Weak-form Efficiency of Carbon Trading Markets: Evidence from Bluenext Spot Market

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ABSTRACT

Reducing the greenhouse gases is urgent need in this century, to see this target several cap and trade markets are working around the world trading emission allowances. Bluenext market is the largest and most liquide one. The aim of this study is to investigate the weak-form efficiency of this market. The EUAs (European Union Allowances) have been traded in two phases since 2005 in Bluenext market. Related to several structural breaks in the time series 4 parametric tests employed to investigate the stationarity of data. ADF test, the most routin method, showed that the time series is non-stationary. The three other tests namely Perron, ZA and KPSS tests the data considering its structural breaks and confirmed the first test and showed that the time series has a unit root and follows the Random Walk hypothesis, hence the market indicate the Efficient Market Hypothesis.

Keywords: cap and trade markets; weak-form efficient market hypothesis; Bluenext; structural breaks; stationary; unit root; Random Walk hypothesis.

ÖZ

Bu tez çalışması “Bluenext” piyasasındaki “zayıf verimli piyasa” hipotezini test etmeyi hedeflemektedir. Ilk aşamada çevresel ve emisyon çalışmalarına ve neden bu gibi çalışmalara ihtiyaç duyulduğu üzerinde durulmuştur. Ikinci bölümde emisyon çalışmalarına ağırlık verilmiştir. Çeşitli birim kök testleri uygulamaları sonucunda, “Bluenext” piyasasında verimlilik hipotezi Kabul edilmiştir. Uygulanan birim kök testleri arasında ADF, Perron, KPSS, ve yapısal kırılmaları da dikkate alan ZA yaklaşımları mevcuttur.Yürütülen testler sorucunda, birim kök ve rastsal yürüyüş olduğu, ve dolayısıyla “Verimli Piyasa” hipotezinin kabul gördüğü ortaya konmustur.

Anahtar Kelimeler: Karbon Piyasaları; Verimli Piyasa Hipotezi; Yapısal Kırılma; Durağanlık.

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To My lovely mother

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ADF	Augmented Dickey Fuller test
AIC	Akaike Information Criterion
AUD	Australian Dollar
CBEEX	China Beijing Environmental Exchange
CCX	Chicago Climate Exchange
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CH4	Methane
CO2	Carbon Dioxide
EC	European Climate Exchange
EEX	European Energy Exchange
EMH	Efficient Market Hypothesis
EPA	United States environmental protection agency
ERU	Emission Reduction Units
EUA	European Union Allowances
EU ETS	European Union Emissions Trading System
F-gases	Fluorinated gases

GH	Greenhouse Gases
GP	Genetic Programming
HF	Hydro Fluorocarbons
IC	Intercontinental Exchange
JC	Japan Climate Exchange
JI	Joint Implementation
KPSS	Kwiatkowski-Phillips-Schmidt-Shin test statistic
LM	Lagrange Multiplier
N2O	Nitrous Oxide
NGACS	NSW Greenhouse Gas Emissions
NSW GGAS	NSW Greenhouse Gas Abatement Scheme
NYSE Euronext	New York Stock Exchange Euronext
NZ ETS	New Zealand Emissions Trading Scheme
OECD	Organisation for Economic Co-operation and Development
Perro	Perron Test
PFC	Perfluorocarbons
RGGI	Regional greenhouse gas initiative
SBC	Schwarz Bayesian Criterion

SF6	Sulfur hexafluoride
TCX	Tianjin Climate Exchange
UNFCCC	United Nations Framework Convention on Climate Change
VER	Verified Emission Reductions
ZA	Zivot and Andrews test

Chapter 1

INTRODUCTION

Our planet is warming from North Pole to South Pole. It affects the world and it's getting worse day by day. We can categorize the effect of climate change to 3 classes; physical, ecological, social. Physical impacts are like extreme weather (conditions such as more tsunami, drought), Glacier retreat and disappearance, increased volcanism, more Earthquakes, Ocean acidification, Oxygen depletion, rising Sea level and Ocean temperature. As Ecological impacts can mention that plants in many areas are leafing earlier, in Europe birds have changed their migrations also in Australia and North America; furthermore we can see fish and oceans' plankton transfer from cold- to warm-adapted communities. Social impacts can be seen in changes in Food supply, Health, Malnutrition. [Rosenzweig et al. (2007)]

Energy Supply (26%), Industry (19%), Land Use and Forestry (17%) are the most important causes of Greenhouse gas emissions in 2004; the other ones are mentioned as Agriculture (14%), Transportation (13%), Commercial and Residential Buildings (8%) and the last one Waste and Wastewater (3%). [Source: National CO2 Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-2008.]

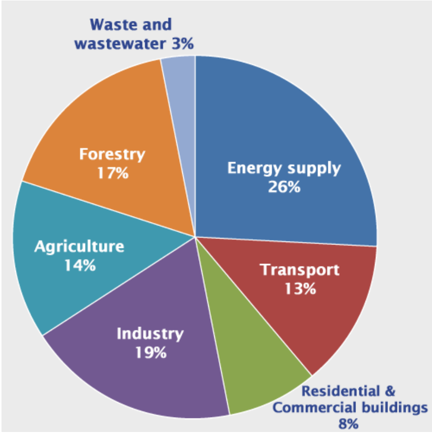


Figure 1: Causes of GHG

Related to EPA's report (2008), China, the United States and the European Union are the key CO2 emitters in the world; India, Russia, Japan and Canada stand after these countries in ranking.[Source: IPCC (2007)]

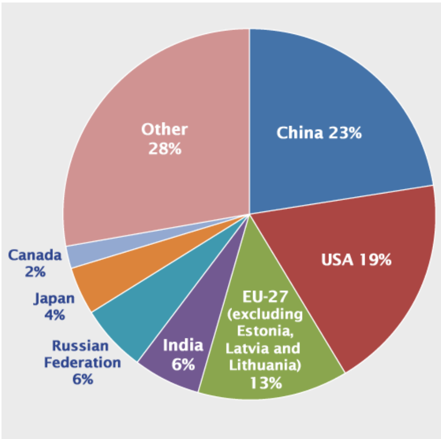


Figure 2: GHG by countries

CO2, CH4, N2O are the main GHG emitted by human activities at global scale. Other greenhouse gases include the Fluorinated gases (F-gases) emitted by Industrial processes, refrigeration, and the use of a variety of consumer products contribute, which include HFCs, PFCs, and SF6.[Source: IPCC (2007)]

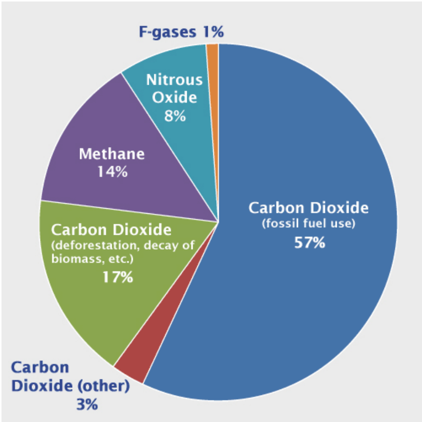


Figure 3: Continents of GHG

World Bank reports (2012), state that the temperature of planet will be 4 degree Celsius upper in the end of this century in compression its level in beginning of the century. Related to World Bank Group President Jim Yong Kim's states, the planet is 0.8 hotter than pre- industrial level now, and it must be avoided; we should be responsible for climate changes to leave a same world for our children.

So as we can see there's an urgent need to use methods to reduce the amount of most important emission (CO_2) by setting emission targets on industrial sectors which pollutes the planet to gain more commercial profits. On 11 December 1997, in Kyoto, Japan, a protocol adopted to set mandatory obligations to reduce emissions of greenhouse gases industrialised countries. To get the aim, 37 industrialised countries are committing themselves to decrease their emitting targets under the Kyoto protocol. These countries apply some structures like cap and trade to get the point.

Cap and trade market is a market in which the firms which need emission permits or allowances will buy these permissions from the firms which need less and have extra ones. Indeed, sellers take advantage of reducing pollution and buyers pay charge for polluting. There are several cap and trade markets in the world for six green house gases. The greenhouse gas (GHG) and emmision trading market, its structure and schemes working around the world, most important CO_2 trading exchang markets and their products are explained more detail in chapter3.

The aim of this study is to investigate the efficient market hypothesis (weak-form) of carbon trading markets.

The Efficient Market Hypothesis (EMH) has three forms:

1. Weak –form efficiency: in which price reflects all historical information. Traders can't use technical analyze to predict future prices, whereas some can obtain excess returns using fundamental analysis.

2. Semi-strong form efficiency: price reflects all publicly like available information including financial statements and news reports so no approach for predicting like fundamental or technical analyze can be useful.

3. Strong form efficiency: price reflects all information, including public and private information, so no investor can find undervalued stock. Some says who gain too much profit in this form is more lucky.

as Fama (1965) and Malkiel (1973) point out in weak-form efficiency the prices in the market are completely random and prediction is impossible.

"Random walk" theory created by Bachelier (1863) is a relevant viewpoint to EMH, which states that the prices in the efficient financial markets are not connect to each other and don't follow any trend and move randomly.

This study focuses on weak-for efficiency and investigates if the market prices follow random walk or not. The thesis employs ADF, Perron, KPSS and ZA test to investigate the stationarity of timeseries and indicate the EMH.

1.1 Structure of the Thesis

This thesis is organized as follows: chapter 2 reviews literatures studied in the field; chapter 3 explains the emission trading schemes around the world and their features, the carbon cap and trade markets working under this schemes; chapter 4 focuses on the data, specification of stationary, unit root, random walk and the econometric methods of testing them; Chapter 5 is the empirical results of these tests; and the last chapter is the conclusion of this thesis.

Chapter 2

LITERATURE REVIEW

Related to that the carbon trading market is a new market, there are few studies about these markets, especially the efficiency of these markets.

For the first time, Daskalakis and Markellos (2008) studied the efficiency of European carbon markets by analyzing the spot and future market data from three most important European carbon markets, namely Powernext, Nord Pool and ECX (European Climate Exchange). They used econometric methods to examine the weak form efficiency in the markets. By employing variance ratio test they showed that during the first-phase in EU ETS (2005-2008), the behaviour of the markets is not consistent with weak form efficiency. Whereas after starting the second-phase the weak form of efficiency in named markets is detected.

Montagnoli (2010) investigates the efficiency of the Bluenext, the largest carbon market under EU ETS by utilizing the variance ratio test to see if the returns in this market follow the martingale difference sequence or not. They came to the same conclusion as before study, that the phase I is inefficient and the early periods of phase II shows the weak form efficiency.

In premier studies about efficient market, the most famous one is Fama (1965) which proposed the efficient market hypothesis (EMH) as: "A market where there are large numbers of rational, profit-maximizers actively competing, with each trying to predict future market values of individual securities, and where important current information is almost freely available to all participants". In Fama's own words, "In an efficient market, on the average, competition will cause the full effects of new information on intrinsic values to be reflected instantaneously in actual prices". He implies that stock price movements are not correlated to such a degree that one can truly profit from the insignificant auto-correlations. When data is reflecting the random walk, the market is efficient. The theory of random walks says that successive price changes are independent, i.e., the past cannot be used to predict the future. Later in (1970) he supports his earlier investigation.

But Bachelier (1900) had explained the efficient market earlier. He studied this as his PhD dissertation. He implied that the likelihood of prediction of fluctuations in markets can be assessed mathematically and these fluctuations are randomly.

Kendeall (1953) state that by random walk, the share price changes should be independent of each other and that they should conform to some probability distribution. He divided the time series trend to a long term movement and the residuals for the short term fluctuations. He analysed London share price indices by finding serial correlation coefficients for the first difference of weekly observations. In general, these coefficients did not differ significantly from zero, and so supported the random walk hypothesis. So he concluded that investors could not make money by watching price movements and investing in shares which were apparently rising.

Lo and MacKinlay (1988) proposed the conventional variance ratio test. After that, the variance ratio test became the most popular method to investigate the random walk. This test is predicated upon the fact that for price movements that follow random walks, the variance of the log-price relatives, log Pt - log Pt-1, sampled at regular intervals of length time t, is n times the variance of the log-price relatives sampled at intervals of length time t/n.

Kim and Shamsuddin (2008) test the random walk by adopting multiple variance ratio test to examine the efficiency of the Asian stock market. They used nine Asian countries stock markets and argued that the EMH varies depend on three classes as developed countries, advanced emerging and secondary emerging. First class (developed countries) shows weak form efficiency while advanced emerging shows inefficiency and the third class (secondary emerging) shows a little signs of efficiency.

Azad (2009) compared parametric tests and nonparametric test by employing individual as well as panel unit root tests (parametric) and two variance-ratio tests (nonparametric) imply that using unit root test or variance ratio test is indifferent for investigating the EMH when the data is daily, but it may differ by weekly data. Unit root test is a parametric test to recognize stationarity of the series, which imply that if the series is non-stationary the data follows the random walk, so the market is efficient.

Shi (2011), by employing the robust serial correlation test investigate the efficiency of Chinese stock market. The article came to conclusion that Shanghai market is weak-form efficient.

Chen and Yeh (1997) tested the EMH by genetic programming (GP). They argued that using GP-based model is giving the better result than variance ratio test by 50%.

Most traditional method to investigate the stationary is augment dickey-fuller which is the extended study of dickey-fuller (1981). Related to that ADF doesn't consider the structural breaks, Perron (1989) implies that this will lead to accepting a false unit root. So he improved the ADF test in 1997.

Kwiatkowski et al. (1992) is well-known in unit root test between econometrics as KPSS which shows better answers than ADF. The test has a null of stationarity of a series around either mean or a linear trend; and the alternative assumes that a series is non-stationary due to presence of a unit root. In this respect it is innovative in comparison with earlier Dickey-Fuller test, or Perron type tests, in which null hypothesis assumes presence of a unit root.

Zivot and Andrews (1992) also suggest a method to test stationary when there's one break in trend. Narayan and smyth (2005) employs this model and and LM panel unit root test to test the unit root in OECD stock market beside Im et al. (2003)'s t-bar panel unit root test. They investigate among 22 countries and found that the series are following random walk.

Alberola, Chevalier and Cheze studied the price and structural breaks in European carbon prices (2008). They run the unit root test two times, first time they supposed there are two breaks and used Lee and Strazicich (2003), and then for one break they test Lee and Strazicich (2001).

Himalal (2008) tests some Nepalese macroeconomic indicators by both ADF and Perron tests. There's an obvious structural break related to civil war, so he tests the data one time considering the break by Perron and the other time denying it by ADF. He concludes that by Perron method two indicator shows stationary out of eight.

Lee et all (2010) investigates EMH in stock prices in 32 developed countries, in addition 26 developing countries. To analysing this multiple structure break panel data he employed Carrion-i-Silvestre et al (2005)'s method beside employing traditional methods like ADF, pp which indicate unit root for all investigated markets. Moreover they used KPSS for testing multiple structure breaks and came to conclusion that developed countries shows evidence of EMH at 1 percent level. They also used the panel LM test.

Chapter 3

CARBON TRADING IN THE WORLD

3.1 What's Environmental Finance?

Related to "American Heritage Dictionary"'s definition, it is the one part of environmental economy, which mainly studies how to use variety financial instruments to protect environment and biodiversity. It's a new field relating finance sectors to environmental sectors. The first course of environmental finance was taught by "Richard L. Sandor" at Columbia University in 1992.

3.2 Emission Trading Schemes Around the World

On 11 December 1997 in Kyoto, Japan, a protocol adopted named "Kyoto protocol" to make 37 industrialized countries reduce their emissions. In 2001, more details adopted for implementation in Marrakesh, called "Marrakesh accords." This protocol started to force these countries from 16 February 2005. Its target is to reduce the amount of green house gases (GHG) by 5% lower than its level in 1990. The protocol defines three mechanisms for these countries to limit their pollutions: firstly international emission trading (is famous as carbon market), secondly the clean development mechanism (CDM), and lastly the joint implementation (JI).

Carbon trading market is a "cap and trade" system in which they restrict the emitting by letting a cap for pollution emitted by factories. Usually governments of countries sell or gave the emission permits to the firms which are supposed to emit the pollution in that amount. If these firms pass the limit, they have to pay taxes or other penalties considered by government, but there are also some other firms which improved their production system or for any other reasons has less emissions. So there became a market in which the firms which need emission permits or allowances will buy these permissions from the firms which need less and have extra ones. Indeed, sellers take advantage of reducing pollution and buyers pay charge for polluting. There are several cap and trade markets in the world for six green house gases, this study will focus on carbon emission trading as mentioned in introduction related to its intense share in pollution.

The clean development mechanism, named as CDM, allows the industrialised countries to reduce the emission emitted in developing countries by projects like solar power or other improvement systems (described in Article 12 of Kyoto protocol). These countries can meet their cap targets by trading "certified emission reduction" (CER) from these projects.

The joint implementation, known as JI, let the developed and industrialised countries to earn emission reduction units (ERUs) from an emission-reduction or emission removal project domestically (in industrialised countries). By projects mostly replaced the powers, JI projects implemented in industrialised countries which have obligation to limit their emission (defined in Article 6 of Kyoto protocol). Russia and Ukraine have most JI projects in the world far from other counties. These countries can sell their Emission Reduction Units (ERUs) to increase their emission allowances or keep their reduction targets. Each CER and ERU is equivalent to one tonne of CO_2.

There is several emission trading schemes working currently around the world. The most important and biggest among all is the European Union Emissions Trading System (EU ETS).

3.2.1 The European Union Emissions Trading System (EU ETS)

It's the first emission trading scheme in the world which launched in 2005. The participating countries involved 27 EU member states, Norway, Liechtenstein and Iceland. It consist of three phase: first phase started in 2005 to end of 2007, it continued as phase two from 2008 to December 2012 and phase three will start from Jan 2013 and will last for 7 years. Each period has its special reduction target and the total reduction is supposed to be 21 % in compression to levels in 2005, in addition 60-80% below the 1990 levels by 2050. Installations such as power stations, combustion plants, oil refineries and iron and steel works, as well as factories making cement, glass, lime, bricks, ceramics, pulp, paper and board are regulated under this scheme and are obligated to keep their emission under the cap.

It covers the emissions like CO2, N2O, adipic and gloxylic acids, PFCs from the aluminium sectors.

Banking and borrowing is allowed in this scheme. Banking means that in a certain period, installations can use surplus EUAs from last years. In Borrowing they can borrow EUA from next years. If regulated sectors can't meet their targets, then they have to pay penalties. They should deliver the non-delivered allowances in the next period and pay the penalty fine which was40 euro per tonne CO2 from 2005-2007 and 100 euro in next period.

The EU ETS allows CERS and ERUs be traded beside EUAs. To increase the liquidity, non-emitting installations are allowed to trade in EU ETS.

3.2.2 Regional Greenhouse Gas Initiative (RGGI)

Like EU ETS, it's a cap-and-trade programme performed in the United States. RGGI established in 2005 but start to work in 2008 and covers the power plants. States of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont are participating in this program. Through independent regulations, each state limit the emission considering the pre-defined cap, issue the allowance and trade these allowances in related quarterly auctions. States are supposed to use the money raised from these auctions to fund green agenda programs and energy efficiency.

The target is to reduce the emission 10% by 2018. Related to RGGI's 2012 report the scheme went so far from its target and reduced the emission 30% lower than 2005 level. RGGI is considering lowering its cap to meet the increase in allowance prices and lower emission production.

There's a three year control in this program, after each three year each obligated plant has to present an allowance for each tonne CO2 emitted.

The penalty for power firms which can't meet their cap at third year control is to pay three times of non-delivered certificates at next compliance date.

Like EU ETS banking is allowed in RGGI.

3.2.3 The NSW Greenhouse Gas Abatement Scheme

NSW GGAS is a mandatory emission trading scheme aims to reduce GHG emitted from the electricity producing. It was a voluntary programme when it established in 1997, but in became a mandatory in 2003. Due to World Bank reports NSW GGAS is the world's the first-largest obligated cap-and-trade GHG market outside the Kyoto protocol related markets.

The scheme obligates Electricity sellers, retailers and generators - collectively referred to as Benchmark Participants - in New South Wales to reduce their emissions 5% under the 1990 levels to achieve the global target set in Kyoto protocol. NSW GGAS sets annual targets and benchmark participants have to meet their limits based on their share in the market. NSW GGAS works different than the EUEST which obligates emitters to submit one EUA for each tonne of carbon emitted; The NSW scheme makes electricity retailers to buy a specified number of NGACSs – credits for NSW GHGs- for each unit of electricity they sell. NGACS like EUAs are selling in unit of Tonnes of CO2.

Participants should pay penalty if fail to meet their targets. The penalty was set at AUD 12 per tonne of CO2 in 2010 and it will be increased by 1 AUD each year until 2013. Additionally, it's possible to transfer into the next year an emissions surplus equal to 10% of their benchmark in all years of GGAS, but the surplus must be decreased that year or the penalty must be paid.

3.2.4 The New Zealand Emissions Trading Scheme (NZ ETS)

New Zealand is a signatory to the Kyoto Protocol, so to meet the obligations under UNFCCC established the NZ ETS. All six Kyoto Protocol Greenhouse gases (CO_2, CH_4, N_2O, PFCs, HFCs, SF_6) are traded in this scheme.

The scheme covers following sectors during these years: Forestry (January 2008), Liquid Fossil Fuels and Stationary Energy & Industrial (July 2010), Synthetic Gases and Waste (January 2013) and the last one agriculture (January 2015).

The NZ ETS is different from other cap and trade programs related to it doesn't consider any cap on greenhouse gas emitted. It's a market-based program, under which obligated sectors are required to monitor emissions, purchase emissions units, and submit them to Government after year end. They have to present one emission unit issued unit for each two tonnes of CO2 emitted (it doesn't matter if it's an international Kyoto unit or a New Zealand), or can buy NZ units from the government at a fixed price of NZ$25.

Participates can receive the Tradable emissions permits by two ways; one way is free allocation of permits to existing emitters (known as Grandfathering); the other one is by auction. Firms which use grandfathering permits and aimed to reduce emission intensively will give fewer permits in next years.

Allocation in the scheme is based on the average emissions per unit of output within a defined activity. Some sections like emissions-intensive industry (based on their output-intensity) and the commercial fishery sector (based on their history) are receiving free allocation; beside agriculture (99%). Liquid fossil fuel and stationary energy sectors (including electricity generators) and landfill operators will not get any free allocation.

There are penalties considered for participants who are not able to deliver their allowances. They are obligated to deliver those allowances -in some cases will be extended two times the firs amount- plus NZ$30-60 per tonne.

Like other schemes banking is allowed but they can't borrow from next years.

There is some criticism on this scheme. Indulgent free allocation of these units is being criticized by some stakeholders due to being ineffective in reducing emissions.

3.2.5 Tokyo's Emissions Trading System

The Tokyo Metropolitan Government has introduced the world's first cap and trade program at the city. Since urban areas account for more than half of the world's citizenry but almost 70% of the whole energy use, targeting the city level for the abatement of GHG emissions has essential importance to meeting goals for CO2 reduction.

The ETS covers around 1,340 large facilities including industrial factories, public facilities, educational facilities, etc. as well as, commercial buildings to reduce the amount of CO2. Many legislative and administrative organs of the central government, such as the Prime Minister's official residence, the Diet Building, the Ministry of the Environment, the Ministry of Economy, Trade and Industry are also under the cap.

It started to work in April 2010 with the target to reduce emissions by 25% from 2000 levels by 2020. It works in two phase: first phase started from 2010 aim to reduction the emission by 6-8%of 2000 levels in 2014 , second phase with a possible further 17% reduction by the end of the second compliance period (2015-2019).

Banking is allowed under this cap and trade system. Participants can bank the surplus when their emissions during a given compliance period are less than the emissions allowances. Banking can be a motivation for facilities to reduce GHG emissions ahead of schedule. Furthermore it can apply as a protection against unexpected developments, including an unexpected appreciation in the value of transactions.

Due to ensuring a consistent reduction in GHG emissions ahead of schedule borrowing is not permitted.

Allowances for the obligated facilities are allocated according to the grandfathering method based on past emissions.

・Allowances: Base-year Emissions × Compliance factor × 5 (years)

・Base-year emissions: Average of the past 3 years

The Governor of Tokyo determined the compliance factor for the first compliance period in March 2009. The compliance factor for next phase will be determined before 2015 and is managed to be stricter.

Penalties are considered in the ETS for facilities (buildings/factories) which can't meet their targets. They have to pay fines (up to ¥500,000), will be "named and shamed" by government and have to meet 1.3 times of their older targets in next year.

3.3 Most Important Carbon Trading Markets

There are many financial markets around the world which are trading the emission under the schemes mentioned above. The largest and most liquid one is BlueNext.

3.3.1 Bluenext

BlueNext is the international carbon and environmental assets stock exchange formed on 21 December 2007 in Paris with NYSE Euronext holding a 60% interest while the remaining 40% is held by Caisse des Dépôts. Bluenext is the leading spot exchange trading emission in Europe after taking over the carbon trading business of Powernext, while Powernext just has its electricity market. BlueNext has opened 4 separate markets and brings together 95 active members, principally banks, energy producers and suppliers, and specialist intermediaries, aimed to be a world leader for trading in environment-related instruments.

Blunext offers both spot and futures on carbon trading but its spot conracts are more known through the world. It consists of two spot markets in carbon assets to cover both EUA (European Union Allowances) and CER (Certified Emission Reduction) trading. It has also launched two future markets for the named assets. With its strong experience in the Kyoto credits market, BlueNext is also a key player in organizing auctions of European allowances.

BlueNext has two other strategies: first to expand the business to Asia and ammerica and make a global arket which works under the regulatory of Kyoto protocol, second to have global clientele in the energy and financial communities.

To gain its targets and set up an international carbon-trading related information platform, BlueNext signed a partnership agreement with the China Beijing Environmental Exchange (CBEEX) in June 2009 to sell the CBEEX's CDM projects to European and U.S. buyers. This would create a voluntary carbon standard for CBEEX. Moreover, BlueNext is deputed in the USA by its majority shareholder NYSE Euronext. There are a number of U.S. companies as members on the exchange.

There are some other carbon markets that Bluenext have to compete with them like European Climate Exchange, Nord Pool, European Energy Exchange and Green Exchange which will be explained bellow.

3.3.2 European Climate Exchange (ECX)

The European Climate Exchange (ECX) is a famous market for trading CO2 emissions in Europe and international, which launched by the Chicago Climate Exchange in 2005 in London, also a member of the Climate Exchange Plc group of companies. The market was bought by Intercontinental Exchange (ICE) in April 2010. ICE ECX emissions products have more than 100 global firms' traders such as Barclays, BP, New edge, and attract over 80% of the exchange-traded volume in the European market.

The products involve futures and option contract based on the underlying EU Allowances (EUAs) and Certified Emissions Allowances (CERs).

3.3.3 Nord Pool

Nord Pool Spot is the largest market for electrical energy in the world, offers both day-ahead and intraday markets to its customers. It was the first exchange market in the world which starts trading EUAs. USA allowed to trade and clear Nordic, international and carbon products. The market operates in Norway, Denmark, Estonia, Sweden, Lithuania and Finland.

3.3.4 European Energy Exchange

The European Energy Exchange (EEX) is Germany's energy exchange that operates spot and derivatives market platforms for trading in energy and energy-related products such as physical electricity, emissions and contracts on natural gas and coal. There are more than 220 participants in this trading. EEX operates both spot and derivatives markets in emission allowances since 2005. EEX and Eurex have been cooperating in emissions trading since 2007 with trading of the already available EUA Futures on EEX for the Kyoto phase 2008-2012 and Eurex is the major owner now. CER Futures are traded on the EEX from March 2008.

3.3.5 Green Exchange

Green Exchange founded in New York (2008), offered trading in global carbon-based contracts, such as EUA, CER and verified emission reductions (VER/VCU). The Exchange market is competing Chicago climate exchange.

3.3.6 Chicago Climate Exchange (CCX)

Chicago Climate Exchange is North America's only voluntary, legally running greenhouse gas emission reduction program which offset projects in North America and Brazil, from 2003 through 2010. More than 400 members such as Ford, Motorola and Du point or some municipalities like Chicago and Oakland or some universities like Michigan University or farmers are involved in this market.

3.3.7 China Beijing Environment Exchange (CBEEX)

China Beijing Environment Exchange (CBEEX) was established as China's first domestic and international environmental equity public trading platform which covers more than 12 chemicals (2007).

The exchange was authorized by the Beijing Municipal Government and initiated by the China Beijing Equity Exchange (CBEX). As china is the biggest producer of CERs, CBEEX partrenerd with BlueNext to offer CERs since 2009.

3.3.8 Tianjin Climate Exchange (TCX)

Tianjin Climate Exchange (TCX) is the first domestic carbon market cap-and-trade scheme exchange founded in September 2008.

TCX is a joint venture between Chicago Climate Exchange (owned 25%), CNPC Assets Management Co., Ltd. (owned 53%), and by Tianjin Property Rights Exchange (owned 22%), the country’s largest oil and gas producer.

As China does not have a national cap on emissions, any such scheme would be voluntary, similar to the situation in the US when the Chicago Climate Exchange launched in 2003.

Two emission namely carbon dioxide and as sulphur dioxide are traded in this market beside water pollutants.

3.3.9 Japan Climate Exchange (JCX)

Japan Climate Exchange is founded by Sojitz Corporation (holding 60%) and Smart Energy Co. (holding 60%) in April 2010 to reduce GHG emissions.

After Japan's Earthquake in March, there has been a growing global trend towards the use of thermal energy including natural gas and coal, so CO_2 emissions are rising. Related to this increment, the prices of CERs and EUAs in the European Union have increased by about 10% between early March and mid-May of this year.

3.3.10 Carbon Match

Carbon Match is the first online emissions trading platform for carbon credits in New Zealand to trade emission under the New Zealand's carbon trading scheme.

Prices set by the competitive and transparent interaction of buyers and sellers, although identities are withheld.

Chapter 4

DATA AND METHODOLOGY

4.1 Data

The thesis investigates the efficiency in the most liquid and largest spot carbon trading market, Bluenext. In this study, "efficiency" is related to informational efficiency. There are other emission trading markets as mentioned in chapter 3, but not investigated in this study related to that some of those are specialist in option and futures (not the aim of this study), and there was not available data for other markets.

Data from BlueNext is in two part related to two phase of trading under EU ETS. First part starts from 06/24/2005 till 04/25/2008 and involves 708 observation of closed daily spot price of EUAs. Next part is related close daily price of EUAs to second phase of EU ETS, starts from 26/02/2008 and ends in 30/11/2012 which makes 1,183 observations.

4.2 Econometric Methodology

4.2.1 Specification of Random Walk, Stationary and Unit Root

Random walk: The random walk is said to have a unit root and is a non-stationary process. There are two types of random walks: (1) random walk without drift (i.e., no constant or intercept term) and (2) random walk with drift (i.e., a constant term is present).

1. Random Walk without Drift: Suppose u_t is a white noise error term with mean 0 and variance σ_2. Then the series Y_t is said to be a random walk if

$Y_t = Y_{t-1} + u_t$

It is a non-stationary stochastic process. In practice Y_0 is often set at zero, in which case $E(Y_t) = 0$.

2. Random Walk with Drift: it modifies the above formula as follows:

$Y_t = \delta + Y_{t-1} + u_t$

For the random walk with drift model:

$E(Y_t) = Y_0 + t \cdot \delta$

$var\ (Y_t) = t\sigma^2$

In short, RWM, with or without drift, is a non-stationary stochastic process.

Stationary: Time series is stationary if its mean and variance do not vary systematically over time. Time series might be equal to its value plus a purely random shock (or error term). Thus, this means a random walk phenomenon.

Specification of Stationarity:

Mean: $E\ (Y_t) = \mu$

Variance: $var\ (Y_t) = E\ (Y_t - \mu)^2 = \sigma^2$

Covariance: $\gamma_k = E[(Y_t - \mu)\ (Y_{t+k} - \mu)]$

In short, if a time series is stationary, its mean, variance and autocovariance (at various lags) remain the same no matter at what point we measure them; they are time invariant.

Such a time series will tend to return to its mean (mean reversion) and fluctuations (its variance) around this mean will have a broadly constant amplitude.

Unit root: If write the RWM as

$Y_t = \rho Y_{t-1} + u_t \qquad -1 \leq \rho \leq 1$

and ρ = 1, above formula becomes a RWM (without drift). If ρ is in fact 1, we face what is known as the unit root problem, that is, a situation of non-stationarity in this case the variance of Y_t is not stationary. The name unit root is due to the fact that ρ=1.

Thus the terms nonstationarity, random walk, and unit root can be treated as synonymous.

To recognize the efficiency of the market, we should know that if the time series is a stationary series or not. In the absence of unit root (stationarity), the series fluctuates around a constant long-run mean and implies that the series has a finite variance which does not depend on time. On the other hand, non-stationary series have no tendency to return to long-run deterministic path and the variance of the series is time dependent. Non-stationary series suffer permanent effects from random shocks and thus the series follow a random walk. The employed tests to investigate the unit root for time series are explained in follow.

4.2.2 Augmented Dicky-Fuller Test (ADF)

The most routine way to test the stationary is ADF test (1979) in which structural break is not considered.

ADF tests the null hypothesis of $\alpha = 0$ against the alternative hypothesis of $\alpha < 0$:

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \varepsilon_t$$

Where Δ is the first difference; y_t is the tie series testing; t denotes the time trend variable; k is the number of lags which are added to the model to ensure that residuals; ε_t denotes white noise.

To distinguish the optimal lag length, SBC and AIC are employed. if the null test rejects it means that the time series is stationary.

4.2.3 Perron Test

Perron (1989) implies that in the evidence of structural breaks, ADF tests are biased towards the non-rejection of the null hypothesis and will accept the non-stationary wrongly.

Perron modified the Dickey-Fuller tests by including dummy variables to investigate series by one fixed structural break. If there is no break, this test is less reliable than ADF test.

Three equations test the unit root under perron's model:

$Z_t = \alpha_0 + \alpha_1 DU_t + d(DM)_t + \theta_t + \lambda Z_{t-1} + \sum\delta\ \Delta Z_{t-1} + \varepsilon_t$ [1]

$Z_t = \alpha_0 + \gamma D_t^{*} + \theta_t + \rho Z_{t-1} + \sum\delta\Delta Z_{t-1} + \varepsilon_t$ [2]

$Z_t = \alpha_0 + \alpha_1 DU_t + d(DM)_t + \gamma D_t + \theta_t + \lambda Z_{t-1} + \sum\delta\ \Delta Z_{t-1} + \varepsilon_t$ [3]

where the intercept dummy DUt denotes a change in the level; $DU_t = 1$ if ($t > TB$) and zero otherwise; the slope dummy DT_t (also DT_t*) represents a change in the slope of the trend function; $DT^* = t\text{-}TB$ (or DT_t *= t if $t > TB$) and zero otherwise; the crash dummy *(DTB)* = 1 if $t = TB$ +1, and zero otherwise; and *TB* is the break date. Each of the three models has a unit root with a break under the null hypothesis, as the dummy variables are incorporated in the regression under the null. The alternative hypothesis is a broken trend stationary process.

4.2.4 Zivot and Andrews

For trends in which the break is unknown and there's no fixed break, Zivot and Andrews offers an alteration of Perron’s test. They improved the perron's model by three other models to test the stationary. A one-time change is adopted in the level, slope and both together in model I, II and III respectively.

$\Delta y_t = c + \alpha y_{t-1} + \beta_t + \gamma DU_t + \sum d_j \Delta y_{t-j} + \varepsilon_t$ [I]

$\Delta y_t = c + \alpha y_{t-1} + \beta_t + \theta DT_t + \sum d_j \Delta y_{t-j} + \varepsilon_t$ [II]

$\Delta y_t = c + \alpha y_{t-1} + \beta_t + \theta DU_t + \theta DT_t + \sum d_j \Delta y_{t-j} + \varepsilon_t$ [III]

where DU_t is an indicator dummy variable for a mean shift occurring at each possible break-date (TB) while DT_t is corresponding trend shift variable. If t>TB then $DU_t = 1$, $DT_t = t - TB$; otherwise zero. The Zivot and Andrews method regards every point as a potential break-date (TB) and runs a regression for every possible break-date sequentially.

The test statistic is the minimum of all the t-tests. The null hypothesis is a unit root process without any structural breaks and the alternative hypothesis is a trend stationary process with possible structural change occurring at an unknown point in time.

4.2.5 KPSS

The KPSS test is the Lagrange multiplier (LM) or score statistic for testing $\sigma^2_\varepsilon = 0$ against the alternative that $\sigma^2_\varepsilon > 0$ and is given by:

$KP\ SS = (T^{-2}\sum s^2_t)/ \lambda^2$

Where $S_t = \sum u_j$, u_t is the residual of a regression of y_t on D_t and λ^2 is a consistent estimate of the long-run variance of u_t using $\hat{u}_t$. Under the null that y_t is I(0), Kwiatkowski, Phillips, Schmidt and Shin show that KPSS converges to a function of standard Brownian motion that depends on the form of the deterministic terms D_t but not their coefficient values β. In particular, if $D_t = 1$ then

$$KP\ SS \rightarrow \int_0^1 V_1(\ 1\ )d_r$$

where $V_1(r) = W(r) - rW(1)$ and $W(r)$ is a standard Brownian motion for $r \in [0, 1]$.

If $D_t = (1, t)'$ then

$$KP\ SS \rightarrow \int_0^1 V_2(\ 1\ )d_r$$

where $V_2(r) = W(r) + r(2 - 3r)W(1) + 6r(r^2 - 1) \int_0^1 W(\ s\ )ds$

The stationary test is a one-sided right-tailed test so that one rejects the null of stationary at the 100*α % level if the KPSS test statistic is greater than the 100*(1 − α) % quantile from the appropriate asymptotic distribution. So, the null hypothesis in this model is different from the three last models.

Chapter 5

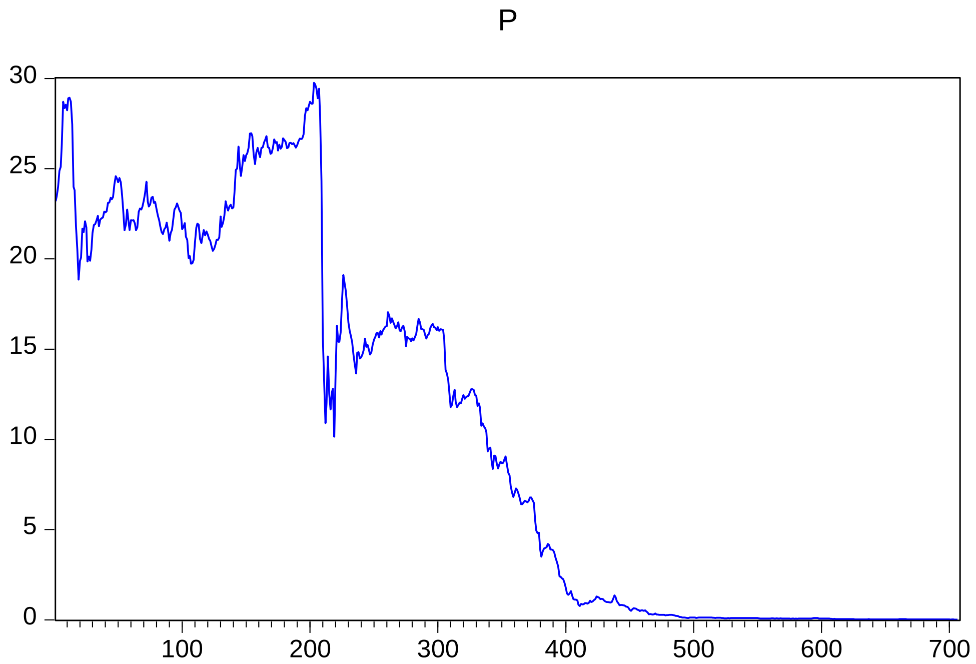
DATA ANALYSIS AND EMPIRICAL RESULTS

As mentioned in chapter 5, this study investigates the stationarity of time series based on ADF, perron, KPSS and ZA tests.

5.1 Testing Stationary by ADF Test

5.1.1 Phase I in Bluenext (2005-2007)

As shown in below graph, there's a structural break and trend in the related time series. To recognize the stationary the ADF test is employed.



Graph 1: closed daily spot price of Bluenext market, phase I

ADF verifies the unit root in 3 steps: firstly including trend and intercept, secondly including intercept and finally without including any test equation. The result is as below:

Table 1: ADF test, phase I

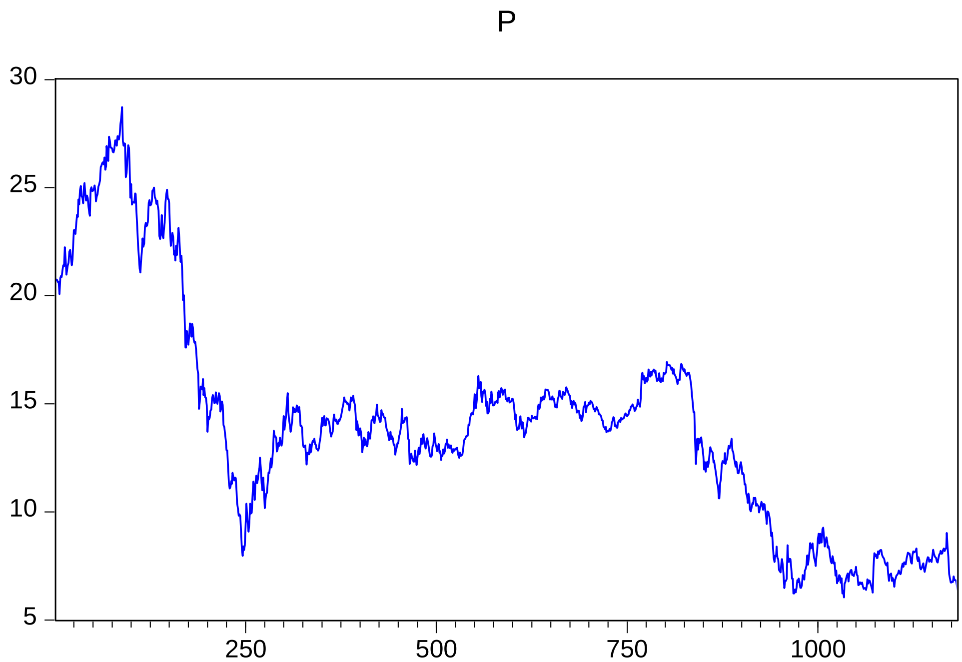
Bluenext phase I	critical values:	t-statistic	ADF test	Status
Trend & Intercept	1% levels	-3.971104	-2.612011	Non-stationary
	5% levels	-3.416195		
	10% levels	-3.130392		
Intercept	1% levels	-3.439384	-1.229178	Non-stationary
	5% levels	-2.865417		
	10% levels	-2.568891		
None	1% levels	-2.568242	-1.620273	Non-stationary (at 1% and 5%) Stationary (at 10%level)
	5% levels	-1.941272		
	10% levels	-1.616398		

The null Hypothesis is that the time series has a unit root.

Testing ADF with intercept and trend shows the time series is non-stationary in all three critical levels (1%, 5% and 10%). After testing ADF including intercept, it shows the same result as last step. In last step it shows a different result, time series is stationary but at 10% confidence level.

5.1.2 Phase II in Bluenext (2008-2012)

The graph of daily closed price of Blunext between 2008 and 2012 is shown below:



Graph 2: closed daily spot price of Bluenext market, phase II

Analysis of this time series by ADF shows that it's non-stationary in all levels including intercept or not.

Table 2: ADF test, phase II

Bluenext phaseII	**critical values:**	**t-statistic**	**ADF test**	**Status**
Trend & Intercept	1% levels	-3.965829	-1.860336	Non-stationary
	5% levels	-3.413618		
	10% levels	-3.128866		
Intercept	1% levels	-3.439384	-1.044565	Non-stationary
	5% levels	-2.865417		
	10% levels	-2.568891		
None	1% levels	-2.568242	-1.495452	Non-stationary
	5% levels	-1.941272		
	10% levels	-1.616398		

Analysis of this time series by ADF shows that it's non-stationary in all levels including intercept or not.

5.2 Testing Stationary by Perron Test

5.2.1 Phase I in Bluenext (2005-2007)

The table below is the result of time series of first phase analysed by E-views which shows this series is non-stationary considering the structural break.

Table 3: Perron test, phase I

Bluenext phase I	Test critical values:	t-statistic	Perron test	Status
Trend & Intercept	1% levels	-6.32	-5.174066	Non-stationary
	5% levels	-5.59		
	10% levels	-5.29		
Intercept	1% levels	-5.92	-4.345728	Non-stationary
	5% levels	-5.23		
	10% levels	-4.92		
Trend	1% levels	-5.45	-3.554088	Non-stationary
	5% levels	-4.83		
	10% levels	-4.48		

5.2.2 Phase II in Bluenext (2008-2012)

The perron test results non-stationary for time series in phase two either.

Table 4: Perron test, phase II

Bluenext phaseII	Test critical values:	t-statistic	Perron test	Status
Trend & Intercept	1% levels	-6.32	-3.824731	Non-stationary
	5% levels	-5.59		
	10% levels	-5.29		
Intercept	1% levels	-5.92	-2.637442	Non-stationary
	5% levels	-5.23		
	10% levels	-4.92		
Trend	1% levels	-5.45	-2.926044	Non-stationary
	5% levels	-4.83		
	10% levels	-4.48		

5.3 Testing Stationary by ZA Test

5.3.1 Phase I in Bluenext (2005-2007)

By ZA test in E-views, the study conclude that the first phase time series is stationary except when analyzing considering both trend and intercept in 1% confidence level.

Table 5: ZA test, phase I

Bluenext phase I	Test critical values:	t-statistic	ZA test	Status
Trend & Intercept	1% levels	-5.57	-5.122918	Non-stationary (at 1% level) Stationary (at 5% and 10% level)
	5% levels	-5.08		
	10% levels	-4.82		
Intercept	1% levels	-5.34	-4.207293	Non-stationary
	5% levels	-4.93		
	10% levels	-4.58		
Trend	1% levels	-4.80	-3.634908	Non-stationary
	5% levels	-4.42		
	10% levels	-4.11		

5.3.2 Phase II in Bluenext (2008-2012)

The test shows this time series is stationary in all steps and all confidence levels.

Table 6: ZA test, phase II

Bluenext phaseII	Test critical values:	t-statistic	ZA test	Status
Trend & Intercept	1% levels	-5.57	-3.97	Non-stationary
	5% levels	-5.08		
	10% levels	-4.82		
Intercept	1% levels	-5.34	-2.82	Non-stationary
	5% levels	-4.93		
	10% levels	-4.58		
Trend	1% levels	-4.80	-3.44	Non-stationary
	5% levels	-4.42		
	10% levels	-4.11		

5.4 Testing Stationary by KPSS Test

5.4.1 Phase I in Bluenext (2005-2007)

The null test in this test is the time series has a unit root. Below is the table of final results of testing KPSS by E-views. Related to the KPSS's t-statistic greater than the critical values the null hypothesis is rejected and the time series is stationary in first step (including intercept and trend). Same as first step, while testing the time series with the method just including the intercept, the t-statistic is significantly greater than critical values, hence reject the null hypothesis.

Table 7: KPSS test, phase I

Bluenext phase I	**Test critical values:**	**t-statistic**	**KPSS test**	**Status**
Trend & Intercept	1% levels	0.216000	0.379754	Non-stationary
	5% levels	0.146000		
	10% levels	0.119000		
Intercept	1% levels	0.739000	2.929067	Non-stationary
	5% levels	0.463000		
	10% levels	0.347000		

5.4.2 Phase II in Bluenext (2008-2012)

The time series in this phase is stationary due to t-statistic bigger than all critical values (table below)

Table 8: KPSS test, phase II

Bluenext phase II	**Test critical values:**	**t-statistic**	**KPSS test**	**Status**
Trend & Intercept	1% levels	0.216000	0.343	Non-stationary
	5% levels	0.146000		
	10% levels	0.119000		
Intercept	1% levels	0.739000	2.60	Non-stationary
	5% levels	0.463000		
	10% levels	0.347000		

5.5 Overall Results

The study employed several econometric parametric methods to investigate the unit root. The tests for unit root and satationarity are ADF, Perron, ZA, and KPSS. The final result of this study is shown in the below table:

Table 9: conclusion table

	ADF test	**Perron test**	**ZA test**	**KPSS test**
Phase I	Non-stationary	Non-stationary	Non-stationary	Non-stationary
Phase II	Non-stationary	Non-stationary	Non-stationary	Non-stationary

Relating to features in above table, the Bluenext market in both phases of its activity has a non-stationary time series which lead to conclusion that it's an efficient market in weak-form.

Chapter 6

CONCLUSION

There's an urgent need to use methods to reduce the amount of most important emission (CO_2) by setting emission targets on industrial sectors which pollutant the planet to gain more commercial profits.

On 11 December 1997, in Kyoto, Japan, a protocol adopted to set mandatory obligations to reduce emissions of greenhouse gases in industrialised countries. To get the aim, 37 industrialised countries are committing themselves to decrease their emitting under the Kyoto protocol targets. These countries apply some structures like cap and trade to get the point.

Carbon trading market is a "cap and trade" system in which they restrict the emitting by letting a cap for pollution emitted by factories. Usually governments of countries sell or gave the emission permits to the firms which are supposed to emit the pollution in that amount. If these firms pass the limit, they have to pay taxes or other penalties considered by government, but there are also some other firms have fewer emissions. So there became a market in which the firms which need emission permits or allowances will buy these permissions from the firms which need less and have extra ones.

The aim of this study is to investigate what are cap and trade markets around the world and if these markets are efficient markets for trading or not.

There are several emission trading schemes working currently around the world namely as EU ETS, RGGI, GGAS, NZ ETS and Tokyo- ETS. Most important emission trading markets working under these schemes are named as Bluenext (the headquarter is in Paris, founded in 2001 and trading Future and spot EUAs, CERs), European Climate Exchange (ECX), Nord Pool, European Energy Exchange, Green Exchange, Chicago Climate Exchange (CCX), China Beijing Environment Exchange (CBEEX), Tianjin Climate Exchange (TCX), Japan Climate Exchange (JCX) and carbon match.

Related to that all these markets are new, finding the daily spot data was not possible for all of them; the only available data during this study was data from Bluenext market, so the thesis focus on investigating the weak-form efficiency on this market.

With a quick look at data graph it can be considered that data has a structural break in 2007 and 2011.

There are other papers studied the efficiency of carbon markets before, but without considering the effect of structural break in spot price data.

Montagnoli implies that first phase is inefficient in weak-form whereas the second phase shows weak-form informational efficiency (2010) using variance ratio test.

Daskalakis and markellos study the inefficiency of this market in first phase and its reasons (2008).

To investigate the EMH, we have to know that whether the time series is stationary or not. Due to structural breaks in time series, the study employed several econometric parametric methods to investigate the unit root. The tests for unit root and satationarity are ADF, Perron, ZA, and KPSS. The final result of this study is shown in the below table:

Table 9: conclusion table

	ADF test	**Perron test**	**ZA test**	**KPSS test**
Phase I	Non-stationary	Non-stationary	Non-stationary	Non-stationary
Phase II	Non-stationary	Non-stationary	Non-stationary	Non-stationary

Considering that the ADF tends to recognize the unit root in time series, and it's obvious that there are structural breaks in the time series, the study implies other econometric tests to study the stationary such as perron, ZA and KPSS.

So relating to features in above table, the Bluenext market in both phases of its activity has a non-stationary time series which lead to conclusion that it's an efficient market in weak-form.

6.1 Limitations of the Study and Further Research

The first aim of this study was to investigate the efficiency of carbon all around the world, but it is limited to research just in Blunext market due to that the data of Bluenext was the only available and accessible spot data to reach. Most of Other markets data were more expensive than can be afford by a master student individually and the others were not accessible by the data searchers available in the university.

Further studies can be employed to investigate all markets efficiency (named in the study in chapter 3) beside the Bluenext from USA, to Japan.

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