DRIVERS OF CARBON PRICES IN THE EUROPEAN UNION EMISSION TRADING SCHEME

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ABSTRACT

DRIVERS OF
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This thesis analyzes the interaction of the carbon prices in the European Union Emissions Trading System (EU ETS) with other macroeconomic variables. In the thesis, the relationship of carbon prices with the indicative variables related to industrial production, economic expectations, weather conditions and stock markets, mainly fossil fuels, has been discussed within the framework of ARDL (autoregressive distributed lag) co-integration method. Both the long-term and short-term relationships of this interaction have been put forward. In addition, the causality relationship between the variables is presented by adopting the Toda-Yamamoto Granger Non-Causality test approach.

Keywords: European Union Emission Trading Scheme; Climate Change; Carbon Pricing, ARDL, Toda-Yamamoto Granger Non-Causality test

ÖZ

AB ETS SİSTEMİNDEKİ KARBON FİYATLARININ
BELİRLEYİCİLERİ

Uludağ, Arda
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Bu tez, Avrupa Birliği Emisyon Ticaret Sisteminde (AB ETS) piyasa koşullarında belirlenen fiyatların diğer makroekonomik değişkenlerle olan etkileşimini incelemektedir. Tezde karbon fiyatlarının başta fosil yakıtlar olmak üzere, sanayi üretimi, ekonomik beklentiler, hava koşulları ve hisse senedi piyasalarına ilişkin gösterge niteliğindeki değişkenlerle olan ilişkisi ARDL (otoregresif dağıtılmış gecikme modeli) eşbütünleşme yöntemi çerçevesinde tartışılmıştır. Bu etkileşimin uzun ve kısa vadeli ilişkisi ortaya konulmuştur. Tez kapsamında ayrıca, Toda-Yamamoto Granger Nedensellik Analizi yaklaşımı benimsenerek değişkenler arasındaki nedensellik ilişkisi sunulmuştur.

Anahtar Kelimeler: Avrupa Birliği Emisyon Ticaret Sistemi, İklim Değişikliği, Karbon Fiyatlandırma, ARDL, Toda-Yamamoto Granger Nedensellik Analizi

To My Family

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LIST OF ABBREVIATIONS

AIC	Akaike's Information Criterion
AR	Autoregressive
ARCH	Autoregressive conditional heteroskedasticity
ARDL	Autoregressive lag distributed
CaT	Cap-and-Trade Scheme
CBDR	Common but differentiated responsibilities
CDM	Clean Development Mechanism
CEF	Climate and Energy Framework
CEP	Climate and Energy Package
CER	Certified Emission Reduction
CH_4	Methane
CIF	Cost, insurance and freight
CO_2	Carbon dioxide
CPM	Carbon Pricing Mechanism
EEX	European Energy Exchange
ERF	The Emissions Reduction Fund
ERU	Emission Reduction Unit
ESI	Economic Sentiment Indicator
EU ETS	European Union Emission Trading System
EU	European Union
EUA	European Union Allowance
FPE	Final Prediction Error
GARCH	Generalized autoregressive conditional heteroskedasticity
GHG	Greenhouse Gases
GWh	Gigawatt hours
HDD	Heating Degree Days Index
HQ	Hannan-Quinn information criterion
ICE	InterContinental Exchange

IET	International Emission Trading
IPI	Industrial Production Index
ITMO	Internationally Transferred Mitigation Outcomes
JI	Joint Implementation
LDC	Least Developed Country
MSR	Market Stability Reserve
N_2O	Nitrous Oxide (dinitrogen oxide)
NAP	National Allocation Plan
RGGI	The Regional Greenhouse Gas Initiative
SIC	Schwarz information criterion
SF_6	Sulfur Hexafluoride
SGER	The Specified Gas Emitters Regulation
STOXX50	Euro Stoxx50 Index
STOXX600	Euro Stoxx600 Index
tCO_2e	a ton of carbon dioxide equivalent
TTF	Title Transfer Facility
UNFCCC	United Nations Framework Convention on Climate Change
US	United States of America
VAR	Vector autoregressive
VECM	Vector error correction mechanism

CHAPTER 1

INTRODUCTION

In recent decades, international community has started to pay increasing attention to the adverse effects of climate change since simmering concerns have grown dramatically as extreme weather events, natural disasters, ecosystem degradations and extinction of some species have become more frequent. However, one of the most influential factors which increases the ambition of combatting climate change is its economic impacts. If the current trend in global warming continues, it is expected that much more serious economic and environmental consequences will arise in the future. Nevertheless, not all of the regions of the world are affected from climate change in the same way. The most damaging effects of climate change have been observed in developing countries than the developed countries which could be considered as the primary blameworthy actors for climate change because of their industrialization process. Among the reasons of this difference lack of sound and adequate infrastructure and climatically risky locations of developing countries could be cited.

As a multi-faceted global challenge, climate change cannot be considered as a problem that should be addressed by only major countries; on the contrary it requires a collective struggle and cooperation at international level. In this context, climate change has taken an important place in the agenda of the global public since the early 1990s. Parallel to these developments, the United Nations Framework Convention on Climate Change (UNFCCC) was set up in 1992, and the basis of the international climate change regime was laid down and a roadmap was drawn out with the general outlook for the future. With the adoption of the Kyoto Protocol in 1997, the details of this general framework have been clarified. During this period, the general approach to climate change has been designed such that developed countries should bear the brunt of climate change by taking necessary measures to mitigate their emissions and also provide adequate support in financial, capacity-building and technology themes to developing countries.

Notwithstanding over the course of time, it has been observed that developing countries have been significantly differentiated in terms of economic structures from the early 1990s and some of the countries in this group have also begun to contribute to worsening climate change problem. The changes in the economies of developing countries have led to changes in the approach for the responsibility sharing among parties to cope with the adverse effects of climate change. Concordantly, the Paris Agreement, which forms the basis of climate change policies for the post-2020 period, was adopted as a result of the negotiations that endured by the end of 2015 with respect to the evolution of developing countries. The most important feature that differentiates the Paris Agreement from the former ones is that the responsibility of reducing greenhouse gas (GHG) emissions previously charged only on developed countries, has become widespread throughout all countries.

Stressing that climate change is a serious market failure, solutions should be designed to cope with market failures by eliminating externalities due to climate change. This aspect of the issue has been studied extensively in academia and by international organizations in the recent period. In this context, countries may prefer implementing conventional tools like regulatory and supervisory measures for facilities which give rise to emissions. However; resorting only to measures within certain regulatory and supervisory mechanisms would negatively affect the national economies and bring serious costs to economic actors. Especially, in recent years when the global financial crises seriously have weakened the economies, it has become a necessity to implement policies to combat climate change with cost-effective, flexible and innovative methods. In this context, the struggle against climate change, which has a multidimensional structure in terms of the effects, needs to be supported not only by environmental policies but also in different areas by different policy tools. At this point, carbon pricing tools, which are becoming increasingly popular with applications in many countries, are at the forefront.

Historically, it is observed that carbon pricing mechanisms have started to be implemented in the Nordic countries in the early 1990s through carbon taxes. Besides, one of the first primitive examples of emission trading schemes (ETS) was set up in the USA in the same years and the schemes impose an upper limit on sulfur dioxide (SO_2) emissions. When the time span from the 1990s to the present is considered, it is seen that there are three different periods in the development of carbon pricing policies. In the first period of 1990-2005, developed countries have started to implement the carbon tax for the first time and taken early actions in this direction. The second period between 2005 and 2011 was the beginning of the Kyoto Protocol and it also came to the forefront as a period in which the EU Emissions Trading System (EU ETS) came into force and more types of greenhouse gas emissions were included in the scope of the Scheme and a rapid expansion was seen. From 2012 to the present, it has been observed that the effectiveness of the Kyoto Protocol has weakened, and carbon pricing tools have emerged at new, national, regional or city levels in both developed and developing economies encouraged from the ambition of the Paris Agreement.

Nevertheless, many developing countries today prefer a carbon tax to implement as carbon pricing tools, but they have already planned or scheduled to add the ETS or to convert the tax directly into ETS after reaching an adequate maturity. In this respect, it would not be wrong to say that by considering its environmental effectiveness, ETS could be perceived as a more advanced policy tool to combat with climate change. Considering the urgency of this problem to take necessary actions, ETS initiatives are likely to increase. In this regard, the fundamentals of ETS must be comprehensively analyzed and its economic impacts should be well understood.

In this study, emission trading schemes and one of the most successful examples, the European Union Emission Trading Scheme (EU ETS), will be presented and reviewed econometrically. The main aim of the study is providing a better understanding of the operationalizing of the market by analyzing interactions among emission allowance prices, macroeconomic and other relevant variables like weather conditions, fuel switching prices. In other words, the drivers of allowance prices in the EU ETS are tried to be crystallized. With more facilities and countries captured by the emission trading schemes, understanding the dynamics and causality relationships in the market will be very critical for policymakers, facilities, and researchers in order to rationalize their expectations on the emission trading market. This is critical not only for current appliers of ETS but also for developing countries which decide to raise ambition to combat against climate change. Therefore, the other aim of the study is to give an idea about the functioning of ETS and showing the possible effects of the scheme for other countries, if they decide to apply the mechanism.

The most important feature that differentiates this study from its peers is the inclusion of the effects of the Paris Agreement and following two years into the analysis. In this way, all the building blocks of the international climate change regimes can be handled together and an adequate timeframe to see the effects of regime changes can be captured clearly. By this way, the EU ETS has been put forward to reflect current developments in a more holistic way. Moreover, instead of daily data, monthly price movements are preferred order to investigate the relationship among carbon prices and other variables such as economic sentiment indicator, industrial production index which are published on monthly basis. Last but not least, the causality directions of the relationship among variables are also revealed.

Within this framework, in the first chapter of the thesis, fundamentals of emission trading schemes under climate change regime is described. Focusing on the economic perspective of the climate change, carbon pricing tools, milestones for global climate action and emission trading are evaluated. In the second chapter the EU Emission Trading System which is the first major carbon market and still the largest cap-and-trade system is introduced. In this chapter background and the building blocks of the scheme is shared. Additionally, the price movements in the EU ETS are also analyzed in general terms. Econometric analysis of macroeconomic interactions among allowance prices and other selected variables in Phase II and Phase III of the EU ETS will be presented in the third chapter of the thesis. In this chapter, the interaction among European Union allowances (EUA) prices and fossil fuel prices, economic activity and temperature indicators are investigated within the framework of ARDL model and Toda-Yamamoto Non-Granger Causality test for the period between January 1, 2008 and December 31, 2017.

According to the regression results, the relationship among the EUA prices and variables has been analyzed. For the long-run, coal price and industrial production index (IPI) affect the EUA prices positively, on the other hand, gas price affects it in the opposite direction. In this long-run interaction, IPI has a dominant role as the driver of EUA prices. For the short-run, while 2 months lagged economic sentiment indicator (ESI) and one month lagged of the EUA itself affect the EUA prices negatively, one month lagged heating degree days (HDD) index affects EUA prices positively. Results of the Toda-Yamamoto Non-Granger Causality test are also remarkable. Within this interaction, it is found that weather conditions only affect the natural gas prices. It is also asserted that economic expectations lead to industrial production path significantly as it is expected. However, strikingly, it is identified that when the economic expectations are shaped directly by the natural gas prices which is a relatively cleaner input, industrial production processes are directly affected by coal prices. This finding may imply that industrial processes still rely on dirtier inputs. Since industrial production affects only natural gas prices among fossil fuels, this evidence may give a signal which shows that industrial production processes may be shifted towards using natural gas more than coal when the economic expectations have started to be considered. Furthermore, while natural gas prices have impact on EUA prices directly, any direct effect from EUA prices to fossil fuel prices cannot be observed.

As demonstrated by ARDL model and Toda-Yamamoto Non-Granger Causality test results, we can argue that there is an obvious interaction among macroeconomic variables and EUA prices. However, the magnitude of this relationship, the direction of causalities or significance of these interactions may change in the future phases or years. It is important to note that, the EU has shown a great ambition for transforming its economy to a low carbon one by aligning its policies and its prosperous emission trading schemes. Besides currently implemented policies, with the Paris Agreement, a new global policy framework for international climate change regime has been established and the EU has played a vital role in this process as a leader. To this extent, as the rules, procedures, and modalities related to international emission trading in the Paris Agreement is going to be determined in the international negotiations, emission trading will steal the spotlights in the climate action. Because of this reason understanding the interactions among carbon prices and other macroeconomic variables will be crucial and thus, the developments in the interactions presented in this thesis should be cautiously followed by policy makers and market players.

CHAPTER 2

FUNDAMENTALS OF EMISSION TRADING SCHEMES UNDER CLIMATE CHANGE REGIME

Stressing that climate change is acknowledged as not only an environmental problem but also an economic problem, some economic tools have been introduced by various countries and regions in order to fight against the adverse effects of it. In this framework, the most known policies introduced are command and control measures and carbon pricing mechanisms. Since climate change is considered as a market failure which is a result of not being able to reflect its costs into the pricing mechanism, both of these two approaches base on coping with adverse effects of the climate change while creating a cost component for enterprises which are responsible from environmental damage.

Among these practices, emission trading schemes come to fore as more powerful tools in terms of emission reduction since their ability to bring certainty in emission reduction is observed. The significance of these schemes has also been recognized by the international community and because of this reason, this mechanism, relevant regulations and provisions have been included in all critical international agreements established in the context of climate change. This chapter begins with the presentation of historical milestones for global climate action particularly from the perspective of emission trading mechanisms. Then, in which sense climate change is handled as an economic issue and to this extent, how carbon pricing policies contribute to the fight against climate change is explained.

Table 1: Carbon Pricing in Implementation or Scheduled

Country/Region	Starting Year	Country/Region	Starting Year
Finland Carbon Tax	1990	UK Carbon Price Floor	2013
Poland Carbon Tax	1990	Shenzhen pilot ETS	2013
Norway Carbon Tax	1991	Shanghai pilot ETS	2013
Sweden Carbon Tax	1991	Beijing pilot ETS	2013
Denmark Carbon Tax	1992	Guangdong pilot ETS	2013
Slovenia Carbon Tax	1996	Tianjin pilot ETS	2013
Estonia Carbon Tax	2000	France Carbon Tax	2014
Latvia Carbon Tax	2004	Mexico Carbon Tax	2014
EU ETS	2005	Spain Carbon Tax	2014
Alberta SGER	2007	Hubei pilot ETS	2014
Switzerland ETS	2008	Chongqing pilot ETS	2014
New Zealand ETS	2008	Korea ETS	2015
Switzerland Carbon Tax	2008	Portugal Carbon Tax	2015
Liechtenstein Carbon Tax	2008	BC GGIRCA	2016
British Columbia Carbon Tax	2008	Australia ERF Safeguard Mechanism	2016
RGGI	2009	Fujian pilot ETS	2016
Iceland Carbon Tax	2010	Washington CaT	2017
Tokyo CaT	2010	Ontario CaT	2017
Ireland Carbon Tax	2010	Alberta Carbon Tax	2017
Ukraine Carbon Tax	2011	Chile Carbon Tax	2017
Saitama ETS	2011	Colombia Carbon Tax	2017
California CaT	2012	Massachusetts ETS	2018
Japan Carbon Tax	2012	Argentina Carbon Tax	2019
Australia CPM (2012 - 2014)	2012-2014	South Africa Carbon Tax	2019
Québec CaT	2013	Singapore Carbon Tax	2019
Kazakhstan ETS	2013		

Source: World Bank and Ecofys, 2018.

2.1. Milestones for Global Climate Action and Emission Trading

Although the interest in the issue of climate change has been intensified in the early 19^{th} century in the framework of scientific research, the global discussions have accelerated since the mid-20^{th} century. During the period when scientific studies related to climate change paced, many meetings were held in order to be able to find a solution with the participation of many countries to eliminate or at least reduce the adverse effects of climate change.

In this context, one of the leading conferences was held with the participation of 172 countries in Brazil. As a result of the UN Environment and Development Conference, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted on 3-14 June 1992. On the basis of the UNFCCC, the Kyoto Protocol, which set out concrete targets and details of implementing the Convention was finalized in 1997. For the period after the Kyoto Protocol, there has been long-lasting debates in the international community and at the end of 2015, the agreement which will serve to design international climate change regime after 2020, namely the Paris Agreement, has been prepared.

2.1.1. The United Nations Framework Convention on Climate Change (UNFCCC)

The UNFCCC is a legal document that was signed by 154 nations and the European Union (EU) during the Rio Conference. The ultimate aim of the framework is to achieve sustainable levels of GHG accumulation in the atmosphere that prevents dangerous human-induced effects on the climate system. The framework was enacted on 21 March 1994. As of October 2018, 196 countries and the EU have become parties to the UNFCCC.

Under the UNFCCC, developed countries are considered to have historical responsibilities for climate change. In this respect, it was decided that developed countries would pledge binding numerical targets in emission reduction and also provide financial assistance to developing countries. In this context, the two lists, Annex-I and Annex-II countries are determined to differentiate which countries will only commit quantitative emission reduction targets and which countries will be responsible for financial support. These obligations of the parties under the UNFCCC are determined by considering the Common But Differentiated Responsibilities

(CBDR)[1], the specific development priorities, targets and national and regional circumstances. Despite the UNFCCC does not include any specific article related to emission trading schemes, the UNFCCC is set up as a framework that outlines the basis of the international climate regime. In this context, the Kyoto Protocol is drafted to form the implementation process of the regime.

2.1.2. Kyoto Protocol

The Kyoto Protocol, set up under the UNFCCC, was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 19 February 2005. Two prominent features of the Kyoto Protocol can be considered as bringing binding emission reduction commitments on the parties listed in Annex-I and introducing flexibility mechanism which enables cost-effective emission reduction opportunities for the parties. In this context, it is aimed to ensure that the Annex-I parties reduce their GHG emissions by at least 5% of the 1990 level for the period between 2008 and 2012 referred as the first commitment period and reduction and controlling of the targets have been identified for these Parties. The targets are listed in the Annex-B list of the Kyoto Protocol which is presented in Table 2.

In order to support the parties in achieving their targets, the Protocol has introduced three different tools under the flexibility mechanism. These tools are; International Emission Trading (IET), Clean Development Mechanism (CDM) and Joint Implementation (JI).

The IET mechanism is based on Article 17 of the Kyoto Protocol. According to this article, the parties to Annex-B list may carry out international emission trading in order to fulfill their responsibilities under the Protocol. In this framework introduced, countries are given the opportunity to sell the emission rights that are distributed to

[1] The principle of common but differentiated responsibilities (CBDR) implies that all parties have a common responsibility for combating the climate change problem, but different responsibility is assumed for the different parties, taking such matters as historical responsibilities, national conditions and development priorities of the countries into account.

them but not needed, to countries that need additional emission rights to meet their targets. Thus, a new commodity which is referred as "carbon trading" is created. This new commodity can be used for emission reduction and can also be traded (UNFCCC, n.d.).

Table 2: Annex-B of the Kyoto Protocol

Parties	Emission Reduction Targets
Bulgaria*, Czech Republic, Estonia, EU (15)[2], Latvia*, Lithuania*, Lichtenstein, Monaco, Romania*, Slovakia*, Slovenia*, Switzerland	-8%
United States**	-7%
Canada, Hungary*, Japan, Poland*	-6%
Croatia*	-5%
New Zealand, Russian Federation*, Ukraine*	0%
Norway	1%
Australia	8%
Iceland	10%
* Economies in Transition ** Although the US has set a target in the Kyoto Protocol Annex-B list, it has not become a party to the Protocol.	

Source: https://unfccc.int/process/the-kyoto-protocol, accessed on 15 September 2018.

The CDM is based on Article 12 of the Kyoto Protocol and it aims to incentivize Annex-I countries to support sustainable development in countries not involved in the Annex-I and reducing global emissions that help to achieve the final objective of the Convention. Within the framework of this mechanism, if an Annex-I country makes an investment which includes curbing or capturing emissions as the primary

[2] As of 1997, when the Kyoto Protocol was adopted, the Member States of the EU are referred to as the 15 Member States. These countries; Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom of Great Britain and Northern Ireland. In addition, the 8% emission reduction target set for the Member States is distributed among the Member States.

objective or co-benefits of the project in a non-Annex-I country, Annex-I country is able to earn certificates called Certified Emission Reductions (CERs)[3], which are issued for abatement of per ton of carbon dioxide equivalent (CO_2e). These certificates which are also named as emission credits can be traded to meet the emission reduction commitments of Annex-I countries under the Protocol. This mechanism could be used by either government agencies or firms. Additionally, these CERs can be subjected to trade. For instance; if a French firm, which is placed in an Annex-I party, conducts a project for afforestation in Ethiopia, which is a non-Annex-I country, according to the emission reduction that is achieved, French firm will get a CER. Furthermore, this French firm may use these certificates either to meet requirements in the EU ETS or it can sell to other firms or government agencies. This is also known as an offsetting mechanism. The mechanism enables flexibility in meeting sustainable development and emission reduction commitments for the Annex-I countries.

Joint Implementation (JI) is another mechanism introduced under the Kyoto Protocol similar to CDM. Differently, it enables to earn Emission Reduction Units (ERUs)[4] per ton of CO_2e from the projects provided from Annex-I parties to another Annex-I party.

The Kyoto Protocol was designed to be valid until 2012 as an agreement with binding and punitive elements for the implementation of the UNFCCC. However, in 2009,

[3] CER is a certificate which can be earned from CDM projects. To this extent, countries with emission reduction or limitation commitment (Annex-B countries under Kyoto Protocol) can obtain CERs by investing in emission mitigation projects in developing countries (non-Annex-I) like forestation.By using these certificates, countries may comply their emission reduction targets or facilities may use the CERs for meeting the requirements to surrender allowances under the ETS. Under this scheme, emission reduction generated by the Annex-B countries are certified according to the abatement of per ton of carbon dioxide equivalent (CO_2e).

[4] ERU is a certificate similar to CER but differently it can be earned from JI projects and this mechanism allows Annex-I countries to obtain the ERUs albeit from the investments in another annex-I country. Like CERs, ERUs are issued regarding to the abatement of per ton of carbon dioxide equivalent (CO_2e) and can also be used by countries to comply with emission reduction commitments and by facilities to comply with holding necessary amount of allowance under the ETS.

the efforts to determine the international climate change regime after 2012 were blocked due to serious disagreements among countries. As a result, it was decided to maintain the Kyoto Protocol until 2020 and to continue to work for a new Agreement for the period after 2020. As a result of these efforts, the Paris Agreement has been concluded in 2015.

2.1.3. Paris Agreement

The Paris Agreement was adopted in 2015 as a consequence of long-lasting negotiations to determine the climate change regime after 2020. The Agreement, which entered into force on 4 November 2016, has 184 parties by January 2019. The Agreement aims to strengthen the combat against climate change in the context of sustainable development and reduction of poverty. Within the Agreement the target is determined to limit the global average temperature rise to well below 2°C, and pursuing efforts to 1.5°C before the end of the century, to strengthen low emission development, to ensure that financial flows will help developing countries to combat the adverse effects of climate change and to reduce emissions (UNFCCC, 2015). The view that the developed countries are only held accountable for the damage they have caused to the environment during the industrialization stages from the UNFCCC to the Paris Agreement will change in the new period. Additionally, especially in the last 20 years, it is undeniable that developing countries have contributed to the acceleration of climate change due to growth dynamics not based on environmentally sustainable premises. Thus, in the post-2020 period, a more comprehensive and dynamic structure, in which both developed and developing countries will be brought together in the struggle for climate change, becomes inevitable.

The role of the emissions trading system in the international climate change regime after 2020 is covered in Article 6 of the Paris Agreement. According to this article, IET, CERs and ERUs will continue to be used by international and domestic markets in order to meet the obligations of market participants. On the other hand, IET, CERs and ERUs will be dealt together under a common name called Internationally

Transferred Mitigation Outcomes (ITMO). Most importantly, the Agreement is going to promote the implementation of international emission trading markets in this way. However, the details on the implementation of this specific article of the Paris Agreement have not yet been clarified. As time passes, discussions on this article have been intensified at the international climate change negotiations, however, there are still many blurry areas for this issue.

In brief, it is not possible to consider climate change just as an environmental problem at present. With its devastating adverse effects on economies, it should be handled as a market failure and it should be solved within this frame. That is why, as the climate change rises to the top of the international agenda, international agreements have been set up with the participation of all countries. However, the parts of international agreements related to economic and financial topics have always been the most controversial sessions during the international negotiations due to the conflict of interest among developed and developing countries (Carbon Brief, 2018). At the very end, under these agreements, the emissions trading system and related economic instruments have been involved as a vital element to combat against climate change.

2.2. Economic Perspective of Climate Change

In order to have a better understanding of emission trading schemes and carbon pricing, it is necessary to put forward the economic problems they address. Since climate change is considered as a market failure, starting with the explanation of this concept and then extending towards externalities and public goods will be appropriate.

Generally, if production of a good or service is left entirely to market conditions and then this good or service cannot be produced at the level that maximizes social utility, this situation is called "market failure". To be more specific, when the social benefits cannot be maximized while the social costs cannot be minimized for the whole segments of the society, one may state that the markets are not "Pareto-efficient". In a Pareto-efficient market, all costs and benefits are included in the production or consumption decisions of households and companies. Otherwise, there may be overproduction or underproduction of goods and services (Hebling, 2012). This prevents the social well-being from being maximized and therefore, the state intervention becomes inevitable. At this point, it will be useful to touch upon the concept of “externalities”.

An externality appears when an economic actor positively and/or negatively influences the activities of other economic actors as a result of her/his production or consumption activities. In other words, it can be said that externalities are related to the welfare of some economic actors not only in their own activities but also in activities under the control of other economic actors (Tietenberg and Lewis, 2011). When the economy is not at Pareto-efficient level due to the presence of externalities; costs and benefits that drive the production, consumption and investment decisions of households and firms cannot be reflected utterly in the transactions. In case of such a situation, market mechanisms become ineffective, thus the functioning of the market mechanism could be deteriorated. Therefore, if externalities exist in the market, a value that cannot be reflected in the prices of goods and services arises (Buchanan and Stubblebine, 1962).

Among important reasons for market failures, one is “public goods”. These goods have two basic characteristics which are; non-rivalry and non-excludability in the consumption of goods (Cornes and Sandler, 1986). More precisely, it is possible to talk about the presence of a public good if the cost of providing the good or service for an additional person does not change and if it is impossible for individuals to be excluded from the consumption of the good or service. To this extent, it is vital to note that if the individual benefits are less than the social benefits, but the individual costs are greater than the social costs in the supply of the goods, there is a risk of not offering public goods. In this direction, the government takes on the responsibility and handles supplying the goods or services which are desirable for social benefit and finances itself (Samuelsson, 1954). In this manner; services such as justice, security and compulsory education can be given as examples for public goods.

Another point that needs to be underlined is the “free-rider problem”. This problem is that those who benefit from public goods do not participate in the costs of these goods. If there is no financial contribution or if this contribution is not adequate, this situation leads to underproduction or no production of these goods at all. When jointly owned resources are taken into consideration, free riding also leads to overuse of these resources. As a matter of fact, while economic actors act individually and rationally, they tend to use the resources in order to maximize their own interests albeit not of society. That is the reason, they tend to overuse the supplied goods and services, causing depletion of resources. Therefore, there exists an imbalance between supply and demand of this jointly owned resources, if the government does not intervene and this problem is called the “tragedy of commons" (Hardin, 1968).

Despite the fact that public goods have long been regarded as a term at national or local scale, recently “global public goods” term has been developed (Goodstein, 2014). This term is used for goods and services like the environment, climate and health which have much larger externalities and influence the entire international community. In this context, since the countries cannot be excluded from access to these goods, they tend to get benefit from the efforts of other countries without bearing the brunt of producing these goods. Hence, a good that provides benefits without an additional cost for the international community, is tended to be supplied less than the adequate level. Conversely, if a global public good creates a negative externality for the international community, it is tended to be supplied more than needed (Nordhaus, 2009).

Although at the first glance, the climate change seems to be a global environmental problem, in the light of the above-mentioned issues, it is necessary to consider it within the context of market failures. In this respect, the evaluation of climate change within the framework of all these concepts will make it easier to understand the economic challenges. Climate change is a global problem that appears as a result of economic activities linked to a variety of areas like energy, industry, transport and land use. Hence human-induced climate change causes negative externalities on the most basic scale. Despite the fact that the production activities which cause GHG emissions creating additional costs for the entire world and the future generations, these activities have not been subjected to any charges or fees for a very long period. Furthermore, since the adverse effects of GHG emissions are not observed by the international community in the short run, there are no economic incentives for the reduction of them. That is why economic actors do not feel obliged to compensate for the negative externalities they have caused. In this context, as long as policymakers do not intervene the markets, climate change is regarded as an externality that is not corrected by any market mechanism (Stern, 2007).

Climate is a public good with respect to the framework of the aforementioned qualifications. The climate is considered to be a commodity that does not cause others to use less by consuming more by one actor. For this reason, an economic actor who cannot afford to pay, will not be excluded from the benefits of this commodity. Hence, climate change can be also shown as an example of externality and global public good because markets do not supply such a public good in the correct amount and spontaneously (Grasso, 2004). However, there are some important features that distinguish climate change from other externalities. For instance, its effects are permanent and mounting over time and there is a big uncertainty about its effects in terms of size, variety, and timing. Additionally, it is also difficult to predict the exact impact of climate change on the global economy. All these features make climate change the biggest market failure that the world has ever seen (Stern, 2007).

Reducing GHG emissions is also perceived as a global public good. However, without any incentives, states are reluctant to achieve this reduction. For this reason, governments are encouraged to build international climate change regimes, as is agreed in the UNFCCC, the Kyoto Protocol, and the Paris Agreement. On the other hand, if a collective action cannot be implemented; despite all these efforts, the free-rider problem cannot be resolved (Bodansky et al., 2017). Even if the countries endure all costs to reduce their own emissions, while the others remain unresponsive, the return of these positive actions will be inadequate. Thus, as a tragedy of commons example, countries are reluctant to take actions to reduce the effects of their emissions on humanity (Tirole, 2012). Due to this fact, in the context of combating climate change, it has become inevitable for international agreements to be established with certain responsibilities to all parties.

At this point, many countries have made public policies based on international agreements in terms of the fight against the negative effects of climate change. Historically, environmental policies seem to be based on regulatory measures such as setting certain standards or prohibiting the use of certain products which are known as command and control tools. Command and control mechanisms can be defined as punitive regulations that impose restrictions on emissions only by obeying certain rules and/or criteria in order to prevent air and water pollution. In other words, the authority mandates to polluters to obey emissions and technology standards in their production processes. This mechanism can be used for various purposes, but most common examples are observed as diminishing vehicle emissions by determining emission standards, regulating exhaust controls, restricting vehicle driving in order to decrease mileage rates; dwindling use of fossil fuels by prohibiting particular fuels for specific purposes, mandating for installation of environmental structures to plants etc. For instance, Energy Policy Conservation Act which was published in 1975 in the US, Canadian Environmental Protection Act which was put into force in 1999 and European Union Emission Standards (EURO) for cars and commercial vehicles sold in Europe which have been implemented since 1991 can be shown as developed countries' command-and-control experience. Also, in some megacities in the world including Beijing, Mexico City and Delhi in order to protect the environment while decreasing the congestion, license-plate based driving is implemented. This policy prohibits drivers from using their personal vehicles for some predetermined days. This ban is generally applied according to the digits on the plates of vehicles. Additionally, in some countries like Chile, in order to reduce air pollution, shutting down factories, ban on biomass use for the purpose of heating in houses was also introduced in 1997. Another remarkable example for these policies could be given from Beijing where the 2008 Olympic Games held in. In order to prevent air pollution and improve its quality, major emission sources were shut down permanently or temporarily not only in Beijing but also in neighbor cities, while some of them were relocated (Blackman et al., 2018).

However, from an economic perspective, command and control measures do not usually provide efficient results due to the being inflexible (Aldy and Stavins, 2012). The underlying reason for this is that all companies must bear the costs incurred as a result of the measures introduced by the command and control mechanisms without any options. Command and control mechanisms are highly criticized by these features because they cannot create incentives to support environmental-friendly production processes due to the fact that firms focus on only complying with established standards (Aldy and Stavins, 2012; South Africa National Treasury, 2013). In other words, the measures and rules are dictated to the stakeholders without giving them any flexibility.

On the other hand, market-based mechanisms such as emission trading system and carbon taxation aim to reduce market failure by imposing a price on externalities. Thus, the economic actor who causes emissions of GHG has to consider environmental costs while making the investment and/or production decisions. In the environmental economics literature, market-based mechanisms often referred to as being able to cope with the problem of externalities, are usually addressed within the framework of two different approaches by Arthur Pigou and Ronald Coase. Both approaches suggest the use of economic instruments to align costs with social and private benefits and to avoid market failures. The main difference is; while the Pigouvian approach focuses on price-based instruments (e.g. carbon taxes), the approach put forward by Coase focuses on quantity-based instruments (e.g. emissions trading schemes). These two methods rely on the introduction of a price on CO_2 emissions per ton that cause environmental externality. For this reason, both mechanisms are referred to as carbon pricing tools, and in recent years they have been frequently brought to the fore. In the next part, carbon pricing policies will be presented briefly.

2.3. Carbon Pricing as a Tool for Emission Mitigation

It is worthwhile to touch on the details of the two economic approaches which could be considered as the basis of carbon pricing mechanisms. The names of these two methods which are used to cope with the problem arising from externalities come from two well-known economists; Arthur Pigou and Ronald Coase.

The Pigouvian approach aims to internalize environmental externalities; foreseeing that a value which is equal to the level of social benefit and to the social cost of externality should be defined in the system and should be internalized in the price mechanism. By this way, all costs and benefits could be reflected in the prices. From an environmental perspective, if there is a polluter in the economy, it should take its environmental damage into account as a cost input. This well-known phenomenon is also named as “the principle of polluter pays". Within this frame, the government may put a tax which is equal to the social cost that polluter causes, and in this case, it could be called as “carbon tax”. The carbon tax is a typical "Pigouvian tax". Pigou's proposed solution is to put taxes in a structure where there are competitive markets, and the state has an active role. The most important feature of this method is providing the most economically efficient solution. However, it is extremely difficult to calculate environmental benefit or harm. It is claimed that this policy cannot respond certainly to emission reduction purposes. For instance, if a carbon tax level is determined at a very low level, which is theoretically below social cost, economic actors will not curb their emissions and they can prefer to pay the tax rather than changing their production and consumption behavior. Therefore, carbon taxes cannot assure a quantity targeting for emission reductions.

On the other hand, different from Pigou, Coase emphasizes that there is no need to use the most economically efficient method to solve externality problems. At this point, it is worth to emphasize that Coase has never touched upon a solution that recommends emissions trading schemes. John Dales, one of the pioneers who adapted Coase's approach to fight against environmental externalities, argued that environmental externalities could be internalized by a market mechanism called "pollution market" in the book titled "Pollution, Property, and Prices" published in 1968. Basically, the theory asserts that the problem can be solved between the polluters and those who are damaged as a result of pollution reciprocally (McKibbin and Wilcoxen, 2002). Proposing a solution to the externality problem is based on the imbalance between marginal cost and marginal utility. According to Coasian approach, this problem could be solved by the creation of tradable property rights in a market mechanism. In this way, both the pricing and efficient allocation of polluting resources would be attained. In Coase's approach, it is claimed that the compensation of the damage suffered by the parties will bring the economy to the Pareto-efficient equilibrium as a result of a negotiation between the parties. Thus, the costs and benefits would be internalized. This approach is based on the functioning of a competitive market mechanism such as the Pigouvian approach and assumes that the transaction costs are negligible (close to zero) and the property rights are precisely defined (Coase, 1960). However, as the opposite of the Pigovian method, this approach obviously enables quantity targeting for emission reductions.

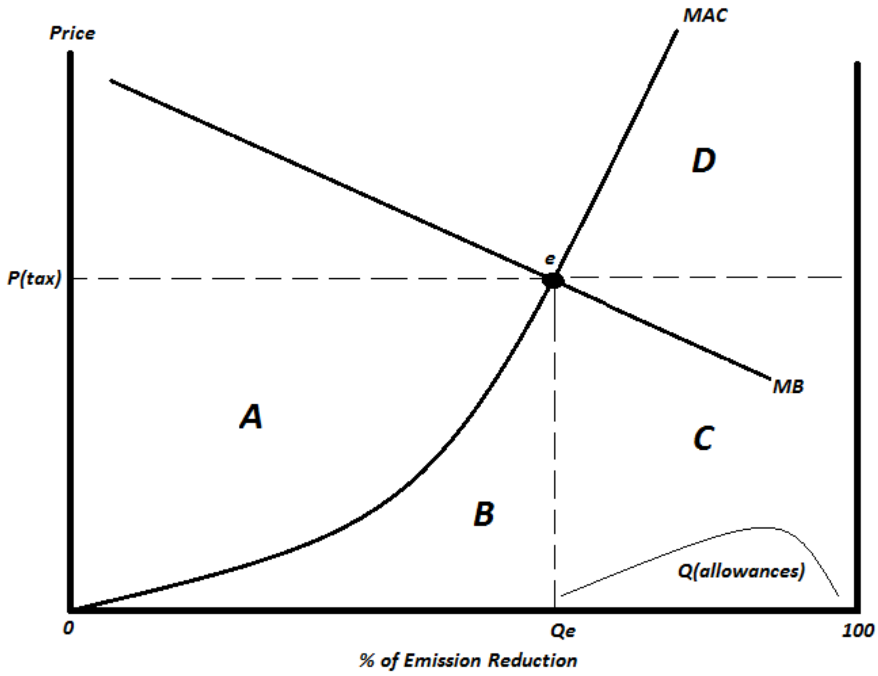

Figure 1: Functioning of Carbon Pricing

From theoretical perspective, in Figure 1, the functioning of carbon pricing policies is presented. In this graph, MAC represents the marginal abatement costs curve while MB stands for marginal benefits from the emission mitigation. Theoretically, it is known that marginal benefits from emission reductions are less than the costs of this mitigation. Thus, the MB curve is flatter than the MAC curve (Newell and Pizer, 2003). In order to present the basic rationale behind the carbon pricing, in this figure, it is assumed that there is only one polluting firm in the market and the information in the market is perfect. In this economy, the level of emission reduction is committed to Qe. In order to achieve this abatement, in case of the carbon tax, the government should impose a carbon tax at the price level where MAC and MB are equal at equilibrium. According to this model, for the firm, if MAC is below the tax level, curbing its emissions by using its own sources will be more beneficial than paying the tax. Otherwise, the firm will choose to pay the tax and continue to pollute. In this case cost of emission, abatement is calculated as the sum of B and C areas, while the government revenue is C. On the other hand if the government has decided to reduce emission by applying an emission trading mechanism, the point on the vertical axis called as Qe will be the cap level. Assume that the allowances are freely allocated and in order to fulfill the requirements in the scheme, firm needs to hold an appropriate amount of allowances (Q(allowances) = 100-Qe). In the scheme, the cost of emission reduction of this policy for the firm will be equal to B area.

After explaining the fundamentals of the Pigouvian and Coasian approaches regarding their abilities to cope with externalities, it is possible to review succinctly two carbon pricing policy tools which are emission trading schemes and the carbon tax.

2.3.1. Emission Trading Schemes (ETS)

The ETS is defined as a market-based tool used to reduce GHG emissions efficiently by determining a cap for the emission level. This approach is based on the Coasian method as it is stressed, and it emphasizes that the problem arises from non-excludability which is a typical feature of a public good. Then it is claimed that if a good has an owner, this problem can be resolved where this ownership exists by default (Helm, 2005). In a Coasian approach, the most important part of the solution is bargaining or negotiating in order to reach the optimal solution between the two sides who causes externalities and who is exposed to it. As mentioned before, in the Coase's model, there are important assumptions such as the presence of a fully competitive market, the parties with property rights having equal power to negotiate and the efficiency is provided by the market mechanism. According to Dales (1968), property rights in the context of climate change are called as emission allowances. The system reaches the market solution through transferable allowances. In doing so, the regulatory authority has no duty except to determine only the total GHG ceiling and distribute emissions allowances in this framework (Hahn and Stavins, 2010). In Table 3, emission trading schemes that are currently implemented and price levels in these markets are shown (World Bank and Ecofys, 2018).

Table 3: Emission Trading Implementations and Price Levels in 2017

Country/Region	Price Level ($/t$CO_2$e)	Country/Region	Price Level ($/t$CO_2$e)
Alberta SGER	23	Shenzhen pilot ETS	7
Korea ETS	21	Saitama ETS	6
South Korea ETS	21	Shanghai pilot ETS	6
EU ETS	16	Tokyo CaT	6
California CaT	15	Chongqing pilot ETS	4
New Zealand ETS	15	RGGI	4
Ontario CaT	15	Fujian pilot ETS	3
Québec CaT	15	Guangdong pilot ETS	2
Beijing pilot ETS	9	Hubei pilot ETS	2
Switzerland ETS	8	Tianjin pilot ETS	1

Source: World Bank and Ecofys, 2018

In the context of the design of an ETS, first of all, determining an upper limit, scope and coverage and then the allocation method of allowances is important. Implementing an offsetting policy with carbon credits stand out as an optional preference for an ETS design.

Within ETS, an upper limit is imposed on the total amount of emissions in the economy, and the amount of emission allowances is determined regarding this ceiling. In this context, each allowance is equal to one ton of emission. Allowance prices are determined in the market where they are traded. The market price and the polluter's willingness to pay for it determine which economic actors will continue to pollute and which actors will invest in emission reduction technologies (Weishaar, 2013). Thus, it is expected that the allowance buying and selling behavior of facilities in the ETS framework will be affected by the marginal cost of emission mitigation (Klepper and Peterson, 2006). Emissions trading ensure the certainty on the emission mitigation level rather than its cost because in this scheme the cap for emission level is critical. With this feature, ETS is considered by many economists and politicians as a market-based and productive policy tool among environmental policies (Jaehn and Letmathe, 2010).

The scope of an ETS refers to which sectors and gases will be covered by the scheme. To this end, capturing whole sectors in the economy as much as possible is preferred in order to curb emissions in a cost-effective way. However, administrative costs to monitor accurate emission data from firms are usually considerably high. Moreover, particularly for emission-intensive and export-oriented sectors, being captured within an ETS may bring a comparative disadvantage in international trade and therefore this may cause a carbon leakage to some extent. In other words, firms that are subjected to an additional cost which are brought with a carbon pricing policy may move their activities and facilities to another destination in where there is no such regulations or relatively smaller costs. Thus, due to the costs emerged as the result of the ETS, the economy may suffer, and this will harden the acceptability of carbon pricing mechanism in the society. Oppositely, if the authority decides to limit the scope of ETS with specific sectors in order to protect its economy, this may distort inter-sectoral competitiveness in the economy by creating additional costs for firms in one sector while firms in the other sectors sustain their businesses-as-usual (PMR and ICAP, 2016).

On the other hand, in terms of gases covered, it is possible to capture not only CO_2 emissions but also other greenhouse gases like CH_4, N_2O, HFC etc. within the scheme. This is also related to the institutional and technological capacity that the country has to monitor emissions from greenhouse gases. For measuring the effects of capturing additional greenhouse gases into the scheme, a study conducted in the US reveals that one-third more emission reduction could be achieved as a result of including greenhouse gases other than CO_2 (Metcalf and Weisbach, 2009).

Each facility subjected to ETS regulation must hold adequate allowances which are equal to the amount of emissions they are responsible for. In the beginning, the allowances are allocated to facilities by the designated authority regarding various criteria like historical emissions of the facility, sectoral benchmark or output-based allocation for each facility. Additionally, these allowances can be allocated freely and/or by auction. While in the free allocation facilities bear just the cost of emission allowances, in the auctioning a revenue for government is also generated and this revenue is generally used for environmental and low-carbon investments. After the first allocation of allowances which could also be named as the primary market, if these facilities need additional allowances, they should make trading in the secondary market.

The trading prices of the emission allowances are determined in the secondary market. If the ceiling is designated at low levels, the price will soar, and therefore a stronger signal will be generated to reduce emissions or vice-a-versa. This will ensure that products which have lower emissions are preferred. By predetermining and announcing the upper limit, the long-run predictability and investment decisions of the market participants can be shaped accordingly. When the price trends in the world by 2017 are observed, prices change from 1 USD/tCO_2e to 20 USD/tCO_2e. Highest allowance price is seen in South Korea, while the lowest is in Tianjin pilot ETS in China (World Bank and Ecofys, 2018).

Moreover, the facilities can use national or international emission units with the prescribed characteristics. As aforementioned these are CERs and ERUs which are covered by the Kyoto Protocol, to fulfill their obligations. Thus, as incentives are created for cleaner energy projects, flexibility is provided to businesses under ETS to meet emissions reduction obligations.

In emission trading systems, emission allowances allocated to covered facilities could be kept for later use if they exceed the need in the relevant period. This process is called banking. In other words, if a business can manage to keep its emissions below the limit set for it, it has the right to bail on the grounds that it may need future emissions allowances. Nonetheless, emission allowances that are not used could be sold to other businesses that need them. This flexibility provided by the trading system ensures that emissions are reduced in the most cost-effective way.

2.3.2. Carbon Tax

The carbon tax is defined as a tax or a charge per ton of CO_2 equivalent (tCO_2e), based on the CO_2 or CO_2e content of a good or service in order to reflect the social and environmental adverse externalities resulting from GHG emissions (OECD, 2013). Another definition of a carbon tax is that it is a means of taxing different energy sources on the basis of their CO_2 emission intensity. Besides, as in all other environmental taxes, the main purpose of a carbon tax is incentivizing investments to increase environmental quality and shaping the behavior of producers and consumers in a more environmentally friendly way by price signals through tax scheme. As mentioned, a carbon tax is considered as an example of Pigouvian taxation based on the fact that the polluting actor pays for while carrying out an economic activity. This additional price will soar the cost of inputs in the goods and services introduced, affecting the decision-making mechanisms of producers and households, thus eliminating externalities through the pricing mechanism.

Carbon taxes cannot attain a certain level of reduction in emissions while they cause a reduction of GHG emissions by creating a final unit cost element per ton of CO_2e. Unlike emissions trading systems, a carbon tax aims to reduce the emissions of the enterprises over the price mechanism by selecting the most cost-effective method (World Bank, 2014). Contrary to the command and control methods, how to remove this cost is left to the facilities themselves. In Table 4, current carbon tax implementations and price levels in these schemes are presented (World Bank and Ecofys, 2018).

Key design components of carbon tax schemes can be counted as the level of the tax rate, the point of regulation; either upstream or downstream, the scope and the coverage of tax, and how the revenue generated from the tax is used by the government (Narassimhan et al., 2018).

Table 4: Carbon Tax Implementations and Price Levels in 2017

Country/Region	Price Level ($/t$CO_2$e)	Country/Region	Price Level ($/t$CO_2$e)
Sweden Carbon Tax	139	Alberta Carbon Tax	23
Switzerland Carbon Tax	101	Slovenia Carbon Tax	21
Liechtenstein Carbon Tax	101	Portugal Carbon Tax	8
Finland Carbon Tax	77	Latvia Carbon Tax	6
Norway Carbon Tax	64 – 4***	Colombia Carbon Tax	6
France Carbon Tax	55	Chile Carbon Tax	5
Iceland Carbon Tax	36	Japan Carbon Tax	3
Denmark Carbon Tax	29 (25)**	Mexico Carbon Tax	3 – Less than 1*
British Columbia Carbon Tax	27	Estonia Carbon Tax	2
UK Carbon Price Floor	25	Poland Carbon Tax	Less than 1
Spain Carbon Tax	25	Ukraine Carbon Tax	Less than 1
Ireland Carbon Tax	25	Alberta Carbon Tax	23

***In Norway upper limit of carbon tax is 64 $/t$CO_2$e, while lower limit is 4 $/t$CO_2$e.
**In Denmark, carbon tax for f-gases is 25 $/t$CO_2$e.
*In Mexico, upper limit of carbon tax is 3 $/t$CO_2$e, lower limit is less than 1 $/t$CO_2$e.

Source: World Bank and Ecofys, 2018

In the Pigouvian approach, it is assumed that the information is perfect and due to this fact, the optimal tax rate can be calculated with social costs and social benefits precisely. However, in real-world practices, particularly for themes like climate change which contains tremendous uncertainty about its effects, timing etc. this assumption causes imprecise results in carbon tax analysis (Helm, 2005). Additionally, since there is no consensus on the emission level which is socially optimal, determining the tax rate which maximizes social benefit is impossible (Mankiw, 2009). In this manner when the global tax levels are considered, it is seen that these rates vary between less than 1 USD/tCO_2e and 149 USD/tCO_2e. While high rates are applied, by-and-largely, in Nordic countries whose long-lasting experience lead this situation; lowest rates are preferred in Poland, Ukraine and Mexico (World Bank and Ecofys, 2018).

Another important design element of a carbon tax is determining the point of compliance, instead of regulated facilities in the ETS. Ideally, it is expected that carbon tax scheme should cover whole sectors in the economy which are responsible for emissions. To this end, the point of compliance could be either at upstream which implies that tax is collected from the producer of emission sources or downstream which means the point that the product is consumed. Theoretically, in order to have an effective carbon tax, it is necessary to cover all emitting sources in the economy; however, in practice, sectors that constitute the largest part of total greenhouse gas emissions or where greenhouse gas emissions can easily be measured are covered by the tax. The method is decided according to the institutional capacity for both collecting tax and gathering emission data and the legislative regulations (Ramseur et al, 2013). It should also be emphasized that the scope and the coverage of a carbon tax scheme is important since they show that which sources and greenhouse gases are subjected to tax. The tax can be imposed on the emitting source regarding the total emissions, amount consumed or produced, or carbon content of the source. Since different types of fossil fuels emit different amount of CO_2, the method preferred affects the tax revenue and its effectiveness directly. It is recommended that imposing the tax considering carbon content or the amount consumed or produced will lead higher effective tax rates due to the fact that this type of approach enables taxing carbon-intensive fossil fuels like coal much more than the cleaner ones (Metcalf and Weisbach, 2009). In terms of tax coverage similar to ETS, it is possible to impose the tax just on the CO_2 emissions, as well as other greenhouse gases like CH_4, HFC etc.

Carbon taxes are criticized by their potential to be regressive. Due to the fact that the share of the costs of energy products is much higher for low-income households relative to rest of households, it is expected that the additional tax burden comes from energy products which are derived from carbon tax falling onto this group of people (Hassett et al., 2009). At this point, the role of governments is crucial not to let them be culprits for climate change. Because of this reason, the success of the carbon tax policies cannot be assessed only by its emission mitigation ability but also its ability to use the revenue generated in order to compensate the costs of households effectively (Aldy and Stavins, 2012). That is why the revenue recycling is one of the crucial design elements. It is possible to use revenues in order to cut other taxes like corporate, payroll and income taxes, making climate-resilient and green investments or earmarking the amount collected to funds which have specific environmental purposes.

In a nutshell, ETS and carbon tax are very powerful tools to fight against the adverse effects of climate change. On the other hand, it should not be forgotten that not all countries have the same level of development, economic conjuncture, and similar administrative structure and emissions. Therefore, a common and homogenous carbon pricing structure, or namely one-size-fits-all policy, should not be expected to have the same level of effectiveness for all countries. For instance, when the developing countries which put regulations into effect to fight against climate change are considered, it is observed that they primarily adopt carbon taxes. The carbon tax is easy to apply by modifying current tax schemes and it causes less implementation and administrative costs relative to ETS since it does not require the introduction of new market infrastructure and relevant legislation. However, these countries have shown a tendency to improve their climate change policies by replacing or harmonizing carbon tax with ETS. From this perspective, although carbon tax is cost-effective for facilities, easily applicable and cheaper from administrative perspective compared to others, ETS can be considered as a more advanced tool to fight against climate change due to its quantitative emission ceiling ability. Likewise, policies related to emission trading schemes were frequently involved in international platforms in the fight against climate change. In the next chapter, one of the most important initiatives which aim to overcome the climate change problem with the help of market mechanism, European Union Emission Trading Scheme (EU ETS), will be described with its highlights and historical milestones.

CHAPTER 3

OVERVIEW OF THE EUROPEAN UNION EMISSION TRADING SCHEME (EU ETS)

While the climate change phenomenon gains importance in the global agenda, the EU has always played a spearheading role in these discussions. Within this respect, in the adoption of the UNFCCC, the Kyoto Protocol and recently the Paris Agreement, the EU has provided a considerable contribution in international negotiations and come to the fore with its environmental policies at regional level.

To this extent, the EU ETS is set up as the first major carbon market and still one of the largest cap-and-trade schemes aiming emission mitigation. This exemplary emission trading scheme is applied in 31 countries that are 28 European Union Member States plus Iceland, Liechtenstein and Norway and it covers nearly 45% of the emissions from these countries. With its size, it covers almost 75% of international emission allowance trading. The EU ETS, which started operation in 2005, has entered the third phase that covers the years between 2013 and 2020. Allowances generated under the EU ETS are subjected to trade in over-the-counter, spot and future markets. European Energy Exchange (EEX) located in Germany and the InterContinental Exchange (ICE) located in the United Kingdom are venues used for EU ETS trading operations. The emission allowances are quoted to these markets under the name of European Union Allowances (EUAs).

The main objective of the Scheme is to help companies to curb their emissions in a concrete and the most cost-effective manner as much as possible and in this way, support the EU's efforts to achieve its emission reduction target. Additionally, the Scheme aims to be a significant driver not only for the Union but also for the investments in clean technology and low carbon development, especially in developing countries by allowing the use of international emission units like CERs and ERUs for the covered facilities (European Commission, 2016). Besides straightforward environmental targets, by using EU ETS, the EU aims to achieve smooth transition towards low carbon economic structure and also to provide a solid regulatory and supervisory framework for firms which are able to participate to the ETS market. With the incentives generated through the EU ETS, changing the fuel mix in Europe from fossil fuel dominant to renewable sources is also targeted. By this way, the EU aims to reduce energy intensity and decarbonize the Union.

In order to explain the fundamentals of the EU ETS, this chapter covers the background of the Scheme, building blocks for operationalizing it, historical analysis of pricing in the EU ETS and the developments that can be described as turning points for the Scheme.

3.1. Political Background of EU ETS

Under the Kyoto Protocol, legally binding GHG reduction target for the EU had been identified and because of this reason introduction of new policy instruments to meet these commitments had become a must-have for the EU (European Commission, 2015b). Within this context, as it is mentioned in the previous chapter, the EU had undertaken an 8% reduction in emissions compared to 1990 levels in the first commitment period of the Kyoto Protocol. Hence, in order to achieve this target, the EU had set up a policy mix which also included a cap-and-trade system namely the EU ETS.

In March 2000, the European Commission published "Green Paper on GHG Emissions Trading within the European Union". The document contains drafts of the first design of the EU ETS. With this document, the legal preparations for the first phase of the EU ETS were completed as a result of a series of interviews with stakeholders (Commission of The European Communities, 2000). Thus, with the adoption of Directive 2003/87/EC in 2003, it was accepted that EU ETS would come into force in 2005. This stage was planned as the pilot phase to run from 2005 through 2007. Later on, this trial period was followed by starting the complete implementation phase between 2008 and 2012 in which EU had targets to achieve stemming from Kyoto Protocol Commitment Period. Though there was not a direct link between the Kyoto Protocol and the establishment of the EU ETS, since an international emission trading mechanism was already captured in the Protocol as a flexibility mechanism, it is possible to say that Kyoto Protocol had influenced the EU ETS in order to support the Member States to meet the emission reduction commitments (Wettestad, 2009).

Afterwards, since the Kyoto Protocol's first commitment period covered 5 years between 2008 and 2012, the EU has developed a strategy which will last until 2020 when the legal term of the Kyoto Protocol ends. With this long-run perspective, the EU has prepared an action plan which consists of specific and quantitative targets to implement actions against climate change. To this extent, a policy mix named as "2020 Climate and Energy Package" (CEP), has been prepared and consists of three targets which are; reducing GHG emissions by 20% compared to 1990 levels, raising the ratio of renewable energy sources to total energy consumption to 20% level and mount up energy efficiency by 20% by 2020 (European Commission, 2008).

In order to reach the GHG emission mitigation goal, one of the most prominent regulations under the Package is the strengthening of the EU ETS. It is expected to meet 2/3 of the emission mitigation target with an emission trading scheme. For the given period, with the EU ETS regulations, it is aimed to decrease GHG emissions of the facilities which are included in the scope, by 21% compared to 2005 levels (European Commission, 2009).

At the beginning of the EU ETS, the ceiling on emissions has been left to the Member States in Phase I and II through National Allocation Plans (NAPs). In other words, a bottom-up approach has been adopted. However, after the regulations aforementioned had been entered into force, it has been decided to apply a uniform emission cap in the ETS and freely allocated part of the emission allowances had diminished. Instead, these have started be distributed by auctioning gradually to the facilities which are comprised in the scope of the ETS after 2013. By 2013, at least 20% of total allowance allocation is planned to be based on auctioning and this rate will be increased to 70% by 2020 and to 100% by 2027 (European Commission, 2009).

Furthermore, the EU has extended its perspective for a longer time period until 2030 and it has prepared a new policy mix known as the "2030 Climate and Energy Framework" (CEF). With this strategy, the same targets committed in the 2020 Package have been moved far beyond the current levels. According to the Commission's proposal, GHG emission reduction target is 40% mitigation domestically in 2030 compared to emissions in 1990 while the Member States' current commitments are still in place. This target is predicted to come from the ETS and the measures applied at the national level for the non-ETS sectors. It is foreseen that ETS will contribute to the target by delivering mitigation at the level of 43% in 2030 compared to 2005 levels while this rate is 30% for non-ETS sectors (European Commission, 2014).

One of the significant reasons for the new framework is fixing market imbalances in the EU ETS. The global economic crisis of 2008 has lowered the industrial production then due to decreased demand in the market, an allowance surplus has occurred, and this has led to plummeting in prices in the market. Therefore, one of the key areas that the new framework should address, is determined as reforming the ETS. Although in 2013, the auctioning of 900 million emission allowances were postponed, according to the estimations, it is expected that the surplus will not be corrected even after 2020. Since the ETS has been acknowledged as the main instruments to shift towards low carbon economy, the Commission has proposed setting up a market stability reserve (MSR) which will start to serve the EU ETS by 2019 (European Commission, 2014). It is announced that MSR is going to serve for the purpose of setting the current surplus of allowances and enhancing the resilience of the Scheme to shocks by regulating the allowance supply. The MSR is an automatic adjustment scheme with a pre-defined set of rules in terms of auctioning implementations. With this mechanism, it is aimed to protect the market from shocks and other types of imbalances. By using this mechanism, it is possible to compensate supply of allowances even there is a sudden, and temporary upward demand shock. To this end, 900 million allowances postponed will be auctioned by the Reserve in 2019-2020. Additionally, the Reserve will announce the total number of allowances in circulation annually to improve market transparency (European Commission, 2015a).

The EU has also a roadmap for a much longer period which put forward its transition towards low carbon economy by setting up "2050 Low Carbon Roadmap Document". It is a very comprehensive document that considers the cost-efficient emission reduction ways for the European economy in order to enhance it in both environmental and energy consumption perspectives. In this roadmap, it is suggested to cut emissions to 80% compared to 1990 levels by 2050. In this process achieving 40% emission reduction by 2030 and 60% by 2040 with the contributions of all sectors, and last but not least realizing these targets in a feasible and affordable manner is proposed (European Commission, 2011).

At this point, some key features of these targets should be noted. For the goal that aims to reduce emissions by 80%, the vital point is that the emission-cutting will be provided through domestic reductions rather than relying on international credits. Another issue to be emphasized is that the contributions should come from all sectors, but this common action may encompass some differentiation among sectors. In this process, electricity can gain importance in order to fulfill the gap in fossil fuels in transport and heating. Absolutely in this manner, electricity sources must rely on renewables like wind, solar etc. or low-emission sources like nuclear plants. It is important to note that this roadmap does not include any role for the EU ETS textually. However, on account of raising the ambition of emission mitigation target, obviously, the EU has a very powerful ETS tool to reach this objective.

3.2. History of Prices and Milestones for the System

In the EU ETS, each phase has its own characteristic features and specifications. For instance, owing to the fact that in Phase I, there was not a concrete emission data of facilities and lack of bankable allowances, the pricing behavior was completely different from other phases. Another example is about determining the cap level which was left to each Member States in Phase I and II by NAPs. However, this structure has been changed in Phase III and it is decided that this cap should be common and regulated by the Commission. On this ground, before moving further, it is beneficial to mention general specifications of phases and the price movements in the market.

3.2.1. Phase I

The first phase of the EU ETS which captures the period between 2005 and 2008 is called "learning by doing" period by the European Commission. This is a premature version of the ETS when it is juxtaposed with the Scheme in action today. The ultimate aim of this period is to prepare the Scheme for Phase II in which the EU should meet emission reduction targets determined under the Kyoto Protocol.

In Phase I, the coverage of system was limited with CO_2 emissions from energy-intensive industries like oil refineries, coke ovens, iron and steel plants, cement clinker, glass, lime, bricks, ceramics, pulp, paper, and board and power stations and other combustion plants which exceeded a threshold level. In this stage, the Scheme included only 27 Member States of the European Union and it was only allowed to trade EUAs. In other words, CERs and ERUs could not be used to meet the requirements of the Scheme. Since this period was considered as a pilot phase, almost all allowances were freely distributed to facilities. Another important feature of this phase is that the banking mechanism was not available, thus facilities covered by the Scheme could not transfer the allowances which they did not use to the following phase.

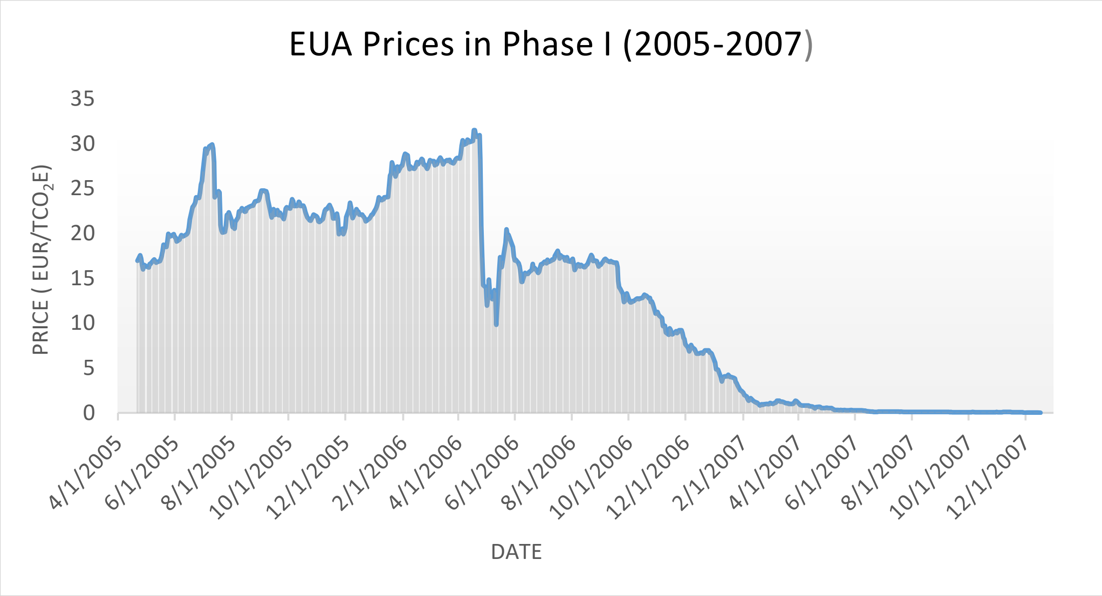

Figure 2: EUA Prices in Phase I (2005-2007)

Source: ICE Futures Europe, EUA Futures.

On the other hand, at the end of this period, the price of EUAs dropped to zero after gathering the actual emission data, because it was realized that there was a significant difference between allocations based on estimations and accurate levels of allocations. In other words, there was an oversupply of EUAs in the market, which led to a decrease in prices. Owing to this mismatch, the aim of achieving market efficiency in this phase had failed. Another explanation for this price crash in the market relied on the non-bankability of allowances for phase II (Alberola et al., 2008). On account of not being able to use allowances in the next phase through banking, the demand for EUAs diminished over time. Despite all the problems encountered in this period, Phase I can be found successful for putting a price for carbon, enabling the trade of EUAs within the EU region and setting up an infrastructure of monitoring, reporting and verifying mechanism which is the fundamental pillar to gather emission data of facilities captured in the emission trading scheme.

3.2.2. Phase II

The second phase of the EU ETS was critical for the EU in order to meet the commitments given under the Kyoto Protocol's first commitment period. For the period between 2008 and 2012, the EU had committed to reduce its emissions by 8%. The base year in this target was defined according to GHG types. For CO_2, CH_4 and N_2O, the base year was decided as 1990 except for Bulgaria, Hungary, Slovenia, Poland, and Romania. For fluorinated gases which are HFCs, PFCs and SF_6 the base year was defined as 1995 except for Austria, Croatia, France, Italy, and Slovakia.

In this phase of the EU ETS, 3 new countries outside of the European Union which are Iceland, Liechtenstein and Norway had participated to the ETS. The emission cap of this phase was lowered by 6.5% compared to 2005 levels and free allocation of allowances slightly decreased to 90% of total allocations. In this period facilities were allowed to use offset mechanism by buying international credits such CERs and ERUs. For instance; if a German facility captured by the EU ETS invest in a deforestation project in Kenya, the emission reduction from this project is calculated and a CER which is equal to this reduction amount is issued for the German facility. To follow up this acquisition, German facility is able to use this CER in order to meet a part (for Phase III; up to 11% of the allowances which were allocated to the facility in Phase II) of its emission reduction requirements within the framework of this offset mechanism of the EU ETS. However, with the regulations in the EU ETS, facilities cannot use this mechanism to comply with the whole cap requirement in the ETS, in other words, the use of offset mechanism is limited by a predetermined level.

In the previous phase there was a lack of concrete and reliable emission data. However, in this phase, the cap on allowances had been reduced in a more consistent way and this decrease was the result of gathering accurate and actual data on emissions. However, because of the 2008 global economic crisis which give rise to a tremendous fall in industrial production and economic activities, the demand for EUAs diminished while permission for using CERs and ERUs raised the supply of allowances in the market. In this period, the price of EUA declined from 30 Euro/tCO_2e in July 2008 to 10 Euro/tCO_2e in February 2009. After a fluctuation within the range of 18 Euro/tCO_2e and 10 Euro/tCO_2e, with the impulse of the European debt crisis in 2011, price levels had experienced another record low towards 7 Euro/tCO_2e levels. In June 2011, the European Commission has limited the use of CERs and ERUs coming from certain activities for facilities which use them for the purposes of compliance within the EU ETS. In this frame, the European Commission has decided that the facilities captured by the EU ETS cannot use CERs and ERUs generated from industrial gas projects by 2013. In more detail, credits from the projects based on trifluoromethane (HFC-23), chlorodifluoromethane (HCFC-22) and N_2O which are used for adipic acid have not been allowed to be used anymore in the EU ETS. Moreover, this regulation also included that by 2012 facilities cannot use any CERs for the abovementioned purpose, unless the project is in a Least Developed Country (LDC) (European Commission, 2014).

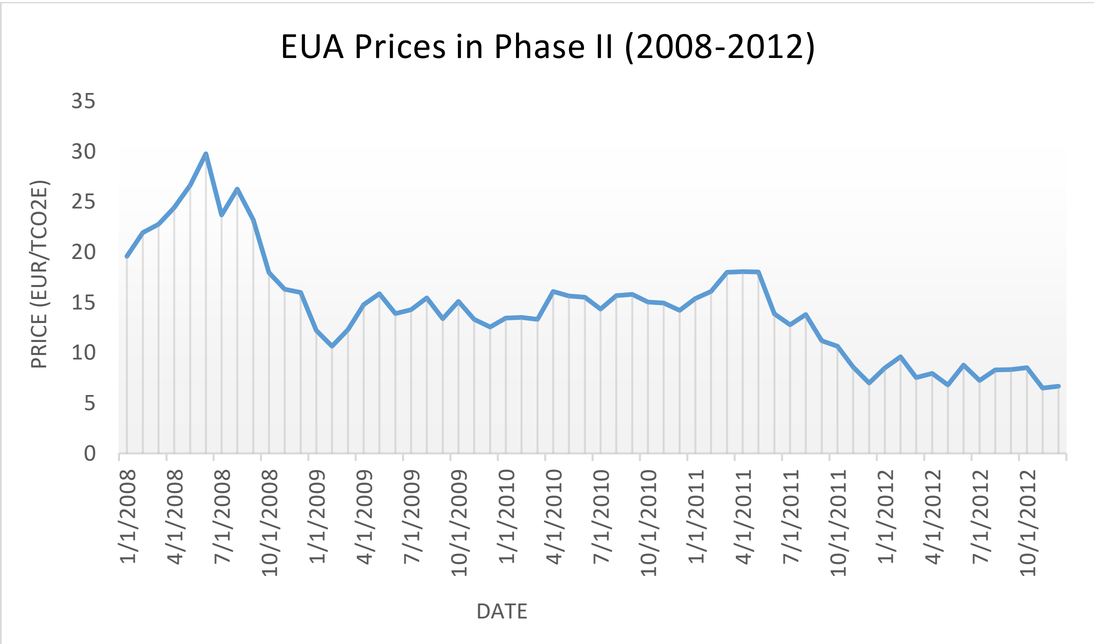

Figure 3: EUA Prices in Phase II (2008-2012)

Source: ICE Futures Europe, EUA Futures.

Furthermore, also in June 2011 a draft regulation related with the EU ETS was presented by the European Commission in the EU Climate Change Committee and this draft played a significant role in coping with imbalances in the market. This regulation contained some measures on security requirements for the market players and the use of funds collected in the Scheme. Since before 2011 in the EU ETS, fraud activities have been widespread, and the market conditions were not facilitative for the new entrants to the market, the European Commission decided to regulate the market. The Commission has increased the security inquiries for market participants while for new entrants, a fund has been set up to lead those making investments for low carbon areas by 2013. All of these new regulations have affected both demand and supply sides of EUAs in the market.

3.2.3. Phase III and Beyond

Compared to earlier periods, Phase III of the EU ETS has become distinct as a result of important regulations. In this period, European Union Member States adopted the 2030 CEF framework, in which the expected outcome for the EU ETS had been declared as cutting emissions from sectors captured by the EU ETS by 43% compared to 2005. Thereafter, from 2021 onwards; the cap is going to be lowered by 2.2% annually until 2030 (European Commission, 2015c).

To achieve these targets, a major reform for the EU ETS has been taken into action. To that end, instead of nationally determined cap, a common EU-wide emission cap has been adopted for the third period of the EU ETS. In other words, in the first two periods, a bottom-up approach has been implemented in which each country could set its own national emission ceiling, while in the third period, a top-down approach has been applied by setting a single emission ceiling for the Union. Within this framework, during the third period of the EU ETS (2013-2020) it is envisaged that the cap is going to be reduced by a linear reduction factor of 1.74% annually to mitigate emission by 21% in 2020 compared with the level of 2005. As of 2030, the Commission notes that this value will reach to 43% (European Commission, 2015c).

Although free allocation for industrial facilities except power generation sector is still in charge, free allocations of emission allowances for the rest of facilities have been reduced and the auctioning has been designated as the current allocation method. It is to safeguard for the power generation sector from the risk of carbon leakage which can damage the global competitiveness of sectors in the ETS. As it is aforementioned, in Phase II, the EU ETS had distressed by the huge amount of allowance surplus in the market in consequence of slowdowns in the European economy and high imports of international credits which caused a depreciation of EUA prices. To overcome this problem and also to fix the system for potential market inefficiencies in the future, in Phase III some short and long-run measures have been defined into the framework of the Scheme.

For short-run, with the EU ETS Auctioning Regulation enacted in 2014, it was decided that auctioning of 900 million allowances have been postponed until the period of 2019 and 2020 which implies diminishing the supply of allowances for a while. This policy is named as “Back-Loading”. With this measure, while the number of allowances auctioned in Phase III has not been reduced, by regulating their distribution within the phase, it is aimed to set the supply side of the market to prevent price downfalls.

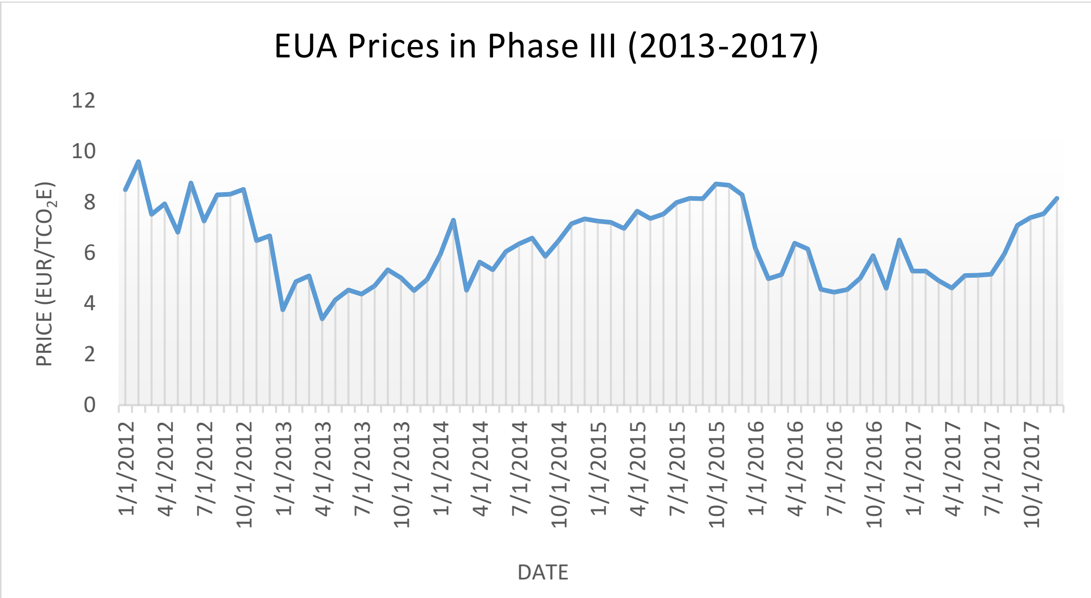

Figure 4: EUA Prices in Phase III (2013-2017)

Source: ICE Futures Europe, EUA Futures.

In this phase, prices fluctuated between 3.4 Euro/tCO_2e and 9.6 Euro/tCO_2e. The peak and bottom levels had been observed within the first year of Phase III. An upward trend from 3.4 Euro/tCO_2e to 8.67 Euro/tCO_2e was observed between April 2013 and November 2015. However, the most dramatic change in prices had been seen in December 2015 when the Paris Agreement had been concluded. On monthly basis, the EUA prices had decreased by almost 43% to 4.98 Euro/tCO_2e in February 2016 from 8.67 Euro/tCO_2e level in November 2015. Nevertheless, after April 2017 this trend had been reversed. The EUA prices had increased from 4.9 Euro/tCO_2e to 8.15 Euro/tCO_2e in 9 months.

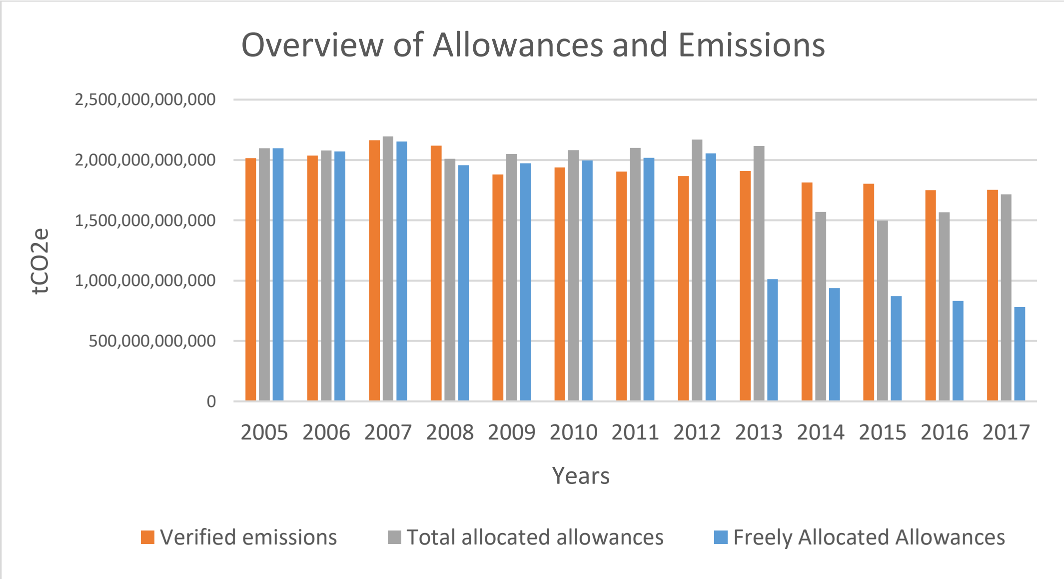

Figure 5: Allowances and Emission in EU ETS by Phases

Source: EEA, EU Emissions Trading System (ETS) Data Viewer, Dashboard, Published: 10 Jul 2018

Last but not least, in order to interpret the price movements, it is also important to underline how the allocation of allowances has been changed phase by phase. In Figure 5, the verified emission of the facilities captured by the EU ETS, and the total amount of allocations are shown. Freely distributed allowances are also presented separately from total allocations. According to the figures, in Phase I and Phase II, except in 2008, total allowances have been higher than the verified emissions. By 2013, with supply-side regulations like diminishing the rate of free allocations, more strict market entrance end registry rules, limiting the use of carbon credits etc. it can be seen that this trend has been reversed, except 2013.

To sum up, the EU has always come to the fore as a region that attaches importance to the fight against the adverse effects of climate change. It is possible to understand this both in its engagement and constructive approach in international climate change negotiations and in the policy instruments that are already implemented. The EU

ETS, the first established and still the largest cap-and-trade system, is of a great example in this context. From this long-lasting successful model of the ETS, there are lots of key lessons to be learnt such as, step-wise implementations by cutting into phases the process helps to learn and better implication of the Scheme. Accurate data and a solid monitoring of the emissions are required, to design the system as flexible as possible to adapt to unexpected and unforeseen impacts of economic crisis which causes oversupply of allowances, price volatilities etc. Moreover, the ETS has begun to be viewed as an auxiliary tool for longer-term and low-carbon growth models not only by developed countries but also by developing countries. It also shows that decoupling economic growth from greenhouse gas emission is possible and cost-effective. In this context, the EU ETS has become an example for more and more countries. For this reason, it is critical to understand and reveal the relationship of the EUA with other variables of the economy. This relationship is tried to be envisaged by examining the EUA price movements and associated variables during the implementation period of EU ETS.

CHAPTER 4

DRIVERS OF EUA PRICES IN PHASE II AND PHASE III (2008 -2017)

In this section, it is desired to find an answer for which macroeconomic variables have effect on EUA prices and for which variables EUA plays role as a driver. For this purpose, firstly the literature on price interactions between allowance prices and macroeconomic variables will be scrutinized. Then the data used in the analysis and the methodology adopted will be introduced. Following these descriptions, the empirical results will be shared which are derived from ARDL regression and Toda-Yamamoto Granger Non-Causality Test.

4.1. Literature Review on Price Interactions between EU ETS and Macroeconomic Variables

Since the introduction of the EU ETS in 2005, market participants, academicians and other relevant actors have tempted to define the interconnection between the EU ETS and other macroeconomic variables such as economic activity, fossil fuel prices, policy interaction, and even temperature conditions. These studies have been intensified after the Phase I of the EU ETS has been operationalized.

Due to the fact that the EU ETS is defined as a market-based policy tool to fight against climate change, it is necessary to describe the demand and supply side of this market. This taxonomy has been established by Christiansen et al. (2005) and it is laid out by Rickels et al. (2007) more profoundly. Although it is a very early analysis, Christiansen et al. (2005) claim that for the Phase I of the EU ETS; policy interactions which imply regulatory actions about the Scheme could be considered as supply-side variables; while weather conditions, fuel-switching behavior and production level in the economy are playing a decisive role on the demand side of the Scheme. Rickels et al. (2007) extend this finding and they argue that since the EU ETS is a market designed by policy-makers artificially, the policy decisions incorporate cap level, allocation and auctioning methods adopted for allowances, usage of CERs and ERUs in meeting the requirements, usage and flexibility of the banking mechanism, and penalties for non-compliance as the main drivers for the supply side of the EU ETS. On the other hand, they argue that fuel prices, economic activity and climatology are the demand side drivers.

However, in the literature, researches on the supply side of the market could not be developed as much as the demand side, because of the lack of data and also the difficulty of producing quantitative data for such policy interactions. Despite this adversity, some studies like Alberola et al. (2008), Conrad et al. (2012), Fan et al. (2017) include institutional and policy interactions in their research. Due to the plethora of policy interactions for the Scheme, these studies are based on bulky and high frequency datasets which are daily or even hourly. As the result of these relatively limited researches, the effectiveness of regulatory decisions is proved, and it is underscored that policy adjustments which regulate emission allowance supply and demand for the future period have considerable effects.

For the demand side, variables are categorized as fossil fuel prices, economic activity and climatology drivers as it is mentioned. Since fossil fuels are leading energy sources which causes high amount of CO_2 emissions, there is a cornucopia of analysis that investigates the relationship between the EUA and fossil fuel prices. In such wise, either spot or future contract prices of oil, coal and natural gas are subject to analysis. Oil is one of the primary commodities which has been expected to have a significant impact on prices, particularly at the earlier stages of the EU ETS because in addition to its role in energy production as an input, natural gas contracts were also indexed to oil prices. This evidence is also underlined by Convery and Redmond (2007). Additionally, in 2016, petroleum and products which includes oil also represents 34.6% of EU-28 energy consumption composition. (European Commission, 2018). To this extent, according to the studies which investigate the role of oil in the EUA price dynamics, Mansanet-Bataller et al. (2006), Rickels et al. (2007), Mansanet-Bataller et al. (2011), Bredin and Muckley (2011), Creti et al. (2012), Rickels et al. (2014) detect a positive influence of oil on the EUA prices, while Hammoudeh et al. (2014) argue that the sign of this effect is negative. The reason for this difference might be related to the type of oil used in the analysis because unlike other studies, Hammoudeh et al. (2014) conduct their analysis based on crude oil instead of brent oil and since the pricing dynamics in the West Texas Intermediate is different than its European counterpart, the result of Hammoudeh et al. (2014) should be interpreted with a different point of view.

Another important fossil fuel in the EU is coal which represents 14.7% of the energy mix of EU-28 in 2016 (European Commission, 2018). Alberola et al. (2008), Mansanet-Bataller et al. (2011), Schumacher et al. (2012) Aatola et al. (2013), European Commission (2014) find that coal prices have negative effects on the EUA prices because when the prices of coal decrease, facilities are prone to use cheaper coal in their production process and this leads a raise in emission which requires holding more emission allowance to meet requirements within the EU ETS. Last but not least the other fossil fuel in Europe is natural gas and its share in the EU-28 energy consumption composition is 23.4% in 2016 (European Commission, 2018). According to the studies, there is a mixed outlook for the sign of the effect of natural gas. Mansanet-Bataller et al. (2006), Rickels et al. (2007), Alberola et al. (2008), Fezzi and Bunn (2009), Mansanet-Bataller et al. (2011), Schumacher et al. (2012), Aatola et al. (2013) and Hammoudeh et al. (2014) claim that the natural gas is an important driver of the EUA prices and it affects prices positively. On the other hand, Chung et al. (2018) which also covers Phase III price dynamics in their analysis argue that the sign of natural gas is negative due to the fact that decreasing demand for natural gas leads to an increase in the usage of dirtier fossil fuels which causes an upward trend in emissions and higher carbon prices. Furthermore, besides the conventional fossil fuel classification, in terms of determining the drivers of EUA prices, a theoretical price which shows that the equilibrium price level at which facilities exchange from coal to gas-based power production is employed in some studies. Mansanet-Bataller et al. (2011), Creti et al. (2012), Schumacher et al. (2012), Koch et al. (2014), Rickels et al. (2014) adapt this price indicator into their researches and they find that it affects EUA prices positively. In the next section, in which data descriptions are given, more information about this variable will be provided. Succinctly, as it is aforementioned, it is hard to stress concrete results in terms of the sign or the power of fossil fuels as drivers of EUA prices. This might stem from the difference of periods or phases analyzed in the studies. While some analysis captures only Phase I price dynamics in their analysis, some of them include both Phase I and II. Additionally, some researches also capture available data from Phase III. When it is considered that the price dynamics in the pilot period of the EU ETS, Phase I, do not run sturdily, involving this period into the analysis may distort results. In Table 5, periods covered in the selected studies are presented.

Another reason of the disparity among empirical results might be resulted from the different prices reviewed. Within this context, Mansanet-Bataller et al. (2006), Aatola et al. (2013) use forward prices, Rickels et al. (2007), Alberola et al. (2008), Fezzi and Bunn (2009), Nazifi and Milunovich (2010), Hinterman (2010) and Hammoudeh et al. (2014) handle spot prices. On the other side, Bredin and Muckley (2011), Mansanet-Bataller et al. (2011), European Commission (2014) and Chung et al. (2018) adapt future contract prices into their analysis.

Emission level in an economy is very closely related with the macroeconomic performance of that country. On the expansionary path of the business cycle, facilities ramp up their production level and this will lead an increase in emission level, by and large. On the contrary, for instance the recent global economic crisis which impaired industrial production tremendously, had caused an essential decrease in the demand for emission allowances, besides the contraction in the economies had led allowance surpluses in the EU ETS. Since most of the industries are covered by the emission trading schemes and represent a great proportion of emissions in the economy, adding industrial production level into analysis would provide not only concrete backward-looking information about the macroeconomic performance of the economy but also a proxy data for measuring the demand for emission allowances.

Table 5: Selected Studies and Covered Years and Phases

<table>
<tr><th colspan="3">PHASE I</th><th colspan="5">PHASE II</th><th colspan="5">PHASE III</th></tr>
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<tr><td>Mansanet-Bataller et al. (2006)</td><td colspan="8">Hammoudeh et al. (2014)</td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td colspan="2">Rickels et al. (2007)
Fezzi and Bunn (2009),
Benz and Trück (2009)</td><td colspan="3">Mansanet-Bataller et al. (2011)</td><td></td><td></td><td></td><td rowspan="2"></td></tr>
<tr><td colspan="3">Alberola et al. (2008),
Nazifi and Milunovich (2010),
Oberndorfer (2009),
Keppler and Mansanet-Bataller (2010)
Hinterman (2010)</td><td colspan="5">Lutz et al. (2013),
European Commission (2014)</td></tr>
<tr><td colspan="5">Bredin and Muckley (2011)</td><td></td><td rowspan="2"></td><td colspan="6">Chung et al. (2018)</td></tr>
<tr><td colspan="7">Creti et al. (2012)</td><td rowspan="2"></td><td rowspan="3"></td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td></tr>
<tr><td colspan="8">Koch et al. (2014)</td></tr>
<tr><td></td><td colspan="7">Chevallier and Zhu (2017)</td></tr>
<tr><td colspan="9">Aatola et al. (2013)</td></tr>
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According to Alberola et al. (2008), carbon prices are affected not only by the costs of emission abatement options but also business-as-usual production of the industry. Chevallier (2011) also touches upon the significance of industrial production and state that the EUA prices are positively correlated with the growth of the economy. To follow up these discussions, the EU industrial production index is involved in various analyses. Bredin and Muckley (2011), European Commission (2014), Koch et al. (2014) are some of these studies which detect a positive effect from industrial production to the EUA prices as it is theoretically expected. Koch et al. (2014) move these studies one step further and also include a forward-looking proxy which is economic sentiment indicator in their research. This index measures expectations and forecasts of economic actors about the future of the economy. The authors argue that the economic sentiment indicator has a positive impact on the EUA prices. Conrad et al. (2012) argue that expectations about the economic performance of Germany and the US are closely related to carbon price movements because improvement in the expectations about economic growth of these countries affects immediately EUA prices. Besides industrial production index and economic sentiment indicator, the performance of stock exchange markets is another variable that is commonly used as a proxy for gauging expectations about economic activity. In this manner, Schumacher et al. (2012), Rickels et al. (2014) claim that equities and stock exchanges have a positive impact on the EUA prices, while Bredin and Muckley (2011) argue the opposite. On the other hand, Creti et al. (2012) find that for Phase I of the EU ETS, stock markets affect the EUA prices negatively but in the next phase, this finding is reversed. This contradiction proves one more time that analytical results are highly related not only to the econometric approach adopted but also the period subjected to the analysis.

In various studies such as Considine (2000) and Staffell and Pfenninger (2018), short-run effects of climate conditions on the emissions are emphasized. For instance; according to Considine (2000), short-run energy demand is closely related with seasonal and stochastic weather conditions and this also affects carbon emissions. In this study he emphasizes the positive relationship between heating degree days and carbon emissions. In other words, warmer climate and weather conditions causes a decrease in energy demand which lead less carbon emissions in the US. Furthermore, Staffell and Pfenninger (2018) argue that as European policies move towards decarbonization of energy production, the effects of weather conditions through renewable energy sources will strengthen. Specifically, Christiansen et al. (2005)

underscore that the temperature affects the EUA prices. Relying on findings from such studies, the role of weather conditions in the energy demand has been revealed by a plethora of authors. Within the context of carbon pricing, adding a proxy variable which represents weather conditions into the analysis has become a widely used method. To this extent Mansanet-Bataller et al. (2006) and Rickels et al. (2007) find that extremely cold weather conditions have a positive effect on the EUA prices due to the increasing requirement of heating. In the further extensions of these studies, Rickels et al. (2014) claim that there is a positive relationship between hydro-capacity of the France and the EUA prices. As a result of high precipitation in a season, hydro capacities will rise which will be a leading indicator of a higher necessity of heating due to seasonal weather conditions. On the contrary, in the study conducted by the European Commission (2014) and Koch et al. (2014), data on the share of electricity generated from renewable energy sources in the total electricity production (RES-E) is used as a weather proxy and the negative effect of this variable is explored. The reason behind this result is that the RES-E variable also implies that if the share of renewable sources in the energy mix increased, the use of fossil fuels would decline and then the emissions could be abated. Taking all of these researches into considerations, it could be concluded that fossil fuel prices, electricity prices, indicators for macroeconomic and weather conditions are in interaction since the beginning of the ETS. Despite the fact that there is somewhat consensus on the determinants of the EU ETS prices, the econometric modeling approaches used to catch this relationship vary regarding the frequency, quality and theoretical consistency of data.

To find a long-run relationship and short-run interactions among variables, co-integration-based methods which are vector autoregressive (VAR) regressions, vector error correction mechanism (VECM) regressions and autoregressive lag distributed (ARDL) regressions are often used. Keppler and Mansanet-Bataller (2010), Peri and Baldi (2011), Bredin and Muckley (2011), Creti et al. (2012), European Commission (2014), Hammoudeh et al. (2014), Chung et al. (2018) adapt co-integration techniques into their research. As an extension of these approaches

Granger causality relationships are also analyzed by some studies. Keppler and Mansanet-Bataller (2010) and Nazifi and Minunovich (2010) are leading studies which reveal the relationship among various variables and the EUA prices. In order to summarize literature review, table 6 is presented below.

Table 6: Selected Studies and Variables Used

AUTHORS	METHOD	FREQ	INDEPENDENT VARIABLES
Mansanet-Bataller et al. (2006)	LS	Daily	• EUA forward prices • Natural gas future prices • Coal future prices • Brent oil future prices • A weather index established by authors including the minimum air temperature, the mean air temperature and the maximum air temperature
Rickels et al. (2007)	OLS-GARCH	Daily	• Brent oil spot prices • Natural gas spot prices • Coal RB Index • Hot and cold days index established by authors
Alberola et al. (2008)	OLS	Daily	• EUA spot price • Brent oil futures prices • Natural gas future prices • Electricity prices • Clean dark spread • Clean spark spread • Fuel-switching prices • European temperatures index published by Tendances Carbone
Benz and Trück (2009)	ARCH-GARCH	Daily	• EUA Spot prices • EUA AR-GARCH
Fezzi and Bunn (2009)	SVAR	Daily	• EUA forward prices • Day-ahead electricity prices • Natural gas prices
Oberndorfer (2009)	Pooled OLS	Monthly	• EUA settlement price • Stock returns of electricity corporations captured by Euro Stoxx Utilities Index • Natural gas forward prices • Brent oil forward prices • EuroStoxx
Keppler and Mansanet-Bataller (2010)	Granger Causality Test	Daily	• Spot and futures EUA prices • natural gas forward prices • Coal forward prices • electricity prices • Eurostoxx600 • European temperature index published by Tendances Carbone.
Nazifi and Milunovich (2010)	VECM-Granger Causality Test	Daily	• EUA spot and future prices • Electricity prices • Natural gas prices • Coal prices • London Crude Oil-Brent Index • Daily atmospheric temperature

Table 6 (continued)

Hinterman (2010)	ARCH	Daily	• EUA over-the-counter prices • Natural gas future prices • Coal Prices • European Climate Assessment and Dataset • Nordic reservoir levels
Bredin and Muckley (2011)	Modified Johansen (1988) cointegration test (capture ARCH process)	Daily	• EUA Future prices • brent oil future prices • clean dark and spark spreads • temperature deviations from seasonal averages • EUROSTOXX50
Mansanet-Bataller et al. (2011)	VAR-VECM-TGARCH	Daily	• EUA future prices • secondary CER (sCER) data • Brent oil future prices • Natural gas futures prices • Coal prices • Fuel-switching prices • Industrial Production Index • Economic Sentiment Indicator
Creti et al. (2012)	Johansen Cointegration Test- FM-OLS-DOLS- VECM	Daily	• EUA Future prices • ICE Brent oil Futures prices • Fuel-Switching Price • EUROSTOXX 50
Lutz et al. (2013)	Markov regime switching extended with GARCH	Daily	• EUA Futures • Coal futures • Natural gas futures • Brent oil prices • EUROSTOXX 50 • Thomson Reuters/Jeffries Commodity Research Bureau Index (CRBI) • Moody's average annual yields of US corporate long-term bonds rated AAA and BAA • Deviations from average temperature
P. Aatola et al. (2013)	OLS-IV-VAR	Daily	• EUA forward prices • German electricity forward prices • Nord Pool electricity forward prices • Mineral Price index • Steel Price index • Paper Price index • Gas forward prices • Coal forward prices • Oil forward prices • FTSE350 • Water reservoirs • Gas storage
European Commission (2014)	ARDL	Monthly	• EUA prices • Industrial Production Index • Coal prices • Electricity produced by renewables • Electricity produced by hydroelectric
Hammoudeh et al. (2014)	NARDL-ARDL	Monthly	• EUA spot prices • Crude oil spot prices • Natural gas spot prices • Coal spot prices • Electricity prices

Table 6 (continued)

Koch, Fuss, Grosjean, Edenhofer (2014)	OLS	Monthly	• Natural gas future prices • Coal future prices • EUROSTOXX 600 Index • Economic Sentiment Indicator • RES-E production data from European Network of Transmission Systems Operators for Electricity (ENTSO-E) • Monthly issued CER data from IGES CDM Project Database
Tan, Wang (2017)	Quantile regression	Daily	• EUA future prices • Brent oil prices • Natural Gas prices • Coal Prices Index • EUROSTOXX 50 • CRB (Reuters/Jefferies commodity research bureau) • Treasury bill yield (90 day US T-bill • Junk bond yield
Zhu and Chevallier (2017)	Johansen's Cointegration – Ridge Regression - Granger Causality Test	Monthly	• Brent oil prices • Coal future prices • British Gas futures index prices • EEX electricity futures prices • Tendances Carbone's EU temperature index monthly • Tendances Carbone's industrial production index
Chung et al. (2018)	DSEG-VECM	Monthly	• Australian Thermal Coal Price • Brent oil Futures Index • Nature Gas Future Index • UK Power Future Index • Industrial Production Index • Economic Sentiment Index • Euro Area Bank Lending Index • Average Temperature Maximum Index • Average Temperature Minimum Index • Average Precipitation Index • CER Futures Price

4.2. Data and Methodology

After scrutinizing the literature to determine which variables and methods will be used in the analysis to detect the relationship between the EUA prices and its determinants, firstly the data selected will be introduced. At the next stage, the most appropriate model and the methodology regarding the data specifications selected and will be explained briefly.

4.2.1. Data

In this part, the data used in the modeling exercise will be described. To this extent, primarily the EU ETS prices, namely EUA, as the dependent variable will be introduced. The EUA will be followed by the description of fossil fuel prices, macroeconomic activity variables, weather variables and dummy variables adapted into the model. In this study for the price movements future contract prices are selected because they are more liquid and also are not affected from dramatic structural changes unlike spot prices (Bredin and Muckley, 2011). Additionally, instead of daily data, monthly data is preferred in order to abstain from misleading price movements based upon low daily trading volumes as it is stated in Oberndorfer (2009) and to compare price movements with other variables which are monthly published like Industrial Production Index and Economic Sentiment Indicator. Furthermore, the natural logarithmic forms of variables are used to avert non-linearity.

4.2.1.1. EU ETS Prices

Emission allowance prices (EUA) are provided in monthly frequency and they are obtained from Intercontinental Exchange (ICE) in Euro/metric ton. In the EU ETS, one lot of EUA subjected to trade, consists of 1,000 CO_2 emission allowances and each one represents one ton of CO_2e. To express the price movements, instead of spot prices, future contracts rolled-over in December of the current year are selected since December ended contracts have the highest volumes of trading among other maturities.

Data prior to January 2008 is not included in the study because Phase I is considered as a pilot period for the EU ETS, as it is aforementioned. Additionally, since there was a ban on banking in Phase I, incorporating Phase I with other phases may give rise to inconsistent interpretations (Hintermann, 2010). Therefore, the sample period for the analysis begins on January 1, 2008, and finishes on December 31, 2017. To cope with such problems, Phase II and the first 5 years of Phase III has been incorporated in the sample. The sample covers 120 monthly observations.

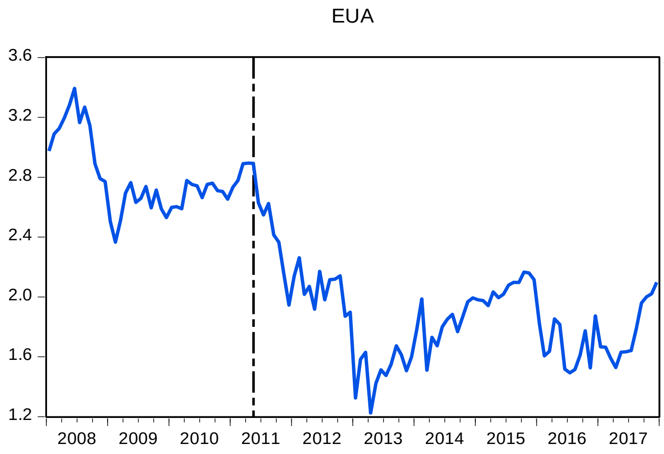

Figure 6: EUA Prices

4.2.1.2. Fossil Fuels

The linkages between energy markets and carbon markets have been subjected to lots of academic researches due to the fact that the bulk of the global CO_2 emissions are generated from oil, gas, coal combustion. Moreover, most of the electricity generation is based on fossil fuel use, so it is obvious that the process in which such emitting inputs used should be affected by carbon prices.

According to EUROSTAT, the share of renewable energy sources in electricity production has increased from 17% in 2008 to 30% in 2016. This implies that even there exists a considerable effort in order to raise the share of renewable energy where fossil fuel and nuclear-based energy sources have still dominated the electricity production. In the EU, fossil fuel-based power plants are responsible for 44% of electricity consumption while the share of nuclear and hydro based power plants are responsible for 26% and 12%, respectively. Other renewable energy sources like wind, biofuels and solar are only responsible for 18% totally. Although, in order not to neglect the effects of power generation based on renewable energy sources, in modeling exercise, the UK electricity base load index is used to represent electricity prices and it is obtained from the ICE. However, this variable is statistically insignificant in all model variations, therefore it has not been covered in the thesis.

Coal is counted among leading energy products and it has a heterogeneous structure which varies according to different geological specifications, heating values, chemical composition and physical features (Albrecht et al., 2014). Solid fuels which consist of various types of coals account for 9% of the EU's energy imports in 2016. McCloskey Coal Industry Services (MCIS) is a leading price index for European coal markets. The prices provided by this service include cost, insurance and freight (CIF) and these prices are gathered from the deliveries to Amsterdam, Rotterdam and Antwerp (ARA) ports. The price information is published by McCloskey in a cooperation with Argus as a Physical Coal Price Index (API2). To this extent, data on coal future prices are obtained from the CME database by using Coal (API2) CIF ARA (ARGUS-McCloskey). Future contracts which are rolling over December of the current year are preferred for the analysis. The price data has been provided in US Dollars/metric ton.

Natural gas is another key driver chosen for this study because it is a primary resource to meet energy demand. While it is majorly used in power generation, it is also an important input for heating in buildings, industrial products which capture steel, paper, ceramic etc., industrial oil and gas operations and transportation. It is also used as a raw material to produce fertilizers, ammonia, methanol and hydrogen. According to 2016 figures, natural gas is the second biggest energy product imported into the EU as 24% of total energy imports. Moreover, natural gas has the majority in primary energy for heating and cooling per energy carrier in the EU (Honoré, 2018). Since natural gas is a heterogeneous fossil fuel, its place of origin has a great importance in price determination. The Henry Hub located in the US and the National Balancing Point (NBP) in the United Kingdom are among the most liquid natural gas markets in the world. According to the ACER data for market overview in 2011, NBP is the sole hub in Europe with a churn rate[5] higher than 10 (ACER, 2012) and as reported

[5] Churn rate is an important indicator that is used to measure the liquidity of the hub and it is calculated as a share of the volume of natural gas subjected to trade in the hub to the volume of natural gas physically produced and traded in the region where the hub operates in.

by to the recent ACER data published in 2018, NBP is still the most important with Dutch Title Transfer Facility (TTF) (ACER, 2018). The follow-up hub which is Zeebrugge in Belgium has a 4.4 churn rate in that year (ACER, 2012). This information shows us that in order to represent natural gas price movements in the EU, NBP can be considered as a leading indicator. To access price data CME database is used and, in this database, the UK NBP Natural Gas Futures which rolls over in December of the current year are selected in GBP currency. The unit subjected to the trade is 1,000 therms of natural gas per day and in this sense, 1 therm is equal to 29.3071-kilowatt hours.

Petroleum products where oil has the highest share, are the main energy products imported into the EU by the rate of 2/3 of total energy imports. It is used for transport, heating and cooling in buildings, power generation and industrial processes. On the other hand, in terms of power generation, oil has lost its significance in the EU, except in Malta and Cyprus. (Albrecht et al.,2014), because in power generation it has started to affect the process indirectly. For instance, the effects of oil on the coal prices could be seen through the costs from the fuels used in the coal extraction process and the transportation of this coal. On the other hand, while previously oil-indexed long-run natural gas contracts are affected significantly by oil prices, with the replacement of indexation with hub-based pricing, it has lost its significance in natural gas pricing. However, it has continued to affect the natural gas prices via transportation costs since oil is a globally traded commodity and since then regional and local price differences are held at a minimum. Information on future contracts of brent oil is accessed from ICE Futures Europe, and it is quoted in US Dollar. The size of this contract is 1,000 barrels. Similar to coal and natural gas prices, for contract rollover period, December of the current year is selected and is given as US Dollar/Barrel.

For all data, in order to harmonize EUA prices which are expressed in Euro with fossil fuel prices data which are provided in US Dollars and GBP, European Central Bank (ECB) exchange rates are used for currency conversion. Price movements of the fossil fuels are shown in Figure 7. According to the figure, it can be easily seen that all of three fossil fuels follow a somewhat similar path within the time period between 2008 and 2017.

Table 7: Correlation among Fossil Fuels

	Coal	Brent Oil	Natural Gas
Coal	1	0.524	0.604
Brent Oil	0.524	1	0.716
Natural Gas	0.604	0.716	1

Until 2011, a high correlation had been observed among all fossil fuels. However, after 2011 this correlation has been weakened. This finding is also shared by Albrecht et al. (2014). For the whole sample period, the correlation among fossil fuels is presented in Table 6. Moreover, the correlation among oil and other fossil fuels has been diminished due to the replacement of oil-indexation pricing with hub-based pricing as aforementioned.

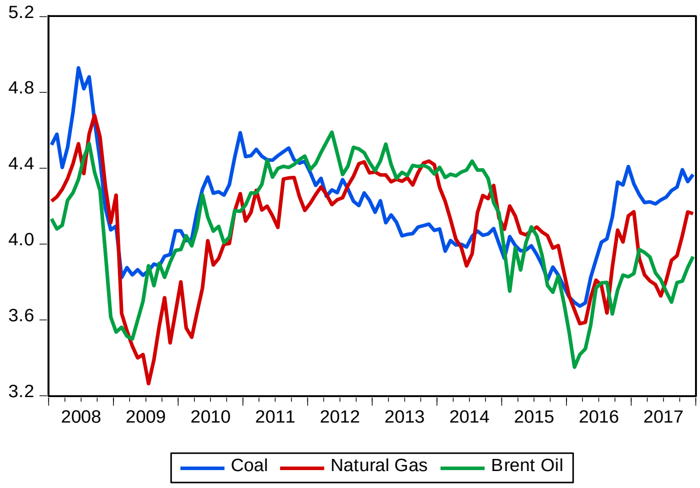

Figure 7: Fossil Fuel Prices

The last but not least, the fuel-switching price is also included in the research. It is a theoretical price to find an equilibrium price level used in order to represent the exchange from coal to gas-based power production. In more detail, it could be defined as a price level that electricity producers can make a profit from changing their production method from coal-fired generation to gas-fired generation. This ratio considers efficiency, emissions intensity factor and price levels of both coal and natural gas inputs as parameters for calculation. Regarding this price, facilities captured by the ETS can switch coal-based production to natural gas-based production, if the allowance price is above the switching price level and vice-a-versa. To this extent for coal-fired power plant efficiency rate is 0.38 while emission intensity factor is 0.96 tCO_2/MWh. For a natural gas-fired power plant, these rates are 0.5 and 0.411 tCO_2/MWh, respectively.

$$\text{Fuel Switching Price} = \frac{(\text{Natural Gas Price} / 0.5) - (\text{Coal Price} / 0.38)}{0.96 - 0.411}$$

The values for thermal efficiencies and emission factors are collected from Thomson Reuters Point Carbon database. Relying on these values, the ratio is calculated as above. Within the scope of this study, price levels used in the fuel switching price are derived from one-month forward prices.

4.2.1.3. Macroeconomic Activity Variables

Economic activities, expectations, and risk behavior are also considered as some of the key drivers of carbon prices. The increase in economic activities will boost production processes conducted by a higher amount of electricity and since electricity is generated by coal and natural gas inputs, raising production will drive up emission and implicitly demand for the EUAs. The same rationality is also valid for economic expectations and risk perception of market actors.

In this framework, the industrial production index (IPI) which is published by EUROSTAT can give a concrete overview of economic activity. IPI is a backward-looking indicator for business cycle conditions to capture monthly changes in the output of industries.

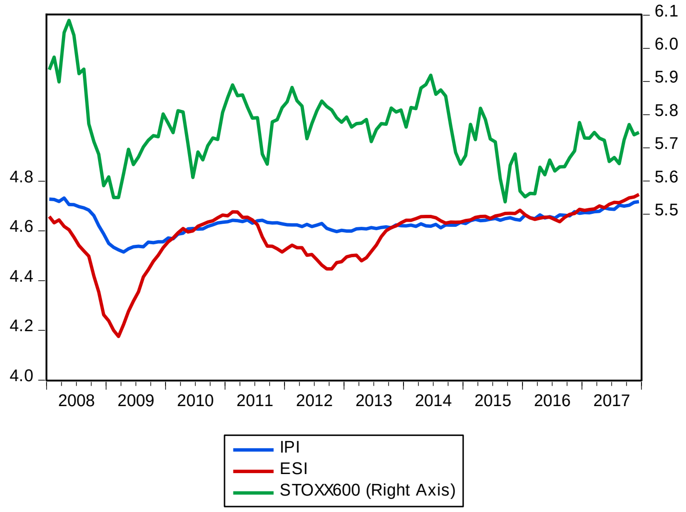

Figure 8: Macroeconomic Activity

Economic Sentiment Indicator (ESI) is another instrument used in our research. This is another composite indicator published by EUROSTAT and it compiles the indexes prepared to measure confidence levels of industry, construction, retail trade, services sectors and consumers in an economy. ESI could be considered as a forward-looking indicator to estimate expectations of participants about economic activity.

Table 8: Correlation among Macroeconomic Activity Variables

	IPI	ESI	STOXX600
IPI	1	0.709	0.289
ESI	0.709	1	0.167
STOXX600	0.289	0.167	1

STOXX Europe 600 Oil & Gas (STOXX600) is a sectoral exchange market index which bunches oil and gas firms together. The index includes the leading 20 firms whose primary revenue source is oil and gas. The index is dominated by French and Great Britain firms whose weights are 33% and 32.2%, respectively. They are followed by Italian, Norwegian, and Spanish firms with 10.4%, 8.6%, and 5.8%

weights, respectively. STOXX600 can also be considered as a forward-looking indicator like ESI.

4.2.1.4. Variable for Weather Conditions

Emission trading schemes are closely linked with weather conditions due to the fact that almost 55% of emission allowances are held by facilities operated in heat or electricity sectors (Chevalier, 2017). This implies that extreme weather conditions like severe cold in winter can trigger the demand for heat and/or electricity consumption by households. Therefore, in the wake of this hoisted demand, more emission may be emitted by producers and this may increase the requirement for more emission allowances by facilities in the EU ETS. On the opposite direction, in a severe hot and dry season, due to the lack of adequate precipitation which is used as hydropower resource in a nuclear power generation process for instance, nuclear energy could be replaced by other conventional energy generation methods which are generally based on coal and/or natural gas (Chevalier, 2017). Since this chain reaction may soar the emissions by coal and natural gas producers, this will be reflected as the demand for emission allowances.

Concisely, an indicator which represents the temperature and weather conditions in the EU may play an essential role in EUA price drivers. To this extent in this study, heating degree day index (HDD) which is published by EUROSTAT will be used. The aim of HDD is to define the need for heating energy requirements of buildings and it is presented as a weather-based index. It is important to underline that by 2018 buildings in the EU are accounted for 40% of total energy consumption and 36% of total CO_2 emissions. (European Commission, 2018) By this index, a period of severe cold could be calculated regarding both outdoor temperature and average room temperature.

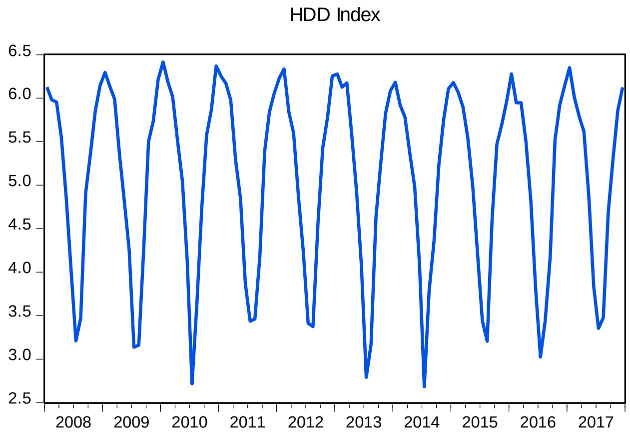

Figure 9: Heating Degree Days (HDD) Index

The HDD is provided in the country-specific form on monthly basis. Thus, in order to reflect the geographical distribution of the data correctly, index values are recalibrated by weighting with the population. Additionally, the variable is intentionally used seasonally unadjusted.

4.2.1.5. Dummy Variables

Dummy variables used in the study represent structural breaks observed in time series. In order to find out whether there is a break or not, breakpoint unit root test for the dependent variable is used. Additionally, during the modeling exercise stability analysis (CUSUM and CUSUM-Squared tests) show the exact dates when the model becomes unstable.

To this extent, "Dummy for 05.2011" is used for the first structural break that comes from the breakpoint unit root test run on the EUA price series. This dummy variable incorporates the effects of the European Debt Crisis and the European Commission's EU ETS regulation proposal which is presented in the previous chapter. After this date, the EUA prices had plummeted to the lowest levels since March 2009.

The other dummy variable which is “Dummy for Paris Agreement” implies that there is a structural break with the end of UNFCCC Negotiations held in December 2015 and the publication of the final version of the Paris Agreement. Despite it does not include explicit regulations or directions for the EU ETS, it shows a great ambitious towards low carbon economy and it introduces new mechanisms which can be integrated into the EU ETS after a while. This dummy variable has been identified from CUSUM and CUSUM-Squared stability analysis.

It is important to note that during the modeling study, the dummy variable for the transition from Phase II to Phase III is also considered; however, according to the regression results, this dummy is not statistically significant in any model structure and this finding is completely consistent with the finding of Tan and Wang (2017) which stated that none of the Phases division is statistically significant.

Table 9: Summary Table on Variables

Variables	Abbreviation	Data Source
European Union Allowances	EUA	ICE Exchange
Coal Futures (API2 CIF ARA (ARGUS-McCloskey)	Coal	CME database
UK NBP Natural Gas Futures	Gas	CME database
Brent Oil Futures	Brent	CME database
Fuel Switching Prices	FS	Author's Calculations
Industrial Production Index	IPI	EUROSTAT
Economic Sentiment Indicator	ESI	EUROSTAT
STOXX Europe 600 Oil & Gas Index	STOXX600	Reuters
Heating Degree Days Index	HDD	EUROSTAT

4.2.1.6. Summary and Descriptive Statistics

This study comprises Phase II and the first 5 years of Phase III of the EU ETS and it consists of EUA prices, natural gas, and coal future contracts prices and a theoretical fuel-switching price derived from these two contracts, industrial production index, economic sentiment indicator and STOXX600 prices. On the other side, CER and ERU prices are shown as significant drivers to explain EUA price dynamics (Mansanet-Bataller et al. 2011). However, with the regulations adopted in July 2011, in the beginning of Phase III of the EU ETS, the usage of offset tools has been constrained proportionally. Because of this reason, it is preferred not to include CER and ERU prices in this analysis.

Descriptive statistics of the variables used in the analysis is shown in Table 10 and statistics, show that EUA, oil, gas, ESI, and HDD are normally distributed at 5% significance level, while coal, IPI, STOXX600 and F.S. are not normally distributed according to the Jarque-Bera test statistics.

Table 10: Descriptive Statistics of Variables

	EUA	Oil	Coal	Gas	IPI	STOXX 600	FS	ESI	HDD
Mean	2.184	4.098	4.178	4.065	4.632	5.754	3.593	4.581	5.095
Median	2.074	4.116	4.170	4.142	4.630	5.759	3.618	4.633	5.487
Maximum	3.394	4.590	4.930	4.679	4.732	6.084	4.709	4.747	6.416
Minimum	1.224	3.351	3.673	3.264	4.515	5.537	2.560	4.176	2.683
Std. Dev.	0.523	0.315	0.254	0.299	0.046	0.105	0.426	0.118	1.061
Skewness	0.357	-0.398	0.382	-0.597	-0.220	0.368	0.099	-1.468	-0.685
Kurtosis	2.051	2.004	3.009	2.637	3.234	3.504	2.520	4.993	2.174
Jarque-Bera	7.051	8.119	2.916	7.793	1.239	3.984	1.351	62.968	12.782
Probability	0.029	0.017	0.233	0.020	0.538	0.136	0.509	0.000	0.002

4.2.2. Methodology and Model Specification

Autoregressive distributed lag (ARDL) approach and Toda-Yamamoto Granger Non-Causality Tests are used to conduct the analysis. Before moving onto the empirical analysis, these two approaches will be reviewed comprehensively.

4.2.2.1. Autoregressive Distributed Lag (ARDL)

In this research, a linear dynamic model which relies on Pesaran et al. (2001) multivariate autoregressive distributed lag (ARDL) approach to define short-run and long-run dynamics of prices in the EU ETS over the sample period between 2008 and 2017 in monthly basis is used. ARDL is a co-integration method to detect the short and long-run relationships among variables simultaneously developed by Pesaran and Shin (1999). Later, their method had been improved by Pesaran et al. (2001).

In the literature, on time series great importance is attached to the stationarity of the variables used in the studies. If this condition cannot be held, the researcher can suffer from spurious regression results. Additionally, as Maddala (2001) mentions time series tend to be non-stationary. The most prominent feature of the ARDL technique is making it possible to use both I(1) and/or I(0) variables together compared to other methods, particularly the famous Johansen method. Thus, it is possible to apply ARDL irrespective of the order of integration of the dataset unless having I(2) variables where the dependent variable should be I(1). This characteristic of ARDL also differs itself from VAR models. If one wants to work with non-stationary data through VAR models, this researcher needs to take the difference of the data and this operation causes loss of information and the loss of long-run relationship between series especially in small sample series (Brooks, 2014).

Since the ARDL technique looks for short and long-run equilibrium simultaneously, the error correction mechanism works without dropping long-run information. Additionally, due to the fact that ARDL enables to work with different lags for each variable unlike the other techniques, modeling exercise becomes more flexible to detect optimal lags for variables (Pesaran et al. 2001).

On the other hand, ARDL is not a sensitive technique to sample size which means that it is a more appropriate method for small samples (Pesaran and Shin 1998, Pesaran et al. 2001, Adom et al. 2012). A simple form of ARDL (p, q) model can be written as;

$$\vartheta(L)y_t = a_0 + \gamma(L)x_t + u_t \tag{1}$$

where, a_0 is the intercept term, L is the lag operator, $\vartheta(L)$ is a p-order polynomial, $\gamma(L)$ is a q-order polynomial, u_t is a random error term. This equation can be expressed in a different form by expanding lag polynomials as follows;

$$y_t = a_0 + \vartheta_1 y_{t-1} + \ldots.. \vartheta_p y_{t-p} + \gamma_1 x_{t-1} + \ldots \gamma_q x_{t-q} \ldots + u_t \tag{2}$$

To determine the short and long-run relationship among variables, the ARDL model may be used by considering its F-bounds test results. The F-bounds test is based on the Wald test; however, it uses different critical values provided by Pesaran et al. (2001) for the co-integration test. The null hypothesis of this F-statistics is that there is no co-integration among variables. Critical bound for I(0) implies that for F-statistics below the values of I(0) critical values, the null hypothesis is not rejected. In other words, there is no co-integration relationship among the variables. On the contrary, if F-statistics are above the I(1) critical bounds, this means that a co-integration relationship exists among variables. If the result of F-statistics lies between the I(0) and I(1) bounds, it implies inconclusiveness.

For this study which researches the interaction between the EUA prices and other variables, the linear regression can be expressed as follows by assuming n independent variables;

$$(Y) = a + \theta(X_1) + \pi(X_2) + \varphi(X_3) + \rho(X_4) \dots. + \tau(X_n) + u_t \quad (3)$$

where *Y* is the EUA prices, from X_1 to X_n are explanatory variables, a is the intercept and u_t is the disturbance term. In this respect, an ARDL representation of the equation above is formulated as follows:

$$\Delta(Y) = a_0 + \sum_{i=1}^{p} \emptyset_i \Delta (Y)_{t-i} + \sum_{i=1}^{q} \theta_i \Delta (X_1)_{t-i} + \sum_{i=1}^{q} \pi_i \Delta (X_2)_{t-i} + \sum_{i=1}^{q} \varphi_i \Delta (X_3)_{t-i} + \sum_{i=1}^{q} \rho_i \Delta (X_4)_{t-i} + \dots + \sum_{i=1}^{q} \tau_i \Delta (X_n)_{t-i} + \delta_1 (Y)_{t-1} + \delta_2 (X_1)_{t-1} + \delta_3 (X_2)_{t-1} + \delta_4 (X_3)_{t-1} + \delta_5 (X_4)_{t-1} + \dots + \delta_m (X_n)_{t-1} + \varepsilon_t \quad (4)$$

where Δ denotes the difference operator, and ε_t is the white noise residuals.

To detect the existence of co-integration relation, in this equation F-bounds test can be applied and the null hypothesis of this modified Wald test method will be H_0: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \dots = \delta_m = 0$. If a long-run relationship exists, then the long-run model will be as follows:

$$ln(Y) = \sigma + \sum_{i=1}^{p} \mu_1 (Y)_{t-i} + \sum_{i=1}^{q} \mu_2 (X_1)_{t-i} + \sum_{i=1}^{q} \mu_3 (X_2)_{t-i} + \sum_{i=1}^{q} \mu_4 ln (X_3)_{t-i} + \sum_{i=1}^{q} \mu_5 ln (X_4)_{t-i} + \dots + \sum_{i=1}^{q} \mu_m ln (X_n)_{t-i} + \omega_t \quad (5)$$

where σ is the intercept term, μ_i denotes the long-run coefficients and ω_t is the error term. For short -term relationship, the Error Correction Mechanism (ECM) regression is shown below;

$$\Delta(Y) = \alpha_0 + \sum_{i=1}^{p} \alpha_1 (Y)_{t-i} + \sum_{i=1}^{q} \alpha_1 (X_1)_{t-i} + \sum_{i=1}^{q} \alpha_1 (X_2)_{t-i} + \sum_{i=1}^{q} \alpha_1 (X_3)_{t-i} + \sum_{i=1}^{q} \alpha_1 (X_4)_{t-i} + \dots + \sum_{i=1}^{q} \alpha_1 (X_n)_{t-i} + \lambda EC_{t-1} + \upsilon_t \quad (6)$$

where λ denotes the speed of adjustment and the EC is the residual series that are obtained from the co-integration regression and υ_t is the disturbance term.

Despite the ARDL and related ECM results show very comprehensive information on the relationship among variables, these methods do not capture the direction of causality between the variables. Therefore, to follow-up the regression results, it is beneficial to touch upon Toda-Yamamoto Granger Non-Causality Test and its details.

4.2.2.2. Toda-Yamamoto Granger Non-Causality Test

Theoretically, Granger-causality and similar causality tests are labeled as sensitive to the number of lags used in the model and other specifications of the regression (Gujarati, 1995). When there is an integration among variables, the classic F-test process cannot provide consistent results (Gujarati, 2006). Since test statistics have not a standard distribution, F-statistics cannot be used to find Granger-causality. For such cases, the Toda-Yamamoto approach has been introduced by Toda and Yamamoto (1995). This method consists of a modified version of the Wald test for an autoregressive model structure. The modified structure of the Wald test comprises an asymptotic distribution of the Wald statistic. In other words, it regards an asymptotic $\chi2$-distribution. The most important feature for this causality test is that this method can be used with variables which have different order of integrations and when co-integration exists among variables (Toda and Yamamoto, 1995; Dolado and Lütkepohl, 1996).

To conduct the Toda-Yamamoto method, first, it is necessary to find the maximum order of integration of variables used in the analysis. Then this level is called "p". Next, it is required to find the optimal lag length of the model regressed. The appropriate maximum lag length is called as "m". Then a VAR model in the level of variables is established with the lag order of "p+m". At the final stage, a typical Wald $\chi2$ test is set to apply the Toda-Yamamoto Granger non-causality test.

To illustrate this method following formula is given in which a bivariate VAR ($m+p_{max}$) comprised of X and Y according to the Yamada (1998), is used;

$$X_t = \omega + \sum_{i=1}^{m} \theta_i X_{t-i} + \sum_{i=m+1}^{m+p_{max}} \theta_i X_{t-i} + \sum_{i=1}^{m} \varphi_i Y_{t-i} + \sum_{i=m+1}^{m+p_{max}} \varphi_i Y_{t-i} + \varepsilon_{1t} \quad (7)$$

$$Y_t = \gamma + \sum_{i=1}^{m} \tau_i Y_{t-i} + \sum_{i=m+1}^{m+p_{max}} \tau_i Y_{t-i} + \sum_{i=1}^{m} \vartheta_i X_{t-i} + \sum_{i=m+1}^{m+p_{max}} \vartheta_i X_{t-i} + \varepsilon_{2t} \quad (8)$$

where ω, θ,φ, τ, ϑ and γ are parameters of the model while the p_{max} is the maximum order of integration found among variables. The null hypothesis of non-causality test can be expressed as H_0: $\delta_i = 0$, $\forall$ i=1, 2,...., m.

4.3. Empirical Analysis and Results

After describing the data and reviewing the methods adopted in the study, in this section the conducted analysis is explained. In this respect, primarily unit root tests are presented. Then a bunch of models which have different variables in each is analyzed and for the most proper one, diagnostic tests are being applied. Following, F-bounds tests and model interpretations are given and short and long-run relationships are introduced. Last but not least, Toda-Yamamoto Granger Non-causality test is held in order to introduce the direction of causalities in this relationship.

4.3.1. Unit Root Tests

To make a sound and robust estimation for our analysis, it is necessary to ensure that all variables used in the regression are integrated of order less than 2 and the dependent variable is non-stationary. To this extent, we conduct both Phillips-Perron (PP) and Augmented Dickey-Fuller (ADF) tests to reach a consistent result. The null hypothesis for both tests is that variable follows a unit root process.

Table 11: Summary Table for PP Unit Root Test

UNIT ROOT TEST TABLE (PP)									
At Level									
	EUA	**Coal**	**Gas**	**Oil**	**IPI**	**STOXX600**	**FS**	**HDD**	**ESI**
t-Statistic	-18.139	-24.015	-25.768	-16.471	-21.417	-32.939	-26.611	-40.183	-19.153
Prob.	***0.3723***	***0.1435***	***0.1006***	***0.4555***	***0.2290***	***0.0173***	***0.0839***	***0.0019***	***0.3243***
Stationarity	no	no	no	no	no	**	*	***	no
At First Difference									
	ΔEUA	**ΔCoal**	**ΔGas**	**ΔOil**	**ΔIPI**	**ΔSTOXX600**	**ΔFS**	**ΔHDD**	**ΔESI**
t-Statistic	-134.014	-94.044	-102.638	-86.538	-97.904	-108.923	-111.169	-46.152	-50.013
Prob.	***0.0000***	***0.0000***	***0.0000***	***0.0000***	***0.0000***	***0.0000***	***0.0000***	***0.0002***	***0.0001***
Stationarity	***	***	***	***	***	***	***	***	***
Notes: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%. and (no) Not Significant *MacKinnon (1996) one-sided p-values.									

According to PP test statistics, logarithmic forms of the EUA, coal, gas, oil prices and IPI are integrated into I(1), while the price level of STOXX600, HDD, and FS are integrated into levels, in other words, they are I(0) according to different significance levels.

Table 12: Summary Table for ADF Unit Root Test

UNIT ROOT TEST TABLE (ADF)									
At Level									
	EUA	**Coal**	**Gas**	**Oil**	**IPI**	**STOXX600**	**FS**	**HDD**	**ESI**
t-Statistic	-18.653	-19.773	-22.655	-16.471	-32.996	-31.856	-25.254	-25.684	-28.293
Prob.	***0.3476***	***0.2965***	***0.1849***	***0.4555***	***0.0171***	***0.0233***	***0.1120***	***0.1027***	***0.0573***
Stationarity	no	no	no	no	**	**	no	no	*
At First Difference									
	ΔEUA	**ΔCoal**	**ΔGas**	**ΔOil**	**ΔIPI**	**ΔSTOXX600**	**ΔFS**	**ΔHER**	**ΔESI**
t-Statistic	-133.818	-92.591	-102.486	-86.800	-30.905	-108.924	-111.195	-102.49	-48.544
Prob.	***0.0000***	***0.0000***	***0.0000***	***0.0000***	***0.0300***	***0.0000***	***0.0000***	***0.0000***	***0.0001***
Stationarity	***	***	***	***	**	***	***	***	***
Notes: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%. and (no) Not Significant *MacKinnon (1996) one-sided p-values.									

For ADF test statistics, IPI data is also integrated into levels, so I(0). However, in ADF, ESI becomes stationary at level while FS and HDD become stationary at I(1). It is concluded that there is no unit root in differences in both tests. It is important to note that neither series is I(2). This is vital for our analysis to conduct the ARDL approach as described above.

In brief, the variables that we use in our analysis contain different order of integrations which are I(0) and I(1). For further analysis, we begin to conduct a deeper analysis of modeling practice.

4.3.2. Model Estimation

For model selection, first, we need to determine which variables should be included in the regression. Within this scope, looking for different model specification could be beneficial in order to define the most appropriate variables. In this process, it is begun by including all variables described above in the regression. Then regarding their significance, they are deleted and/or replaced. Since in ARDL, determining the lag structure is crucial, at first step it is necessary to specify the appropriate lag length for the model taking into consideration the variables used. In this selection process, an optimal combination of the model is calculated based on the Akaike Information Criteria method (AIC).

For the analysis, four models are reviewed in which the EUA prices is selected as the dependent variable. In first regression (1), coal and natural gas prices, IPI, ESI, and HDD index are selected as independent variables. Dummy variables for 05.2011 and Paris Agreement are also added to the regression. In the second model (2), just coal and natural gas prices variables are replaced by fuel switching prices. In addition to the variables chosen in (2), in the third model (3), oil prices and STOXX600 index are also captured. In the fourth model (4), FS is replaced with coal and natural gas prices to see the effects of oil and STOXX600 index on the first model structure. The results of ARDL regression are shown in Table 13 and Table 14 below.

Table 13: Short Run Coefficients

Variable/Model	(1)	(2)	(3)	(4)
CointEq (-1)	-0.394441*** [-7.446258]	-0.284492*** [-5.788713]	-0.391611*** [-7.639154]	-0.380947*** [-7.400464]
C	-13.81483*** [-7.448608]	-6.170693*** [-5.794859]	-5.647405*** [-7.644009]	-11.59315*** [-7.404565]
Δ EUA (-1)	-0.190981** [-2.495605]	-0.210884** [-2.592907]	-0.161604** [-2.195424]	-0.189105** [-2.467129]
Δ Gas	-0.077056 [-0.720891]			-0.054503 [-0.516242]
Δ IPI	1.383322 [0.990379]			
Δ ESI	1.210599* [1.749843]	2.380758*** [3.236040]		1.107796 [1.598686]
Δ ESI (-1)	0.189422 [0.214185]	-0.235831 [-0.281618]		-0.389866 [-0.502509]
Δ ESI (-2)	-1.671861** [-2.444228]	-1.418731* [-1.914350]		-1.457572** [-2.139955]
Δ HDD	0.040534** [2.281597]		0.036792* [1.794598]	0.033329* [1.905095]
Δ HDD (-1)			-0.041333** [-2.006659]	
Dummy for 05.2011	-0.245744*** [-6.128649]	-0.265084*** [-5.137738]	-0.195886*** [-5.595213]	-0.226009*** [-5.898709]
Dummy for Paris Agreement	-0.395249*** [-6.460412]	-0.138932*** [-3.395614]	-0.345201*** [-6.191944]	-0.376093*** [-6.331329]
R^2	0.461378	0.338102	0.402212	0.455563
AIC	-1.353106	-1.198291	-1.326047	-1.352063

Note: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%. t-statistics are in brackets.

Table 14: Long Run Coefficients

Variable/Model	(1)	(2)	(3)	(4)
Coal	0.502953** [2.416466]			0.586505** [2.016632]
Gas	-1.160986*** [-4.897760]			-0.967265*** [-3.650504]
Oil			-0.873049*** [-4.092484]	-0.275522 [-0.963269]
FS		0.181789 [1.276628]	0.513834*** [3.992325]	
IPI	9.318889*** [4.690320]	4.887644** [2.022850]	3.252063*** [2.727250]	7.663902*** [3.227675]
STOXX600			0.607104 [1.114987]	0.416726 [0.761773]
ESI	-0.606233 [-1.185503]	0.322695 [0.439540]	0.062997 [0.158396]	-0.443652 [-0.788118]
HDD	0.008981 [0.287069]	-0.040576 [-0.946237]	-0.002252 [-0.055347]	-0.010462 [-0.291733]

According to both R^2 and AIC statistics, the first model specification is selected to be analyzed in-depth. It has the highest R^2 and the lowest AIC value relative to other models but also all the variables used in this model are statistically significant either in short or long-run. To juxtapose regression (1) with regression (4); model (1) does not include oil and STOXX600 variables which are statistically insignificant in (4), although R^2 and AIC statistics are very close to each other. Regressions (2) and (3) which involve FS variable instead of fossil fuels separately, have lower R^2 and higher AIC statistics compared to other models.

Before progressing further, it is useful to assess the findings from modeling exercises with earlier studies. In model (1), oil and FS variables cannot be used as determinants of the EUA prices. While not using FS is consistent with the findings of Rickels et al. (2014) and Delarue (2010), this is not compatible with the results of Creti et al. (2012) and Hammoudeh et al. (2014). On the other hand, Rickels et al. (2014) and Creti et al. (2012) argue that oil is a statistically significant explanatory variable for the EUA, but Reboredo (2014) reveals contrary results. Oberndorfer (2009) and Rickels et al. (2014) also claim that stock market indicators like STOXX600 are statistically significant in their models. However, FS, oil and STOXX600 have not been comprised in our final model in order to maximize model selection criteria and R^2.

Table 15: F-Bounds Test Results

Model	**(1)**		**(2)**		**(3)**		**(4)**	
F-statistic	8.805224		6.455900		7.886037		6.397999	
	I(0)	***I(1)***	***I(0)***	***I(1)***	***I(0)***	***I(1)***	***I(0)***	***I(1)***
10%	2.26	3.35	2.45	3.52	2.12	3.23	2.03	3.13
5%	2.62	3.79	2.86	4.01	2.45	3.61	2.32	3.5
2.5%	2.96	4.18	3.25	4.49	2.75	3.99	2.6	3.84
1%	3.41	4.68	3.74	5.06	3.15	4.43	2.96	4.26

As aforementioned, in the model selection process AIC approach is used. According to this criterion, to find the optimal specification it is necessary to look for the model which gives the lowest value. The results for the top 20 models selected are presented in the Figure 10.

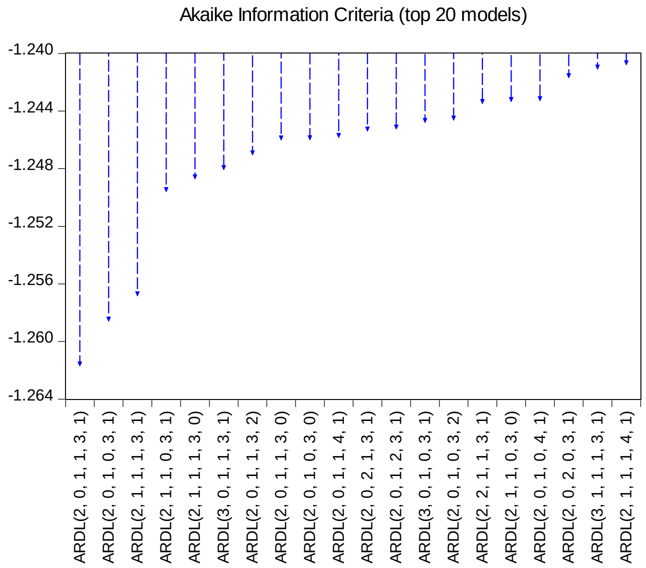

Figure 10: Akaike Information Criteria (AIC) Selection Process

Taking these results into consideration, model specification with ARDL (2,0,1,1,3,1) is selected because this lag structure has the lowest value for our regression. This lag structure implies to use 2 lags for the EUA, no lag for coal, 1 lag for gas, IPI and HDD and 3 lags for ESI. Then ARDL regression can also be formulated as follows:

$$\Delta(EUA) = -13.814 - 0.394(EUA)_{t-1} + 0.198(Coal)_t - 0.458(Gas)_{t-1} + 3.676(IPI)_{t-1} - 0.239(ESI)_{t-1} + 0.003(HDD)_{t-1} - 0.191\,\Delta(EUA)_{t-1} - 0.08\Delta(Gas)_t + 1.383\Delta(IPI)_t + 1.211\Delta(ESI)_t + 0.189\Delta(ESI)_{t-1} - 1.672\Delta(ESI)_{t-2} + 0.040\Delta(HDD)_t - 0.246\,[(EUA) - (0.503(Coal)_{t-1} - 1.161(Gas)_{t-1} + 9.319(IPI)_{t-1} - 0.606(ESI)_{t-1} + 0.009(HDD)_{t-1}) - 0.246\,(DUMMYFOR05.2011) - 0.395(DUMMYFORPARISAGREEMENT)] \qquad (9)$$

Before starting the in-depth analysis of the model results, to avoid estimation bias primarily it is required to conduct diagnostic tests including Stability tests consisting of CUSUM and CUSUM-Squared, Lagrange Multiplier (LM) test, Autoregressive Conditional Heteroskedasticity (ARCH) test.

4.3.3. Stability, Autocorrelation and Heteroskedasticity Tests

To measure the soundness of the regression, we need the make diagnostics tests which are stability, autocorrelation, and heteroskedasticity. Firstly, the stability of the regression with CUSUM and CUSUM Squared tests are analyzed to ensure that there are not any recursive residuals because of structural breaks which are not reflected in the regression via dummy variables. As it can be seen in the graphs presented below, in both tests model performs well and stays between the 5% significance levels which means that dummy variables selected are appropriate and it is not necessary to add another dummy variable to represent a structural break.

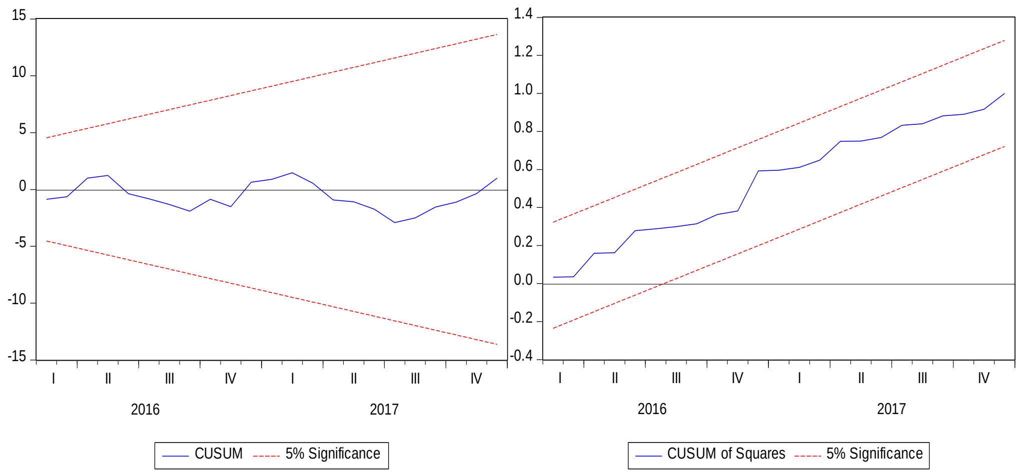

Figure 11: CUSUM and CUSUM-Squared Tests Results

At the next stage, it is important to measure whether there are any autocorrelation or heteroskedasticity problems. The null hypothesis for the autocorrelation test is that the residual series are serially uncorrelated. F-statistic for this test is 0.472 and p-value is 0.8276 which implies that the null hypothesis cannot be rejected, thus there is no autocorrelation problem.

Table 16: Breusch-Godfrey Serial Correlation LM Test Results

Null hypothesis: No serial correlation			
F-statistic	0.471894	**Prob. F (6,94)**	0.8276
Obs*R^2	3.421100	**Prob. $\chi2$ (6)**	0.7544

For heteroskedasticity, the ARCH test could be applied. For this test, the null hypothesis is that residuals are homoskedastic. F-statistic is 1.84 and p-value is 0.126 for this test proves that there is no heteroskedasticity problem.

Table 17: Heteroskedasticity Test: ARCH Results

Null hypothesis: No ARCH effect			
F-statistic	1.842127	**Prob. F (4,108)**	0.1260
Obs* R^2	7.217232	**Prob. $\chi2$ (4)**	0.1248

4.3.4. Bounds Test and Model Interpretation

After checking the diagnostic tests, it is possible to interpret the ARDL regression. As shown in the table below, in the ARDL model, first we need to look at F-value in Bounds Test to check the existence of co-integration among variables subjected to the research. The null hypothesis of the Bounds test stands for no co-integration among variables. F-value of Bounds test is 8.805 and this value is higher than both I(0) and I(1) critical value bounds. In other words, rejecting the null hypothesis is possible, therefore it can be concluded that co-integration among variables exists.

Table 18: F-bounds Test Results

Test Statistic	**Value**	**Signif.**	**I(0)**	**I(1)**
F-statistic	8.805224	10%	2.26	3.35
k	5	5%	2.62	3.79
		2.5%	2.96	4.18
		1%	3.41	4.68

Since a co-integration relationship exists, it is necessary to check its meaningfulness. To do this check, it is possible to look for the t-Bounds test which shows whether existing co-integration relation makes sense or not. The null hypothesis shows nonsensical co-integration. Since the t-statistic is higher than both I(0) and I(1) critical bounds in absolute terms, it is possible to reject the null hypothesis.

Table 19: t-Bounds Test Results

Null Hypothesis: No levels relationship				
Test Statistic	**Value**	**Signif.**	**I(0)**	**I(1)**
t-statistic	-7.446258	10%	-2.57	-3.86
		5%	-2.86	-4.19
		2.5%	-3.13	-4.46
		1%	-3.43	-4.79

After checking all the tests and they point that there is a meaningful co-integration relationship. Therefore it is possible to analyze variables one-by-one regarding their short-run and long-run effects. Short-run analysis implies that all variables may change from one month to other, however, in long run there is a steady state for the economy, thus, variables are not affected by short-time shocks or price volatilities. Within this framework, according to co-integration relationship, in the long-run coal prices are statistically significant at 5%. Natural gas prices and IPI are statistically significant at 1% significance level in long-run. On the other hand, the HDD and ESI are not statistically significant in the long-run.

When we look at the signs of coefficients, all of them are consistent with expectations. According to the ECM regression results shown below, the speed of adjustment value is -0.39, and it is statistically significant. This value implies that 39% of the change in the price level of EUA into disequilibrium can be corrected within 1 month.

Table 20: ECM Regression Results

Variable	Coefficient
CointEq(-1)	-0.394441*** (-7.446258)
C	-13.81483*** (-7.448608)
∆(EUA(-1))	-0.190981** (-2.495605)
∆(GAS)	-0.077056 (-0.720891)
∆(IPI)	1.383322 (0.990379)
∆(HDD)	0.040534** (2.281597)
∆(ESI)	1.210599* (1.749843)
∆(ESI(-1))	0.189422 (0.214185)
∆(ESI(-2))	-1.671861** (-2.444228)
Dummy for Paris Agreement	-0.395249*** (-6.460412)
Dummy for 05.2011	-0.245744*** (-6.128649)

Note[1]: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%. t-statistics are in brackets.

Note[2]: For further analysis, findings which are significant at 10% are disregarded.

Nonetheless, for short-run, the change in natural gas, coal, prices and industrial production index are statistically insignificant to explain the change in EUA prices. These results contradict with Nazifi and Milunovich (2010) in which they claim that while there is no long-run relation between fossil fuels and EUA, albeit a relationship exists in the short-run. On the other hand, the finding that IPI does not affect EUA prices in the short-run is compatible with the results of the study conducted by the European Commission (2014).

Meanwhile in the short-run, lagged values of EUA prices and ESI, HDD index and dummy variables are statistically significant. The result for ESI implies that economic expectations have a determining role in short-run on EUA prices with differenced effect. While all other variables are constant, if the level of the economic sentiment indicator 2 months ago had decreased by 1%, current EUA prices will increase by 1.67%. This finding could be depicted such that as the expectations of economic actors for the economy getting worse, they prone to invest less in low carbon production methods and such a downturn in expectation shows its impact on EUA prices in 2 months. Then, the change in investment decision leads to an upward trend in emissions and boost the usage of cheaper and dirtier inputs like coal.

Furthermore, the EUA prices are affected by their lagged value negatively, in other words, current EUA prices will recede by 0.19%, if lagged prices of EUA increases by 1%. This is the evidence that price of EUA captures the history of price changes and it asserts that as EUA prices decrease, facilities boost their demand for EUA in the next period. This finding is also proved by Fezzi and Bunn (2009), Hammoudeh et al. (2014), European Commission (2014). Additionally, HDD which is used as a proxy for weather and temperature conditions affects EUA prices immediately. Assuming that all other conditions are the same, if the value of HDD rises by 1%, EUA prices will surge by 0.04%. By the same token, for the short-run period the evidence for the significance of the HDD implies that fossil fuel consumption is still a crucial driver to meet the heating requirements of buildings in Europe and this points out that for the covered period, renewable sources fail to be considered as a perfect substitute of fossil fuels in this area. The effectiveness of weather and temperature conditions on carbon prices is also argued by Alberola et al. (2008), Chevallier and Zhu (2017) and Zhaou et al. (2017). On the contrary, the significance of climatic variables is rejected by Lutz et al. (2013), Hintermann et al. (2016); and Koch et al. (2014). For this variable the difference in results might be due to the preference of proxy variables to represent weather conditions. For instance, while Lutz et al. (2013) use renewable energy production capacity as an indicator, Hintermann et al. (2016) use electric load values, hydro and wind power provisions. Besides these proxies Bredin and Muckley (2011) use absolute deviations from mean temperatures as indicator of weather and temperature conditions.

Furthermore, as the result of the analysis, it is observed that both of dummy variables are significant at 1% level. To this wise, the Paris Agreement affected EUA prices negatively by 0.39%. Despite the fact that the Paris Agreement could be seen as the powerbroker treaty in the fight against climate change, due to the blurry, unclear and disputable articles about the emission trading mechanisms in the Agreement, assertive statements made on the success of the Agreement have not found a ground in the EU ETS. Moreover, other dummy variable which stands for EU ETS regulation changes has an impact on EUA prices by 0.25% in negative way.

Table 21: Levels Equation

Variable	Coefficient
Coal	0.502953** (2.416466)
Gas	-1.160986*** (-4.897760)
IPI	9.318889*** (4.690320)
HDD	0.008981 (0.287069)
ESI	-0.606233 (-1.185503)
Case: Unrestricted Constant and No Trend *Note: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%. t-statistics are in brackets.*	

In long-run, coal prices affect EUA prices positively because increasing demand for coal causes higher emissions. Then facilities raise their demand also for more emission allowances. To this extent, while all other variables are constant, an increase by 1% in the coal prices leads a 0.5% increase in EUA prices. The positive coefficient of coal prices is a contrary finding with Alberola et al. (2008), Mansanet-Bataller et al. (2011), Schumacher et al. (2012), Aatola et al. (2013), European Commission (2014) and Rickels et al. (2014). The reason may be related to the preference of the features of the coal variable because as it is mentioned also in their paper, Schernikau (2010) and in Zaklan et al. (2012) argue that there are various prices for coal which differ according to their maturities, trading places, type of contract etc.

Natural gas prices have a negative effect on EUA prices due to the fuel-switching behavior of facilities. In other words, since the natural gas is less emitting input than coal, a boost in the demand for natural gas decreases the requirement for additional emission allowances. If natural gas prices increase by 1%, this gives rise to 1.16% decline in carbon prices. This result is endorsed by Bertrand (2013) and he finds that with the increase in the demand for natural gas in power generation, CO_2 demand is diminished and thereby EUA prices are affected negatively. It can be noticed that the signs of coal and natural gas are different from those specified in most of the literature review. This discrepancy could arise from including more years into this analysis.

Similarly, with soaring industrial production, EUA prices climb up. Moreover, a surge by 1% in the IPI paves the way for an increase by 9.32% in allowance prices, and this consequence shows that the most influential factor among variables selected for this study on the EUA prices in the long run is IPI. This finding may be an evidence of the fact that industrial production fundamentals mostly continue to rely on dirty inputs in production processes. The positive effect of the IPI is consonant with the findings of Alberola et al. (2009), Chevallier (2011) and Sousa and Aguiar-Conraria (2014).

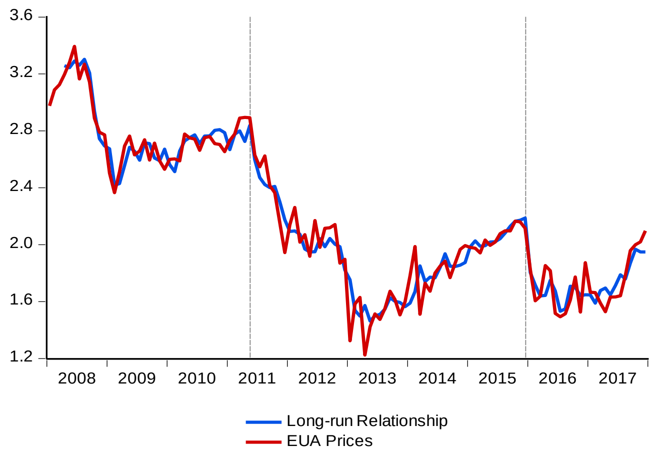

Figure 12: EUA Prices and Long-Run Relationship

To visualize the fitness of co-integration relationship and the dependent variable, the figure 12 is presented. It is obvious that there is a close relationship between these two lines.

At the next stage of the study, the causality puzzle among variables will be solved. In other words, causality direction among EUA prices and other variables through the Toda-Yamamoto Granger Non-Causality Test is tried to be derived.

4.3.5. Toda-Yamamoto Granger Non-Causality Test

The Toda-Yamamoto Granger non-causality test that is used to find the causality relationship among variables which are integrated of different orders are applied in the study since our variables consist of both I(0) and I(1). Another characteristic of this method can be counted as the ability of application for both co-integrated and not co-integrated series. The preconditions of this test are that inverse roots of autoregressive characteristic polynomial should not exceed the limits of the unit circle and the existence of the co-integration. These specifications are important to enable the test to estimate robust causality results. The process is embarked with the selection of proper lag structure.

Table 22: VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	330.9633	NA	1.66e-10	-5.490584	-5.058553	-5.315247
1	968.1695	1173.801	4.37e-15	-16.03806	-14.74197	-15.51205
2	**1054.638**	**150.1819**	**1.82e-15***	**-16.92347***	**-14.76332***	**-16.04679***
3	1086.739	52.37554	1.98e-15	-16.85507	-13.83085	-15.62771
4	1115.998	44.65911	2.29e-15	-16.73681	-12.84853	-15.15878
5	1136.656	29.35538	3.15e-15	-16.46765	-11.71530	-14.53894
6	1187.236	66.55325*	2.61e-15	-16.72345	-11.10704	-14.44406

According to the VAR lag order selection criteria test, FPE, AIC, SC, and HQ indicate that 2 lag structure is the most suitable one for our model. Furthermore, since inverse roots of AR characteristic polynomial are in the limits of the circle shown in the graph below the Toda-Yamamoto Granger non-causality test can be conducted.

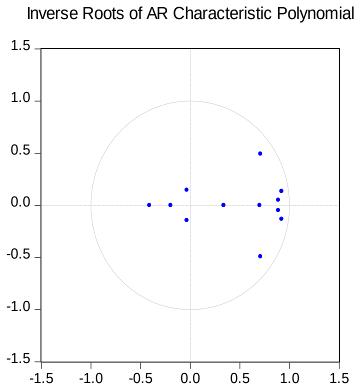

Figure 13: Inverse Roots of AR Characteristic Polynomial Graph

In order to meet the preconditions for the Toda-Yamamoto Granger non-causality test process, lastly it is required to check the co-integration relationship among the variables.

Table 23: Unrestricted Cointegration Rank Test (Trace) Test Results

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.382793	113.1871	95.75366	0.0019
At most 1	0.219322	57.21119	69.81889	0.3308
At most 2	0.164596	28.49053	47.85613	0.7920
At most 3	0.033938	7.629114	29.79707	0.9980
At most 4	0.027100	3.623986	15.49471	0.9315
At most 5	0.003760	0.436963	3.841466	0.5086
Trace test indicates 1 cointegrating eqn(s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level **MacKinnon-Haug-Michelis (1999) p-values				

Table 24: Unrestricted Cointegration Rank Test (Maximum Eigenvalue) Results

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.382793	55.97590	40.07757	0.0004
At most 1	0.219322	28.72066	33.87687	0.1822
At most 2	0.164596	20.86141	27.58434	0.2847
At most 3	0.033938	4.005128	21.13162	0.9994
At most 4	0.027100	3.187024	14.26460	0.9335
At most 5	0.003760	0.436963	3.841466	0.5086

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

According to both of Johansen's Trace Test and Max. Eigenvalue Test, one can easily observe the presence of one co-integration equation at 5% significance level. The existence of co-integration relation paves the way for conducting the Toda-Yamamoto Granger non-causality test and the summary results are presented in Table 25.

Table 25: Summary of Granger Causalities

Null hypothesis: Not Granger cause						
Dependent Variables	**EUA**	**Coal**	**Gas**	**IPI**	**ESI**	**HDD**
Independent Variables	Coal**	EUA	EUA	EUA	EUA**	EUA
	Gas***	Gas***	Coal**	Coal***	Coal	Coal
	IPI*	IPI	IPI**	Gas*	Gas**	Gas
	ESI	ESI	ESI	ESI***	IPI	IPI
	HDD	HDD	HDD *	HDD	HDD	ESI

Note: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1%.

Taking all the relationship among variables which are obtained from the Toda-Yamamoto Granger non-causality test into consideration, the relationship between EUA, gas, coal, IPI, ESI, and HDD are visualized as Figure 14.

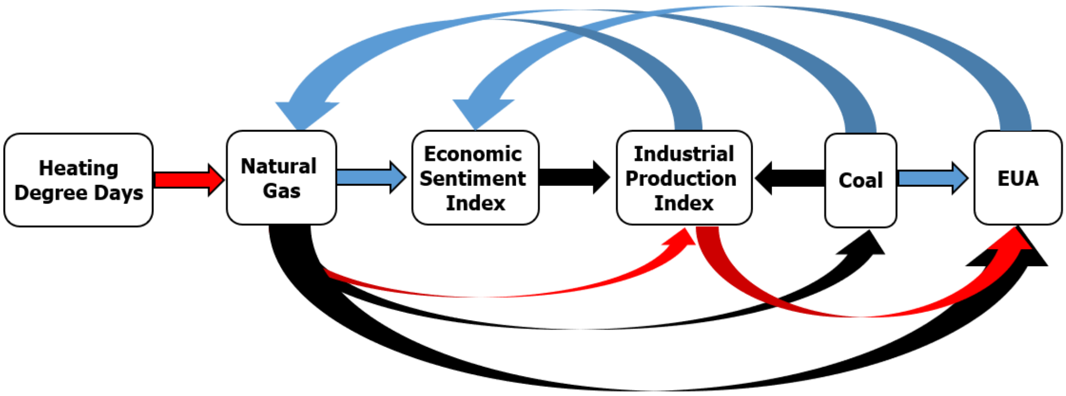

Figure 14: Granger Causality between Variables[6]

According to the test results, weather conditions only affects natural gas prices directly.[7] This finding is utterly the same as the results of Keppler and Mansanet-Bataller (2010) which capture solely the first 3 years of Phase II. This means that the effect of this variable comes through all variables which are affected by natural gas since the natural gas prices comprehensively interact with other variables. It affects ESI, coal and EUA directly. With an alternative statement, due to the fact that natural gas is the prevailing energy source in terms of heating, worsening of weather conditions in the EU may lead to a surge in natural gas consumption and this will pave the way for an increase in the prices of EUA. Furthermore, another interesting interaction observed in the analysis is that natural gas affects directly ESI which, but coal is not a decisive factor for ESI directly. This may pinpoint the fact that when economic expectations are shaped, coal-based investments are considered less than

[6] Red lines represent significance at 10%, Blue lines stand for significance at 5% and Black lines show significance at 1% level.

[7] This relationship is significant at 10% with 0.0567 p-value, however it is included in the analysis since it is considered as an important relationship to mention due to theoretical concerns. For further analysis, findings which are significant at 10% are disregarded.

natural gas-based investments which may alternatively signify that investment decisions have become shaped by less polluter energy sources like natural gas rather than the polluter ones like coal.

On the other hand, natural gas is affected by IPI and coal. Therewithal, coal has a direct effect on EUA, gas and IPI. This result shows that industrial production in the countries captured in the EU ETS is fed by coal and natural gas prices, however, the industry has a force to affect natural gas prices. This may pinpoint that European industry still heavily relies on dirty inputs and industrial production causes to environmental maleficence. It is worth to emphasize that there is no straight-forward Granger-causality observed from EUA neither to coal nor to natural gas prices. This shows that carbon pricing policies are still powerless to affect fossil fuel consumptions.

On the EUA prices, the effect of natural gas comes from both directly and indirectly through ESI and IPI. At this point, it is also observed that there is a feedback mechanism between EUA prices and ESI which implies that EUA is considered as a determinant that affects the decisions and expectations of economic actors.

It is also possible to argue that ESI which is guided by expectations about macroeconomic activity has a role in industrial decision-making process due to the one-way Granger causality from ESI to IPI. This finding is endorsed by theoretical expectations because while ESI is a forward-looking indicator, IPI is a backward-looking one. This ordinary finding makes interactions among variables more intriguing when other causalities are taken into consideration. When the economic expectations are shaped directly by natural gas which is a relatively cleaner input, industrial production processes rely on dirtier input which is coal. Moreover, according to test results, though coal has an impact on industrial production, industrial production affects only natural gas among fossil fuels. This evidence may be construed as industrial production processes may be shifted towards using natural gas more than coal after the economic expectations have started to be considered and this may be signal for the transition towards low-carbon economy in the EU, but still in it is early to make such a conclusion.

CHAPTER 5

CONCLUSION

Since extreme weather events, natural catastrophes, ecosystem degradations and extinction of some species have started to be observed more often, climate change has become one of the most discussed topics in the global agenda. In this context, as a result of the international negotiations held under the United Nations since the beginning of the 1990s, legal texts such as the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol and recently the Paris Agreement have been put forward. These texts capture not only environmental principles, rules and procedures but also provide financial flows from developed country parties to developing country parties in order to support their efforts to cope with the adverse effects of climate change. More importantly, they also aim to establish international emission trading mechanisms in order to promote the actions taken by parties to curb their emissions in a cost-effective way.

The previous international climate change regime is based on only developed countries' bearing the brunt of emission reduction. With the new regime established with the Paris Agreement, all countries are committed to undertake the responsibility for emission reduction regarding the common but differentiated responsibilities and their respective capabilities. In this context, developing country parties have started to implement various policy options in the fight against climate change. In this manner, mainly countries put into action two different policy tools which are command-and-control tools and carbon pricing tools. Due to the fact that command-and-control mechanisms impose significant costs on economic actors and this may affect the economies adversely, especially during financial crises which have seriously weakened the economies, it has become necessary to carry out policies to combat climate change with cost-effective and innovative methods. In this context, the struggle against this multi-dimensional problem should be supported not only by environmental policies but also by different policy tools in different policy areas.

Stressing that climate change is a serious market failure, the solution must be designed in a way to remove externalities rooted by climate change and therefore internalizing costs into the price mechanism. As a matter of fact, countries intend to carry out their emission reduction targets in a way that minimizes the costs for their economies while internalizing the externalities due to climate change. At this point, it is important to use carbon pricing tools to combat climate change which is also regarded as the biggest market failure seen in human history. In particular, over the last 20 years, carbon pricing practices have become more widespread worldwide in the fight against climate change.

Emission trading schemes (ETS) and carbon taxes are the most common tools among carbon pricing mechanisms. While carbon taxes are preferred to limit emission by ensuring a specific amount of public revenue, emission trading schemes have specific emission reduction targets, but the amount of public revenue generated is ambiguous. Since emission trading schemes require very comprehensive administrative details like monitoring the emission data of each facility subjected to the scheme which bring considerable costs for governments, developing countries prefer to apply carbon tax at first by amending their current tax structures to some extent. However, due to the urgency of taking concrete actions to combat against climate change, even developing countries have started to schedule or consider emission trading schemes either as an extension of current carbon tax structures or as a substitute. In other words, since the adverse effects of climate change are getting stronger and harmful, the policy priorities have started to be shifted from generating public revenues to mitigate emissions urgently. Therefore, it is likely to expect that in the near future, the number of emission trading schemes will be increased, and the effectiveness of currently applied schemes will be improved.

Among the ETS implementations, the European Union Emission Trading Scheme (EU ETS), which came into force in 2005, has been a spearhead example for other country practices in terms of design with its scope, the dimensions it reaches and also the challenges that are encountered. The Scheme captures 31 countries and covers nearly 45% of the emissions from the European Union (EU), Iceland, Liechtenstein, and Norway. The EU ETS accounts for 75% of international emission allowance trading. The fact that the EU ETS has experienced a lot of challenges to overcome price volatilities and to sustain market stability, the Scheme includes fruitful lessons to be learnt for other systems. The pricing behavior have been hampered seriously because of the global financial crisis, fraud activities due to the loose registry requirements for new entrant actors in the market, the European Debt crisis and the inadequate progress in the international climate change negotiations. Since an increase in emission allowances prices implies additional costs for facilities captured by the Scheme or vice-a-versa, it is expected that these price fluctuations will have spillover effects on the other macroeconomic variables. In this context, with the policy interactions like regulations put into force by the European Commission, carbon prices are tried to be kept under control.

Regarding all of the aforementioned issues, the main purpose of the thesis is to discover the drivers of the EU ETS by analyzing the interactions among allowance prices and macroeconomic variables including energy markets, stock markets, industrial performance, economic expectations, and other relevant variables. In this way, it is aimed to contribute a better understanding of the functioning of the market. For this reason the relationship between the EU ETS and price developments in other relevant markets and/or indicators will be clarified. Understanding this will contribute to the idea of how the ETS can be used more effectively in the future, as well as providing lessons for the countries planning to use ETS as a policy tool. As a matter of fact, the correct interpretation of the relationship of ETS with other variables will help the market players covered by ETS to use this market more accurately and interpret the price movements properly.

In this study, the Autoregressive Distributed Lag Model (ARDL) has been adopted due to the specifications of the data used. i.e. the variables include both non-stationarity and also stationarity at level. In order to find the causality directions among the variables, Toda-Yamamoto Non-Granger Causality test methodology is used because of the same reasons that are encountered in the ARDL approach. The time period subjected to the analysis starts on January 1, 2008 and ends on December 31, 2017. In other words, the analysis captures the Phase II and the first 5 years of Phase III of the EU ETS which means that it involves 120 monthly observations.

The contribution of this thesis to the literature is primarily including the Paris Agreement and the following years in order to put forward the functioning of the EU ETS by considering the effects of this historical agreement. It is also aimed to show the effects of the Paris Agreement in a more holistic manner from the EU ETS perspective. Additionally, another novelty of this thesis is to visualize causality directions of the variables interacted within this new international climate change regime.

According to the regression results, the relationship among the European Union Allowance (EUA) prices and variables has been detected for both short-run and long-run. In this context, in the long-run, while coal price and industrial production index (IPI) affect the EUA prices positively, natural gas price affects it in the opposite direction. The opposite signs of natural gas and coal prices indicate that fuel switching behavior of facilities become clearer regarding environmental concerns. Since energy production majorly relies on natural gas and coal, and oil has lost its effectiveness on these two fossil fuels due to the paradigm shift like replacement of oil-indexation with hub-based pricing in gas, the oil price has no impact on the EUA prices. Moreover, IPI has a dominant role in the price determination of EUA. This may point out that European industry still uses dirty inputs and the Union industry runs within an environmentally harmful process.

On the other side, in the short-run, while 2 months lagged economic sentiment indicator (ESI) and one month lagged of the EUA itself affect the EUA prices negatively, one month lagged heating degree day (HDD) affects EUA prices positively. The result for ESI could be interpreted in such a way that as firms worsen their expectations about the economy, they may invest less in low carbon production methods and this shift may trigger emissions upward and usage of cheaper and dirtier inputs like coal. As a result of this sequence, emissions will cause a rise in demand and price. The significance of one month lagged EUA prices implies that price of EUA contains the history of price changes because it is affected from the previous period. Therefore, this also indicates that when EUA prices decrease, facilities raise their demand for EUA in the next period. Moreover, the significance of the HDD shows that the heating requirements of the buildings is also a driver of EUA prices in the short-run period. This finding implies that heating of buildings in Europe relies on fossil fuel consumption and renewable sources have not reached to an adequate level to cut this link yet and failed to be considered as a perfect substitute of fossil fuels.

According to the regression results, the historical Paris Agreement affects the price determination negatively. This is an unexpected finding at first sight because it can be interpreted that the assertive statements made on the success of the Agreement have not found a ground in the EU ETS. Conversely, markets are affected negatively by the blurry, unclear and disputable articles in the Agreement. Frankly, by 2018, rules, procedures, and modalities towards international emission trading mechanism are still in discussion. Therefore, the regression results may not be regarded as surprising.

The other dummy variable is used to represent EU ETS regulation change. This change has affected both the supply and demand sides of the market. The regulation had rearranged the rules and procedures in terms of the entrance to the market in order to cope with the fraud activities in the Scheme, the usage of funds generated within the Scheme, allocation of allowances and also with the regulation the use of carbon credit in order to meet the requirements of the Scheme had been limited to a certain level. Moreover, 2011 was the year when the effects of the European Debt Crisis have been felt by the European economies. According to the regression results, this dummy variable affects the EUA prices negatively. This finding signifies that the effect of increasing the security measures for the entrance to the market which decreases demand due to the diminishing number of market players is dominant over the supply side effects of the regulation which covers limiting the carbon credit uses. On the demand side also, security measures have a stronger effect on EUA prices than the supports provided for new entrances to the market.

When the causality relations are analyzed, primarily it is observed that the weather conditions only affect the natural gas prices. This finding can be interpreted in the following way; since in the EU natural gas is the dominant source for heating purposes if weather conditions worsen, natural gas consumption increases, and this leads to an upward movement in the prices.

Another finding is that natural gas has an effect on economic sentiment indicator, while this is not the case for coal. In other words, economic expectations are determined by considering natural gas prices rather than coal prices. This finding implies that while economic expectations are shaped, coal-based investments are considered less than natural gas-based investments. The reason behind this attitude could be the changing investment path towards low carbon options. It should also be underlined that there is a mutual and significant relationship among coal and natural gas prices. Thus, it is not possible to say that coal prices have no role on economic sentiments, the impact of this interaction may be observed indirectly.

Moreover, economic expectations lead to industrial production path significantly as it is expected. Besides this finding, both of the fossil fuels subjected to the analysis have an effect on industrial production, but while coal directly affects it, natural gas has an impact through coal. In other words, the fuel-switching behavior is the main determinant in the industrial production process. This implies that to a larger extent

European industry still relies on dirtier inputs like coal instead of more environmental and clean ones. Additionally, this conclusion is utterly consistent with the current overview of the European energy profile. (European Commission, 2018). According to the European Commission, figures show that combustible fossil fuels account for 48.7% of the net electricity generation in 2016, while 26.5% comes from nuclear sources and the rest from renewable sources. Nevertheless, it is also important to touch upon the point that when these figures are analyzed, it can be expected that with the energy and environment strategies and plans, these figures will shift towards more environment-friendly energy production methods. A firm indicator of this situation is that according to the figures published by European Commission, when the sources of energy production in 2016 are compared with the figures in 2006, it is shown that the share of combustible fossil fuels has decreased from 56.8% to 48.7% (European Commission, 2018).

According to the 2014 figures published by the EEA, the largest share of all electricity consumption in the EU belongs to industry sector with 37%. Moreover, despite a significant decrease in the share of fossil fuels in the electricity mix, they are still the dominant inputs with 42%. In the energy mix, the share of the coal and lignite is 25% and the share of natural and derived gas is 15% (EEA, 2017). These facts lead another interesting finding from the analysis. According to the Toda-Yamamoto Non-Granger Test results, while coal affects industrial production, only the natural gas is affected by industrial production. This may refer to industrial production processes have shifted towards using natural gas more than coal. When it is considered that the share of coal and lignite is higher than the natural gas and derived gas in the electricity mix and the largest share of electricity consumption belongs to the industry, one may expect that industrial production leads coal and lignite prices directly. However, this is not the case in our analysis. Industrial production only affects natural gas in a direct way. This finding can be confirmed from the EEA figures which show that in 2014 the amount of coal in total electricity generation has diminished by 21% compared to 1990, while the share of natural gas in it has increased by 119% in terms of Gigawatt hours (GWh) in the same period (EEA, 2017). Therefore, it is possible to expect that in near future the interaction between EUA prices and natural gas prices will be incremented.

Furthermore, a direct effect from EUA prices to fossil fuel prices cannot be observed. This leads us to another important interpretation which is that the price of the carbon is still ineffective to shift fossil fuel demands in a direct way. On the other hand, the EUA price shows its effects on natural gas and coal in a very indirect way. The price of carbon has an impact on economic expectations and then industrial production decisions. On the next stage these decisions lead to natural gas demand and through fuel switching behavior it affects coal prices.

Taking all of these points into consideration, we can argue that there is an obvious interaction among macroeconomic variables and EUA prices. However, its magnitude, causality directions, significance may be subjected to change in the future. It should be emphasized that, as a leader in the fight against the adverse effects of climate change, the EU has shown a great ambition for transforming its economy to a low carbon one by aligning its policies. Additionally, after the rules, procedures, and modalities related to international emission trading mechanism established under the Paris Agreement determined in the international negotiations, the progress for emission trading will gain a tremendous momentum. Succinctly, to have a well understanding of the conditions of and paths towards green economies, the developments in the interactions presented in this thesis should be closely watched.

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APPENDICES

APPENDIX A

Table 1: ARDL Model Results for EUA

Variables	Coefficients	t-Statistic
C	-13.81483	-6.042702
EUA (-1)	0.414578	4.884625***
EUA (-2)	0.190981	2.366411**
COAL	0.198385	2.188318**
GAS	-0.077056	-0.598207
GAS (-1)	-0.380884	-3.707938***
IPI	1.383322	1.030390
IPI (-1)	2.292429	1.813145**
ESI	1.210599	1.358350
ESI (-1)	-1.260300	-0.851541
ESI (-2)	-1.861283	-1.365498
ESI (-3)	1.671861	2.132787**
HDD	0.040534	2.530476**
HDD (-1)	-0.036991	-2.288849**
Dummy for Paris Agreement	-0.395249	-6.005377***
Dummy for 05.2011	-0.245744	-4.878542***
R^2	0.951406	
Adjusted R^2	0.944190	

(1) Dependent Variable is EUA
(2) Selected Model is ARDL (2, 0, 1, 1, 3, 1) and model selection method is Akaike info criterion (AIC)
(3) Dynamic regressors (4 lags, automatic): COAL GAS IPI ESI HDD
(4) Fixed regressors: Dummy for Paris Agreement, Dummy for 05.2011, C
(5) *p<.1, **p<.05, ***p<.01

Table 2: Toda-Yamamoto Test Results

Dependent Variables

EUA		COAL		GAS	
Variables	**Chi-Sq**	**Variables**	**Chi-Sq**	**Variables**	**Chi-sq**
GAS	19.69622***	**EUA**	4.433311	**EUA**	5.222600
IPI	6.958195*	**GAS**	14.58575***	**COAL**	8.697630**
HDD	0.382896	**IPI**	4.259015	**IPI**	7.994850**
ESI	6.140243	**HDD**	2.679642	**HDD**	7.533851*
COAL	7.841092**	**ESI**	0.441239	**ESI**	2.732211

Dependent Variables

IPI		HDD		ESI	
Variables	**Chi-Sq**	**Variables**	**Chi-Sq**	**Variables**	**Chi-sq**
EUA	0.507385	**EUA**	1.754489	**EUA**	10.34390**
COAL	22.82738***	**COAL**	3.454996	**COAL**	6.101400
GAS	6.607822*	**GAS**	0.228935	**GAS**	8.597689**
HDD	5.273978	**IPI**	1.547027	**IPI**	4.821042
ESI	34.01139***	**ESI**	1.172800	**HDD**	2.145041

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

APPENDIX B: TURKISH SUMMARY / TÜRKÇE ÖZET

Aşırı hava olayları, doğal felaketler ve ekosistem bozulmalarının giderek daha fazla gözlemlenmesi ve bazı canlı türlerinin yok olmaya başlamasıyla, iklim değişikliği uluslararası gündemde en çok öne çıkan konulardan biri haline gelmiştir. Bu bağlamda, 1990'ların başından bu yana Birleşmiş Milletler kapsamında yapılan uluslararası müzakerelerin sonucunda, Birlemiş Milletler İklim Değişikliği Çerçeve Sözleşmesi (BMİDÇS), Kyoto Protokolü ve yakın zamanda Paris Anlaşması gibi yasal metinler oluşturulmuştur. Bu metinler sadece çevresel ilkeleri, kuralları ve prosedürleri değil, aynı zamanda gelişmiş ülkelerden, iklim değişikliğinin olumsuz etkileriyle başa çıkma çabalarını desteklemek için gelişmekte olan ülkelere finansal akışların sağlanmasını da öngörecek şekilde hazırlanmıştır. Bunun yanınsa söz konusu metinler, anlaşmalara taraflar olan ülkelerin emisyonlarını düşük maliyetli bir şekilde azaltmalarını sağlamaya yönelik eylemleri teşvik etmek amacıyla uluslararası emisyon ticareti mekanizmalarını kurmayı da kapsamıştır.

Kyoto Protokolü ile oluşturulan iklim değişikliği rejiminin aksine Paris Anlaşmasıyla birlikte oluşturulan yeni yapıda yalnızca Ek-I listesinde yer alan ülkelerin değil gelişmekte olanlar da dahil olmak üzere tüm ülkelerin emisyon azaltım yükümlülüğü üstlendikleri bir sisteme geçilmiştir. Bir diğer deyişle artık gelişmekte olan ülkelerde de çevre ve iklim politikaları hızla yürürlüğe konulmaya başlanmıştır. Bu kapsamda başvurulan politika araçları arasından kumanda ve kontrol yöntemleri ile karbon fiyatlandırma öne çıkmaktadır.

Kumanda ve kontrol araçları, ekonomide yer alan kirletici aktörlere çeşitli kurallar ve bu kurallara uyulmaması durumunda cezalar getirerek çevresel performansı artırmayı amaçlayan politika araçlarıdır. Buna karşın, söz konusu araçlar firmalara sabit bir maliyet getirmekte, bu nedenle de herhangi bir esneklik sunmamaktadır. Öte yandan, bu araçlar, firmaların mevcut kurallara uymalarının dışında bir çaba sarf etmelerini de teşvik etmemekte, dolayısıyla etki anlamında sınırlı kalmaktadır.

Geçtiğimiz yıllarda yaşanan küresel ve bölgesel çaptaki ekonomik krizlerin yarattığı tahribat düşünüldüğünde iklim değişikliğiyle mücadelede özellikle ekonomik yapıları, gelişmiş ülkelere göre daha kırılgan yapıya sahip gelişmekte olan ülkelerde kumanda ve kontrol araçlarına kıyasla ekonomik olarak daha etkin, esnek ve yenilikçi politikalara ihtiyaç duyulmuştur. Ayrıca iklim değişikliğinin yalnızca bir çevre problemi olmaktan ziyade çok boyutlu bir nitelik taşıması sebebiyle mücadelenin sadece çevre politikaları ile değil, farklı politika alanlarındaki farklı politika araçlarıyla da desteklenmesi gerekmektedir.

İklim değişikliğinin insanoğlunun bugüne kadar karşılaştığı en büyük piyasa başarısızlığı olduğunu görüşüne paralel olarak, iklim değişikliğinin yol açtığı dışsallıkları ortadan kaldıracak ve dolayısıyla çevresel maliyetleri fiyat mekanizmasında içselleştirecek çözümler aranmaya başlanmıştır. Nitekim, ülkeler, iklim değişikliğinden kaynaklanan dışsallıkları içselleştirirken, ekonomileri için maliyetleri en aza indirecek şekilde emisyon azaltma hedeflerini gerçekleştirmeyi amaçlamaktadır. Bu noktada, iklim değişikliğiyle mücadelede karbon fiyatlandırma araçları ön plana çıkmaktadır. Özellikle son 20 yılda, iklim değişikliği ile mücadelede karbon fiyatlandırma uygulamaları dünya çapında daha yaygın hale gelmiştir.

Karbon fiyatlandırma mekanizmaları arasında en yaygın kullanılan araçlar ise emisyon ticareti sistemleri ve karbon vergileri olarak sayılmaktadır. Bu politikalar aracılığıyla belli bir miktar kamu geliri de elde ederek herhangi bir hedef belirlemeksizin emisyonları sınırlamak için karbon vergileri tercih edilirken, emisyon ticareti sistemlerinde ise elde edilecek kamu gelirine ilişkin bir öngörüde bulunamamakla birlikte spesifik emisyon azaltım hedefleri belirlenmektedir. Emisyon ticaret sistemleri sisteme tabi olan her tesisin emisyon verilerini izleme gibi çok kapsamlı idari detaylar gerektirdiğinden, ulusal bütçelere ciddi maliyetler getirmesinden dolayı gelişmekte olan ülkeler, mevcut vergi yapılarını bir dereceye kadar değiştirerek karbon vergisini uygulamayı tercih etmektedirler. Bununla birlikte, iklim değişikliğiyle mücadelede somut eylemlerin hayata geçirilmesinin aciliyetinden dolayı, gelişmekte olan ülkeler dahi, mevcut karbon vergisi yapılarının bir uzantısı olarak ya da bu politikaların ikamesi olarak emisyon ticaret planlarını planlamaya ya da değerlendirmeye başlamışlardır. Diğer bir deyişle, iklim değişikliğinin olumsuz etkileri gittikçe arttığından, politika öncelikleri kamu gelirlerinin üretilmesinden ziyade emisyonların azaltılması yönünde değişmektedir. Bu nedenle, yakın gelecekte emisyon ticaret sistemlerinin sayısının artacağını ve halihazırda uygulanmakta olan programların etkinliğinin artırılmasını beklemek olası gözükmektedir.

ETS uygulamalarından 2005 yılında yürürlüğe giren Avrupa Birliği Emisyon Ticaret Sistemi (AB ETS), kapsamı, ulaştığı boyutlar ve bugüne kadar karşılaştığı zorluklar ve ürettiği çözümler ile tasarım açısından diğer ülke uygulamalarına öncülük etmiştir. Sistem 31 ülkeyi kapsamakta ve Avrupa Birliği ile İzlanda, Lihtenştayn ve Norveç'in emisyonlarının yaklaşık %45'ini kapsamaktadır. AB ETS, uluslararası emisyon ticareti hacminin %75'ini teşkil etmektedir.

AB ETS'nin fiyat dalgalanmalarının üstesinden gelmek ve piyasa istikrarını sürdürmek için birçok zorluk yaşadığı gerçeği, diğer sistemler için öğrenilecek verimli dersler içermektedir. Fiyatlandırma davranışları, küresel mali kriz, Avrupa Borç krizi, sistem dahilinde gerçekleştirilen vergi kaçakçılığı ve dolandırıcılık faaliyetleri ile uluslararası iklim değişikliği müzakerelerindeki yetersiz ilerlemelerden ciddi şekilde etkilenmiştir. Emisyon fiyatlarındaki artış, sistemin kapsamına aldığı için ek maliyet doğurduğundan, bu fiyat değişikliklerinin diğer makroekonomik değişkenler üzerinde bir etki yaratması beklenmektedir. Bu bağlamda, Avrupa Komisyonu tarafından yürürlüğe konulan düzenlemeler gibi politika etkileşimleri ile karbon fiyatları kontrol altında tutulmaya çalışılmaktadır.

Yukarıda bahsedilen tüm konulara ilişkin olarak, bu tezin temel amacı, enerji piyasaları, borsalar, sanayi sektörünün performansı, ekonomik beklentiler ve diğer ilgili değişkenler de dahil olmak üzere AB ETS'de ticarete konu olan emisyon permi fiyatları (EUA) ile makroekonomik değişkenler ile arasındaki etkileşimlerini keşfetmektir. Bu sayede piyasanın işleyişinin daha iyi anlaşılması amaçlanmakta, böylece AB ETS ve diğer ilgili piyasalardaki fiyat gelişmeleri ve göstergeler arasındaki ilişkinin açıklığa kavuşturulması hedeflenmektedir. Bunu ilişkiyi doğru bir şekilde ortaya koyabilmek, ETS'nin gelecekte nasıl daha etkili bir şekilde kullanılabileceği ve ETS'yi bir politika aracı olarak kullanmayı planlayan ülkeler için dersler sunabileceği hakkında bir fikir verecektir. Nitekim, bu ilişkinin doğru bir şekilde ortaya konulması ve yorumlanması, ETS'de yer alan piyasa aktörlerinin de bu piyasayı daha doğru kullanmalarına ve fiyat hareketlerini doğru bir şekilde yorumlamalarına yardımcı olacaktır.

Bu çalışmada, kullanılan verilerin özellikleri nedeniyle ARDL modeli üzerine çalışılmıştır. Zira değişkenlerin bazı durağan değilken, bazıları ise düzey değerde durağanlık sergilemektedir. Değişkenler arasında nedensellik yönünü bulmak için, ARDL yaklaşımında karşılaşılan veri setine ilişkin aynı nedenlerden dolayı Toda-Yamamoto Granger Nedensellik testi metodolojisi kullanılmıştır. Analize tabi tutulan süre 1 Ocak 2008'de başlayıp 31 Aralık 2017'de sona ermektedir. Diğer bir deyişle, analiz AB ETS'nin II. Aşaması ve III. Aşamanın ilk 5 yılını ele alacak şekilde 120 aylık gözlem içermektedir.

Bu tezin literatüre olan katkısı, öncelikli olarak bu Paris Anlaşmasının ve sonrasındaki yılların etkilerini de göz önünde bulundurarak AB ETS'nin işleyişini ortaya koymak ve bu sayede, Paris Anlaşmasının etkilerinin AB ETS açısından daha bütünsel bir şekilde gösterilmesi amaçlanmaktadır. Ayrıca, bu tezin literatüre sunduğu bir başka yenilik de yeni uluslararası iklim değişikliği rejimin altında AB ETS'de etkileşime giren değişkenlerin nedensellik yönlerini görselleştirmek olmuştur.

Model sonuçlarına göre, EUA fiyatları ve değişkenler arasında hem kısa hem de uzun vadede bir ilişki tespit edilmiştir. Bu bağlamda, uzun vadede, kömür fiyatları ve sanayi üretim endeksi, EUA fiyatlarını olumlu yönde etkilerken, doğal gaz fiyatları ise EUA fiyatlarını ters yönde etkilemektedir. Doğal gaz ve kömür fiyatlarının tersi işaretlere sahip olması, tesislerin yakıt değiştirme (fuel-switching) davranışlarının çevresel kaygılar konusunda daha net hale geldiğini göstermektedir. Petrolün enerji üretiminde ağırlığının azalması ve ayrıca doğal gaz fiyatlarının belirlenmesi sürecinde petrol fiyatlarına endeksleme yönteminin yerini enerji merkezi (hub) bazlı fiyatlandırmaya bırakmasıyla petrol fiyatlarının EUA fiyatları üzerindeki etkinliği azalmış, bu durum neticesinde de çalışma kapsamında petrol fiyatlarının EUA fiyatları üzerinde bir etkisi tespit edilememiştir. Ayrıca, sanayi üretim endeksinin EUA fiyatlarına etki etme konusunda baskın bir rolü olduğu bulgusuna erişilmiştir. Bu bulgu, Avrupa'da sanayi sektörünün hala kirli üretim girdilere bağlı olduğunu ve sanayi üretiminin çevreye zararlı olarak sürdürüldüğüne işaret etmektedir.

Diğer taraftan, kısa vadede, 2 ay önce gerçekleşen ekonomik beklentilerin ve EUA'nın bir önceki dönemki fiyatlarının bugünkü EUA fiyatlarını olumsuz etkilediği, bir dönem önceki hava koşullarına ilişkin gösterge niteliği dolayısıyla modele dahil edilen Avrupa'da binaların ısınma ihtiyacı endeksi (HDD) değerlerinin ise bugünkü EUA fiyatlarını olumlu yönde etkilediği tespit edilmiştir. Ayrıca model sonuçlarına göre, firmaların ekonomi ile ilgili beklentilerin kötüleştiği dönemlerde, düşük karbonlu üretim yöntemlerine daha az yatırım yapabilecekleri ve bu durumun kömür gibi daha ucuz ve daha kirli girdilerin kullanımını tetikleyebileceği görülmektedir. Yatırım davranışlarındaki bu değişikliğin de emisyon fiyatlarını yukarı doğru itebileceği çıkarımında bulunmak mümkündür. Bu sürecin bir sonucu olarak, emisyon permilerine olan talep artmakta ve bu da emisyon fiyatlarında yukarı yönlü bir harekete neden olmaktadır. Bir dönem önceki EUA fiyatlarının istatistiksel olarak anlamlı olması ve güncel fiyatları etkileyebilmesi ise, fiyat değişikliklerinin geçmiş fiyat hareketlerine ilişkin bir hafızası olduğuna işaret etmektedir. Sonuçlara göre, tesisler EUA fiyatlarının düşmesini takip eden dönemde emisyon permilerine olan taleplerini de artırmaktadırlar. Ayrıca, binaların ısıtma gereksinimlerinin kısa vadede EUA fiyatlarını etkilediği gözlenmektedir. Bu bulgu, Avrupa'daki binaların ısıtılmasında fosil yakıtların hala önem arz ettiğine, dolayısıyla da yenilenebilir kaynakların bu ilişkiyi ortadan kaldırmak için yeterli seviyeye ulaşmadığını ve fosil yakıtların tam ikamesi olarak piyasada yerini almayı başaramadığını göstermektedir.

Regresyon sonuçlarına göre, tarihi olarak nitelendirilen Paris Anlaşmasının, fiyatları olumsuz yönde etkilediği bulgusuna erişilmiştir. Bu beklenmedik bir bulgu olarak değerlendirilebilir, zira Anlaşmanın başarısı konusundaki iddialı söylemlerin AB ETS'de fiyatlar üzerinde bir karşılık bulamadığını göstermektedir. Aksine, piyasaların, Anlaşma'daki bulanık, belirsiz ve tartışmalı metinlerden olumsuz etkilendiği görülmektedir. Açıkçası, 2018 yılına kadar uluslararası emisyon ticareti mekanizmasına yönelik kurallar, prosedürler ve yöntemler hala tartışılmaktadır. Bu nedenle, regresyon sonuçları çok da şaşırtıcı değildir.

Çalışmada kukla değişkenlerden diğeri ise AB ETS'ye yönelik olarak AB Komisyonu tarafından gerçekleştirilen mevzuat değişikliklerinin etkilerini göstermek için kullanılmıştır. Bu değişiklikler piyasanın hem arz hem de talep tarafını etkilemiştir. Komisyon; AB ETS'de tespit edilen sahtecilik, vergi kaçakçılığı vb. faaliyetleri engellemek için piyasaya giriş kurallarını ve prosedürlerini yeniden düzenlemiş, sistem dahilinde oluşturulan fonların kullanımına yönelik esasları değiştirmiş, emisyon permilerinin tahsisatını ve karbon kredilerinin kullanımlarını bu mevzuat ile düzenlenmiştir. Ayrıca, değişkenin yorumlanmasında, 2011 yılının Avrupa Borç Krizi'nin Birlik ve çevre ülke ekonomileri üzerindeki etkisini gösterdiği yıl olması da göz önünde bulundurulmuştur. Regresyon sonuçlarına göre söz konusu kukla değişken, EUA fiyatlarını olumsuz yönde etkilemektedir. Bir diğer deyişle, piyasa girişine yönelik önlemlerinin getirilmesi sebebiyle azalan piyasa oyuncularının yol açtığı talep kısılmasının neden olduğu etkinin, karbon kredilerinin kullanımına ilişkin sınırlandırmaları yol açtığı arz yönlü etkiden üstün olduğu görülmektedir.

Nedensellik ilişkilerinin yönleri incelendiğinde, öncelikle hava koşullarının sadece doğal gaz fiyatlarını etkilediği görülmektedir. Bu bulgu; hava koşullarının kötüleşmesi durumunda doğal gazın ısınma açısından dominant bir kaynak olması sebebiyle, doğal gaz tüketiminin arttığı ve bu da fiyatlarda yukarı yönlü bir harekete yol açmaktadır şeklinde yorumlanabilmektedir.

Doğal gazın ekonomik duyarlılık göstergesi (ESI) üzerinde bir etkisi varken, bu durumun kömür için geçerli olmadığı bir diğer bulgu olarak öne çıkmaktadır. Diğer bir deyişle, ekonomik beklentiler kömür fiyatlarından ziyade doğalgaz fiyatlarını dikkate alarak şekillendirilmektedir. Bu tutumun arkasındaki sebep, yatırım tercihlerinin düşük karbonlu seçeneklere doğru kaymaya başladığı şeklinde yorumlanabilmektedir. Ayrıca kömür ve doğal gaz fiyatları arasında karşılıklı ve anlamlı bir ilişki olduğunu vurgulamak gerekmektedir. Zira, kömür fiyatlarının ekonomik beklentiler üzerinde hiçbir rolünün olmadığını söylemek mümkün değildir, bu ilişkinin etkisi doğal gaz fiyatları üzerinden dolaylı olarak gözlemlenebilmektedir.

Diğer taraftan teoriye uygun şekilde, ekonomik beklentiler, sanayi üretimi üzerinde etkiye sahiptir. Bununla birlikte, analiz kapsamında ele alınan fosil yakıtlardan kömürün sanayi üretimi üzerinde bir etkisi bulunurken, sanayi üretiminin yalnızca doğal gaza doğrudan etkisi bulunmaktadır. Bu beklenmedik bir bulgu olarak öne çıkmaktadır. Zira, kömür ve linyitin payının, elektrik bileşiminde doğal gazdan ve türetilmiş gazdan daha yüksek olduğu ve ayrıca elektrik tüketiminin en büyük payının sanayi sektörüne ait olduğu düşünüldüğünde, sanayi üretiminin doğrudan kömür ve linyit fiyatlarına yönelmesini beklenmektedir. Bu kapsamda, model sonucunda elde edilen bulgu, Avrupa'da sanayi üretim süreçlerinin doğal gazı, kömürden daha fazla kullanmaya doğru kaydığı, şeklinde yorumlanabilmektedir. Bu nedenle, yakın gelecekte EUA fiyatları ile doğal gaz fiyatları arasındaki etkileşimin artacağını tahmin etmek mümkündür. Buna karşın üretimin hala kömürden etkileniyor olması fosil yakıtlara olan bağımlılığın sürdüğünü göstermektedir.

Öte yandan, EUA fiyatlarının fosil yakıt fiyatları üzerine doğrudan bir etkisi tespit edilememiştir. Bu bulgu, karbon fiyatlandırma politikasının fosil yakıtlarına olan talebi azaltmak konusunda yetersiz kaldığını göstermektedir. Buna karşın, EUA fiyatlarının fosil yakıtlar üzerinde dolaylı etkisi ekonomik beklentiler üzerinden görülmektedir. Bu ilişkiye göre EUA fiyatlarıyla şekillenen ekonomik beklentiler, sanayi üretimini etkilemekte, üretim süreci ise doğal gaz ve doğal gaz üzerinden kömür üzerinde bir etki yaratmaktadır.

Tüm bu bulgular ışığında, EUA fiyatları ile makroekonomik unsurlar arasında çok açık bir ilişki olduğunu söylemek mümkün gözükmektedir. Buna karşın, söz konusu ilişkinin kuvveti, yönü ve anlamlılığı önümüzdeki süreçte değişebilecektir. Nitekim, AB'nin, iklim değişikliğiyle mücadeledeki lider konumu göz önünde bulundurulacak olursa, gelecekte Birlik ekonomisinin hızla düşük karbonlu bir yapıya kavuşacağını söylemek mümkün gözükmektedir. Ayrıca, Paris Anlaşması altında ele alınan uluslararası emisyon ticaret sistemine ilişkin kuralların, prosedürlerin ve rehberlerin uluslararası iklim değişikliği müzakerelerinde netleşmesiyle birlikte, düşük karbonlu ekonomi yolunda atılacak adımların hız kazanacağını söylemek mümkündür. Bu bakımdan bu tezde incelenen EUA ve makroekonomik unsurlar arasındaki ilişkinin önümüzdeki süreçte yakından takip edilmesi, çevreci bir ekonominin yapısının daha iyi anlaşılmasını sağlayacaktır.

APPENDIX C: TEZ İZİN FORMU / THESIS PERMISSION FORM

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YAZARIN / AUTHOR

Soyadı / Surname : Uludağ
Adı / Name : Arda
Bölümü / Department : İktisat

TEZİN ADI / TITLE OF THE THESIS (**İngilizce** / English) : Drivers of Carbon Prices in the European Union Emission Trading Scheme

TEZİN TÜRÜ / DEGREE: **Yüksek Lisans** / Master X **Doktora** / PhD ☐

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