PRICE DETERMINANTS AND VOLATILITY OF CARBON PERMITS: A STUDY IN THE CONTEXT OF EUROPEAN UNION

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Price Determinants and Volatility of Carbon Permits: A Study in the Context of European Union

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The thesis titled **"Price Determinants and Volatility of Carbon Permits: A Study in the Context of European Union"** being submitted by Mr. **Ajay Kumar Dhamija** to the Indian Institute of Technology, Delhi, for the award of the degree of **Doctor of Philosophy** (Ph.D.) is a record of bonafide research work carried out by him. He has worked under our guidance and supervision, and has fulfilled all the requirements for the submission of this thesis, which has attained the standard required for a Ph.D. degree of this institute. The results presented in this thesis have not been submitted elsewhere for the award of any degree or diploma.

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Abstract

Carbon Management is a strategic priority and organizations need to forecast carbon for this purpose. This study finds out the best method to isolate price determinants of carbon permits which are known as European Union Allowance (EUA) in the European Union(EU) and to estimate their returns and volatilities for all three phases of European Union Emission trading Scheme (EU ETS) and the continuous series. European Climate Exchange (ECX) Dec 2007, Dec 2012, Dec 2015 expiry and the continuous Dec 2015 expiry future contracts of EUA are used as predicted variables and National Allocation Plan (NAP) announcements, energy variables (Brent Oil, Coal, and Natural gas), averaged extreme Europe temperature and German Stock Exchange (DAX) index (an indicator of economic activity) as predictor variables. The previous studies in this area have focused on a particular subset of EUA data and do not take care of the multicollinearities. None of these studies has used Artificial Neural Networks(ANN) architectures like Multi Layer Perceptron (MLP) with back-propagation and Genetic Algorithm(GA) for training and Radial Basis Function (RBF) networks for modeling EUA returns. This study uses EUA data from all three phases, namely, 2005-07, 2008-12, 2013-2015 and the continuous series, adopts principal component analysis to eliminate multicollinearities and uses seven constant variance (three linear and four non linear models) predictive models for finding out the price determinants.

The study establishes the Dynamic Linear Regression with Lagged Predictors (DLRLP) model as the best model for forecasting EUA Phase I, Phase II and Phase III returns with estimation set RMSE values 0.09567, 0.02571 and 0.03191 respectively and test set RMSE values 0.09750, 0.03997 and 0.05735 respectively. The ARIMA Errors (AE) model with the estimation set RMSE value 0.02926 and test set RMSE value 0.06169 is established as the best model for forecasting

EUA continuous series returns. The latent factors Switch To Gas (STG) and Clean Spread (CS) capturing the effects of Clean Dark Spread (CDS), Clean Spark Spread (CSS), Switching Price (SP) and Natural Gas Returns; and the variables *napI*, *napII*, *napIII* (NAP events for the three phases),*brent*, *coal* (both energy variables), *dax* (German Stock Exchange index as an indicator of economic activity), *temphot* and *tempcold* (extreme temperature events) have been isolated as price determinants for EUA returns. Even though, the Adjusted R^2 is low, the significant coefficients still represent the mean change in the EUA returns for one unit of change in the predictor while holding other predictors in the model constant. The residual plots of all the models give white noise character and thus indicate that the models are adequate and well specified.

After finding out the price determinants, five Generalized Auto Regressive Conditional Heteroscedasticity (GARCH) variants namely, GARCH, EGARCH, GJR-GARCH, IGARCH and GARCH-M are fitted to estimate conditional returns and volatilities of EUA. The study establishes that the best model for EUA phase I, III and continuous series is ARMA-EGARCH and that for EUA phase II is ARMA-GJR-GARCH, though followed closely by ARMA-EGARCH. The latent factors *STG* and CS and the variables *brent*, *coal* and *dax* have been found as determinants for estimation of conditional returns and volatilities in one phase or the other for EUA returns. Artificial Neural Network (ANN) models, namely, MLP, RBF and Genetic Algorithm (GA) models are used for estimation of EUA returns as these models implicitly incorporate the nonlinear relationship into the model. These results are compared with those obtained from ARMA-GARCH models. The study establishes that the best model for forecasting the EUA returns of phase I and phase II is MLP model while for forecasting the EUA returns of phase III and the continuous series, ARMA-EGARCH outperforms ANN models.

The price of EUA, understandably, moves together with prices of crude oil, coal and natural gas. Using EUA daily returns from 2005 to 2015-covering all three phases of EU ETS and EUA continuous series, volatility spillover from energy markets i.e. brent (crude oil), coal and natural gas markets into EUA markets is investigated using Multivariate GARCH (BEKK-MGARCH) model. The empirical results indicate that there is small but significant volatility spillover from energy

markets into EUA markets. At a substantive level, studies on volatility spillover provide useful information for risk analysis and investment decisions.

For last more than four years Certified Emission Reductions (CERs) have been traded at very low prices due to sluggish demand and absence of new market mechanism. It is important for Clean Development Mechanism (CDM) developers and executive board to look into the strengths, weaknesses and suggestive measures to stabilize the CER market. CER Survey studies so far, have been based on convenience sampling and therefore are limited and can not be fully relied upon. The current study systematically conducts the survey on top 50 companies which retain 55% of the total volume of CERs generated by Indian projects. "CER is cheaper than EUA for Emission Compliance" is rated as topmost strength of CER mechanism followed by "Flexibility by adding CDM option in compliance Toolbox" and "Banking of CERs". "Methodology of Financial Additionality is Subjective" is rated as topmost weakness of CER mechanism followed by "CDM Executive Board Involvement" and "Role of host Countries: Lack of Standard Practices." "Removal of Quantitative Restrictions on CERs" is rated as topmost suggestion for stabilization of CER followed by "Continuation of Banking of CERs" and "Standardizing the CER product". Companies, overwhelmingly, were in favor of continuation of banking and including the carbon emission cost as one of the internal cost of business activity. At a substantive level, the study unearths useful actionable information about CER market.

Carbon Management has emerged as a newer and vastly impacting determinant of financial performance and strategic direction of firms. In this regard, the current study contributes to effective carbon management by finding out the best method to forecast EUA; by isolating the price determinants of EUA; by forecasting the return and volatility of the EUA; by establishing significant volatility spillover from markets of brent, coal and natural gas into EUA markets; and by unearthing the perceptions of the companies about strengths, weaknesses and suggestive measures for CDM market.

सारांश

कार्बन प्रबंधन एक महत्वपूर्ण प्राथमिकता है और संगठनों को इस उद्देश्य के लिए कार्बन के पूर्वानुमान की आवश्यकता है। कार्बन परमिट को यूरोपियन देशों में यूरोपियन यूनियन अलाउंस (EUA) कहा जाता है । इस अध्ययन में कार्बन परमिट के प्राइस डिटर्मिनेन्ट्स (मूल्य निर्धारकों) को पृथक करने की एवं यूरोपियन यूनियन एमिशन ट्रेडिंग स्कीम (EU ETS) के सभी तीनों चरणों और कंटीन्यूअस सीरीज (अनवरत श्रृंखला) के रिटर्न्स (लाभ) और वोलैटिलिटी (अस्थिरता) के पूर्वानुमान की सर्वोत्तम विधि बतलाई गयी है। यूरोपियन क्लाइमेट एक्सचेंज (ECX) दिसंबर 2007, दिसंबर 2012, दिसंबर 2015 और कंटीन्यूअस सीरीज 2015 एक्सपायरी फ़्यूचर्स को प्रिडिक्टेड वैरिएबल्स के रूप में और नैशनल एलोकेशन प्लान्स (NAP) घोषणाएँ , ऊर्जा वैरिएबल्स (ब्रेंट ऑइल, कोयला और प्राकृतिक गैस), औसत यूरोपीय चरम तापमान और जर्मन स्टॉक एक्सचेंज (DAX) सूचकांक (आर्थिक गतिविधियों का सूचक) को पूर्वानुमान लगाने वाले प्रिडिक्टिव वैरिएबल्स के रूप में पयोग किया गया है। इस क्षेत्र सम्बन्धी पूर्व अध्ययनों में EUA के आंकड़ों के उपसमूह विशेष पर ध्यान केंद्रित किया गया और मल्टीकोलीनियैरिटीज़ (बहुसमरैखिकता) की और कोई ध्यान नहीं दिया गया। किसी भी अध्ययन में EUA के रिटर्न्स के अभिकलन के लिए आर्टिफिशियल न्यूरल नेटवर्क्स (ANN) जैसे बैक प्रॉपेगेशन और जेनेटिक एल्गोरिद्म्स प्रशिक्षण युक्त मल्टी लेयर पर्सेप्ट्रोन (MLP) और रेडियल बेसिस फंक्शन (RBF) नेटवर्क्स का प्रयोग नहीं किया गया । प्राइस डिटर्मिनेन्ट्स को खोजने के लिए इस अध्ययन में EUA सम्बन्धी तीन चरणों नामतः 2005-07, 2008-12, 2013-15 और कंटीन्यूअस सीरीज से प्राप्त आंकड़ों का प्रयोग किया गया और प्रिंसिपल कॉम्पोनेन्ट अनैलिसिस (PCA) द्वारा मल्टीकोलीनियैरिटीज़ को दूर करते हुए सात कांस्टेंट वेरियन्स (तीन लीनियर और चार नॉन लीनियर मॉडल्स) फोरकास्टिंग मॉडल्स का प्रयोग किया है।

EUA के चरण I, चरण II, और चरण III के रिटर्न्स का पूर्वानुमान लगाने के लिए एस्टिमेशन सैट (Estimation Set) RMSE 0.09567, 0.02571 और 0 03191 क्रमशः और टैस्ट सैट (Test Set) RMSE 0.09750, 0.03997 और 0.05735 क्रमशः के साथ यह अध्ययन डायनेमिक लीनियर रिग्रेशन विद लैग्गेड प्रिडिक्टर्स (DLRLP) मॉडल को सर्वोत्तम मॉडल के रूप में स्थापित करता है । EUA कंटीन्यूअस सीरीज के रिटर्न्स का पूर्वानुमान लगाने के लिए एस्टिमेशन सैट RMSE 0.02926 और टैस्ट सैट RMSE 0.06169 के साथ ऑटो रिग्रेस्सिव इंटीग्रेटेड मूविंग एवरेजेज़ एरर्स (ARIMA Errors) मॉडल को सर्वोत्तम मॉडल के रूप में स्थापित किया गया है।

स्विच टू गैस (STG) एवं क्लीन स्प्रैड (CS) नामक लेटेंट फैक्टर्स (अन्तर्निहित कारक) क्लीन डार्क स्प्रैड (CDS), क्लीन स्पार्क स्प्रैड (CSS), स्विचिंग प्राइस (SP) और प्राकृतिक गैस के प्रभावों को अभिग्रहण करते हैं। STG, CS,

napI , napII, napIII (तीन चरणों के NAP घटनाक्रम), क्रूड, कोयला (दोनों ऊर्जा वैरिएबल्स), dax (जर्मन स्टॉक एक्सचेंज सूचकांक आर्थिक गतिविधियों के सूचक के रूप में), temphot और tempcold (चरम तापमान घटनाएं) को EUA रिटर्न्स के लिए मूल्य निर्धारक तत्वों के रूप में चिन्हित किया गया है। हालांकि एडजस्टेड (समायोजित) R^2 कम हैं, सिग्नीफिकेंट कोएफ़िशिएंट्स (महत्वपूर्ण गुणांक) फिर भी प्रिडिक्टिव वैरिएबल्स के एक इकाई परिवर्तन से EUA रिटर्न्स में माध्य परिवर्तन दर्शाते हैं, जबकि मॉडल के अन्य प्रिडिक्टिव वैरिएबल्स स्थिर रखे जाएँ। सभी मॉडल्स के रेसिडुअल प्लॉट्स (अवशिष्ट आलेख) व्हाइट नॉइज़ (श्वेत रव) दर्शाते हैं और इंगित करते हैं कि ये मॉडल्स भली प्रकार से निर्दिष्ट एवं पर्याप्त है।

प्राइस डिटर्मिनेन्ट्स को निश्चित करने के पश्चात पांच जेनरलाइज़्ड ऑटो रिग्रेसिव कंडीशनल हीट्रोस्केडेस्टिक (GARCH) मॉडल्स नामतः GARCH , EGARCH , GJR-GARCH, IGARCH और GARCH-M को EUA की वोलैटिलिटी और कंडीशनल रिटर्न्स के पूर्वानुमान हेतु प्रयोग किया गया। यह अध्ययन सिद्ध करता है कि EUA के चरण I, III एवं कंटीन्यूअस सीरीज के लिए ARMA-EGARCH और चरण II के लिए ARMA-GJR-GARCH सर्वोत्तम मॉडल्स है। STG एवं CS नामक लेटेंट फैक्टर्स और क्रूड, कोयला और डैक्स (dax) को EUA रिटर्न्स हेतु एक अथवा अन्य चरणों मैं वोलैटिलिटी और कंडीशनल रिटर्न्स के पूर्वानुमान हेतु डिटर्मिनेन्ट्स (तत्वों) के रूप में पाया गया। ANN मॉडल्स नामतः MLP, RBF एवं GA मॉडल अदि को EUA रिटर्न्स के लिए प्रयोग किया गया है क्योंकि इन मॉडल्स में नॉन लीनियर रिलेशनशिप का समावेश निहित होता है। इन परिणामों की तुलना ARMA-GARCH मॉडल्स से प्राप्त परिणामों से की गयी है | ये अध्ययन सिद्ध करता है कि चरण I एवं II के EUA रिटर्न्स के लिए MLP मॉडल सर्वोत्तम है और चरण III एवं कंटीन्यूअस सीरीज के EUA रिटर्न्स के लिए ARMA-EGARCH का प्रदर्शन ANN मॉडल्स से बेहतर है।

स्पष्ट रूप से दृश्य है कि EUA मूल्य क्रूड, कोयला और प्राकृतिक गैस के मूल्यों के साथ-साथ चलते हैं। EU ETS के तीनों चरणों एवं EUA कंटीन्यूअस सीरीज को समाविष्ट करते हुए और 2005 से 2016 तक के EUA दैनिक रिटर्न्स का प्रयोग करते हुए ऊर्जा बाजार (क्रूड, कोयला और प्राकृतिक गैस) का EUA बाजार में स्पिल-ओवर (प्लवन) को मल्टीवैरिएट GARCH (BEKK -MGARCH) मॉडल का प्रयोग करके पाया गया कि क्रूड, कोयला और प्राकृतिक गैस बाजार का EUA बाज़ार में स्पिल-ओवर अल्प परन्तु अर्थपूर्ण हैं। वास्तविक स्तर पर वोलैटिलिटी स्पिल-ओवर पर अध्ययन जोख़िम विश्लेषण और निवेश संबंधी निर्णय के लिए उपयोगी सूचनाएं प्रदान करते हैं।

पिछले चार से अधिक वर्षों से सर्टिफाइड एमिशन रिडक्शन्स (CERs) का व्यापार, अल्प माँग एवं नवीन बाज़ार के मैकेनिज़्म (क्रियाविधि) की अनुपस्थिति के कारण बहुत कम भाव पर किया जा रहा है । यह क्लीन

डेवलपमेंट मैकेनिज़्म (CDM) विकासकों एवं कार्यकारी बोर्ड के लिए अत्यंत आवश्यक है कि वह इसकी शक्तियों, कमज़ोरियों एवं CER बाज़ार को स्थिर रखने हेतु सुझावों पर ध्यान दें । CER सर्वेक्षणों द्वारा अभी तक किये गए अध्ययन कन्वीनिएंट सैंपलिंग (सुविधाजनक प्रतिचयन) पर आधारित रहे हैं इसलिए ये सीमित हैं और पूर्णरूप से विश्वसनीय नहीं हैं । वर्तमान अध्ययन में पचास से अधिक शीर्ष कम्पनिओं को व्यवस्थित रूप से सर्वेक्षण में शामिल किया गया है जो भारतीय परियोजनाओं से उत्पन्न CER बाजार में समस्त CER मात्रा का 55% CERs रखते है । "एमिशन कंप्लायंस (उत्सर्जन अनुपालन) के लिए CER, EUA से सस्ता है" को CER मेकेनिज़्म की सबसे बड़ी शक्ति के रूप में पाया गया । इसके पश्चात की शक्तियां "कंप्लायंस टूलबॉक्स में CDM विकल्प का शामिल होना" और "CERs की बैंकिंग" हैं । "फाइनैंशियल एडीशनैलिटी (वित्तीय अतिरिक्तता) की कार्यप्रणाली सब्जैक्टिव (व्यक्तिपरक) है" को CER मेकेनिज़्म की सबसे बड़ी कमज़ोरी के रूप में पाया गया । इसके पश्चात की कमज़ोरियाँ "CDM कार्यकारी बोर्ड की भागीदारी और "मेजबान देशों की भूमिका" हैं । "CERs के क्वॉन्टिटेटिव रिस्ट्रिक्शन्स (मात्रात्मक प्रतिबंधों) को दूर करना" को CER की स्थिरता के लिए शीर्ष सुझाव का दर्जा दिया गया | इसके पश्चात के सुझाव "CER बैंकिंग की निरंतरता" और "CER उत्पादों का मानकीकरण" हैं । सभी कंपनियों ने ज़बरदस्त रूप से "बैंकिंग की निरंतरता" और कार्बन एमिशन कॉस्ट (उत्सर्जन लागत) को व्यापारिक गतिविधियों की एक आतंरिक लागत के रूप में स्वीकारने हेतु अपना समर्थन प्रदान किया | इस अध्ययन ने CER बाज़ार के लिए कार्रवाई योग्य उपयोगी सूचना को वास्तविक स्तर पर प्रकट किया है |

कार्बन प्रबंधन का आविर्भाव एक नवीन और व्यापक रूप से फर्मो की नीतिगत दिशा द्वारा वित्तीय कार्यप्रदर्शन के निर्धारकों को प्रभावित करने वाली नीति के रूप में हुआ है | इस संबंध में वर्तमान अध्ययन EUA पूर्वानुमान की सर्वोत्तम प्रणाली की खोज द्वारा; EUA के प्राइस डिटर्मिनेन्ट्स के पृथक्करण द्वारा; EUA की वोलैटिलिटी और रिटर्न्स संबंधी पूर्वानुमान द्वारा; ब्रेंट, कोयला और प्राकृतिक गैस बाजार से EUA बाज़ार में वोलैटिलिटी स्पिल-ओवर के संस्थापन द्वारा और CDM बाजार के लिए कंपनियों की शक्तियां, कमज़ोरियां और सुरक्षात्मक उपाय संबंधी बोध के प्रकटन द्वारा प्रभावी कार्बन प्रबंधन में अपना योगदान प्रस्तुत करता है |

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Glossary

Annex I Countries

Leading industrialized nations (41 countries) that need to cut Green House Gas (GHG) emanations by 5.2% below 1990 level (during 2008- 2012) and assist non-Annex I countries to handle ecological issues.

Annex II Countries

Affluent nations within Annex I (24 countries) that need to extend support in the form of technology and capital to Non-Annex I nations.

Artificial Intelligence(AI)

The study and design of intelligent frameworks that mimic various cognitive functions that are normally attributed to human brain such as thinking, problem solving and learning.

Artificial Neural Networks(ANN)

Massively interconnected networks of artificial neurons (programming constructs that mimic the attributes of biological neurons) armed with algorithms to solve artificial intelligence problems.

Assigned Amount Unit(AAU)

The emission allowances granted by the International Emissions Trading (IET).

Auto Regressive Integrated Moving Averages(ARIMA)

Constant variance model employed to forecast a stationary time series that exhibit a trend along with the 'autoregressive' and 'moving average' characteristics.

Carbon Disclosure Project(CDP)

An organization based in the United Kingdom that works with shareholders and corporations to disclose the greenhouse gas emissions of major corporations.

Carbon Finance

A branch of environmental finance that investigates the financial opportunities and risks of managing in a carbon compelled world.

Certified Emission Reduction(CER)

The emission reductions generated by the Clean Development Mechanism (CDM).

Clean Dark Spread(CDS)

The difference between the price of electricity at peak hours and the price of coal used to generate that electricity, corrected for the efficiency of the coal plant and the costs of CO_2.

Clean Development Mechanism(CDM)

An arrangement for generation of emission reductions from projects in non-Annex I countries that can be used by Annex I countries in meeting their emission reduction targets.

Clean Spark Spread(CSS)

The difference between the price of electricity at peak hours and the price of natural gas used to generate that electricity, corrected for the efficiency of the natural gas plant and the costs of CO_2.

Clean Spread(CS)

A rotated component obtained after Principal Component Analysis(PCA) that captures the effects of Clean Dark Spread (CDS) and Clean Spark Spread (CSS).

Data Mining(DM)

Discovering novel and useful knowledge from existing large data sets incorporating methods from database management, statistics and artificial intelligence.

Emission Reduction Unit(ERU)

The emission reductions generated by the Joint Implementation (JI).

Emission Trading Scheme(ETS)

A scheme where trading of emission allowances takes place.

EURO STOXX 50

Europe's leading blue-chip index covering 50 stocks from 12 Euro-zone countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. It serves as an underlying index for many investment products like Exchange Traded Funds(ETF), Futures and Options, and other structured products.

European Union Allowance(EUA)

Carbon permits used in the European Union Emission trading Scheme (EU ETS). EUAs are issued by the EU member states into the registry accounts of various installations. By April 30 of each year, operators of installations covered by the EU ETS must surrender an EU Allowance for each ton of CO_2 emitted in the previous year.

European Union Emission Trading Scheme(EU ETS)

A scheme covering around $12,000$ industrial installations in fifteen EU member states that together are responsible for 40% of the EU's greenhouse gas emissions. It is thus presently the largest emissions trading scheme in the world.

European Union(EU)

An economic and political union of 27 independent member states of Europe.

Future Contract

A standardized contract between two parties to exchange a specified asset of standardized quantity and quality for a price agreed today with delivery occurring at a specified future date.

Generalized Auto Regressive Conditional Heteroscedasticity(GARCH)

The time series model used to estimate variance of a time series where innovations contribute symmetrically, irrespective of their signs, to the variance of the series.

Genetic Algorithm(GA)

A search heuristic inspired by the processes of natural evolution, such as inheritance, mutation, selection, and crossover and is often used to solve optimization problems.

Heterscedasticity

Refers to time-dependent nature of variance of a time series.

Homoscedasticity

Refers to time-independent nature of variance of a time series.

International Emissions Trading(IET)

Trading that allows Annex I countries to trade their Assigned Amount Unit (AAU) or "allowances" for short. The marginal cost of emission abatement differs among countries and trade could possibly enable the Annex I countries to meet their emission reduction targets at a reduced cost.

Joint Implementation(JI)

An arrangement for generation of emission reductions from projects in another Annex I country that can be used by Annex I countries in meeting their emission reduction targets.

Kyoto Protocol

This is a protocol of United Nations Framework Convention on Climate Change (UNFCCC) to limit the concentrations the GHGs in the atmosphere so that global warming could be arrested..

National Balancing Point(NBP)

A virtual trading location for the trading and exchange of UK natural gas. It is the underlying assest for Inter continental Exchange(ICE) natural gas futures contract.

Non Annex I Countries

Developing nations (145 countries), having no commitments.

Organization for Economic Co-operation and Development(OECD)

An organization of developed countries with high per capita income and high Human Development Index (HDI).

Parsimonious Model

A model that accomplishes a desired level of prediction with minimum number of predictor variables.

Switch To Gas(STG)

A rotated component obtained after Principal Component Analysis(PCA) that captures the effects of Switching Price (SP) and Gas Price.

Switching Price(SP)

The threshold price of carbon permit at which both Clean Dark and Clean Spark spreads become equal.

United Nations Framework Convention on Climate Change(UNFCC)

An international environmental treaty to prevent dangerous anthropogenic interference with the climate system by limiting the greenhouse gas concentrations in the atmosphere.

Acronyms

AAU

Assigned Amount Unit.

ACF

Auto Correlation Function.

ADF

Augmented Dickey Fuller.

AE

ARIMA Errors.

AELP

ARIMA Errors with Lagged Predictors.

AI

Artificial Intelligence.

AIC

Akaike Information Criterion.

ANN

Artificial Neural Network.

API2

All Published Index number 2.

AR

Auto Regressive.

ARA

Amsterdam Rotterdam Antwerp.

ARCH

Auto Regressive Conditional Heteroscedastic.

ARIMA

Auto Regressive Integrated Moving Averages.

ARIMAX

ARIMA with Transfer Function.

ARMA

Auto Regressive Moving Average.

BFMC

Brent Front Month Contract.

BIC

Bayesian Information Criterion.

CCX

Chicago Climate Exchange.

CDM

Clean Development Mechanism.

CDP

Carbon Disclosure Project.

CDS

Clean Dark Spread.

CER

Certified Emission Reduction.

CFC

Chloro Fluoro Carbon.

CIF

Cost Insurance Freight.

COP

Conference of Parties.

CS

Clean Spread.

CSS

Clean Spark Spread.

DAX

Deutscher Aktien IndeX.

DF

Dickey Fuller.

DLR

Dynamic Linear Regression.

DLRLP

Dynamic Linear Regression with Lagged Predictors.

DM

Data Mining.

ECM

Error Correction Method.

ECX

European Climate Exchange.

EEA

European Economic Association.

EEX

European Energy Exchange.

EGARCH

Exponential Generalized Auto Regressive Conditional Heteroscedastic.

EIT

Economies In Transition.

ERU

Emission Reduction Unit.

ESS

Explained Sum of Squares.

ETS

Emission Trading Scheme.

EU

European Union.

EU ETS

European Union Emission Trading Scheme.

EUA

European Union Allowance.

EWMA

Exponentially Weighted Moving Average.

FTSE

Financial Times and the London Stock Exchange.

GA

Genetic Algorithm.

GARCH

Generalized Auto Regressive Conditional Heteroscedasticity.

GARCH-M

Generalized Auto Regressive Conditional Heteroscedastic in Mean.

GCLT

Generalized Central Limit Theorem.

GHG

Green House Gas.

GJR

Glosten Jagannathan Runkle.

HDI

Human Development Index.

HFC

Hydro Fluoro Carbon.

ICE

Inter Continental Exchange.

IET

International Emissions Trading.

IGARCH

Integrated Generalized Auto Regressive Conditional Heteroscedastic.

IID

Independent and Identically Distributed.

IRR

Internal Rate of Return.

JI

Joint Implementation.

LR

Linear Regression.

LULUCF

Land Use, Land Use Change, and Forestry.

MA

Moving Averages.

MAE

Mean Absolute Error.

MCX

Multi Commodity Exchange.

MDA

Mean Directional Accuracy.

MGARCH

Multivariate Generalized Auto Regressive Conditional Heteroscedastic.

MixN

Mixed Normal.

MixStab

Mixed Stable.

MLE

Maximum Liklihood Estimation.

MLP

Multi Layer Perceptron.

MSE

Mean Squared Error.

NAP

National Allocation Plan.

NBP

National Balancing Point.

OECD

organization for economic co-operation and development.

OLS

Ordinary Least Squares.

PACF

Partial Auto Correlation Function.

PCA

Principal Component Analysis.

PFC

Per Fluoro Carbon.

QQ

Quantile Quantile.

RBF

Radial Basis Function.

RGGI

Regional Greenhouse Gas Initiative.

RSS

Residual Sum of Squares.

SP

Switching Price.

STG

Switch To Gas.

STMC

Short Term Marginal Cost of switching.

TGARCH

Threshold Generalized Auto Regressive Conditional Heteroscedastic.

TSS

Total Sum of Squares.

UNFCCC

United Nations Framework Convention on Climate Change.

VaR

Value at Tisk.

WB

World Bank.