Strathmore UNIVERSITY

Fair Price of Carbon Credits: An Account of Incentive Price Offers

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DECLARATION

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the Research Proposal contains no material previously published or written by another person except where due reference is made in the Research Proposal itself.

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Abstract

In this paper, we introduce the relationship between carbon credit prices and incentive bids. We incorporate different carbon trading systems on Certified Emission Reduction units to examine the underlying distribution of their price paths. We adopt the use of software like R and EasyFit to accomplish this task. Based on the analysis of the opening and closing carbon credit prices during 2007 to 2014 from the Emission Reduction Trading System, we establish the distributions as being a Gamma 3p for EUAs and Cauchy for CERs. We also establish the lack there of of independence in the prices of carbon credits in different trading systems and determine the valuation of carbon credit projects implemented in Kenya. We provide the detailed policy implications of the above conclusions especially so for developing economies.

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GLOSSARY OF TERMS

Additional Offsets - Carbon offsets that would not have occurred without the offset project. (one of four criteria to look for when purchasing carbon offsets)

Cap-and-Trade - A regulatory process that places a "cap" on the greenhouse gas emissions industries are allowed to produce. Companies that come in under the cap are entitled to "trade" (i.e., sell) their leftover emission allowances to other companies that have exceeded their limit.

Carbon Allowances - Permits (credits) to emit greenhouse gases for members of a regulated carbon market.

Carbon Sequestration – this is the net process of storing carbon in a carbon sink. Sinks can include terrestrial (soil, trees), oceanic, atmospheric, and geologic. For example, terrestrial sequestration could result when carbon fixed in trees through aforestation, or plants and soil root masses as a result of NoTill practices results in photosynthesis exceeding carbon dioxide release through plant aspiration.

CDM – The **Clean Development Mechanism** (CDM) is an arrangement under the Kyoto Protocol allowing industrialized countries with a greenhouse gas reduction commitment to invest in emission reducing projects in developing countries as an alternative to what is generally considered more costly emission reductions in their own countries. In theory, the CDM allows for a drastic reduction of costs for the industrialized countries, while achieving the same amount of emission reductions as without the CDM. The CDM is supervised by the CDM Executive Board (CDM EB) and is under the guidance of the Conference of the Parties (COP/MOP) of the United Nations Framework Convention on Climate Change (UNFCCC).

EU-ETS – abbreviation for European Union-Emissions Trading Scheme. The EU-ETS is the oversight entity under which pilot-project based carbon trading is being conducted in European Union signatories seeking to comply with the Kyoto Protocol. The pilot project period began in 2003 and will go through 2007. The official period for Kyoto emissions reduction measurement is set for 2008-2012. EU-ETS is the largest GHG emissions cap and trade system in the world, involving multiple countries and sectors. Under this Scheme, electrical and industrial installations must obtain a CO2 permit, monitor emissions, and ensure emissions do not exceed the European Union Emissions Allowances (EUAs) that each holds. The system is patterned after the U. S. sulfur dioxide emissions cap and trade program which has been highly successful in reducing SO2 emissions.

EUA – European Union Emission Allowance

Kyoto Protocol - An international treaty aimed at reducing worldwide greenhouse gas emissions. It is within the Kyoto Protocol that the term "carbon credit" was first introduced.

Offset Certificates - The paper permits issued for your purchase of carbon credits. Offset certificates should include a serial number unique to the offset, as well as total tonnage purchased, the verifier's name and signature, the project location, the owner's name and address, and a vintage date.

Performance Standard - Instead of limiting projects to those that would not be possible without the carbon market, the performance standard counts as offsets any reduction of energy that is below a certain benchmark. Yes, the project may be one that is environmentally-friendly, but it is one that would have happened anyway, regardless of carbon market support. For this reason, avoid offsets associated with the performance standard.

Permanent Offsets - Lasting or guaranteed to be replaced should losses occur. (one of four criteria to look for when purchasing carbon offsets)

Real Offsets - Carbon offsets that have already occurred. (one of four criteria to look for when purchasing carbon offsets)

Regulated Carbon Market - A carbon market in which its participants are legally required to cut their emissions.

Renewable Energy Credits (REC's) - Unlike a carbon offset that represents 1 ton of emission reductions, a renewable energy credit represents 1 MWh of energy generated by a renewable energy source, such as wind, solar and hydroelectric power.

Verifiable Offsets - Carbon offsets that can be quantified, monitored and verified. (one of four criteria to look for when purchasing carbon offsets)

Voluntary Carbon Market - A carbon market in which its participants are not legally required to cut their emissions, but choose to do so of their own accord.

INTRODUCTION

1.1. Background

Concern about the extent of global climate change and its potential consequences has increased dramatically in recent years. Many believe that unprecedented climate changes are occurring as result of man-made emissions of greenhouse gases, the largest source being CO_2 produced by the combustion of fossil fuels in utility and industrial boilers and in internal combustion engines. Thus, any effort to reduce greenhouse gas emissions will start with efforts to restrict these activities. (Darius W. Gaskins & Weyant, 1993)

In building their affluent economies, industrialized countries became dominantly responsible for the climate change problem[1]. The increasing threat of global climate change stimulated international discussions on potential responses and initiated negotiations towards agreements to limit CO_2 (carbon dioxide) emissions which is the largest contributor to global warming. Some ecologically sustainable development efforts, such as reforestation and the use of renewable sources of energy, can provide global environmental benefits by helping to lag the rate of global accumulation of CO_2 caused by emissions from the use of fossil fuels. (Taschini, 2010)

The developing nations are expected to emit an increasing share of future global carbon emissions and consequently cannot be ignored in the strategies to solve the climate problem. These nations have many opportunities to reduce future carbon emissions because they are presently not greatly industrialised. However,

[1] The 24 developed countries that are members of the Organization for Economic Cooperation and Development (OECD) currently produce slightly less than half of the world's carbon dioxide emissions. On a positive note, that percentage, even in the absence of emissions controls, is projected to decrease dramatically by the middle of the next century. (Palanca-Tan, 2006)

the necessary technology and financial resources are concentrated in developed countries. (Swisher & Masters, 1992)

The IPCC (Intergovernmental Panel on Climate Change) reports that developing countries are especially vulnerable to the negative impacts of climate change because many of these countries are in tropical, subtropical and arid regions. Unlike developed countries, they do not have sufficient markets and institutions that can make adaptation easy. The response of developing countries may be restricted by factors such as widespread poverty, inequitable land distribution systems and other infrastructural and economic limitations. (Palanca-Tan, 2006)

In the European Union Emission Trading Scheme for example, several exchanges are committed to the trading of carbon emission allowances. The valuation of these carbon derivatives is important. This is because in the concept of carbon finance, investment decisions yielding carbon emission savings in the form of energy consumption reduction, or its production from renewable sources are examined with respect to all potentially generated carbon assets. The revenue from these assets can be used to partially or wholly pay back the investments. (Fehr & Hinz, 2006)

An Emission reduction credits system provides little incentive to reduce activity levels by developed nations which cause harmful emissions, while a tradable allowance system provides a continuing incentive to reduce emissions by any efficient means, including activity level. The Emission reduction credits system subsidizes the activity level to which it is tied and fails to incorporate the full cost of external harm into the product price. If the permit limit is chosen efficiently, a cap and trade system is more efficient. (Dewees, 2001)

This therefore means that the success of the projects including a carbon finance component is determined by the correct valuation of the carbon assets. Correct in terms of optimizing emission reductions. (Fehr & Hinz, 2006)

1.2. Main developments and trends

In 1979, the World Meteorological Organization (WMO) organized the first World Climate Conference, after which scientific evidence linking Green House Gas (GHG) emissions from human activities with global climate change led to appeals for a global treaty to address the problem. In 1988 the WMO and the UNEP (United Nations Environment Programme) established the IPCC, which in 1990 came up with its First Scientific Assessment. The result of this was the establishment of the INC (Intergovernmental Negotiating Committee) by the United Nations General Assembly, for a framework convention on climate change. The INC drafted the UNFCCC (United Nations Framework Convention on Climate Change) which came into force in 1994. Its supreme body, the COP (Conference of Parties) held its third session (COP3) in 1997 and this is when the COP adopted the Kyoto Protocol. (Palanca-Tan, 2006)

The Kyoto Protocol instructs that industrialized countries commit to reduce their GHG emissions, which can be realised through reducing their current emissions to meet their allowance to emit or through emissions trading.

Emissions trading take place from two alternative baselines; Cap and trade, this specifies the total allowable emissions in permits and allows trading of the same and Emission reduction credits.

In 1997, developed countries including, China, Chile, Belgium, Argentina, Australia among others adopted the Kyoto protocol which is a mandatory constraint on reduction of Green House Gas emissions (Boom & Svendsen, 2000).

Each Annex 1[2] countries signed into the protocol is assigned a carbon allowance through the issue of a permit. A carbon allowance refers to the amount of carbon that can be emitted into the atmosphere which is authorized by the government. In carbon markets, an allowance is commonly denominated as one ton of carbon dioxide or its equivalent. (Bernstein, Montgomery, Rutherford, & Yang, 1999)

Carbon allowance permits can be securitized to form a market based policy instrument called Tradable Emission Permits which assign a monetary value to reducing atmospheric CO_2 in countries using the instrument. The instrument in this case is created through companies lowering the level of offending gases more than is necessary to comply with regulations to have spare permits and subsequently sell these spare permits to companies which exceeded their emission allowance. (Rubin, 1996)

A carbon credit, often called a carbon offset, on the other hand is a financial instrument that represents a tonne of CO_2 or CO_2e (carbon dioxide equivalent gases) removed or reduced from the atmosphere from an emission reduction project, which can be used, by governments, industry or private individuals to offset damaging carbon emissions that they are generating. (Dewees, 2001)

Carbon credits originate from a range of emission reduction activities associated with the removal of existing emissions from the atmosphere and the reduction of future emissions. These are commonly called "methodologies". (Tietenberg, 2000)

Afforestation and reforestation activities are a key means by which existing emissions can be removed from the atmosphere and carbon credits created. On the other hand, construction of a wind farm rather than a coal-fired power station may create carbon credits through reducing future emissions; the latter is

[2] Most of the developed and industrialised countries

an example of a Clean Development Mechanism (CDM) project. (Fehr & Hinz, 2006)

The CDM was established as a "flexible mechanism" by the Kyoto Protocol, to help ANNEX I Parties to meet their emission reduction commitments, while bringing sustainable development benefits to the CDM host countries. The host countries are developing nations. The benefits that a host country may realize are multiple; Transfer of environment friendly technologies, novel capital investments and income growth prospects and an improved quality of life. (Palanca-Tan, 2006)

Carbon credits originated through these CDM activities are compliance credits called Certified Emission Reduction (CER) units. These units are sold to countries or companies with a commitment to reduce emissions.

The other type of compliance credits are Emission Reduction Units (ERUs)[3].

1.3. Problem Statement

CER prices severely impacted by supply - demand mismatch. Individuals/companies have the option to compensate others to engage in the CDM activities on their behalf. These people or organizations acting on their behalf are called offset providers. Given the increased demand for these offsets, there has been a concurrent increase in the number of providers. This supply overload does not necessarily translate to an information overload. The average "consumer" has myriad providers from which to choose but does not always

[3] Like CER in developing nations, within developed nations, a mechanism known as Joint Implementation or JI, produces compliance credits referred to as Emission Reduction Units or ERUs.

have the technical literacy necessary to make that decision. (Dhanda & Hartman, 2011)

Trading the credits implies a cost of 0.10 Euros per CER unit; this is the market price. The World Bank however, has many programs to buy carbon credits either on their own or on behalf of others. They then buy carbon credits from projects that have great development value.

They pay a much higher price for the carbon credits; normally, between 4.00 and 10.00 EURO per CERs. This is 100 times higher (bank, 2014). The incentive may serve the intended purpose of increasing such projects in developing countries or may inevitably prove to be an unreasonable price and cause and overload of suppliers and eventually the abandonment of such project initiatives. The World Bank price in this case is also assumed to have an effect on the market price, which is the price of the allowances traded in the cap and trade system. If its effect on the market price is greatly significant then some of the countries signed into the Kyoto Protocol may opt out of the cap and trade system and join the CDM project implementation bandwagon or resign their commitment to the protocol.

1.3.1. Research gap and link to study

To the best of my knowledge, pricing methodologies recommended by authors imply an underlying Brownian motion distribution. A normality test on observed market prices quickly rejects this strong assumption.

Without a proper carbon price, inefficient energy choices and investments are made. Furthermore, distortions occur in the trade of energy and other goods if various jurisdictions have different carbon prices. (Schott, 2013)

The study therefore seeks to identify the underlying distribution of the price path of the credits and price them accordingly.

1.4. Research Objective

The objective of this research following the spread of the market price and the incentive bid of the World Bank is to;

I. Determine the value of carbon offsetting projects from which carbon credits arise

II. Determine the underlying distribution of both the price path of EUAs and CERs

III. Determine the fair price of these carbon credits incorporating a delayed correlation

1.5. Justification

This study will enable the greater understanding by policy makers and economic students of the carbon market and its guiding pricing mechanisms, both of which are fairly new concepts in the economy.

The study is also beneficial as we can be able to map the potential success or failure of this market onto what that translates about future formulation of the pricing of credits, given the existence and effect of other price offers on the same credits. The results of this study can also be used by economists and economics students for future study on the effect of incentive bids on other aspects of the economy.

LITERATURE REVIEW

2.1. Introduction

It has been contended, by Economists such as Dales (Dales, 1968) and Crocker (1966) that the realisation of a given level of emissions reduction in a least cost fashion can be achieved through a system of tradable discharge permits.

Montgomery (Montgomery, 1972) provided a formal proof of the cost efficiency of such systems. Emissions trading offers significant cost savings for nations and firms addressing climate change and provides important risk management tools and profit opportunities for businesses. Taking advantage of these opportunities requires an understanding of the basic legal and institutional structures for GHG emissions trading systems. A cap and trade system is used and like a pollution tax, the system imposes a price on each unit of pollution emitted which, when traded in markets is set by market supply. (Stewart, Connaughton, & Foxhall, 2001)

In understanding environmental economics, two fundamental ideas come into play. The first is that the optimal level of pollution is rarely zero and, the second is that, marketable pollution permits offer the lowest cost and the most easily implemented means of attaining a given level of pollution control. The two ideas are further supported by the fact that, there are tremendous opportunity costs involved in attempting to achieve zero pollution and the public's health is no more endangered by the marketable permit approach than by any other means of attaining a given reduction in pollution, respectively. (Walbert & Bierma, Autumn, 1988) .

There are a growing number of global analyses that offer regional details on pollution and many models are now available for studying emissions reductions in OECD countries. In the global studies, however, developing countries are aggregated mainly due to lack of appropriate data and institutional information for the countries involved. Some of these developing countries, among them India, Nigeria, Indonesia, and others, have substantial emissions presently or have the potential to increase; this has led to the development of models that can provide valuable insight for the global models, as well as give a realistic picture of the potential for emission reduction in the individual countries. (Weyant, Autumn, 1993)

It has been argued that developing countries should be excluded from emissions trading since their emission levels are not worrying. Literature such as *Effects of Restrictions on International Permit Trading* (Bernstein, Montgomery, Rutherford, & Yang, 1999) put the debate to rest by proving that developing countries will not escape costs, even if they do not participate in emissions trading because of changes in the terms of trade which shift some of the cost of Annex I-only emissions reductions onto developing countries.

The paper also analyses the effects of restrictions on trading and reveals that emissions trading has significant potential to improve welfare for all parties, and the broader and less restricted trading is, the greater that potential. In general, less restricted trading has the potential to benefit developing countries (Palanca-Tan, 2006), confirms this. In their results, developing countries are potentially better off under global trading than under no trading and in general they are better off under Annex I trading than under no trading. Achieving this potential will require delicate negotiations about the initial allocation of permits - the cap assigned to developing countries. Developing countries also benefit from CDM projects. The CDM is designed to support projects to reduce emissions from developing countries, with funding from industrial countries that would receive emission credits (Dhanda & Hartman, 2011).

2.2. Seminal Work

2.2.1. Discussion of theoretical framework

In a theoretical analysis of the political economy of international emissions trading scheme choice, (Boom & Svendsen, 2000) consider three schemes of emissions trading; trade between governments, permit trading and credit trading. For government trade, this would be bilateral trade in large quantities. The architecture of this system together with the limited number of potential traders (the annex B countries) will cause trade to be infrequent.

Trade will be clustered in the beginning and at the end of the commitment period, a well performing market with regular price signals will not exist. In a permit trading system, emission sources trade emission permits directly with each other (Hahn & Stavins, 1999). In a credit trading system, emission sources can also trade directly with each other but a firm can only sell emission credits when an official agency approves of the abatement project[4] started by the firm. Permit trading would be more efficient because of the three systems of trade; it has the lowest transaction costs. Furthermore, in a government trading scheme, there are strategic incentives to misrepresent the costs of abatement during the negotiations with the trading partner and because of the limited number of traders in government trading, certain countries can exert market power (Boom & Nentjes, 2000). The paper concludes that even though permit trading is more efficient, most interest groups prefer a combination of government and credit trading. Environmental organizations prefer credit trading because it restricts trade to non-hot air trade[5] and more importantly, provides them with work,

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[4] Abatement projects are those that reduce the degree or intensity of greenhouse-gas emissions (Fehr & Hinz, 2006)

[5] Hot air refers to the concern that some governments will be able to meet their targets for greenhouse-gas emissions under the Kyoto Protocol with minimal effort and could then flood the

making it possible for them to expand their organizations. In light of this conclusion, other price offers would further increase the hit on participation in permit trading (Boom & Svendsen, 2000).

Discussions about carbon price typically revolve around a carbon tax and a cap and trade emissions market (Schott, 2013). Both have potential to reduce total emissions at the lowest possible cost and are efficient economic instruments. They, however have flaws in reality. A cap and trade system guarantees a specific emissions reduction target but is prone to price volatility. It also generates less revenue compared to a carbon tax because a large proportion of emission permits are not auctioned off.

In EU ETS, absolute caps are determined by an international institution, the European Commission's Emissions Trading Directorate (Ellerman & Buchner, 2008). National governments, however, allocate emission permits and engage in the monitoring of emission levels. A carbon tax provides price stability but makes it uncertain as to how much emission will be reduced and the tax needs to be properly set in order not to put too much burden on emitters but have an impact (Schott, 2013). The price volatility associated with permit trading (King, 2008) would surge the motive of industrialized countries to participate more in , the now assumed crowded, CDM projects to offset their emissions and sell the excess at the higher and guaranteed price offered by other organizations, in this case, the World Bank. Other companies in industrialized countries may see the capping of their emissions to sell off their extra allowances, at volatile prices, as high costs of production and exit the permit trading system. Their alternative, whilst complying with their commitment to the Kyoto protocol would be to engage in implementation of CDM projects which would also come at a high cost

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market with emissions credits, reducing the incentive for other countries to cut their own domestic emissions. (Boom & Svendsen, 2000) because the company has to employ another organization to implement the projects on their behalf to reduce the risk of deviating from their main service/product provision, as reinforced by (Darius W. Gaskins & Weyant, 1993) who confirm that Carbon restrictions place countries that control emissions at a competitive disadvantage in energy intensive industries. Consequently, the cost to countries that control emissions increases with the level of cutback and their impact on global emissions may drop severely if several countries fail to cooperate.

Keohane (Keohane, 2009) argues in favor of a cap and trade system while Metcalf (Metcalf, 2009) proposes a carbon tax. Murray, Newell and Pizer (Murray, Newell, & Pizer, 2009) suggest a Roberts and Spence (1976) type of cap and trade system with an allowance reserve. The latter showed that a mixed system of charges and tradable emission allowances would be preferred to a regulator when there is uncertainty about the actual cost of pollution control.

Schott (Schott, 2013) also points out that, the larger the number of emitters participating in a cap and trade system, the larger will be the number of options for trade and the lower the emission market prices and therefore the compliance costs. In the case of high price offers by other organizations in a different trade system, this would be contradicted with a high demand and supply mismatch. This is due to the fact that the production costs of capping emissions would not be compensated by the low price of the allowance. The supplier of the allowance would rather switch to the system that offers higher prices.

Most of the present research relies on the theoretical results, demonstrated and extensively discussed by (Cronshaw & Kruse, 1966) and (Rubin, 1996) that, in an efficient market, the equilibrium price of the emission permits (or allowances) is equal to the marginal costs of the cheapest pollution abatement solution. This statement reinforces the belief that a high price level for emission permits brings about relevant companies with lower marginal abatement costs in order to exploit consequent price differences. Such companies make profits by lowering the level of offending gases more than is necessary to comply with regulations and subsequently sell their spare permits (Paolella & Taschini, 2008).

In addition to generating revenue for the regulator, certain charges coupled with emissions permits may result in a better instrument than permits alone. Rent capture reduces the purchase price of tradable emission permits. Proof of this is provided by Grafton and Devlin (Grafton & Devlin, 1996) whose paper examines how a regulator may capture this rent. The authors compare four different methods of rent capture; profit, output and input charges and an emission permit rental charge, with respect to their effects on efficiency and the relative burden placed on firms that use "clean" production technologies and those that use pollutant technologies. A profit charge captures rent at a fixed proportion of firm's profits excluding the opportunity cost of owning emission permits. An output and input charge collects rent from firms at a set amount per unit of output and input respectively. An emission permit rental charge is applied at a fixed rate on the rental price of emission permits.

The study makes an assumption that the charges are introduced simultaneously with the allocation of tradable emission permits and that the regulator captures less than the total amount of rent such that permits trade at a positive price. The paper concludes that the short run emissions trading outcome will be distorted by an output and input charge, given that firms are heterogeneous and that depending on the pollution technology, firms will rank the four methods of rent capture differently. For instance, "clean" technology firms are likely to prefer an emission permit rental charge over all others. Policy makers may use this as a method of inducing or rewarding desirable behavior.

A study of the development of a range of projections of the likely costs of alternative levels of control of carbon emissions from the energy sector is done in the paper by Darius and Weyant, *Model Comparisons of the Costs of Reducing CO_2 Emissions* (Darius W. Gaskins & Weyant, 1993). The paper is centered on additional models and methods to the 13 scenarios studied by the twelfth Energy Modeling Forum (EMF 12) working group[6].

The study also shows the possibility of using tax revenues generated from carbon taxes to reduce other taxes, deficit reduction or to add onto the government spending. The carbon tax however, costs the economy in terms of lost output resulting from the increase in the price of goods requiring carbon emissions[7].

Correspondingly, if OECD unilaterally implements a carbon reduction program, carbon emissions in other countries will increase, relative to reference case levels because of the resulting changes in international energy prices. Nonparticipating countries' increased carbon emission is as result of both increased energy intensity of economic activity and through migration of energy intensive production into unconstrained countries, this puts the constrained countries at a competitive disadvantage.

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[6] The EMF 12 working group specified 13 standardized scenarios reflecting a range of carbon emission-control levels as well as sensitivities on key standardized input. These scenarios were ultimately implemented by 14 modeling teams employing a wide variety of techno-economic models, although not every model could implement every scenario. (Darius W. Gaskins & Weyant, 1993)

[7] Under a CO_2 constraint, a carbon tax makes up the difference between the world market and purchaser prices. The tax is endogenous and also serves as an indicator of the marginal cost of the CO_2 target. If the tax is large, society stands to lose considerable production at the margin if the CO_2 is tightened and the marginal cost is high.

Other emission reduction approaches include introducing carbon sequestration[8] into an international agreement concerned with global warming, the Kyoto Protocol included, resolving the permanence issue is key. As discussed by Feng, et al (Feng, Zhao, & Kling, 2002) ultimately, as long as there is less carbon in the air, it does not matter whether the reduction is done by sequestration or emission abatement. They showed that carbon sequestration should be used as timely as possible to ease the pressure on emission abatement and the carbon flow into sinks, lasts until the atmospheric carbon concentration is stabilized. The paper acknowledges that sequestration has the potential of being temporary and cannot be attributed the same value that emission reductions have. It shows the use of special mechanisms used to address this difference and proposes mechanisms to introduce sequestration into a carbon trading market: a pay-as-you-go system, a variable-length system and a carbon annuity account system. The three are all efficient but are not equally feasible to implement.

2.2.2. Mathematical models

Pricing

In an effort to bridge the gap between theoretical studies and observed market price characteristics, emerging empirical studies have been investigating the historical time series of permit price. Benz and Trück (Benz & Trück, 2009) capture the heteroskedastic behavior of the return time series by use of a markov-switching model in their analysis of the short term spot price behavior of CO_2 permits. In contrast, Paolella and Taschini (Paolella & Taschini, 2008) back the use of a GARCH structure to for the analysis of characteristic heteroskedastic dynamics in the returns of $C0_2$ emission permits in the EU ETS. Marc and Luca

[8] The removal and storage of carbon from the atmosphere in carbon sinks, such as oceans, forests or soils through physical or biological processes, such as photosynthesis. Humans have tried to increase carbon sequestration by growing new forests. (http://www.greenfacts.org/glossary/abc/carbon-sequestration.htm)

(Marc & Luca, 2012) generate endogenously the price dynamics of marketable permits under asymmetric information, allowing banking and borrowing. In common with the paper on a quantitative approach to carbon price risk modeling by Fehr and Hinz (Fehr & Hinz, 2006), the paper differentiates short-term and long-term abatement measures. Their model assumes each firm's pollution emission follows an exogenously given stochastic process, there are a finite number of firms and their initial allocation of permits in each period to the firms is predetermined and publicly known. In order to model asymmetry, the authors assume that in each period, a firm knows its own accumulated pollution level and those of the other firms up to the previous period. Paolella and Taschini (Paolella & Taschini, 2008) derive a closed-form pricing formula for European-style options as follows;

Consider two portfolios at time t. One is a European-style call option with a positive payoff (S_T - K) at maturity and the other corresponds to (P - K) / P units of emission permits.

In accordance with their model, at time T, there are only two possible states for the price of emission permits S_T which are 0 and P, therefore both portfolios generate the same profit at maturity:

$$f(S_T) = \begin{cases} P - K, & \boldsymbol{S_T} = P \\ 0, & \boldsymbol{S_T} = 0 \end{cases}$$

In the absence of arbitrage opportunities:

$$C_{\mathrm{E}}(t) = \frac{\mathrm{P} - K}{\mathrm{P}} . \boldsymbol{S_T}$$

Where $C_E(t)$ is the call price at time t.

Similarly, consider a new portfolio long in a European Put with a positive payoff ($K - S_T$) and short in one riskless bond that generates a payoff equal to the strike price K at maturity T. The portfolio's final payoff at time T is:

$$\begin{cases} -K & \text{If } \boldsymbol{S_T} = P \\ 0, & \text{If } \boldsymbol{S_T} = 0 \end{cases}$$

A portfolio long in a European Call C_E and short in one emission permit generates the same payoff.

The absence of arbitrage opportunities generates then the following option-pricing formula for the European Put $P_E(t)$:

$$\boldsymbol{P_E(t) = e^{-r(T-t)}.\ K + C_E(t) - S_T}$$

$$= K.\left(e^{-r(T-t)} - \frac{S_T}{P}\right)$$

Where r is the risk free rate and the right hand side of the equation is positive because the upper bound of the price of emission permits is the discounted penalty. The equation corresponds to the Put Call Parity. The authors prove that the price path of emission permits depends on the future probability of a shortfall in permits, the penalty that will be paid in the event of a shortfall and the discount rate. However, there is no mention of factors such as other price offers on credits affecting the supposed price path.

Seifert, Uhrig-Homburg, and Wanger (Seifert, Uhrig-Homburg, & Wanger, 2008) analyze the CO_2 spot price dynamics and find that CO_2 prices do not follow any seasonal pattern, and discounted prices should possess a martingale property and conclude that an adequate CO_2 price process should exhibit a time and price dependent volatility structure. Daskalakis, Psychoyios, and Markellos (Daskalakis, Psychoyios, & Markellos, 2009) investigate markets for the spot EUAs within the EU ETS and show that a jump diffusion model proposed by Merton (1976) is the best suitable dynamics for spot EUAs (carbon emission allowances) returns. However, Kou (Kou, 2002) shows that a Poisson process of the JDM is lack of a dependent increment to capture volatility clustering. In *Pricing derivatives with modeling CO2 emission allowance using a regime-switching jump diffusion model: with regime-switching risk premium* (Chang-Yi, Son-Nan, & Shih-Kuei, 2015) perform a statistic test that shows the regime-switching jump diffusion model (RSJM) performs better than the jump diffusion model. They propose a RSJM with regime-switching jump intensities modeled by Markov chain to capture the dynamics of the spot EUAs price given by

$$\frac{dS(t)}{S(t-)} = \mu dt + \sigma dW(t) + (e^{Z_n} - 1)d\Phi(t)$$

Where μ and σ are the mean and the return volatility, respectively. The jump component is controlled by $\Phi(t)$ that represents a Markov modulated Poisson Process. The jump component has a low and high jump intensity denoted by λ_1 *and* λ_2 , respectively. When $\lambda_1 = \lambda_2$ the $\Phi(t)$ is reduced to a Poisson process $N(t)$. Hence, it becomes a JDM;

$$\frac{dS(t)}{S(t-)} = \mu dt + \sigma dW(t) + (e^{Z_n} - 1)dN(t)$$

Further, if the jump component is ignored($\lambda = 0$), the JDM reduces to a Black-Scholes model.

The RSJM is able to detect the existence of regime switching shift caused by change in economic states and the volatility clustering driven by Markov-modulated jump diffusion. (Chang-Yi, Son-Nan, & Shih-Kuei, 2015) Show that the carbon-market system is impacted by announcements of CO_2 emissions economic conditions. This study could be improved to include other factors that impact the carbon market system.

Risk

As recounted by Fehr and Hinz, (Fehr & Hinz, 2006) in commodity business, companies that are exposed to risks from several input commodities hedge themselves by an appropriate futures portfolio, consequently price correlations of diverse commodities become essential. In particular, the European energy business is concerned about correlations of EUA and fuel prices. The authors acknowledge that commodity price models, in particular, fuel price models, form an intrinsic part of carbon price description. They further incorporate long and short term abatements in their models as they influence allowance prices in related but conceptually different ways.

The main aspect of the model is to face the individual strategy optimization of single market participants exposed to price risk.

They $\subset N$ such that;

$N \in \mathbb{N}$ Market participants trading carbon allowances at discrete times,$\{0, 1, \ldots, T\} \subset \mathbb{N}$. At these times, they also produce electricity from fossil fuels. The time to maturity T, corresponds to an entire compliance period where agents cover their carbon emissions by allowances or pay penalties. All prices are described by appropriate adapted stochastic processes on a filtered probability space.

A futures trading strategy of agent i is given by the process $\theta^i = (\theta_t^i)_{t=0}^{T-1}$ where θ_t^i for $t = 0, \ldots, T-1$ stands for the number of futures contracts held by the producer $i = 1, \ldots, N$. Wealth follows the recursion

$$V_{t+1}^{\theta^i,A} = V_t^{\theta^i,A} + \theta_t^i(A_{t+1} - A_t) \; t = 0, \ldots, T-1, \; V_0^{\theta^i,A} = 0$$

Where A_T equals the spot price for carbon allowances at time T.

At maturity, each producer, *i*, faces the difference between its actually emitted carbon and that allocated at the beginning. The authors model this quantity by an $\mathcal{F}_T$ measurable random variable Γ^i. The final wealth from trading is then given by:

$$V_T^{\theta^i,A} - \theta_T^i A_T - \pi(\Gamma^i - \theta_T^i)$$

Where π is the penalty and $(\Gamma^i - \theta_T^i)$is the agent adjusted number of credits depending on the actually realized demand.

To model the short term abatement strategies, the authors use the fuel switching[9] price given by:

$$E_t^i = \frac{h_g^i G_t^i - h_c^i C_t^i}{e_g^i - e_c^i} \quad for\ all\ t = 0, \ldots, T-1$$

Where $h_g^i G_t^i$, $h_c^i C_t^i$ are gas and coal spot prices for Agent *i* at time *t* and e_g^i , e_c^i the emissions for gas and coal, respectively.

---

[9] Shift from a fuel system based on coal to one based on natural gas. Because of natural gas' advantage in this respect, fuel switching translates to a deep reduction in CO2 emissions. (Salovaara, 2011)

They further prove that the equilibrium carbon price equals the marginal contribution of an extra allowance to lower the potential payment in the case of non-compliance:

$$A_t^* = \pi \mathrm{E}\left(1_{\{\Gamma - \Pi(\xi^*) \geq 0\}} \middle| \mathcal{F}_T\right) \ For\ t = 0, \ldots, T.$$

Where ξ^* is the global-optimal fuel switching policy

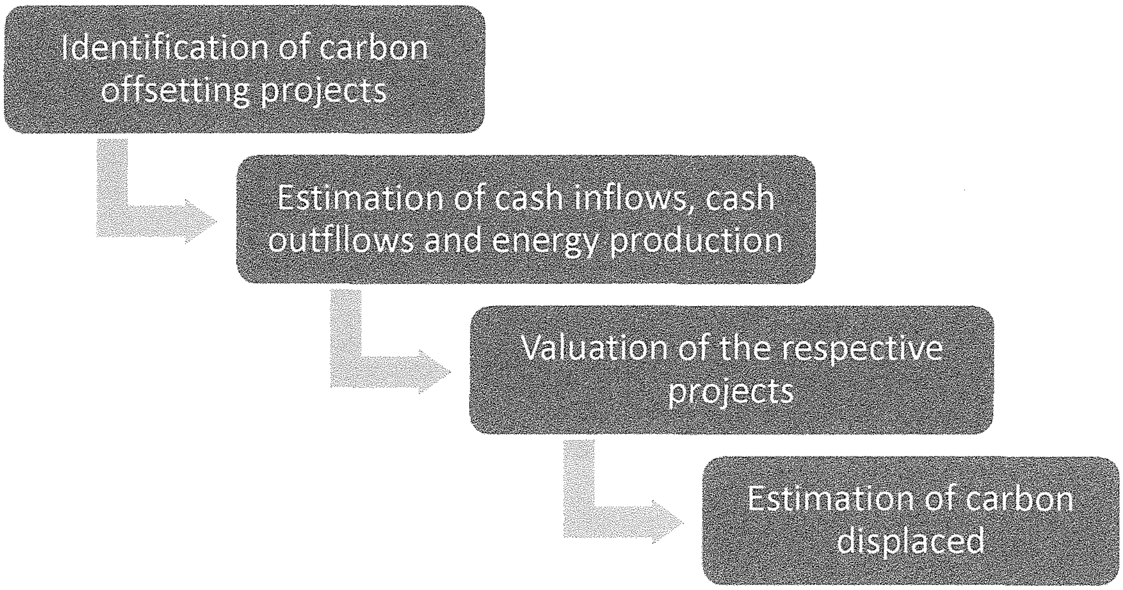
2.4. Research gap

An important limitation to the existing studies is that they focus almost exclusively on developed countries with very little detail on the developing nations. Various types of uncertainty also remain unexplored factors which may affect trading prices and volume and subsequently inhibit the ability of firms to realize potential cost savings. For example, existing regulatory uncertainty may foster increased reluctance on behalf of utilities to choose emissions permits as a compliance strategy, thereby foregoing potential cost savings, also as confirmed by (Boom & Svendsen, 2000) a cap and trade system guarantees a specific emissions reduction target but is prone to price volatility. Consequently, it is important to quantify the effect of other price offers on carbon credits irrespective of the trade system, because this would quantify volatility of the market price of the carbon credits as well.

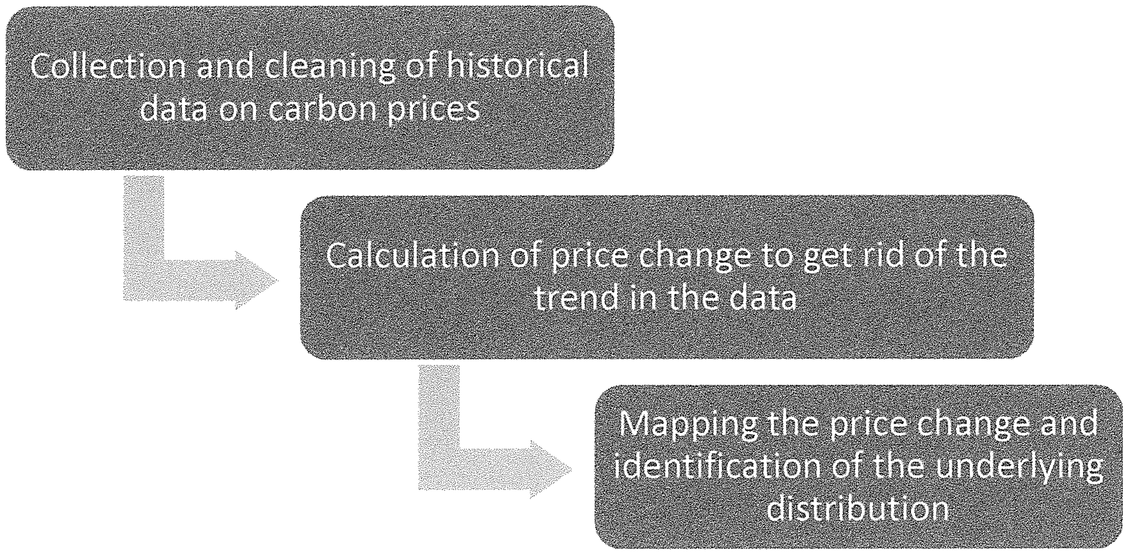
The main contribution of this paper lies in its recognition of other price offers, for instance the World Bank's price, the identification of the underlying price of carbon credits and the valuation of such projects. While there is impressive scholarly work on the carbon market, including pricing and risk, the aforementioned issues have largely been ignored. This paper addresses this gap in literature by the valuation of the projects from which carbon credits are gotten and the identification of the underlying distribution of the price path of the carbon credits.

2.5. Conceptual Framework

In the valuation of the projects;



For the determination of the price path;



METHODOLOGY

3.1. Research Paradigm and Design

Empirical evidence on underlying asset prices and on their derivatives strongly suggests that asset price volatility is stochastic.

3.1.1. Choice of design and justification

In the process of model selection, several models were put into considerations;

Ornstein-Uhlenbeck Process (O-U)

Following Garman (1976), stochastic volatility option prices must satisfy a bivariate fundamental partial differential equation (PDE) in the two state variables, security price and volatility. Stein and Stein (S&S) model volatility as a mean-reverting process with a reflecting barrier at zero. They work with the absolute value of a mean-reverting process. Not properly accounting for this non-negativity condition causes S&S to misdiagnose the impact of stochastic volatility on option pricing. The systematic upward pricing effect, attributed to stochastic volatility by S&S, is in error. Stein and stein (1991) proposes a conditional lognormal diffusion for the security price dynamics (P) subject to a volatility (σ) that also evolves as a diffusion[10], specifically;

$$dP = \mu P dt + \sigma P dz W_1$$

Where μP is the local drift of the process. Stein and Stein model stochastic volatility as the mean reverting diffusion;

$$d\sigma = -\delta(\sigma - \theta)dt + kdzW_2$$

[10] A diffusion process is a Markov process that has continuous sample paths (trajectories). Thus, it is a Markov process with no jumps.

In this case, θ is the long term mean of the volatility process, δ is the mean reverting rate, k reflects the volatility process and W_1, W_2 are independent standard Brownian Motions. S&S validate the use of the arithmetic O-U process above for the instantaneous volatility, which implies that $\sigma(t)$ may become negative, by noting that the volatility enters option pricing only as $\sigma^2(t)$. They contend that this is equivalent to imposing a reflecting barrier at 0 to the process. As verified in literature by Ball and Roma (Ball & Roma, 1994) this is not the case.

The authors further show that the general stochastic volatility option analysis may be extended beyond the volatility specifications proposed by S&S to any security price process that is conditionally lognormal and for which the MGF of the average variance possesses a known analytic form.

They illustrate their methods with an alternative, square-root, model for stochastic volatility, introduced by Heston (1993) that is economically plausible and mathematically tractable whilst taking advantage of work by Cox, Ingersoll, and Ross (1985) in a related but different context. The Cox, Ingersoll and Ross (CIR) limits the tendency to negative values.

Simulation evidence supports a simple approximation for stochastic volatility option pricing that appears to be accurate to the penny for plausible ranges of parameters.

Impulse Response Function

An impulse response function measures the time profile of the effect of shocks at a given point in time on the expected future values of variables in a dynamical system. There are three main issues:

(i) The types of shocks hitting the economy at time t;

(ii) The state of the economy at time t-1 before being shocked; and

(iii) The types of shocks expected to hit the economy from t + 1 to t + n.

Denoting the known history of the economy up to time t - 1 by the non-decreasing information set Ω_{t-1}, the generalized impulse response function of $x_t$at horizon n, advanced in Koop et al. (1996), is defined by

$$GI_x(n, \delta, \Omega_{t-1}) = E(X_{t+n}|\varepsilon_t = \delta, \Omega_{t-1}) - E(X_{t+n}|\Omega_{t-1})$$

The appropriate choice of the hypothesized vector of shocks δ is central to the appropriateness of the properties of the impulse response function. This brings about a problem surrounding the choice of δ. To solve this Sims (1980) suggests the use of the Cholesky decomposition. For simplicity purposes, this model was avoided.

Merton Jump Diffusion

(Merton, 1976) Hypothesizes that the total change in asset price is composed of two parts: the normal small vibrations in price, which are modeled by a geometric Brownian motion, and abnormal large vibrations in price due to the arrival of important information, which are modeled by a jump process.

The jump added in the stochastic process for commodity prices could accommodate large price changes that occur due to important news about the supply and demand conditions in the commodity market. (Hilliard & Reis, 1999)

(Daskalakis, Psychoyios, & Markellos, 2009) Show that a Jump Diffusion Model proposed by Merton (1976) is the best suitable dynamics for spot EUAs returns. (Kou, 2002) However, shows that a Poisson process of the JDM is lack of a dependent increment to capture volatility clustering. In addition, The Merton Jump-diffusion model assumes that jump risk is diversifiable and therefore non-systematic. When jump risk is systematic, a general equilibrium model is required to derive option-pricing formulas.

Multivariate Geometric Brownian motion

In the univariate model, it is assumed that asset prices follow a geometric Brownian motion. The generalization to multiple dimensions takes into account the correlation between the geometric Brownian motions and makes the assumption that the multivariate price process Z follows a multivariate geometric Brownian motion such that $Z = (Z_1, \ldots, Z_k)^{\intercal}$ is a multivariate process defined as;

$$dZ_i = Z_i \mu_i dt + Z_i \sigma_i dW_i$$

With W a vector of correlated Wiener processes such that $E[dW_i dW_j] = \rho_{ij} dt \; for \; i \neq j$ where ρ_{ij} is the covariance between Wiener process i and j; $E[dW_i^2] = dt$; and $dt^2 = 0$ then Z is called a multivariate geometric Brownian motion. (Sierag, 2013)

A GBM process has an advantage in its simplicity and that it only assumes positive values, in line with real asset prices.

3.2. Empirical Strategy

In agreement with the selected methodology, relevant data and data collection techniques are hereby mentioned, in line with the aforementioned research paradigm and design.

3.2.1. Population

In entirety, there are three systems of in the carbon market. These are, Government trading, Permit trading and Emission Reductions trading.

The population of the projects is any project, irrespective of geographic location implemented with the objective to offset carbon dioxide emissions.

3.2.2. Sampling Design and Sample Size

The study places specific focus on permit trading and Emission Reductions trading, specifically certified emission reduction units. Government trading is excluded from the sample, as aforementioned empirical evidence proves; the architecture of this system together with the limited number of potential traders (the annex B countries) will cause trade to be infrequent, if any (Boom & Svendsen, 2000).

Projects that were considered in the valuation process include and are limited to Landfill gas projects, Efficient lighting projects and Wind projects. This is because their data is readily available and they are the most common project installations in the geographic location under consideration; Kenya.

3.2.3. Data Collection Methods

Historic trading prices, with regard to permit trading, are provided on the European Emission Allowance Global Environmental Exchange website while those from Credit Emission Reduction units are provided on the UNFCCC website.

Inputs, project installation costs and expected cash flows from respective carbon displacement projects are provided and were gathered from the GHG Assessment Handbook and Emissions Trading Guide.

3.2.4. Research Procedures

Data analysis involved the use of R to carry out the normality test. This is for the purpose of proving if indeed the underlying price path of the credits follows a Brownian motion. EasyFit, a data analysis and simulation software was also employed in fitting probability distributions to sample data and select the model that best describes the data.

In the valuation of the project installations, the NPV technique was employed. Though it has few disadvantages over other valuation techniques it the following advantages:

1. Ease of computing
2. NPV gives important to the time value of money.
3. In the calculation of NPV, both after cash flow and before cash flow over the life span of the project are considered.
4. Profitability and risk of the projects are given high priority.
5. NPV helps in maximizing the firm's value.

4. RESULTS AND ANALYSIS

4.1. Underlying distribution

In testing whether the underlying distribution of the price follows a Brownian motion, we test the price characteristics against the strongest assumption of the Brownian motion i.e. that the price change is normally distributed

4.1.1. EUA

- A Normal Q-Q Plot of the price change in the EUA appears to be relatively normal. However, a test of significance under;

  H_0: The distribution is normal

  H_a: The distribution is not normal.

  The Shapiro-Wilk normality test, with the test statistics

  - W = 0.8847, p-value = 4.403e-10

  suggests that we should reject the null hypothesis implying that the distribution is indeed not a Brownian motion.

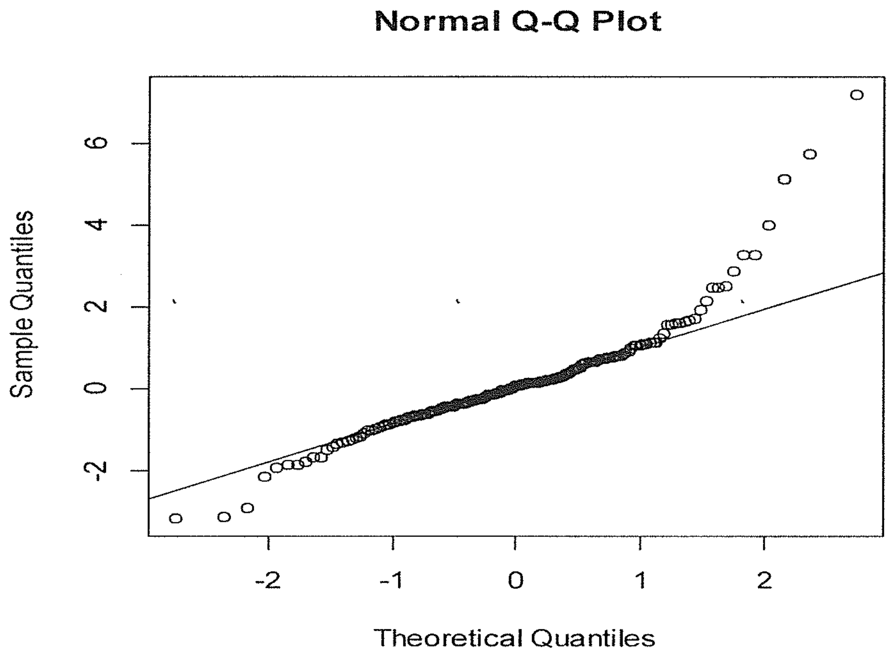


Figure 1: EUA Normal Q-Q Plot

4.1.2. CER

- A Normal Q-Q Plot of the price change in the CER already reveals that the underlying distribution is not normal. To reinforce this implication a test of significance under;

  H_0: The distribution is normal

  H_a: The distribution is not normal.

  is carried out.

  The result is a Shapiro-Wilk normality test, with the test statistics

  - W = 0.8487, p-value = 1.093e-11

  suggesting that we should reject the null hypothesis therefore implying that the distribution is indeed not a Brownian motion.

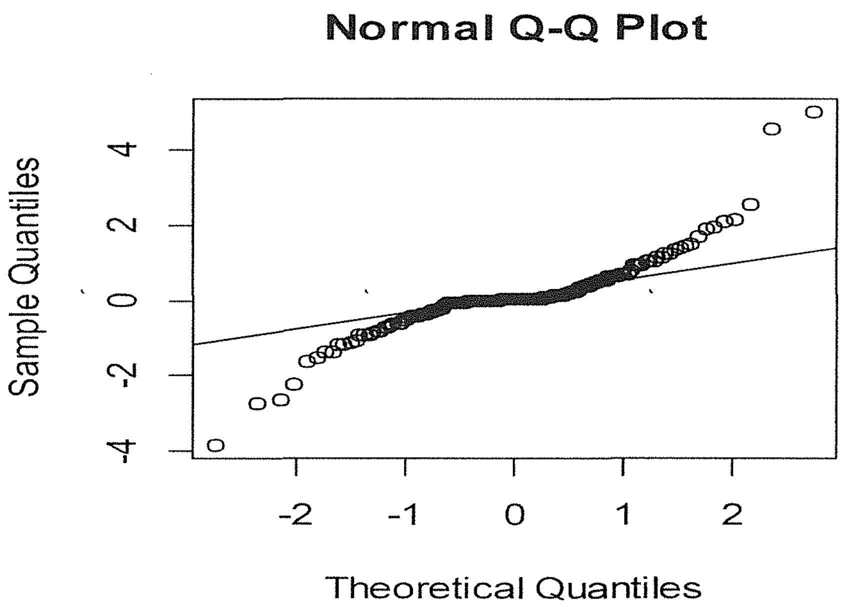


Figure 2: CER Normal Q-Q Plot

Now that we have proven that the distribution are certainly not Brownian motions, the question then becomes, what distribution do they follow?

In the search of the underlying price distribution using EasyFit, which allows fitting probability distributions to sample data and the selection of the model that best describes the data, it is found that EUA prices follow a Gamma 3p (3 parameter) distribution whereas the CER prices follow a Cauchy distribution as illustrated in the figures below.

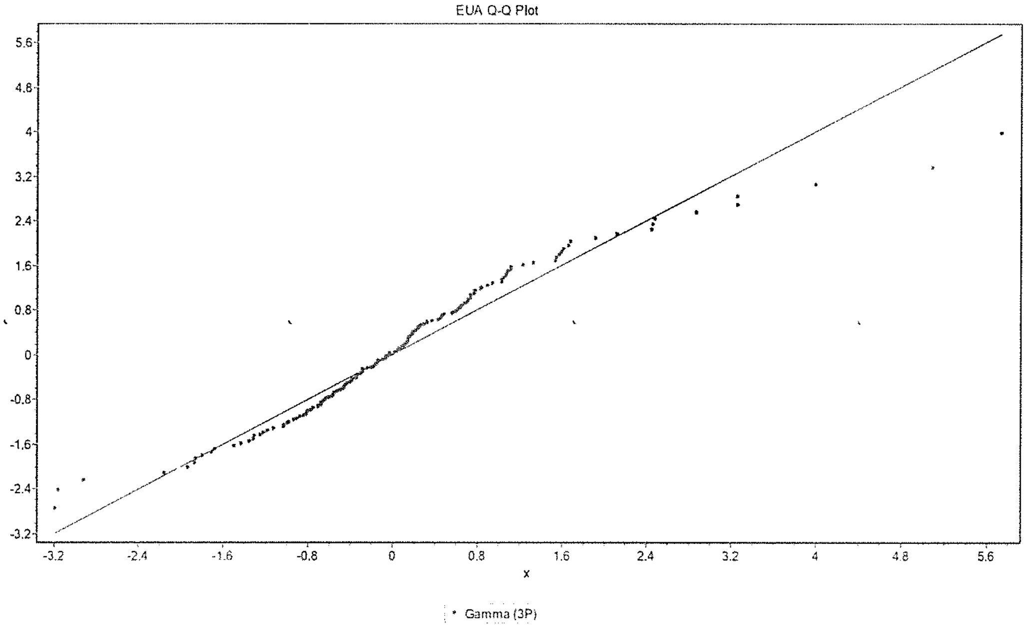


Figure 3: EUA Gamma (3p) Q-Q Plot

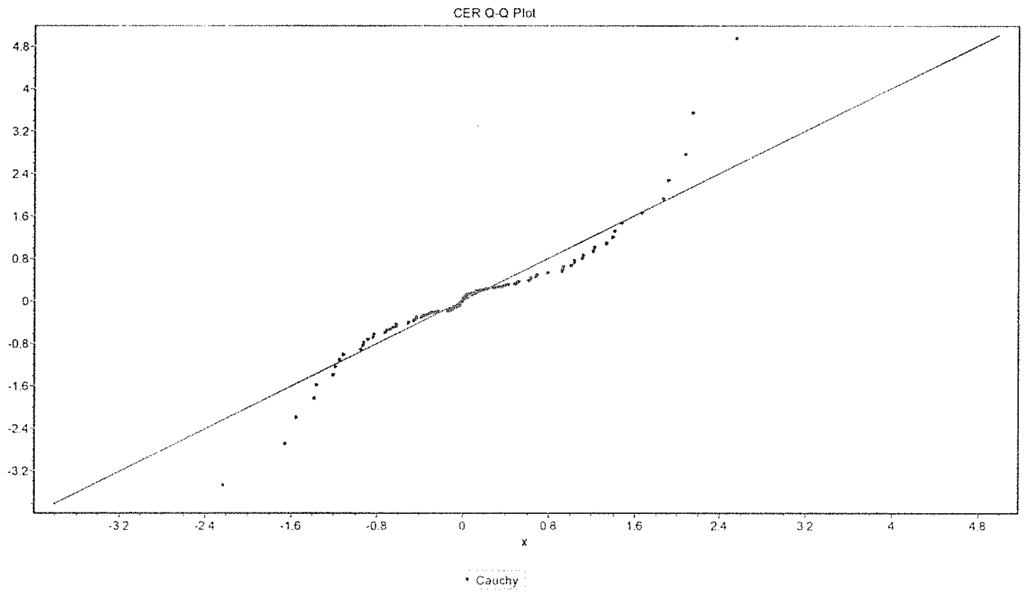


Figure 4: CER Cauchy Q-Q Plot

In testing the significance of the results, the following test statistics are used;

Gamma (3P)					
Kolmogorov-Smirnov					
Sample Size	166				
Statistic	0.08258				
P-Value	0.1964				
Rank	15				
A	0.2	0.1	0.05	0.02	0.01
Critical Value	0.08328	0.09492	0.1054	0.11782	0.12643
Reject?	No	No	No	No	No
Anderson-Darling					
Sample Size	166				
Statistic	2.0166				
Rank	15				
A	0.2	0.1	0.05	0.02	0.01
Critical Value	1.3749	1.9286	2.5018	3.2892	3.9074
Reject?	Yes	Yes	No	No	No
Chi-Squared					
Deg. of free	7				
dom	13.235				

Cauchy					
Kolmogorov-Smirnov					
Sample Size	162				
Statistic	0.09777				
P-Value	0.08442				
Rank	1				
A	0.2	0.1	0.05	0.02	0.01
Critical Value	0.0843	0.09609	0.10669	0.11927	0.12799
Reject?	Yes	Yes	No	No	No
Anderson-Darling					
Sample Size	162				
Statistic	1.9173				
Rank	1				
A	0.2	0.1	0.05	0.02	0.01
Critical Value	1.3749	1.9286	2.5018	3.2892	3.9074
Reject?	Yes	No	No	No	No
Chi-Squared					
Deg. of freedom	7				
Statistic	36.664				

Statistic P-Value Rank	0.06658 14				
a	0.2	0.1	0.05	0.02	0.01
Critical Value	9.8032	12.017	14.067	16.622	18.475
Reject?	Yes	Yes	No	No	No

Table 1: Test Statistics (EUA)

P-Value Rank	5.4298E-6 1				
A	0.2	0.1	0.05	0.02	0.01
Critical Value	9.8032	12.017	14.067	16.622	18.475
Reject?	Yes	Yes	Yes	Yes	Yes

Table 2: Test Statistics (CER)

4.2. Project valuations

The process valuation incorporated the NPV technique in the projects;

1. Efficient lighting
2. LandFill gas
3. Wind

For the relevant calculations, see appendix.

4.2.1. Efficient lighting

Our time 0 in the study is 2006.

It is found that efficient lighting (E.g. a solar project) has relatively high initial costs as well as high initial carbon displacement (carbon emission offset) but as the project becomes more integrated into the environment, the project reaches its optimum displacement after which its displacement power reduces. This is the same for the net costs (negative net costs imply profits).

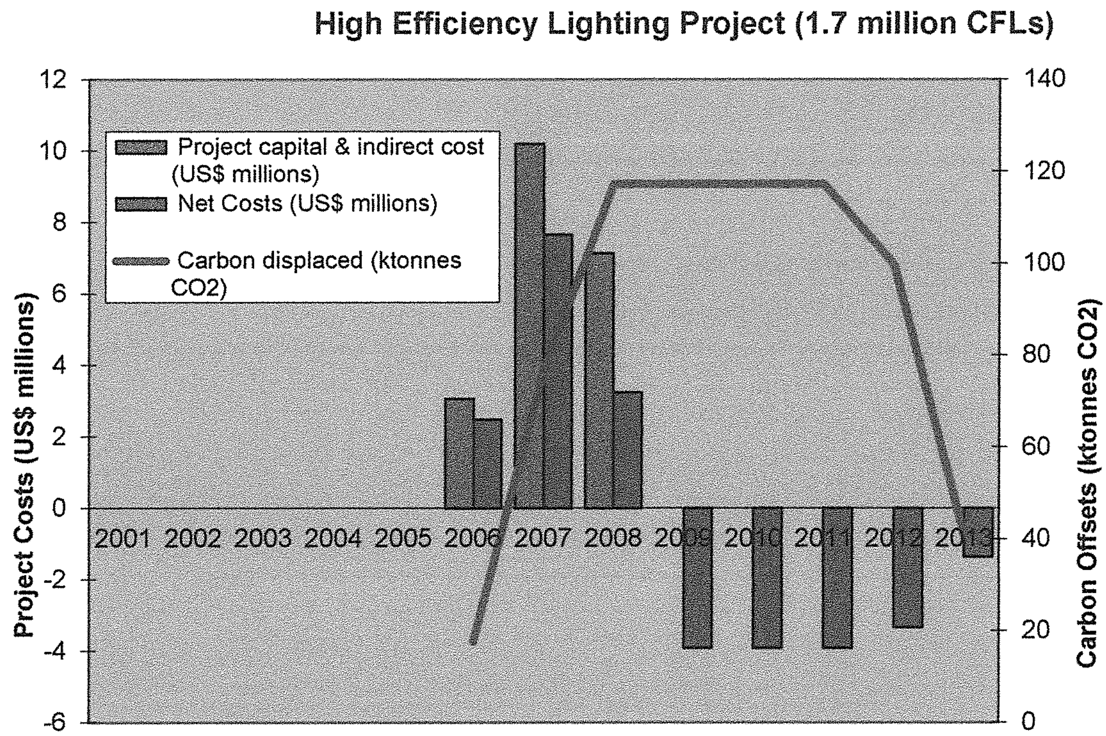


Figure 5: Efficient Lighting

4.2.2. LandFill gas

Our time 0 in the study is 1965.

Landfill gas utilization is a process of gathering, processing, and treating the methane gas emitted from decomposing garbage to produce electricity, heat, fuels, and various chemical compounds. It is quite an effective project in terms of cost because it requires close to negligible initial costs.

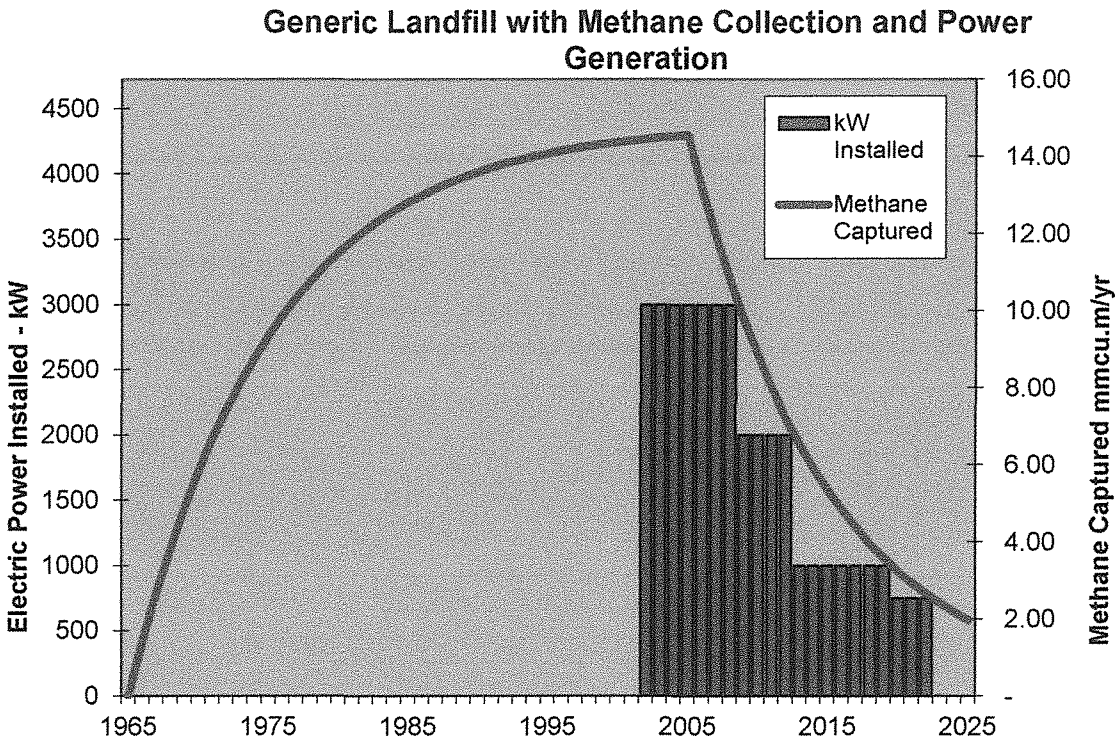


Figure 6: LandFill Gas

4.2.3. Wind

Our time 0 in the study was 2005.

We wind projects maintain a constant amount of carbon displacement because the projects offset carbon dioxide through the use of moving air (wind) which will never be at a zero composition of CO_2.

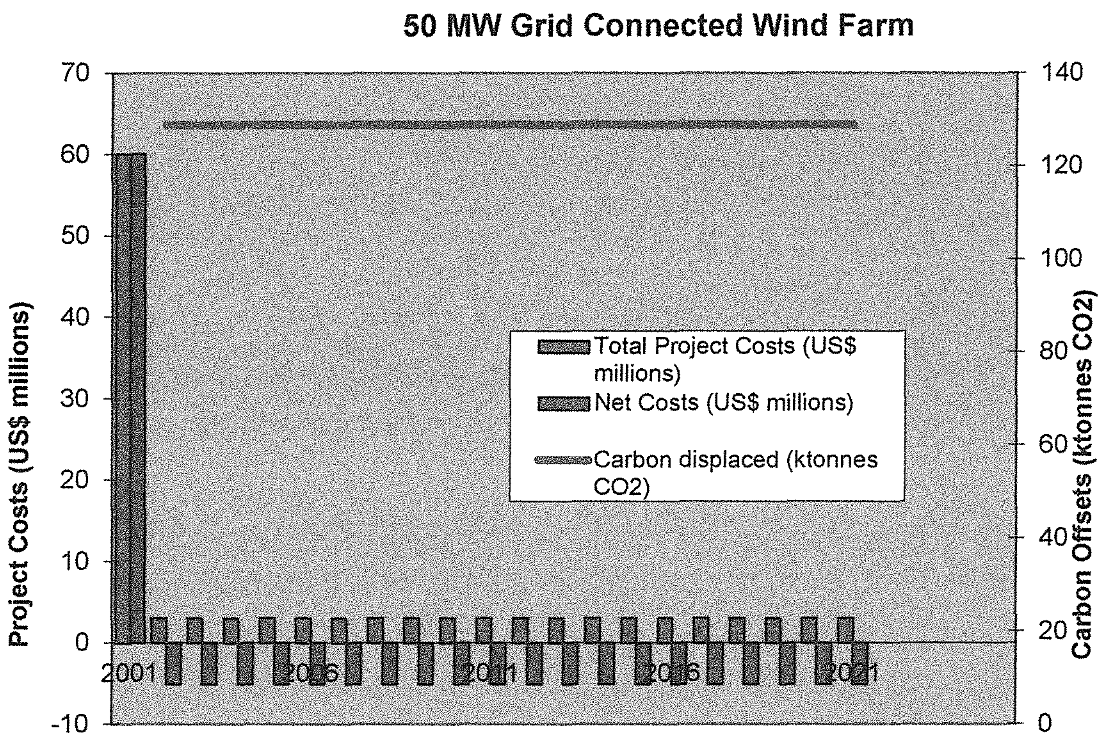


Figure 7: Wind

5. DISCUSSIONS, RECOMMENDATIONS AND CONCLUSION

5.1. Discussions

Discussions about carbon price typically revolve around a carbon tax and a cap and trade emissions market (Schott, 2013). Both have potential to reduce total emissions at the lowest possible cost and are efficient economic instruments. They, however have flaws in reality. A cap and trade system guarantees a specific emissions reduction target but is prone to price volatility. It also generates less revenue compared to a carbon tax because a large proportion of emission permits are not auctioned off.

Such discussions however useful direct focus to the trading mechanisms and project implementation in developed countries.

Our study helps in including developing countries in such discussions by focusing on the footprint of such countries in the implementation of carbon credit projects. This is done through the valuation of projects implemented in Kenya.

There are a growing number of global analyses that offer regional details on pollution and many models are now available for studying emissions reductions in OECD countries. In the global studies, however, developing countries are aggregated mainly due to lack of appropriate data and institutional information for the countries involved. Some of these developing countries, among them India, Nigeria, Indonesia, and others, have substantial emissions presently or have the potential to increase; this has led to the development of models that can provide valuable insight for the global models, as well as give a realistic picture of the potential for emission reduction in the individual countries. (Weyant, Autumn, 1993)

The success of these projects in developing countries is crucial in overcoming the global climate change concerns. This is because developing countries, being less industrialized as compared to developed countries, have a greater potential in the scope of renewable energy project implementations.

5.2. Recommendations

In our study, we show that contrary to popular belief, the price paths of both EUA and CER prices do not follow a Brownian motion. They instead follow a Gamma 3p and Cauchy distribution, respectively.

This makes pricing them a little complicated; Pricing the two should take into account the correlation of the two prices after transforming the same into a complete market setup. Relevant transformations that achieve this task include;

1. Wang transformation
2. Esscher transform
3. Local risk neutral valuation relationship (LRNVR)

Another improvement on the sufficiency of this study would be to incorporate other price offers into the equilibrium price. An example of these price offers is the World Bank price which is intended to act as an incentive to trade and implement carbon offsetting projects.

5.3. Conclusion

In understanding environmental economics, two fundamental ideas come into play. The first is that the optimal level of pollution is rarely zero and, the second is that, marketable pollution permits offer the lowest cost and the most easily implemented means of attaining a given level of pollution control. The two ideas are further supported by the fact that, there are tremendous opportunity costs involved in attempting to achieve zero pollution and the public's health is no more endangered by the marketable permit approach than by any other means of attaining a given reduction in pollution, respectively. (Walbert & Bierma, Autumn, 1988) .

The study therefore set out to value projects from which these objectives can be achieved and establish at what cost are investors trying to reduce pollution and which would be the most efficient. We find this to be Wind projects. Though they have a high initial capital outlay, they maintain a constant carbon displacement and through the trade of these constant offsets, the projects more than pay for themselves.

We also find that the underlying distribution of the price paths of these credits is not a Brownian motion. This calls for further research in transformation of the distributions before embarking on their pricing.

6. Appendix

Carbon Crediting Pricing Analysis

Global Assumptions

Discount Rate	10%		
Carbon displaced (tonnes CO2/MWh)	0.84		
Avoided cost (US$/kWh)	0.035	3.5	c/kWh
PCF share of incremental cost	100%		
PCF share of carbon credits	100%		

Red = global factors to be changed on this sheet.

Blue = same factors mapped onto technology sheets.

α is a multiplicative fudge factor for technology-specific avoided cost.

standard power plant emissions factors

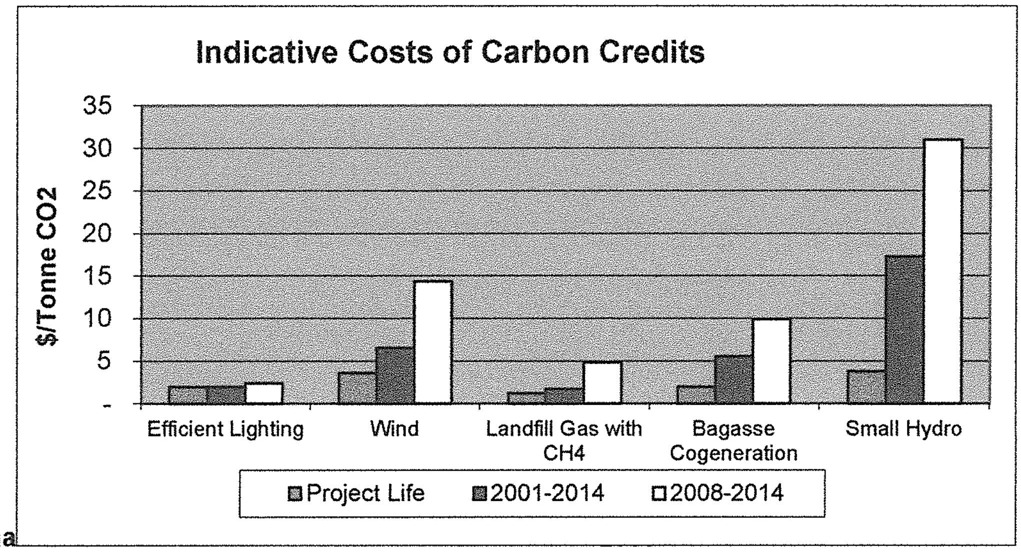
	energy in	*plant effic.*	*energy out*
	tonne CO2/Tj		*tonne CO2/MWh*
coal	95	33%	1.04
fuel oil	77	33%	0.84
natural gas	56	40%	0.50

source: GHG Assessment Handbook & Emission Reduction Trading System

Results

GHG credit cost ($/tonne CO2)	***Project Life***	***2001-2014***	***2008-2014***	α
Efficient Lighting	$ 1.93	$ 1.93	$ 2.39	0.8
Wind	$ 3.59	$ 6.53	$ 14.36	1.5
Landfill Gas with CH4	$ 1.23	$ 1.70	$ 4.83	
Bagasse Cogeneration	$	$	$ 9.95	1.0

	1.99	5.53			
	$	$			
Small Hydro	3.78	17.23	$	31.02	1.0



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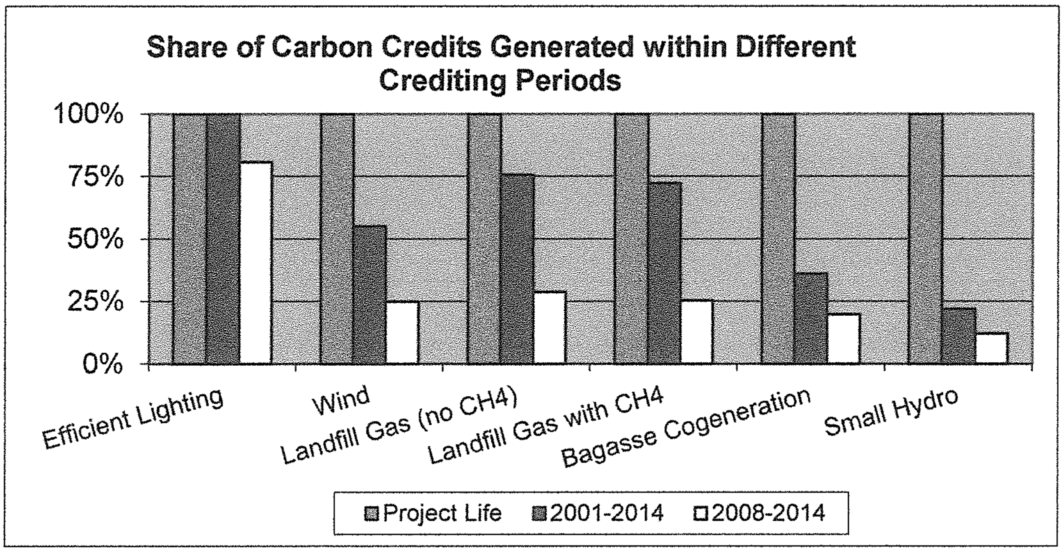
period	***Project Life***	***2014***	***2008-2014***
Efficient Lighting	100%	100%	81%
Wind	100%	55%	25%
Landfill Gas (no CH4)	100%	76%	29%
Landfill Gas with CH4	100%	72%	25%
Bagasse Cogeneration	100%	36%	20%
Small Hydro	100%	22%	12%



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