle because GHGs are uniformly mixed pollutants in the global atmosphere, and the location of emissions (or reductions) has no effect on the impact of climate change. Only the net effect on overall GHG emissions is what matters. Typically, offsets arise through investments in renewable energy, energy efficiency, reforestation, or other projects that reduce emissions or sequester GHGs. Though usually referred to as “carbon offsets”, many projects focus on other GHGs, such as projects based on biomass and industrial methane capture, and emission reductions are measured in carbon dioxide equivalent units (CO₂e).

Carbon offsets provide the basis for two of the Kyoto Protocol’s primary mechanisms for reducing GHG emissions in the context of an international environmental agreement. Under Joint Implementation (JI), industrialized nations can purchase carbon credits (effectively offsets) from emission-reducing projects located in other industrialized nations or nations with transition economies.¹ Under the Clean Development Mechanism (CDM), industrialized countries can purchase offsets in much the same way, though CDM credits are acquired through the finance of projects in developing nations.² Questions about offsets are also playing a pivotal role in determining the future of emission regulation in the United States. Recent drafts of such legislation, for example, allow businesses to offset up to 30% or 63% of their emissions (H.R. 2454).³

In a regulated setting, economic theory makes a clear prediction about what determines the price of a carbon offset, assuming the offset market is perfectly competitive. Regardless of the means by which the offset occurs, the price will be determined by the intersection of the marginal abatement costs of regulated entities and the marginal costs of abatement through offset projects. In this context, offsets would be expected to follow the “law of one price”. In the market for voluntary carbon offsets, however, the way in which prices are determined is less clear. Driven by “pure voluntary” or “pre-compliance” buyers, private firms purchased 66% of the voluntary

¹See *Michaelowa* (1998, 2002) for discussion of the challenges facing JI projects, with particular emphasis on baseline definition and information asymmetry between buyers and sellers.

²See *Victor et al.* (2005), *Wara* (2007), and *Wara and Victor* (2008) for a series of papers that describe and critique the Kyoto’s Protocol’s CDM.

³Further along in the United States are state and regional policies, including the noteworthy examples of California’s AB 32 and the Regional Greenhouse Gas Initiative (RGGI) of 10 Northeastern and Mid-Atlantic states. While negotiations are still underway about the amount of offsets that will be allowed under California’s AB 32, participants in the RGGI are allowed to offset up to 10% of their emission reductions, depending on the price of permits in a cap-and-trade program.

offset volume in 2008, with corporate social responsibility and public relations the most common motivation (Hamilton *et al.*, 2009). It follows that voluntary carbon offsets are impure public goods based on the joint production of private and public characteristics (Kotchen, 2006). Unlike offsets in a regulatory setting, therefore, offset prices in the voluntary market may reflect not only marginal costs, but also preferences for a broader bundle of characteristics. For instance, above and beyond the desire to reduce GHG emissions, private firms and/or individuals may purchase offsets for associated co-benefits such as poverty alleviation and biodiversity conservation. These co-benefits, while public goods unto themselves, may be provided because of private incentives in the form of favorable public relations and reputation effects, giving rise to so-called “charismatic carbon”.

It is increasingly common for businesses, organizations, and individuals to voluntarily purchase carbon offsets. According to Hamilton *et al.* (2009), the number of offsets traded in the voluntary, over-the-counter market increased by 87% from 2007 to 2008, and transactions totaled 124.3 million metric tons of CO₂e. While the quantity of GHG reductions from voluntary offsets is relatively modest, representing 3% of the offsets traded in regulated markets, the money being spent is not trivial. Expenditures in the voluntary market totaled more than US\$700 million in 2008 alone, and forecasts predict further expansion of the market. Among businesses, organizations, and individuals, the motives for voluntary offsets include not only strategies for corporate environmental management and public relations, but also the desire for guilt alleviation (see Kotchen, 2009a; 2009b). Along with the increased popularity of voluntary offsets, however, have come calls for more oversight of the market. In the United States, the Federal Trade Commission (FTC) has begun investigating concerns about the market and whether there is a need for greater consumer protection.

In both regulatory and voluntary settings, offsets generate controversy. Despite the cost savings, there are those who object in principle to the idea of paying someone else to reduce emissions, rather than doing it oneself. More pragmatic concerns tend to focus on whether carbon offsets are additional, permanent, and credible. Offsets are additional only if the project reduces emissions relative to an established baseline level of emissions, typically meaning that the reductions would not have occurred without the offset payment. Though the idea of establishing additionality is simple in theory, the practice of determining baseline trends against which to compare offset projects is a challenging problem without clear guidelines. There are also concerns about the permanence of emission reductions or sequestration, particularly when it comes to forestry-based offsets, which are subject to future uncertainty about land use, forest health, and the risk of fire. These issues have led some to argue that the price of forestry-based offsets should be discounted to reflect the inherent uncertainty of such projects (Pfaff *et al.*, 2000; Kim, McCarl and Murray, 2008). Further issues arise because of asymmetric information. Offset providers know a lot about the projects in which they invest, but offset buyers know only what the providers tell them. The asymmetry gives rise to a standard source of market failure. Consequently, many

third-party organizations have emerged, particularly in the voluntary market, to set standards, audit projects, and verify whether offset providers are delivering on the quality and quantity of their claims.

The present paper seeks to further the understanding of underlying patterns in the market for voluntary carbon offsets. We focus on a fundamental question: What explains the price of voluntary carbon offsets? To answer this question, we estimate hedonic price functions that focus on characteristics of offset providers and offset projects themselves. Characteristics of the offset providers that we consider include geographic location, status as for-profit or not-for-profit, and size in terms of the number of projects being managed. Detailed data on specific offset projects include the nation in which the project is located, different types of third-party certification, and the mechanism by which the project reduces emissions (wind, solar, biomass, forestry, etc.). Our primary source of data is the Carbon Catalog (CC), which is the most comprehensive online directory that provides detailed information on carbon offset providers and projects worldwide. The complete dataset consists of information on 97 offset providers and 280 offset projects.

Some of the main findings of our econometric analysis include the following: Providers located in Europe sell offsets at prices that are approximately 30% higher than providers located elsewhere. Contrary to what one might expect, offset prices are higher, by roughly 20%, when projects are located in developing or least-developed nations. We find evidence that forestry-based offsets sell at lower prices, and the result is particularly strong when the projects are located in developing or least-developed nations. Offsets that are certified to qualify under the Kyoto Protocol sell at a premium of more than 30%, while third-party certification from the Voluntary Carbon Standard (VCS), one of the largest certifiers, is associated with a price discount of nearly 25%.

In the next section, we describe the data used in our analysis and report descriptive statistics that characterize the market for voluntary carbon offsets. Section 3 describes our empirical methods and the results of our econometric analysis at both the provider- and project-level. We then discuss the results along with more general policy implications in Section 4. Finally, Section 5 summarizes and concludes.

2. Data

The Carbon Catalog (CC) is our primary source of data. CC is a publicly available, online directory that provides the most comprehensive and up-to-date information on carbon offset providers and projects worldwide.⁴ CC is a freely available service that does not sell carbon offsets and whose mission is simply to increase transparency in the market. Our dataset includes all providers and projects listed on CC through

⁴All information about the Carbon Catalog (CC), including most of the data used in this paper, is available at the following url: <http://www.carboncatalog.org>.

December 2008. The complete dataset includes observations on 97 offset providers and 280 offset projects.

The offset providers are located in three different regions of the world: Europe (43%), North America (40%), and Australasia (16%). Among all providers, 34% are listed as having not-for-profit status, and it might be of interest that the percentage of not-for-profit providers differs substantially between Europe (29%) and North America (41%).⁵ The majority of providers manage more than one offset project. In particular, the average number of projects per provider is 3.6, ranging from a low of 1 to a high of 28. Among all providers, 35% manage a single project, and fewer than 5% manage 10 projects or more. Offset prices are reported at the provider level and represent the cost in 2007 US dollars of offsetting one tonne of CO₂e.⁶ The price is highly variable among providers, as shown in Fig. 1 and ranges from a low of \$2.55 to a high of \$69.2. The average price is \$18.15, with the majority of offsets selling at prices between \$10 and \$25 per tonne.

CC provides further information about the 280 specific projects listed on its website. Variables central to our analysis are the project's geographic location, mechanism for offsetting emissions, and status regarding selected third-party certification. We do

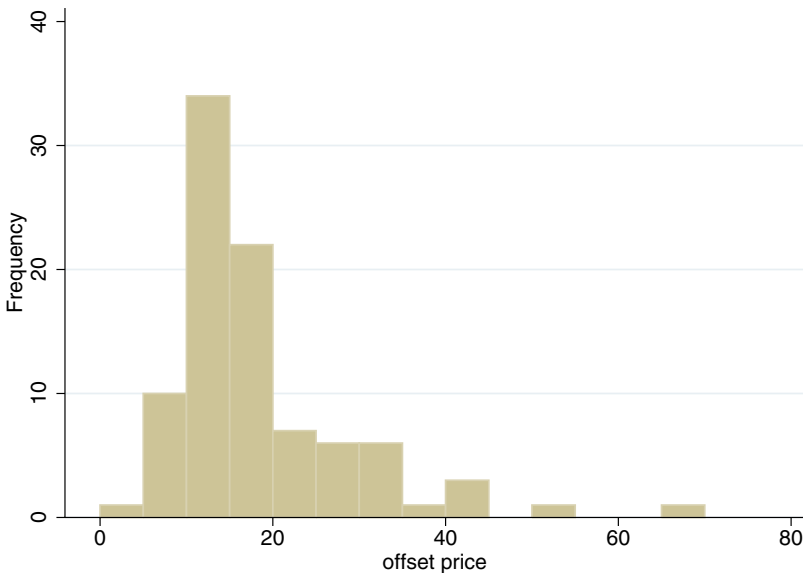


Figure 1. Histogram of carbon offset prices (\$2007s/CO₂e) for providers listed on Carbon Catalog

⁵A possible explanation for the difference between Europe and North America is that the European Union Greenhouse Gas Emission Trading System (EU ETS) has capped industrial emissions for several years, while allowing the purchase of offsets, as explained previously. One would expect this to have increased demand for carbon offsets and therefore increase the incentive to establish for-profit offset providers.

⁶The conversion between different currencies is based on exchange rates in December of 2008.

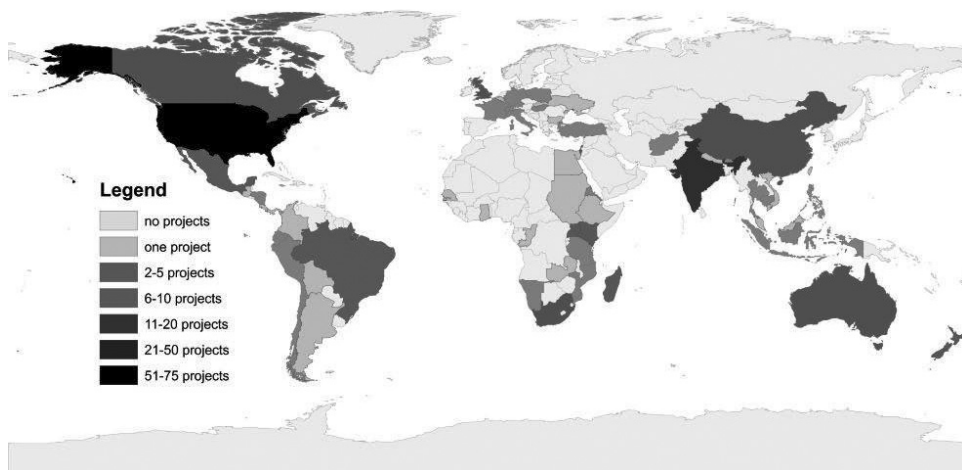


Figure 2. Distribution among nations of offset projects listed on Carbon Catalog

not, however, observe offset prices at the project level. This is because providers that manage more than one project do not typically sell offsets for different prices depending on the particular project. Instead, a provider typically has one price that reflects its portfolio of projects, and our analysis accounts for this feature of the data.

Figure 2 illustrates how the projects are distributed across nations. Asia and North America each host approximately 30% of the individual projects, while Australia, Europe, and South America are each host to between 7% and 9%. We also see that nations with a particularly high number of offset projects are Brazil, China, India, and the United States. For purposes of our analysis, we categorize projects as being located in industrialized, developing, or least-developed nations based on the Organisation for Economic Co-operation and Development (OECD) classification system. The proportion in each category is reported in the upper-left panel of Fig. 3. Roughly the same number of projects, about 44%, are found in industrialized and developing nations, while 11% are located in least-developed nations.

The upper-right panel of Fig. 3 illustrates the breakdown of project type in terms of the mechanism whereby CO₂e emissions are offset. Projects associated with reforestation are most common, comprising 34% of all offset projects. Other categories with a substantial number of projects are biomass methane capture (16%), wind-generated electricity (14%), and industrial methane capture (9%). All other types comprise near or below 5% of all projects. In order of prevalence, the categories include projects based on fuel efficiency, hydropower, fuel substitution, solar power, efficient lighting, environmental building, material substitution, public transportation, heat-electricity cogeneration, and geothermal power. A final category, referred to as market-based, does not have a specified type because it is based on created markets in which offsets are bought and sold from projects of various types. Only a small number of observations fall into this last category and include emission allowances from the Chicago

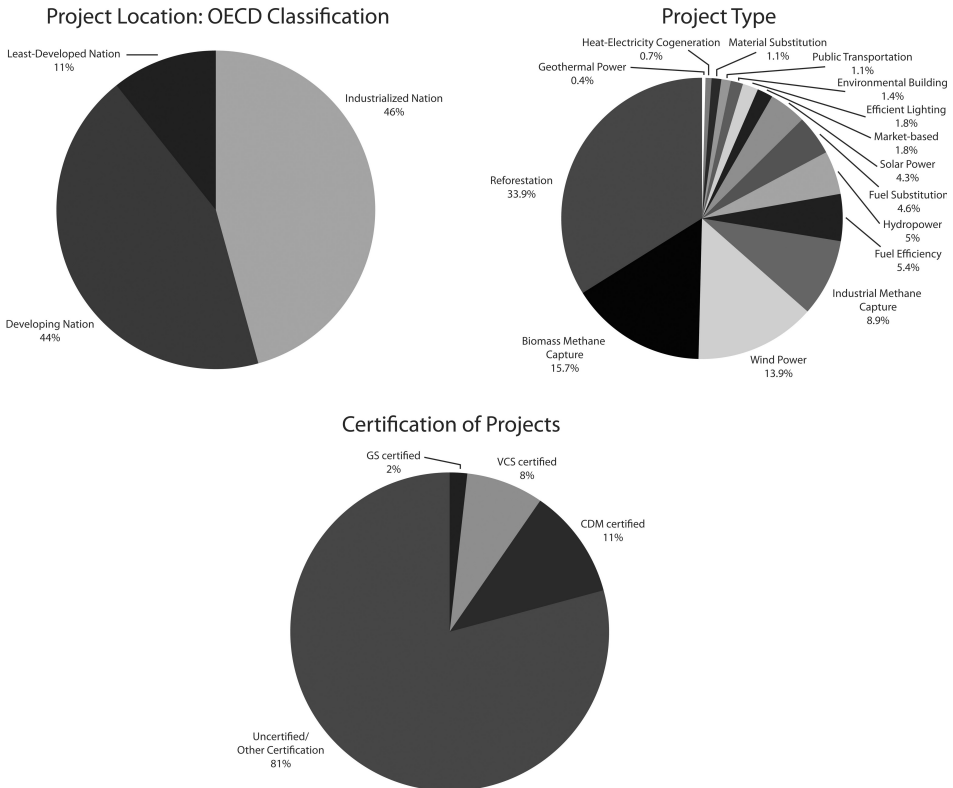


Figure 3. Breakdown of Carbon Catalog offset projects by nation’s OECD classification, certification, and type

Climate Exchange (CCX), New South Wales Greenhouse Gas Abatement Scheme (GGAS), and European Union Greenhouse Gas Emission Trading System (EU ETS).

The final panel in Fig. 3 illustrates data on selected third-party certification of offset projects. CC considers only three types of certification: the Clean Development Mechanism (CDM), the Gold Standard (GS), and the Voluntary Carbon Standard (VCS). CDM projects are those that qualify under the Kyoto Protocol as satisfying criteria allowing industrialized nations to receive credit for emission reductions through the finance of offset projects in developing nations. The GS certification goes above and beyond the CDM in setting high-end offset criteria that promote sustainable development and focus on renewable energy and energy efficiency. The VCS is an independent classification standard that aims to set a quality threshold for the purpose of standardizing and stimulating innovation in the voluntary offset market. The CDM, GS, and VCS certifications account for 12%, 2%, and 8% of the projects in the dataset.⁷ While 80% of the projects in the dataset are not certified by any of these three

⁷One additional clarification is necessary about double counting of three GS projects that are also CDM projects, which is to be expected since GS applies a more rigorous standard. There are, however, two GS projects that are not CDM, and this is because these projects qualify for Joint Implementation (JI) under the Kyoto Protocol.

systems, we do not know whether they are completely uncertified or certified by some other standard. As reviewed by [Hamilton *et al.* \(2009\)](#), there are several other certification standards, but the three considered by CC are the most common.

In addition to the variables described here, we sought to incorporate several other provider- and project-level attributes into our analysis. At the provider-level, we have data on the self-reported efficiency of the operation, which records the percentage of the price that goes to fund the offset-producing project. At the project level, we have data on both the size of the project, in terms of the quantity of GHGs offset, and the time horizon over which the project would operate. The additional variables described in this paragraph are only available for a subset of the providers and projects in the overall data set. For this reason, and because we did not find meaningful results when using the variables, we do not include them in the main results of the paper.

3. Methods and Results

The primary objective of our empirical analysis is to determine which variables explain variability in the price of carbon offsets. We estimate hedonic price functions, where offset prices are explained as a function of provider and project characteristics, at two different levels of data aggregation.⁸ We begin at the provider level and then consider the more disaggregated project level. In both cases, we present multiple specifications to ensure robust results.

3.1. Provider-level analysis

Data on the price of carbon offsets are available at the provider level, so it is natural to begin our analysis with models that seek to explain the price of carbon offsets as a function of general characteristics of the offset providers. We consider whether offset prices differ systematically based on where the provider is located and whether it has for-profit or not-for-profit status. We also investigate the effect on offset price of the number of projects under management, whether the projects are located in non-industrialized nations, whether projects are based on forest carbon sequestration (distinctions based on other project types are made in the next subsection), and whether projects are certified as valid under the Kyoto Protocol.

We estimate regression models with the general form

$$P_i = f(\text{location}_i, \text{nonprofit}_i, \text{numprojects}_i, \text{nonindust}_i, \text{forestry}_i, \text{kyoto}_i) + \varepsilon_i,$$

where P_i is the price of carbon offsets per tonne of CO₂e offered by provider i , location_i is a categorical variable indicating the region where the provider is located (Australasia, North America, Europe), and nonprofit_i is a dummy variable indicating not-for-profit status. The other variables characterize general features of the projects that each provider manages: numprojects_i is the number of offset projects under

⁸See [Rosen \(1974\)](#), [Bartik \(1987\)](#), and [Freeman \(1993\)](#) for the theoretical foundation of the hedonic price method.

management, $nonindust_i$ is the proportion of projects located in either developing or least-developed nations, $forestry_i$ is the proportion of projects with forestry-based carbon sequestration, and $kyoto_i$ is the proportion of projects that have CDM or GS certification.⁹ Finally, ε_i is an error term assumed to be normally distributed. We estimate linear and log-linear specifications using ordinary least squares (OLS). For reasons described below, we also estimate models in which the project-related variables are defined in an alternative way as dummy variables indicating, respectively, whether the provider manages more than one project, whether all projects are located in non-industrialized nations, whether all projects are forestry-based, and whether all projects qualify for inclusion in the Kyoto Protocol.

The empirical model is useful for testing several prior expectations about how the different variables affect offset prices. With increasing returns to scale, providers with a greater number of projects would have lower prices. Given that one justification for offsets in developing nations is to take advantage of low-cost emission reductions, one might expect that prices would be lower for providers located in these nations. Greater demand for offsets certified under the Kyoto Protocol combined with more costly requirements means that providers with more projects certified would be expected to sell at higher prices. Other variables in the model are not associated with clear priors about their expected sign, as plausible factors affecting supply, demand, or both could cause prices to be higher or lower. Nevertheless, based on hedonic price theory, if we observe higher prices for some offset providers, then it must be true at the equilibrium quantities that their offsets are more expensive to produce (have higher marginal costs) and are more desirable to consumers (have higher marginal benefits).

Table 1 reports the results of all provider-level regression models. The linear and log-linear models in column (a) are the specifications with project-level variables as defined initially. We find evidence that a provider's location does have an effect on the price it charges. Offset providers based in North America sell offsets at lower prices than those based in Europe. The difference is statistically significant and, according to the two models, suggests a price discount in North America of \$6.91 on average, or a difference of 29%. We also find evidence, with statistical significance in the linear specification, that prices charged by providers located in Australasia are lower than those located in Europe. In this case, the difference is roughly \$5.94, or 25% on average. There is no statistically significant difference between offset prices of providers located in North America and Australasia.

Another result with statistical significance relates to the effect of CDM or GS certification, which as described above, implies that a project meets certification standards and generates offsets that qualify for emission reductions under the Kyoto Protocol. Based on the linear model, the result is interpreted such that a 10% increase

⁹We do not account for VCS certification in the provider-level analysis. The reason is that CC does not report a transparency measure for providers that includes VCS certification. We did, however, separately collect data from CC on VCS certification and include it in our subsequent project-level analysis.

Table 1. Provider-level regression results.

Variable	(a)		(b)	
	Linear	Log-linear	Linear	Log-linear
North America	-6.909** (2.670)	-0.285** (0.131)	-7.487*** (2.567)	-0.309** (0.127)
Australasia	-5.936* (3.383)	-0.248 (0.166)	-7.061** (3.326)	-0.291 (0.164)
Europe	—	—	—	—
Nonprofit	1.324 (2.290)	0.096 (0.112)	1.728 (1.353)	0.115 (0.116)
Multiple projects	-1.183 (2.356)	-0.054 (0.115)	-0.842 (2.419)	-0.045 (0.119)
Projects in non-industrialized nations [†]	-0.333 (3.027)	0.034 (0.148)	0.158 (2.479)	0.075 (0.122)
Forestry-based projects [†]	-1.385 (2.654)	-0.164 (0.130)	-1.406 (2.577)	-0.172 (0.127)
Kyoto (CDM or GS certification) [†]	13.293*** (3.343)	0.586*** (0.164)	15.435*** (3.937)	0.652*** (0.194)
Constant	20.910*** (3.340)	2.862*** (0.164)	21.404*** (3.162)	2.881*** (0.156)
R-squared	0.319	0.308	0.291	0.269
N	85	85	85	85

Notes: Dependent variable is offset price. Standard errors are reported in parentheses. Multiple projects is defined as the actual number of projects managed by the provider in column (a), while in column (b) the variable is a dummy for more than one project. Variables denoted with [†] are defined in column (a) as the percentage of the provider's projects that satisfy the criteria, while in column (b) the variables are defined as dummies indicating that all or none of the projects satisfy the criteria. Three, two, and one asterisk(s) indicate statistical significance at the 99%, 95% and 90% levels, respectively.

in the proportion of a provider's projects that are CDM- or GS-certified is associated with a \$1.33 increase in the provider's price. It is important to note, however, that the comparison group here includes offset projects that may or may not have obtained some other certification; but in either case, the offsets would not qualify for emission reductions under the Kyoto Protocol. The corresponding result in the log-linear model is that the same 10% increase in the proportion of certified projects is associated with a 5.9% increase in the provider's price.

All other coefficient estimates of interest are not statistically significant. We find no price difference between for-profit and not-for-profit providers. Because providers with more projects do not sell offsets at significantly different prices, we find no evidence in support of increasing returns to scale. If a greater proportion of the projects are forestry-based, prices are not significantly different, though we explore this subject in more detail below. Finally, the effect of a provider having a greater proportion of its

projects in developing or least-developed nations has no effect on price, despite the rationale for low-cost emission reductions in developing nations.

The models in column (b) differ because of variable definitions. As described above, we redefine $numprojects_i$ as a dummy variable indicating more than one project, and the variables $nonindust_i$, $forestry_i$, and $kyoto_i$ are indicators for whether 100% of the provider's projects satisfy the respective categorization. We estimate these models to test whether prices are different for the providers with more uniform criteria for their projects. The information presented for transparency on CC is also formatted in this way. When compared with the models in column (a), the results also provide a robustness check. In general, both sets of models produce very similar results in terms of the sign and statistical significance of coefficient estimates. The new specifications produce larger magnitudes on the provider location results, but none of the redefined variables comes through differently with statistical significance. The interpretation of the coefficient on $kyoto_i$, however, has a sharper interpretation: providers that obtain CDM or GS certification for *all* their projects, compared to those that obtain it for some or none of their projects, set offset prices higher by \$15.44. Based on the log-linear specification, this is an average mark-up of 65%.

3.2. Project-level analysis

The price of a carbon offset is determined at the provider level, but as we have seen, the majority of providers manage more than one offset project, with the average being 3.6. We now estimate hedonic price functions that take advantage of the more detailed data on individual offset projects.

We begin with estimation of regression models that have the general form

$$P_i = f(\text{offsettype}_{ij}, \text{OECD}_{ij}, \text{kyoto}_{ij}, \text{VCS}_{ij}) + \varepsilon_{ij},$$

where the subscript i continues to index providers and j indexes projects. offsettype_{ij} is a categorical variable indicating a project's mechanism for offsetting emissions, which we aggregate into seven categories: forestry, industrial methane, biomass methane, wind, hydropower, solar, and other.¹⁰ OECD_{ij} is a categorical variable indicating whether the project is located in a nation with the OECD's classification of industrialized, developing, or least-developed. kyoto_{ij} is a dummy variable for whether the project has CDM or GS certification, and therefore qualifies for emission reductions under the Kyoto Protocol. VCS_{ij} is a dummy variable for whether the project has obtained third-party certification from the Voluntary Carbon Standard. Finally, ε_{ij} is a normally distributed error term. We again estimate and report both linear and log-linear specifications. For the project-level analysis, however, we report standard errors that are clustered at the provider level. This accounts for the fact that each project is not an

¹⁰The miscellaneous other category includes offsets in the categories mentioned previously as fuel efficiency, hydro-power, fuel substitution, efficient lighting, environmental building, material substitution, public transportation, geo-thermal power, heat-electricity cogeneration, and market-based.

entirely independent observation, in large part because prices are available at the provider level only.¹¹

Here again we consider the model as testing some prior expectations about the effect of different variables. With regard to offset types, supply-side factors are the different marginal costs of reducing emissions from different types of projects. But also affecting prices are demand-side factors for heterogeneous goods that offer different bundles of characteristics. Forestry-based projects may be lower-cost, for example, but consumers may have greater demand for them because of the co-benefits of biodiversity conservation. In this case, the former effect will tend to lower prices, while the latter will tend to raise them. It continues to be true, however, that if we observe higher (lower) prices for some offset types at the equilibrium quantities, then both marginal costs and marginal benefits are greater (lower) for those types of offsets. Following on the previous provider-level analysis, one might continue to expect lower prices for projects located in developing nations, as captured by the OECD variables, but demand-side factors may play a role. If consumers have a preference for income redistribution combined with offsets, then prices could well be higher for projects located in developing nations, even if the costs are lower. Finally, we have an unambiguous prior about the certification variables, as the higher cost of compliance and potentially greater demand would both tend to result in higher prices.

The first set of models in column (a) of Table 2 includes only the categorical variables on offset type, with forestry projects as the omitted category. All coefficient estimates are positive, providing evidence that forestry-based offsets sell at lower prices. In both specifications, statistically significant coefficients are those on the project types of biomass methane, hydropower, solar, and wind. All four have magnitudes that are very similar and are not statistically different from one another. The general pattern in these models is that offsets of these four types, compared to those based on forestry, sell for higher prices between \$5 and \$8 more on average. The difference in price ranges between 40% and 50%. Note that there is no clear impact of GHG type on offset prices: considering methane relative to carbon dioxide, we find a price premium associated with methane capture from biomass but not from industrial sources.¹²

The models in column (b) of Table 2 include the variables on the level of development in the nation where the offset project is located and the different types of third-party certification. When we include these additional variables, the results on differences between forestry and other offset types are weaker. Only the one for solar

¹¹It is worth mentioning, as one might expect, that clustering results in substantially larger standard errors, making statistical inference of the coefficient estimates more conservative.

¹²Consideration of GHG type is potentially important when evaluating offset effectiveness. This is due to the fact that calculation of CO₂e is based on radiative forcing potentials, but this ignores the way that different GHGs last for different durations in the atmosphere (e.g., methane lasts for a much shorter period of time). Accurate comparisons among offset types, from an economic perspective, therefore, should account for the present value of avoided marginal damages.

Table 2. Project-level regression results for offset type.

Variable	(a)		(b)	
	Linear	Log-linear	Linear	Log-linear
Industrial methane	0.156 (2.190)	0.126 (0.226)	0.844 (2.125)	0.158 (0.211)
Biomass methane	7.708*** (2.913)	0.518** (0.235)	3.875 (2.349)	0.325 (0.208)
Hydropower	5.516* (2.871)	0.456* (0.246)	2.716 (2.384)	0.311 (0.214)
Solar	6.159* (3.192)	0.486* (0.252)	6.091* (3.616)	0.490* (0.272)
Wind	5.312* (2.681)	0.428* (0.234)	3.167 (2.592)	0.318 (0.223)
Other	2.519 (2.264)	0.294 (0.221)	2.742 (2.277)	0.308 (0.227)
Forestry	—	—	—	—
Developing nation	—	—	3.307** (1.319)	0.172** (0.083)
Least-developed nation	—	—	3.802* (1.981)	0.208* (0.105)
Industrialized nation	—	—	—	—
Kyoto (CDM or GS certification)	—	—	8.115*** (2.430)	0.407*** (0.119)
VCS	—	—	-2.728 (1.649)	-0.046 (0.125)
Constant	14.225*** (1.970)	2.445*** (0.214)	12.258*** (1.973)	2.335*** (0.212)
R-squared	0.097	0.131	0.222	0.213
N	319	319	319	319

Notes: Dependent variable is offset price. Standard errors clustered at the provider level are reported in parentheses. Three, two, and one asterisk(s) indicate statistical significance at the 99%, 95% and 90% levels, respectively.

continues to have statistical significance, such that offsets from solar-power projects sell for an average premium, compared to those based on forestry, of \$6.09 or 49%. We do find statistically significant differences between offset prices from projects in industrialized and non-industrialized nations. Those based in developing or least-developed nations sell for higher prices on average, between \$3 and \$4 per tonne of CO₂e, or roughly 20%. In these models, the differences between the prices in developing and least-developed nations are not statistically significant. Finally, the models show some differences in price as a result of third-party certification. The coefficient on CDM or GS certification is positive and different from zero with a high degree of

statistical significance, in parallel with the results of the provider-level analysis. Projects with certification that qualifies them for emission reductions under the Kyoto Protocol sell for an average premium of \$8.12 or approximately 41%.

We now focus the analysis on forestry-based offsets. We do so because, as discussed previously, forestry-based offsets are very common and tend to be rather controversial. Furthermore, the results thus far suggest systematic differences in the price of forestry-based offsets. We report regression models in column (a) of Table 3 that are similar to those in column (b) of Table 2, but for the fact that we account for differences in the offset type with only a dummy variable for whether the project is forestry-based. The estimated coefficient, however, is not statistically different from zero. The results for whether projects are located in developing or least-developed nations are very similar to those shown previously, as are those for CDM or GS certification. The main difference between specifications is that the coefficient on VCS certification is now statistically significant. Compared to the unspecified category of other third-party certification or no certification, projects with VCS certification — the largest certifier — are associated with a price discount of approximately \$4.24 or 19%.

Table 3. Project-level regression results focused on forestry-based projects.

Variable	(a)		(b)	
	Linear	Log-linear	Linear	Log-linear
Forestry	−3.725 (2.633)	−0.385 (0.261)	−0.286 (2.429)	−0.152 (0.239)
Developing nation	3.689*** (1.264)	0.193** (0.082)	5.498*** (1.533)	0.322*** (0.083)
Least-developed nation	3.740* (1.889)	0.202* (0.104)	8.330*** (2.126)	0.488*** (0.105)
Industrialized nation	—	—	—	—
Kyoto (CDM or GS certification)	7.783*** (2.451)	0.356*** (0.114)	7.444*** (2.364)	0.326*** (0.108)
VCS	−4.236** (1.654)	−0.192** (0.087)	−4.956*** (1.604)	−0.241*** (0.080)
Forestry × Developing nation	—	—	−5.459*** (1.963)	−0.394*** (0.140)
Forestry × Least-developed nation	—	—	−11.156*** (2.773)	−0.697*** (0.164)
Constant	15.323*** (1.372)	2.654*** (0.079)	14.149 (1.386)	2.575*** (0.078)
R-squared	0.218	0.225	0.252	0.263
N	319	319	319	319

Notes: Dependent variable is offset price. Standard errors clustered at the provider level are reported in parentheses. Three, two, and one asterisk(s) indicate statistical significance at the 99%, 95% and 90% levels, respectively.

The final set of models that we report include interactions between whether the offset project is forestry-based and is located in a developing or least-developed nation. Both of these interactions have coefficients that are negative and highly statistically significant. The results indicate that forestry-based projects that are located in non-industrialized nations are associated with substantial price discounts. Compared to those located in industrialized nations, forestry-based offsets in developing nations sell for prices that are lower by \$5.46 on average, or approximately 39%. The difference is even greater for forestry-based projects in least-developed nations, where the average discount compared to industrialized nations is \$11.16, or nearly 70%. The forestry-based difference between developing and least-developed nations is also statistically significant ($F = 4.46$, $p = 0.038$), indicating an average price difference of \$4.70. In these specifications, we also find that the non-forestry difference between developing and least-developed nations is statistically significant ($F = 3.01$, $p = 0.087$). Considering all other offset types, average offset prices are \$2.83 or 17% higher in least-developed nations compared to developing nations, and both remain significantly higher than the average price in industrialized nations.

4. Discussion

Among the more robust findings of our analysis is that the location of both providers and projects has a significant effect on offset prices. All providers included in the dataset are located in industrialized nations, but those located in Europe sell offsets for an average premium of nearly 30%. Many factors may be contributing to this price differential. Both awareness about climate change and agreement on the need to take action are perhaps greater in Europe than anywhere else in the world. Moreover, as discussed previously, GHG emissions are regulated throughout the European Union, and offsets are allowed as part of both industrial and national compliance strategies. Each of these factors, along with a potential preference for more regional offset providers, may contribute to an increase in demand, and therefore price, of carbon offsets sold by European providers.

Somewhat more surprising is the way that the location of projects themselves affects prices. When considering all types of offset projects, we find that projects occurring in developing and least-developing nations are significantly more expensive than those taking place in industrialized nations, by an average of nearly 20%. Assuming that these nations do not have the most current technology in place, one might expect the cost of emissions abatement in these nations to be lower than that in industrialized nations. This is, after all, the economic rationale for the Kyoto Protocol's CDM. But our empirical results, which show higher prices in non-industrialized nations, are not consistent with this line of reasoning. One possible explanation for the price premium associated with offsets in non-industrialized nations is the desire for wealth redistribution, i.e., poverty alleviation, on the part of offset buyers in voluntary carbon markets. The plausibility of this explanation is strengthened even further by the fact

that in some specifications, we also find significantly higher offset prices when projects are located in least-developed nations compared to developing nations. It is also the case that establishing and managing offset projects in non-industrialized nations can have further challenges that increase the cost due to weaker institutional arrangements.¹³

Among all the types of offset projects considered in the dataset, forestry-based projects are the most common. It is also the case that forestry-based projects are the most controversial. As discussed previously, concerns tend to focus in particular on whether projects that seek to avoid deforestation or promote reforestation are legitimately additional, permanent, or both. At the same time, forestry-based projects are frequently promoted because of associated co-benefits. In addition to carbon sequestration, standing forests provide additional benefits in the form of wildlife habitat and ecosystem services more generally (for examples, see [Foley et al., 2005](#); and [Myers, 1997](#)).¹⁴ We nevertheless find some evidence that forestry-based offsets sell for lower prices than offsets of other types, perhaps reflecting greater uncertainty about additionality and permanence. The stronger result, however, is that forestry-based offsets sell for substantially lower prices than offsets of other types when projects are located in non-industrialized nations, with average prices lower by 40% and 70% in developing and least-developed nations, respectively. With respect to uncertainty, these results may reflect how these nations often lack the institutions required to ensure the quality of forestry offsets, such as secure property rights, good governance, and monitoring infrastructure. Furthermore, lower prices in non-industrialized nations may be related to the lower opportunity costs of land in developing and least-developed nations when kept in forests. Distinguishing between these potential explanations for the lower price of forestry-based offsets in non-industrialized nations is critical, as there is significant international momentum to incorporate reduced emissions from deforestation and degradation (REDD) offsets in the next round of climate negotiations, and these decisions will have important implications for both GHG emissions and land use in the future (see, for example, [Miles and Kapos, 2008](#)).

Demonstrating that offsets represent actual reductions in GHG emissions is essential for the long-term viability of offsets in both a regulatory and voluntary setting. In order to address the information asymmetry that exists between offset providers and buyers, emphasis is increasingly being placed on the importance of developing standards and establishing third-party certifiers to ensure the credibility of provider claims. Such

¹³Though not reported in the paper, we also estimated project-level regression models that included a variable for the level of corruption in the host nation. The corruption variable was based on Transparency International's 2008 Corruption Perceptions Index, available at www.icgg.org. Though we did not find that corruption is associated with higher offset prices, the results for price differences based on OECD classification continue to hold after controlling for corruption.

¹⁴We also estimated, though do not report, project-level regression models that included a variable that attempted to capture the biodiversity benefits associated with the forestry-based projects. This indicator variable was created from the project descriptions on the CC website, based on appearance of the terms "native species", "native forest", or "restoration" in the description. We were unable to identify any impact on price due to the type of forestry project pursued.

certification might be expected to increase the price of offsets for reasons related to both supply and demand. Obtaining certification and/or complying with standards is not only costly; the additional information conveyed through certification might also increase a buyer's willingness to pay. Our results, however, suggest that the impact of certification on offset prices depends on the certifier.

A robust finding is that CDM or GS certification has a positive effect on offset prices, with estimates of the premium ranging between 30% and 65%. Whether this is driven by greater costs or greater willingness to pay is unclear, but a unique feature of these two certifications is that the offsets qualify for emission reductions under the Kyoto Protocol. This feature clearly has an additional benefit in a regulated setting, and to the extent that offsets with this certification are selling in the voluntary market, the premium indicates that offset buyers do in fact attach value to CDM and GS certification. We do not find a similar result for VCS certification. In fact, we find some evidence that VCS certification, the largest non-regulatory certifier, is associated with lower offset prices, when compared to offset projects that are either uncertified or certified by some unspecified other third-party. We do not have a good explanation for this result, though it is consistent with simple descriptive statistics reported in [Hamilton *et al.* \(2009\)](#), where prices are lower for VCS-certified projects than for projects with other third-party certification or no certification. One potential explanation for the VCS discount is that VCS certification, compared to other certifications or no certification, may not allay concerns about additionality, permanence, and verifiability. Other possible explanations range from low costs of compliance with potentially weak VCS standards, an omitted variable in our analysis that is correlated with VCS certification and associated with lower prices, and the general possibility, discussed more below, that prices are not closely related to marginal costs because of a thin market.

5. Summary and Conclusion

The primary aim of this paper is to investigate factors that help explain the large variability in the price of voluntary carbon offsets. Using data listed on the Carbon Catalog (CC), we estimate hedonic price functions using a variety of provider- and project-level characteristics as explanatory variables. We find that providers located in Europe sell offsets at prices that are approximately 30% higher than providers located in either North America or Australasia. Contrary to what one might expect, offset prices are generally higher, by roughly 20%, when projects are located in developing or least-developed nations. But this result does not hold for forestry-based projects. We find evidence that forestry-based offsets sell at lower prices, and the result is particularly strong when projects are located in developing or least-developed nations. Offsets that are CDM- or GS-certified, and therefore qualify under the Kyoto Protocol, sell at a premium of more than 30%, while third-party certification from the VCS, one of the largest certifiers, is associated with a price discount. Variables that do not have a

significant effect on offset prices are the number of projects that a provider manages and a provider's status as for-profit or not-for-profit.

We base our analysis on offset providers and projects listed on CC, which, to our knowledge, is the most comprehensive listing of sellers in the voluntary offset market. While the CC dataset continues to expand and others will surely emerge, future research should take advantage of greater sources of data. We expect that such centralized listings that increase transparency will also promote more competition in the offset market. Despite several robust findings, the market for carbon offsets is still relatively new, and one might reasonably question whether the market is thick enough for competitive pressures to be driving price differences. Also at play are other important variables that we cannot measure directly, such as continuing concerns about additionality, permanence, and credibility. Many of the results presented here are consistent with the market recognizing these concerns, especially those related to a premium for CDM/GS certification and lower prices for forestry-based offsets. But as the market continues to develop, there will be more opportunities to investigate these effects and separate them from potential co-benefits, for which we find no clear results. In conclusion, we emphasize that voluntary carbon offsets are associated with a bundle of characteristics making them well-suited to hedonic analysis, as we have done here, and that understanding what drives prices in this market is increasingly important.

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