Emission trading as solution? A study into the effectiveness of a policy instrument

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EMISSION TRADING AS SOLUTION?

A STUDY INTO THE EFFECTIVENESS OF A POLICY INSTRUMENT

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- ECONOMICS AND GOVERNANCE
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Preface

Dear reader,

In front of you lies the thesis research's elaborations, with the title EMISSION TRADING AS SOLUTION? This research was carried out in the context of graduation from the Master of Public Administration, specialization Economics and Governance at Leiden University.

An elaboration that falls within the thesis capstone; government policy to stimulate the transition towards a low carbon and more circular economy. In which researching the effectiveness of a policy instrument, an emission trading system, is the central question.

Before you continue reading, I would like to take the opportunity to express my special thanks. First, for the cooperation of environmental agencies of various states in providing the most recent statistics. Second, my employer for giving me the space to continue working on this thesis. Finally, a word of thanks to Dr. H. Vrijburg for guidance during the writing of the thesis.

Above all, I hope you enjoy reading and gain new insights.

23 July 2021, The Hague

Patrick Rademakers

Illustration frontpage: (CO2 emissions, 2020)

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1. Introduction

On April 21 2021, the newspaper headline of Het Financieele Dagblad reads as follows: ''*EU approves climate law*''. The article written by McDonalds examines the process of accomplishing this agreement. The central part of the law is about the goals to be achieved; reducing 55 percent CO_2 in 2030 and climate neutral over thirty years, which means that there will be no more net greenhouse gas emissions. Europe wants to achieve this neutrality through cleaner transport, decrease energy produced by fossil fuels , and capturing emissions from industry or planting trees. One of the other measures that are highly expected in emissions trading, as also other nations do. (McDonalds, 2021)

The adoption of the EU climate law came just before a major climate summit that President Joe Biden of the United States had organized. In two days, 40 world leaders gathered online to discuss global climate policy. It was expected that Biden will announce the US climate goal just before this summit. It is now known that the target has been set at a 50 percent CO_2 reduction by 2030.

1.1 Why is CO_2 reduction necessarily?

On November 4, 2016, the Paris Climate Agreement entered into force because at least 55 percent of the attending parties to the convention with at least an estimated 55 percent of the total global greenhouse gas emissions, have deposited their way of ratification. The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels. And to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. The countries of the European Union have signed this and are expected to adhere to it. (The Paris Agreement, 2020)

The reduction of CO_2 is seen as a solution to prevent further climate changes from occurring. Climate change is not only an ecological problem, but the consequences of the ecological changes will also create social problems. These include people who are faced with challenges in terms of extreme weather conditions, health effects, food security, livelihood security, migration, water security and the threat of cultural identities. Even more striking is the observation that inequality is potentially increasing between wealthy and poor countries and between rich and poor countries. Those who are already vulnerable will suffer even more. (The World Bank, 2021) (Byrd & DeMates, 2014)

1.2 The progression of reduction

Following the most recent climate law, the European Union also wants to become the first climate neutral continent in the world. In the context of the Green Deal, introduced by the European Commission, the Green Deal is an ambitious package of sustainable green transition measures that benefit European citizens and businesses. A first roadmap accompanies the package with essential steps, such as even stricter emission standards, investments in research and development, and European nature protection. (Europa Nu, 2020) (European Commission, 2020)

It can be good to paint a picture of the current and future situation. For changes over time at greenhouse gasses, we generally look at the base year 1990. Having a consistent benchmark allows us to compare different values. The objectives of the European Union are therefore about a reduction compared to 1990. Figure 1 shows that since 1990 there has been about over 20 percent less emission of CO_2. The aim is to achieve full neutrality in 2050. With the interim milestone, the achievement of a 55 percent CO_2 reduction in 2030. Figure 1 show the data from the (European Environmental Agency, 2019).

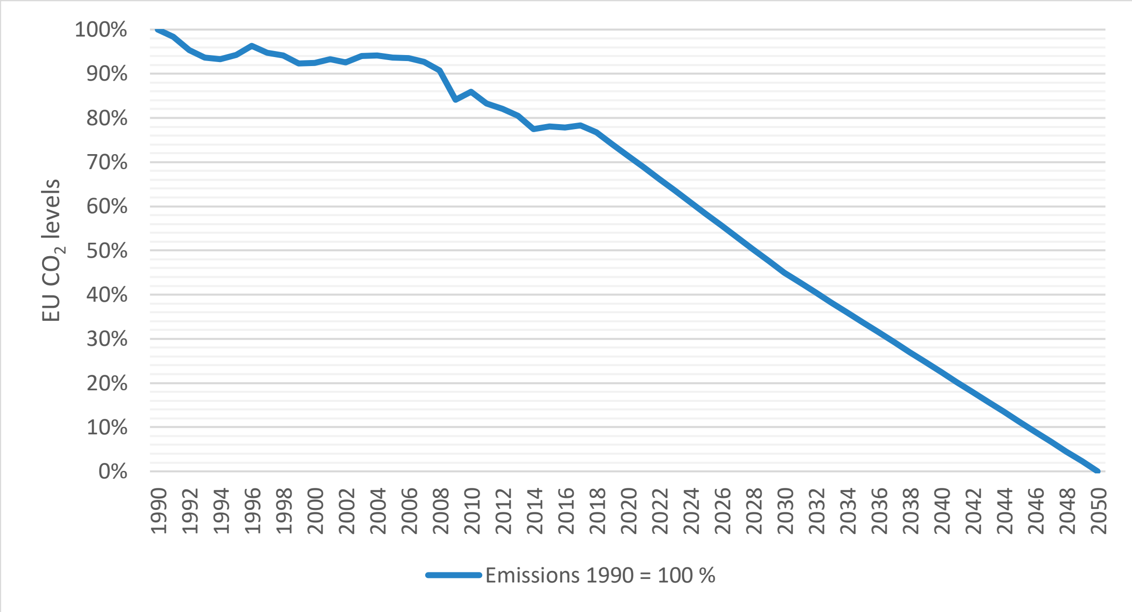


FIGURE 1 – RELATIVE CHANGES IN CO_2 EQUIVALENT COMPARED TO 1990

1.3 Researching ETS as a policy instrument

To ensure that there is a continuous incentive to slow down the growth and ultimately reduce CO_2 emissions, an emission trading system (ETS), also named cap-and-trade system, is in force in Europe that aims to connect an actual price to pollution through market forces. A further explanation of this system later in this research.

That this research into an emission trading system is not the first research in this area is evident from a book written by Hintermann & Gronwald *Emissions Trading As a Policy Instrument: Evaluation and Prospects* about the context of such a policy instrument. They will further discuss aspects such as the economics of regulation, regulatory uncertainty, political economy and the coexistence of different instruments for climate policy. This book is therefore an important tool for sketching the bigger picture for this research. The book by Weishaar specifically discusses the way the system is designed and its implementations. The fact that there is not yet an optimal system and that adjustments will certainly need to be made is also evident from the article *Emissions trading: lessons learned from the 1st phase of the EU ETS and prospects for the 2nd phase* written by Betz & Sato. In this, the authors evaluate the first phase and make recommendations for possible improvements, but also note that many challenges and opportunities are still to be expected. (Hintermann & Gronwald, 2015) (Weishaar, 2014) (Betz & Sato, 2006)

The publication of these works is before the Paris Climate Agreement and provides an evaluation of phases 1 and 2 of the EU ETS, the major phase 3 only started in 2013 and so at the time of publication it was hard to include phase 3 already in the findings. The authors also criticise the system, and worldwide there is disagreement about its effectiveness once the system is implemented. (Nordhaus & Shellenberger, 2009) Specific for the EU ETS system there is the recent article *The impacts of the EU ETS on efficiency and economic performance* (Löschel, Lutz, & Managi, 2019). The authors conclude that none of their identification strategies provides evidence for a statistically significant negative effect of emissions trading on economic performance. On the contrary, the nearest matching results suggest that the EU ETS rather had a positive impact on the economic performance of the regulated firms. At least this is remarkable. However, this is not the first research in the contact of emission trading seen the sources already mentioned, the circumstances have changed in the form of more systems to be able to compare with each other. And more information is also available due to the greater number of years over which a statement can be made.

So it turns out that earlier works are not completely unanimous, or at least see many changes in the future. Now several years later, it is therefore interesting to investigate whether, given the current design of the system, success can also be substantiated in figures. This research aims to investigate the effectiveness of the emission trading system policy, which intends to reduce CO_2 emissions in the participating EU countries by employing pre- existing literature and providing the most recent insights through the use of the newest data available. The research question will be: *To what extent has an emission trading system made an effective contribution to the reduction of CO_2 emissions?* There is an effective contribution to reduction if a conclusion can be constituted based on a statistically significant relationship between the policy instrument and the level of CO_2 emissions.

In this research, an answer to the research question will be sought in the following way. The nature of the CO_2 externality and the possible policy instruments that can be used against this externality will be discussed. This will lead to a hypothesis. In addition, other theories may influence the research and will therefore be cited further. In order to get a better picture of the context, a detailed comparison of current policy in the European Union and the United States is made. The chapter methodology describes the way in which the research will be carried out. Descriptive and statistical methods will ultimately underlie the conclusion of the study.

2. Externalities and policy instruments

Before we go deeper into the element of the policy instrument, it is good to consider the concept of CO_2. The term CO_2 equivalent (CO_2 eq.) will frequently appear in this study. There are several greenhouse gases where CO_2 is most known, but N_2O, CH_4, and Fluorinated gases also cause global warming. Each gas has its Global Warming Potential and can be converted into one central unit, the CO_2 equivalent. Mentioning CO_2 as a greenhouse gas in simple word use, people are actually talking about the CO_2 equivalent.

2.1 Externalities and their solutions

An externality is an unpriced effect of an action. In this case, the emission of greenhouse gasses would be viewed as the occurrence of a negative externality when using fossil fuels. It imposes costs on people who did not create the externality. Due to the absence of pricing in this externality, the private marginal costs were calculated too low in case of this non-regulation. The externality is defined as the difference between the private marginal cost and the social marginal cost. The social marginal cost has a higher price and therefore also a lower demand, compared to the private marginal costs. This is according to the principle of supply and demand. Figure 2 displays global elaboration of this quantity effect. When organisations have to pay for the externality they cause, the expectation is that they will also tend to be more aware of this. Also, when prices for consumers represent their full costs, they are better able to make informed purchasing decisions. (Peace & Ye, 2020) (Lodge & Wegrich, 2012)

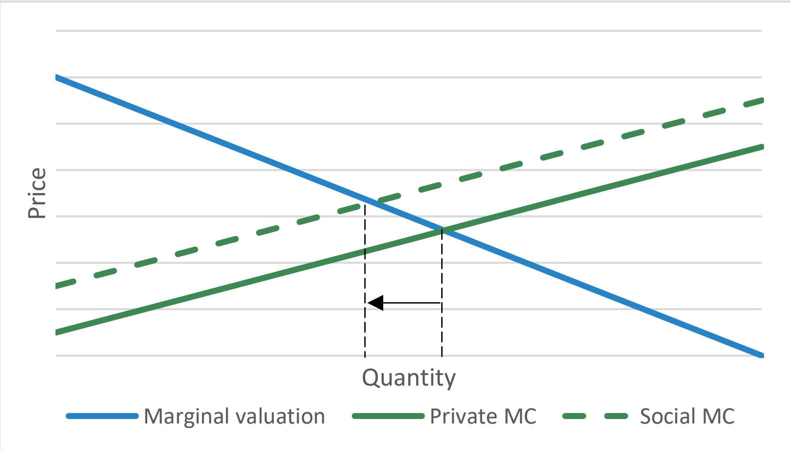


FIGURE 2 – EXTERNALITIES AND MARGINAL COST

There are two ways of overcoming the problem of not including the externality in the private marginal costs: a market-based regulation or command-and-control regulation. Command-and-control generally sets requirements by setting a performance standard or an obligation to take specific measures. In their book (Lodge & Wegrich, 2012) write about making a distinction between technology-, performance- and management-based standards. At technology-oriented standards, there can be prescriptions of particular technologies to reduce pollution. In the case of performance-oriented, there may be a measurement of air quality. The management orientation refers to the specification of managerial systems. The criticisms in setting standards are that this way of steering leaves little to no room for flexibility. The natural differences in adaptation options at companies are also ignored. Setting a standard can result in a lack of innovation when achieving this standard. (Peace & Ye, 2020)

There are also alternatives in this traditional way of regulation, which can be found in the area of market-based regulation. First, there may be a structure built on self-regulation. This structure relies on industry self-regulation and other forms of delegating regulatory power to the industry. The feasibility is complicated by the large scale of the climate problem and, therefore, the emission of greenhouse gasses. The other form is the reliance on applying market mechanisms and economic incentives. The introduction of a tax can be seen as a way to overcome the to low cost price, but it also has disadvantages as like weakening the competitive position. Taxation has many similarities with another policy option, a cap-and-trade program. Both correct the market failure to the correct price and are thus able to price greenhouse gasses. Both methods make use of the efficiency of the market and create revenue. Also, for both, there must be monitoring, reporting and verification, so there is no difference at this part. Even a tax can encourage innovation; it must be paid at all times unless you do not cause any externality. The advantage of a tax is that it is relatively easy to operate and don't have the work of creating a market.

Another way to prevent getting too many externalities, is to set a quota on the quantity of these. So instead of regulating the price, the quantity is regulated. This hinders overconsumption of items that caused externalities. It might lead to welfare losses because producing more with the same externalities can be the result of innovation. A suitable solution would, therefore, be one in which welfare remains the same, stimulate innovation and social costs have been included in the price.

(Peace & Ye, 2020) (Lodge & Wegrich, 2012) (Pew Centre on Global Climate Change, 2009) (Hepburn, 2006)

2.2 Cap-and-trade

Cap-and-trade is based on the theory of supply and demand in which it is a mechanism that controls the implementation of externalities in the cost price. As explained in section 2.1, the consequence of not integrating externality in the cost price is actual overconsumption related to the consequence of climate change caused by CO_2 emission. Cap-and-trade will form a Emission Trading price as result of supply and demand. Because there is still a number of set permits (quota), cap-and-trade makes it mandatory to buy a permit to emit CO_2. The producer can be seen as the demand side here. If you want to produce, emitting CO_2 is normally the cheapest option. You have to buy permits now, so you demand permits. The offer is thus facilitated by a government or by a delegated organisation. It is possible that the supply is further limited every year, which has a price-pushing effect if demand remains the same. Producers could also choose to focus on a lower demand by innovating. Production without sufficient CO_2 permits is subject to a fine, which ensures enforcement.

The great advantage of a cap-and-trade system is that it is less affected by circumstances as described in the next chapter. For example, a decreasing ceiling overcomes the disadvantages of efficiency measures. The ceiling also reduces the tendency for a green paradox to develop. There is a green paradox when previously taken efficiency measures lead to higher demand and therefore net equal disadvantages, instead of a decrease in this. See section 3.1 for a detailed explanation of this phenomenon. In addition, a cap-and-trade system is suitable for responding faster to economic conditions than would be the case with a tax. Because demand is simply lower, a lower price is created immediately. The combination of a clear movement with the economic conditions together with cooperation between different countries creates a certain degree of certainty and predictability that is the same in all countries. Certainty can be seen as one of the basic conditions for willingness to invest in innovation.

Under perfect information circumstances, both taxes and quota yield the same result. But this same result is not the case anymore under imperfect information and uncertainty. If relative to abatement costs marginal damages increase faster with extra emissions then it is better to be sure about the quantity, so a permit system is preferred. If relative to abatement costs, marginal damages are relatively flat with extra emissions, it is better to use the tax, this ensures a maximum on the marginal abatement costs. When the abatement costs of avoiding CO_2 emissions are uncertain, using a price instrument is less efficient than a quantity instrument when the social marginal benefits of that good are relatively flat. This is because the instrument is intended to internalise the marginal benefit curve. Suppose the marginal cost of reducing emissions increases quickly as we move from eliminating the cheap to more difficult emissions sources. Suppose also that, because damages from climate change are a function of the stock of greenhouse gases in the atmosphere, they are only a weak function of emissions over a short period, so that the marginal benefit from abatement is relatively flat. In such circumstances, a price instrument is an appropriate instrument to use. In conclusion, we can say that a quantity instrument is always effective, but may no longer be desirable due to the higher costs. A price instrument is not always effective, but it is therefore more affordable. Cap-and-trade tries to combine both advantages.

(Peace & Ye, 2020) (Pew Centre on Global Climate Change, 2009) (Hepburn, 2006)

2.3 Hypothesis

The hypothesis is that the policy instrument ETS does make an effective contribution to the reduction of CO_2 equivalent. The expected effect is that with an increase in the price for an ETS permit, there is a decrease in the amount of CO_2 equivalent. So there is a negative causal relationship.

ETS is a system that tries to incorporate the non-internalized costs, the gap between private- and social marginal cost, in the final price. The combination of setting a ceiling and the tradability within the set limits creates the phenomenon of a price for a CO_2 permit, the right to emit. Enforcement of the system comes through fines. The ETS price should result from the combination of supply and demand, with an annual decreasing cap together with increasing innovation power and the inescapable emission of CO_2 in certain processes. A higher price makes it more attractive to invest in innovation instead of buying permits. After all, it is to the detriment of the operating result to pay a high price for CO_2, knowing that it may increase further. Investments in lower emissions will eventually lower the cost price, or keep it the same when the price for CO_2 increases, thereby improving the competitive position of the producer. It would also be a disadvantage not to adhere to the prescribed cap, given the costs of high fines. A low price would have little impact on competitiveness and thus does not encourage investment in lower emissions. From this idea, a negative causal relationship between price and CO_2 arises. A higher price should lead to lower emissions. This study therefore further examines the price as the independent variable on the amount of CO2. The quantity restrictions imposed are one of the factors of influence here, but are ultimately expressed in the ETS price. In addition, it can be expected that political exogenous factors also play a role in the reduction of $CO_{2.}$ Despite the major commitment to ETS, it is not the only policy instrument and some rules and laws must be adhered to. As a result, the demand for CO_2 allowances is not excluded from other factors of influence. Given the size of trading periods, the price is expected to be less sensitive to short-term economic effects. It cannot be ruled out that no effect is visible, but these may be less than the visible economic effects.

3. Factors of explaining CO_2 levels

While chapters 1 and 2 have been the introduction to the subject, the research question and the hypothesis, it is important to realize that this does not cover the entire spectrum of CO_2. There are many factors and considerations that influence questions about CO_2. Thus, this chapter will try to outline these additional aspects and thereby try to create a complete basis for the further research method.

3.1 The externality and energy efficiency measures

When a more efficient way of working causes fewer externalities, this can also be seen as an small improvement. However, this is not entirely true. And still the externality is present, only in smaller amounts. As early as 1865, economist William Stanley Jevons observed that improved efficiency in the use of coal does not lead to a decrease, but rather to an increase in the use of coal. Modern economist later re-examined this rebound effect observation. In addition to reducing the amount of energy required for a given service, improved efficiency also reduces the relative cost of use, increasing the amount requested. Overall, this counteracts the reduction in usage achieved through improved efficiency. Besides, improved efficiency increases real incomes and accelerates economic growth, further increasing demand for resources as a result. The Jevons paradox occurs when the effect of increased demand and improved efficiency increases the rate at which resources are used. (Alcott, 2005)

Aiming at reducing externalities solely by striving for higher efficiency is not smart without additional measures according to the Jevons paradox. That is why the environmental economist recommends taking additional measures that keep the cost of using the same. The occurring rebound effect can therefore be prevented by using a cap and trade system or green taxes. For example, Wackernagel and Rees write that efficiency gains must be taxed away and preferably should be reinvested in natural capital rehabilitation. (Wackernagel & Rees, 1997)

3.2 Short-and long run effects of measures

In the article by (Newcomer, Blumsack, Apt, Lave, & Granger, 2018), the authors distinguish between effects on CO_2 emissions in the short and long term. For example, they argue that an increase in the energy price, given the price elasticity, can result in a direct decrease in demand. In the longer term, there will be adjustments based on innovation and adaptability. Industrial installations generally have a long lifespan. Due to the complexity and the development of possible innovations, it is to be expected that there will be a delay in the speed of adaptation; a long-term effect reveals itself here. When the price for a permit in an ETS system shows an increase, it is expected that this will only directly affect the amount of CO_2 to a limited extent. Especially if this price increase continues for some time, the influence on a declining demand will already have been used up. The total costs will simply increase due to a lack of opportunities for structural adjustment and innovation.

3.3 The CO_2 differences between countries

It may make sense that countries do not always make the same policy choices, but rational people would say that there is only one best form of policy. The question is how these differences can then be explained. Already in the 1950s of the previous century, the economist Kuznets developed a theory; arguing that income inequality in a country increases during the industrialisation of a country. When industrialisation continues, this inequality will decrease again. Graphically, this theory would have the perfect parabola shape.

The basis for this theory is that the economies of developing countries are primarily based on agriculture. This basis results in a lot of poverty, but at the same time, not so much inequality. The prevailing poverty affects the majority of the population. Increasing industrialisation means that a particular group can claim higher rewards, but because not everyone benefits directly from this, there is also more inequality. When this industrialisation increases further, more increased prosperity will become available to a larger group. This theory received little criticism until the 1980s, when inequality began to widen again in combination with more developed economies. In the end, the model turned out not to be entirely undisputed. (Zilibotto, 2016) A derived form of this for the environmental economy has been described by (Grossman & Krueger, 1995). They argue that pollution is moderate in an undeveloped economy, but it is increasing as industrialisation and economic progress occur. If this trend continues, pollution will decrease again as new techniques become available, and the focus may also shift from just economic progress to a more inclusive environmental-friendly economy. In the article by (Rothman & de Bruyn, 1998), it is argued that the growth of the economy and the growth of emissions change as society becomes more demanding with regard to the quality of the environment as it gets richer. Society is increasingly perceiving the environment as a consumer good that it consumes during leisure time. Specifically, this desire will continue in the ballot boxes, leading politicians to introduce stricter regulations to protect the environment. These stricter regulations push dirty industries from the economy to other countries with more lenient regulation, after which the developed country simply imports these consumer goods. Consequently, consumption has not become cleaner, it has only been imported.

In more recent research, questions regarding carbon leakage since the introduction of ETS in the EU have also been raised. Carbon leakage is the inability to prevent the relocation of CO_2 intensive industry to regions where regulations are less strict. As a result, the total amount of CO_2 does not decrease, but leaks away from one region to another. No significant evidence for this has been found in the study by Verde. However, the paper also identifies three important alerts to this general conclusion. Firstly, the evidence we have still mainly referred to the first two trading periods. As is also the case in the book Emission Trading Design by Weishaar, mentioned in other paragraphs. Secondly, some heterogeneity of estimated effects is observed, but sectoral patterns hardly emerge. Thirdly, very little explored is whether the EU ETS has had a long-term impact on the economy via investment leakage or firm dynamics. Further empirical studies investigating these long-term effects are welcome. (Verde, 2020)

The above theories can only be tested to a limited extent. In this highly globalised world, it is not always clear how certain currents proceed. This also falls outside the scope of the study. The outlined theories add an explanation of why there may be differences between countries' policies. Economic development can therefore explain this, as can society's call for a more protected environment.

In addition to the policy instrument itself, it is also important on which basis the monitoring of the success of this instrument should take place and how the differences between states can be measured. The Kaya identity could offer a solution here. The identity of Kaya describes four factors that contribute to the total emission level. To be known: population, GDP per capita, energy intensity and carbon intensity. It is a comparison with regard to factors that determine the level of human impact on the climate. In addition, it further highlights the elements of the economy that could be addressed to reduce emissions, notably energy intensity per unit of GDP and emissions per unit of energy.

$$F = P\ x\ \frac{G}{P}\ x\ \frac{E}{G}\ x\ \frac{F}{E}$$

F = global CO_2 emissions from human sources
P = global population
G/P = GDP per capita
E/G = energy intensity of the GDP
F/E = carbon footprint of energy

An analysis using the Kaya identity over different moments in time can provide insight into the changes weighted against known factors. (Peters, Andrew, & Korsbakken, 2017)

3.4 Other factors affecting CO_2

As mentioned earlier in this chapter, there are several reasons why differences occur. There is a choice between the best policy instrument, but the degree of development of an economy can also influence climate measures. As a result, it can no longer always be established that economic growth will also necessarily lead to more CO_2 equivalent.

In addition to economic growth, a growing population can also provide an increasing amount of greenhouse gasses. Because this development the total amount of user units due to increasing demand for energy, means of production and transport needs with growth. The price of fossil fuels can also influence the willingness to invest for greening measures. A higher price makes the payback time shorter and therefore the investment more attractive. This price is then created on the energy market and can be increased additionally by policy measures.

Governments try to achieve the goals as agreed in the climatic agreement by various means. As a result, an ETS system is not the only measure. There must be more measures since ETS only covers the largest and most polluting installations. For example, subsidies are provided to accelerate research and innovation into new techniques, or by positively influencing a cost-benefit analysis for the first generations of windmills and solar panels. Taxes are also indirect collected on highly polluting goods, such as an excise duty on fuels or higher taxes for large or inefficient cars. More about the additional measures will be discussed later in this study.

Policy uncertainty can undermine the ETS system. This uncertainty arises from the adjustments to the system over the years. For example, it turned out that the permits for EU ETS from phase 1 were no longer valid in phase 2. And it was decided to remove permits from the market afterwards in phase 3. The changes were implemented with the best intentions to optimise the system. However, the paradox indicates that these changes create uncertainties and can undermine the support of the system and the willingness to invest. This policy uncertainty is partly related to the other activities undertaken by the government in achieving the climate targets. Strongly vigorous policy, which is intended to lead to improved policy, causes more limited support, precisely because of these changes. (Weishaar, 2014) (Verde, 2020)

3.5 Summary

In this chapter, additional theories are outlined to provide a complete basis for further research. For example, we have seen that focusing solely on efficiency measures is not sufficient to save a lot of CO_2 in the long run. In addition, it is important to consider that some measures do not always have a visible effect immediately, but that this only becomes visible in the long run. When comparing countries, it should also be taken into account that they are not all at the same point in their development. Therefore, the economy is one of the factors to be taken into account when making a comparison between countries. As a final consideration, it should not be forgotten that the political climate and subsequent measures may be the biggest factor of influence. Therefore, the next chapter will elaborate on this specific topic.

4. The current policies

4.1 European Union Emission Trading System

This research does not study the question of which solution is the best. Nevertheless, it is a fact that the application of a cap-and-trade program is part of the European solution. The European Union Emission Trading System (EU ETS) is a policy instrument used to reduce the largest polluters' emissions. By issuing an annual quantity of permits, these permits constrain the size of the external effects. The offered quantity, together with the demand, determines a market price. Organisations that remain below their allocated amount can trade the remaining permits at this market price. So organisations that innovate and release fewer externalities, in this solution see an extra income through this innovation. Organisations that lag innovations still have a way out by purchasing additional permits. Due to innovation, the product price can be lower because of less CO_2 permits, which leads to no restrictions by quantity limitation. It is also possible to increase production with buying extra permits. Social costs are covered while there are also opportunities to increase welfare. There is enforcement through fines when produced externalities without a valid permit. The system also provides financial support for innovative renewable energy technology and carbon capture and storage projects through a fund. Revenues generated from the system also provide EU member states with funding for low carbon and renewable energy programs. Since the beginning of the program, revenue was €50.54 billion, collected in 2019: €14.64 billion. (Hintermann & Gronwald, 2015) (Peace & Ye, 2020)

Some permits are also offered through free allocation to prevent companies in the early years of the system from having insufficient time to adapt and thus avoid high costs. Indirectly, there is also the fear that companies will leave for a country with more favourable conditions. The term carbon leakage has its meaning here. Due to the phenomenon of carbon leakage, strict rules in one area do not always have to lead to a worldwide decline.

To make the major and ambitious plans of the European Union feasible, a great deal relies on this form of market influence. As inability Weishaar mentions is that the system is not designed to deliver high emission allowances prices at times of economic downturn. The question is whether that is desirable. Economic setbacks could be additional constraints if there were also significant high ETS prices. As described in chapter 3, a robust environmental policy can have a depressing effect on the price of fossil resources. As a result of these lower prices, the willingness to invest in innovation could also be affected negatively. (Weishaar, 2014)

4.1.1 The size of the system

Many companies emit pollutant gases, however, since the launch of the EU ETS in 2005, the focus has been on the largest emitters. The system covers the following sectors:

- power and heat generation
- oil refineries, steelworks and production of iron, aluminium, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids and bulk organic chemicals
- commercial aviation in the European Economic Area

The system covers 11.559 installations in the year 2019. Participation in the EU ETS is mandatory for companies in these sectors. Installations, where the emissions are so small that the administrative costs per unit of emissions might be disproportionately high, are allowed to opt-out from the EU ETS. Installations are considered as small emitters if they emit less than 25 kilotons CO_2 annually and, if they are combustion installations, have a thermal rated input below 35MW. (European Commission, 2020) (European Commission, 2015) In practice, the EU ETS program in 2017 included 1.727 megatons CO_2 on total European size of 4.492 megatons CO_2. (European Environmental Agency, 2019)

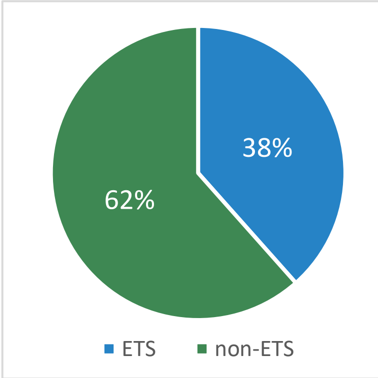


FIGURE 4 – DISTRIBUTION OF CO_2

4.1.2 Annual cap, banking and stability

If innovation would have a depressing effect on the permit price, caused by lower demand, it is necessary to set limits to the supply side. There is an annual cap for this;, a decreasing supply can also influence to encourage innovation. To continue to promote future innovation and thus CO_2 reduction, a particular stable but also minimal price is required. A decreasing supply ensures a constant minimum price height. The cap of permits as determined at the start of the system is therefore lowered annually. From 1.74 percentage from 2013 and 2.2 percentage from 2021 onward in order to achieve the end goal, climate neutral in 2050. During the first phase (2005-2007), in the absence of reliable emissions data, caps were set based on estimates. As a result, the total amount of allowances issued exceeded emissions, and that made the price low at the start. That this price did not reach the zero is due to expected scarcity in the very long run. In 2007 the price of allowances fell to zero when it was announced that permits from phase 1 could not be taken from phase 1 to phase 2. For phase 2 (2008 - 2012), the cap was lowered considerably, and the ratio between a free distribution and tradable distribution was adjusted. In the aftermath of the economic crisis, the price fell sharply from mid-2011 to mid-2017 to a level of just over 3 euros. After which the price rose again to about 35 euros today. (CBS, 2020) (Markets Insider, 2020) (European Commission, 2020)

Banking can also be used for permits. Permits that appear to be leftover remain valuable, because they can also be used in subsequent years. So there is no annual obligation to use everything. Conversely, it is not allowed to use permits from the future now. It must be said, however, that having many permits for future use is capital-intensive and involves risks of speculation. As a result, short-term expectations also influence the price. There has also been a Market Stability Reserve since 2019. This mechanism prevents an accumulated surplus or permits from causing the price to fall too much. The market is stabilised by removing unused permits from the market or introducing additional permits to the market. In general, the moment when the permits become available in the market in a particular phase differ under the Market Stability Reserve. They will only disappear permanently if there is an imminent structural surplus. (European Commission, 2020)

If there is a greenhouse gas emission under the EU ETS without a permit in return, action will be taken by imposing a fine. This fine initially concerned 40 euros per tonne exceeded and later increased to 100 euros per tonne. The height of the fine must at least value the caused damage from the externality CO_2, and must be proportionally higher to prevent companies preferring the fine above buying a permit. Compared to a possible tax, the fine of 100 euros is expected to higher than the tax, because there is no need for a deterrent effect as it needed in the case of working with permits.

4.1.3 Effort Sharing Legislation

Besides the policy instrument of ETS, there are additional regulations for the reduction of greenhouse gasses in the European Union. This additional regulation establishes binding annual greenhouse gas reduction targets for the Effort Sharing member states for the periods 2013 – 2020 and 2021 – 2030. These targets mainly relate to the sectors that are not covered by ETS, such as transport, buildings, agriculture and waste. Each state has its reduction target depending on the degree of development, whereby a reduction of 30 % must be achieved by 2030 based on a joint average. In contrast to sectors in the EU ETS, which are regulated at the EU level, individual states are responsible for national policies and measures to limit emissions from the sectors covered by Effort Sharing legislation. Examples include financial incentives for clean energy generation or a ban on cars' sale with a conventional combustion engine. (European Commission, 2020) However, an additional ETS can also be deployed at a national level, as is the case in Germany for the transport and heating sectors starting in 2021, so writes the Press and Information Office of the Federal Government on their website. (Press and Information Office of the Federal Government, 2019)

Examples include financial incentives for clean energy generation or a ban on cars' sale with a conventional combustion engines. Such as standard setting for cars and large vehicles in road transport or measures to improve buildings' energy performance, eco-design requirements for energy-related products, and energy labelling systems to inform consumers. However, most additional measures take place at the national level. According to the EU, the mutually different approach between countries will undoubtedly occur, but it is precisely this country-specific approach that increases the effectiveness and efficiency of measures. (European Commission, 2020)

Although there seems to be more freedom in this sector not restricted by ETS, the importance should certainly not be underestimated. As also shown in Figure 4, a majority of 62% of the European Union's emissions fall under this national coordination. Where the implementation of ETS is seen as a possibility with achieving the overall abatement goal at least costs, complementary measures may hinder this by forcing implementing high-cost regulation. This complementary measures can be found in specific standard-setting, taxes and subsidies. (Hintermann & Gronwald, 2015) (Lodge & Wegrich, 2012)

4.2 Regional Greenhouse Gas Initiative

The EU ETS system was the first major system in the world when it was founded, but is no longer the only one in its existence. Several countries or regions within countries now have a ETS system or are considering implementing one. The Regional Greenhouse Gas Initiative (RGGI) is an example of regional or interregional system in the US. Other regional examples of ETS systems occur in Canada, Japan and China. See Appendix 1 for a complete map of other ETS systems in the world.

4.2.1 The size of the system

RGGI is a cooperative effort among the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont to cap and reduce CO_2 emissions from the power sector. Within the RGGI states, fossil-fuel-fired electric power generators with a capacity of 25 MW or greater are required to hold allowances equal to their CO_2 emissions over a three-year control period. This partnership entered into force in 2009, with the current situation being that Virginia and Pennsylvania have planned to join this group in 2021.

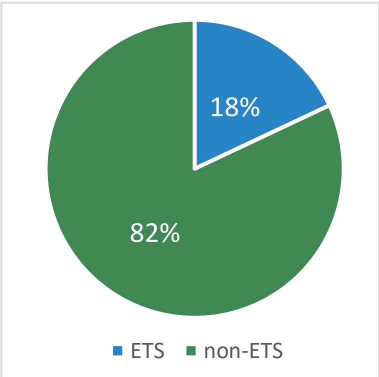


FIGURE 5 – DISTRIBUTION OF CO_2

More than 90 percent of allowances are distributed through quarterly auctions. These auctions generate revenue, which participating states can invest in strategic energy benefit programs. These could be programs dealing with energy efficiency, clean and renewable energy, and greenhouse gas reduction. Since the beginning of the program, revenue was $ 3.4 billion, collected in 2019: $ 284 million.

Because the RGGI cooperation is only about regulation in the fossil-fuel-fired electric power generators, the share compared to the states' total emissions is much smaller than that of the EU ETS. The number of installations covered by this system was 576 in 2018.

4.2.2 Annual cap, banking and stability

At RGGI, the total number of permits, just like EU ETS, was much greater than necessary in the first phase, which is why a new limit was introduced after a program check in 2012. The RGGI CO_2 cap decrease by 2.5 percent every year in the period from 2015 to 2020. For the period 2021 to 2030, the decrease will be stronger at 3 percent per year. A difference is here with the EU ETS where the decrease is smaller by 2.2 percent per year and also only from 2021. (RGGI, Inc., 2020)

Banking of permits is allowed without restrictions, but regulations include adjustments to the cap to address the aggregate bank by reducing the number of allowances available for auctions in future years by the number of allowances not used for compliance in previous control periods. Borrowing of future permit is not allowed.

Since 2014 there is a cost-containment reserve, where permits are released to the market when certain trigger prices are reached. Besides, an emissions containment reserve will be added in 2021. That means that allowances will be withheld from circulation if certain trigger prices are reached. These will not be re-offered for sale again.

At the RGGI system there is also a fine for the companies who emit greenhouse gases without the right permits. But there is no fixed price for the fine as it is at the EU ETS.

(International Carbon Action Partnership, 2020) (RGGI, Inc., 2020)

4.3 California cap-and-trade

Another system that does add a price at greenhouse gasses is the California Cap and Trade system. This ETS system is slightly smaller in size than RGGI and has only been in operation since 2012. This smaller size is largely since it is only one state, but a fairly large one. However, this one state can adhere to the RGGI due to the broader scope. Also interesting here is the higher carbon price that comes out as a market result at this moment than at RGGI, but the price is California was over longer time still lower than under EU ETS.

4.3.1 The size of the system

The system includes electricity generators and large industrial facilities emitting 25 kilotons of CO_2 or more annually. This brings the number to 450 installations. The system also includes distributors of transportation, natural gas, and other fuels. The system is therefore considerably larger in relative size than the EU ETS. In particular, the size is increasing strongly due to the addition of the energy and transport sector. In the European Union, road transport accounted for about 25% of the total amount of emissions. Taking this into account, the difference between the two is already a lot smaller. Since the beginning of the program, revenue was $ 12.5 billion, collected in 2018: $ 3.065 billion.

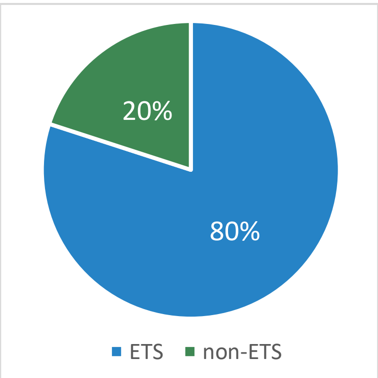


FIGURE 6 – DISTRIBUTION OF CO_2

4.3.2 Annual cap, banking and stability

No major adjustment has yet occurred, other than a change in the decline of the annual cap. The decline was 2 percent per year, but has increased to 3 percent per year for the period 2015 to 2020. Part of the permits are distributed through free allocation, but the vast majority by auctions. The system has a multi-year compliance period to buffer annual variations in product output.

Banking for later periods is allowed, but there is a general holding limit. Borrowing of future permit is not allowed. In the situation that there are unsold permits from past auctions, they will be removed from circulation and will gradually be released for sale at auction after two consecutive auctions are held in which the sale price is higher than the minimum price. However, if any of these allowances remain unsold after 24 months, they will be placed into CARB's reserve tiers and price ceiling. 4 percent of allowances are held in a strategic reserve to contain costs. There is talk of a fine at the California system when greenhouse gases are emitted without the right permits, but there is no fixed price as it is at the EU ETS.

(California Air Resources Board, 2019) (International Carbon Action Partnership, 2020) (European Environmental Agency, 2019)

4.4 The United States Effort Sharing Legislation

The 20 states that make up the control group are not entirely exempt from policies to limit greenhouse gas emissions. U.S. states have a great deal of autonomy in this area. Nevertheless, the federal government has also taken essential actions on this subject over time. Although there is no complete abstention from rules in the control group, they are much less enriching than the use of an ETS system with additional regulations and policy. The effect is also less disruptive because it affects both states with ETS and states without ETS.

For example, the Clean Air Act of 1963 can be seen as the first law in which there is already talk of regulation, or control, in the field of environmental policy. In the early years, this law was mainly aimed at improving air quality, which would be directly detrimental to public health or welfare. This does not include an indirect disadvantage such as global warming due to greenhouse gases.

Since the Supreme Court of the United States ruling, the EPA has begun to regulate greenhouse gases under the Clean Air Act from mobile and stationary air pollution sources. According to Section 202 of the Clean Air Act, standards for mobile sources have been established, and greenhouse gasses from stationary sources are currently controlled under the authority of Part C of Title I of the Act.

The fact that a successful federal approach is still not forthcoming is evident from the fact that the U.S. has not ratified nor withdrawn from the Kyoto protocol and is, therefore, an exceptional case in the rest of the world. Furthermore, notable events are that the Clinton administration initially committed the U.S. to lower their greenhouse gas emissions to 1990 levels by 2000 through his biodiversity treaty. Also, a British Thermal Unit Tax and Climate Change Action Plan was announced, calling for a tax on energy heat content and plans for energy efficiency and joint implementations. (Berke, 1993) (T DeAngelis, 1994)

In 2002, President Bush announced his alternative to the Kyoto Protocol, proposing a plan to reduce greenhouse gas intensity by 18 percent in 10 years. Specifically, greenhouse gas intensity is the ratio of greenhouse gas emissions to economic output, meaning that emissions would continue to grow under this plan, but at a slower pace. On the other hand, there were attempts to have climate change denied by scientists, something that was never proven to be true. (BBC News, 2001) (Dickinson, 2007)

In the run-up to his presidency, Obama's already discussed the New Energy for America Plan. This is a plan to invest in renewable energy, reduce reliance on foreign oil, address the global climate crisis, and make coal a less competitive energy source. Shortly after the elections, there was also the idea that the US should enter a cap and trade system to limit global warming. The American Clean Energy and Security Act, a cap and trade bill, was passed in 2009 in the House of Representatives but was not passed by the Senate. In 2015, Obama also announced the Clean Power Plan, which is the final version of regulations initially proposed by the EPA the previous year, and which pertains to CO_2 emissions from power plants. With the Clean Air act as the basis again. (ChangeDotGov, 2008) (Malloy & Serfaty, 2015)

Former President Trump has just aimed to stimulate the coal industry. The Obama-era climate rules were withdrawn to grow the coal sector and create new jobs. The President has indicated that any climate change policies that they believe are stunting U.S. job growth will not be pursued. The government is also withdrawing six executive orders to reduce climate change and carbon dioxide emissions and call for a review of the Clean Power Plan. The global community saw the intention to withdraw from the Paris Climate Agreement as a new low point. (Chestney, 2017) (Merica, 2017)

The two largest U.S. parties have taken different positions on the issue of global warming and climate change policies. The Democratic Party is trying to develop policies that curb the harmful effects of climate change. The Republican Party, whose leading members have repeatedly denied the existence of global warming, continues to meet its party goals of expanding the energy industry and curbing the EPA's efforts. Therefore, it is expected that these party lines will be continued during the new administration of president Biden. (Democrats, 2020) (Brownstein, 2020)

4.5 Summary

It may be clear that a comparison between the different regions is not easy. The size of each ETS policy instrument varies between 18 percent and 80 percent of the total economy. In general, the ETS instrument's structure does not deviate, and for example, all have options for banking and a decreasing annual cap. Differences are mainly found in the span of polluters. Also, in no region is it just a matter of conducting ETS, but a combination of different policy instruments. The political context here ultimately has a strong influence on ETS's size and the number of other measures.

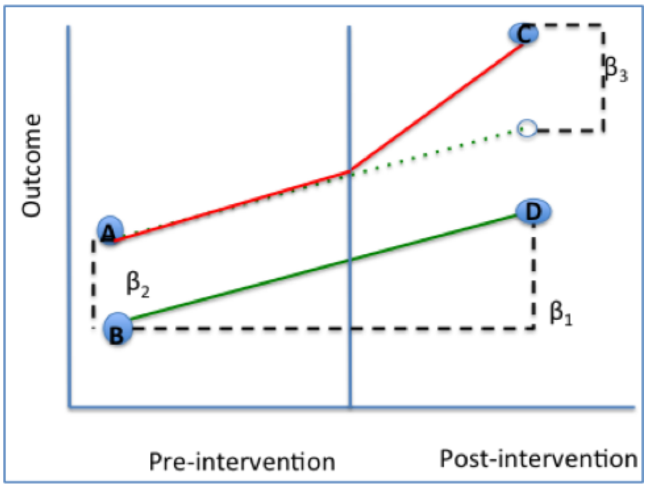
5. Methodology

This chapter will explain which method is used and why this is the best method for the research question. In addition, it will be clarified how the necessary data has been collected and how it can best be analysed.

5.1 Differences-in-differences

Ideally, the difference-in-differences method (DID) was used for the statistical analysis in this study. But the regression analysis that is shown in chapter 8 will be based on multivariate regression. The multivariate panel regression in chapter 8 closely resembles the DID methodology by using the ETS price as the main explanatory variable instead of an ETS treatment dummy. And besides by introducing more variation, the treatment dummy is not available because the research was not able to find CO_2 emissions for sufficient jurisdictions without an ETS system, and the ETS-systems researched differ amongst each other. Instead of the ETS treatment dummy, the analysis uses the ETS price, which is something that differs between the various ETS systems over time. This could be problematic since the ETS price is subject to internal endogenous influences. This is overcome because the identification is based on the fact that the ETS price being a sufficient statistic for the underlying differences in strictness of the ETS system.

DID is still applied for the descriptive statistics shown in chapter 7. Therefore, it is still relevant to explain this research method in more detail. DID is often used to estimate the treatment effect on the treated, although, with stronger assumptions, the technique can be used to estimate the average treatment effect in the population. Therefore, this method is often used to estimate the impact of specific policy interventions and policy changes. This method recognises that in the absence of random assignment, treatment and control groups are likely to differ for many reasons. The DID identification strategy's central concept is to estimate the difference of the mean outcomes of treated and controls after the treatment and subtract the outcome difference that had been there before the treatment had any effect. The mean changes in the outcome variables for the untreated over time are added to the mean level of the outcome variable for the treated before treatment to obtain the mean difference if everyone had received treatment. If the following formulated assumptions hold, this strategy will indeed identify a causal effect.



β1 time trend in control group

β2 difference between the groups pre-intervention

β3 observed deviation from expectation in non-treated over the time period

FIGURE 7 – DID EXAMPLE

The first assumption is based on the fact that only one of the possible outcomes is indeed true for every member of the population. A perfect randomised setting does not exist, but the method tries to find a reliable counterfactual. This assumption derives from the so-called stable unit processing value. It is essential that treatments are fully represented and that there are no relevant interactions between the population members.

The second assumption is based on the fact that the differences in the expected potential nontreatment outcomes over time are unrelated to belonging to the treated or control group in the post-treatment period. It implies that if the treated had not been subjected to the treatment, both subpopulations would have experienced the same time trends conditional on the time variable. These counterfactual are conditional datapoints that shows what would have been true under different circumstances. This also implies that the covariates should be selected to capture all variables that would lead to differential time trends. At the same time, the distribution differs between treated and controls. As the nontreatment potential outcomes share the same trend for treated and nontreated, any deviation of the trend of the observed outcomes of the treated from the trend of the observed outcomes of the nontreated will be directly attributed to the effect of the treatment. And not to differences in other characteristics of the treatment and control group.

The parallel trend assumption is the most critical of the assumptions to ensure DID models' internal validity and is also the hardest to fulfil. It requires that in the absence of treatment, both groups are constant over time. Visual inspection is helpful when you have observations over many time points. It has also been proposed that the smaller the period tested, the more likely the assumption is to hold. As stated at the beginning of this section, it is impossible to determine a treatment dummy due to a lack of CO_2 emissions for sufficient jurisdictions without an ETS system. The treatment in this research is the introduction of ETS in a specific group. Therefore, the aim was to show a decline in the post-period compared to the group in which no intervention would continue. The study tries to determine whether there is a similar trend in the pre-intervention period and whether there is a deviating trend in the post-intervention period in chapter 7 by using descriptive statistics.

Descriptive statistics help to image, describe and summarise the results of the data found. When analysing, the overview can quickly be lost in large quantities. Descriptive statistics are, therefore, not able to independently draw conclusions about the hypotheses stated. The use of descriptive statistics helps display data in a meaningful way, which makes it easy to interpret data. Line, column or cell charts are common forms in this. In addition to these figures, it can also be expressed in numbers in the form of an average, standard deviation, minimum and maximum. As mentioned at the beginning of this section, the DID method is still the basis for the more visual descriptive statistics. By means of these methods, it is checked in the graphs whether a change in the trend line is visible before or after the implementation. Because there are several points of implementation, there is also a disturbance in the DID displays. Different systems were introduced at different times. In the absence of sufficient historic data, a representation for the European system in the descriptive statistics is more limited.

(Lechner, 2011) (Angrist & Pischke, 2015) (Columbia University Mailman School of Public Health, 2019)

5.2 Research approach

As described in paragraph 5.1, the hypothesis is researched using the difference-in-difference method, which will be supplemented with the descriptive statistics method. The research will be split into parts, and the first part will try to paint a picture of the impact of the different ETS systems on the results through changes in the European figures since from that system is the most data available. This results in descriptive statistics, and a firm conclusion based on these data should not be drawn. An evident change after the moment of entering may demonstrate an effect here. A large part of the research will consist of comparison with other regions to reach a thorough difference analysis first based on descriptive statistics. The last part of the research will be performed with a regression analysis using the software Stata, which can be read in chapter 8.

Several countries or areas are pricing greenhouse gas in any form. As can be read in the theoretical framework, it was decided to compare the EU, the RGGI and California cap and trade systems. Two other systems are included in the table below to show why they did not become part of the research. Although the table shows that South Korea would be the most suitable in terms of size and carbon price, it still falls out due to a possible lack of figures. The system has only been in operation since 2015 and has data available for up to three years. Discovering multi-year trends will consequently be more unreliable. On the other hand, New Zealand has the most data available for comparison, but the small size might be affected by the possible influence of outliners. A difference-in-difference analysis can be made when approximately the same data are available over the same period. This condition makes it essential that the system has a minimal size, has been in operation for some time and that the countries are somewhat comparable. Despite the fact that the first part of the descriptive statistics aims to study the effectiveness of the EU ETS, if only Europe were to be considered, the problem is that all EU countries fall under the same regime and therefore changes can not be easily recognised through a regression discontinuity analysis. This situation requires a particular form of difference-in-difference research.

	EU ETS	RGGI	Korea	New Zealand	California
Since	2005	2009	2015	2008	2012
Emissions (Mt)	4.323	608	710	81	444
Carbon price	\$27.81	\$5.98	\$25.59	\$16.33	\$16.84
Population	512.300.000	50.300.000	51.600.000	4.800.000	39.590.613

TABLE 2 COMPARISON OF ETS WORLDWIDE

Choosing a system that is deployed in parts of the United States also has a significant advantage. Since the entire United States is not subject to an ETS regime, there are possibilities to form a control group. Obviously, there are differences between the RGGI and the California system, but all of these can now be viewed against the control group and with the situation as it is in Europe.

The formation of the control group depends on the geological spreading across the United States, the state's size, and the degree of information availability on the historical CO_2 equivalent of the state. The total number of states is 50, of which 48 form the contiguous states. Of these 48, 11 falls under the ETS regimes, the remaining 37 sets a control group of 20 states. Appendix 2 contains a map of the states that are part of the control group.

However, within the limitations of the availability of historical data, it is possible to make a good analysis based on multivariate regression due to the presence of large price differences at the same moment in time. These were already shown in table 2, but are also shown below in figure 8. After all, based on the hypothesis, price is also considered as a variable influencing the amount of CO_2.

Scientists from the German Institute for Economic Research have calculated that a price of more than 40 euro per emitted tonne of CO_2 could affect the price of power from coal in a way that would make other energy sources more competitive. As can be seen in figure 22, a price of at least 40 euro/dollar has not been reached before. It is interesting to take a closer look at the price, what exactly is the meaning of this number in relation to CO_2? (Appunn & Sherman, 2018)

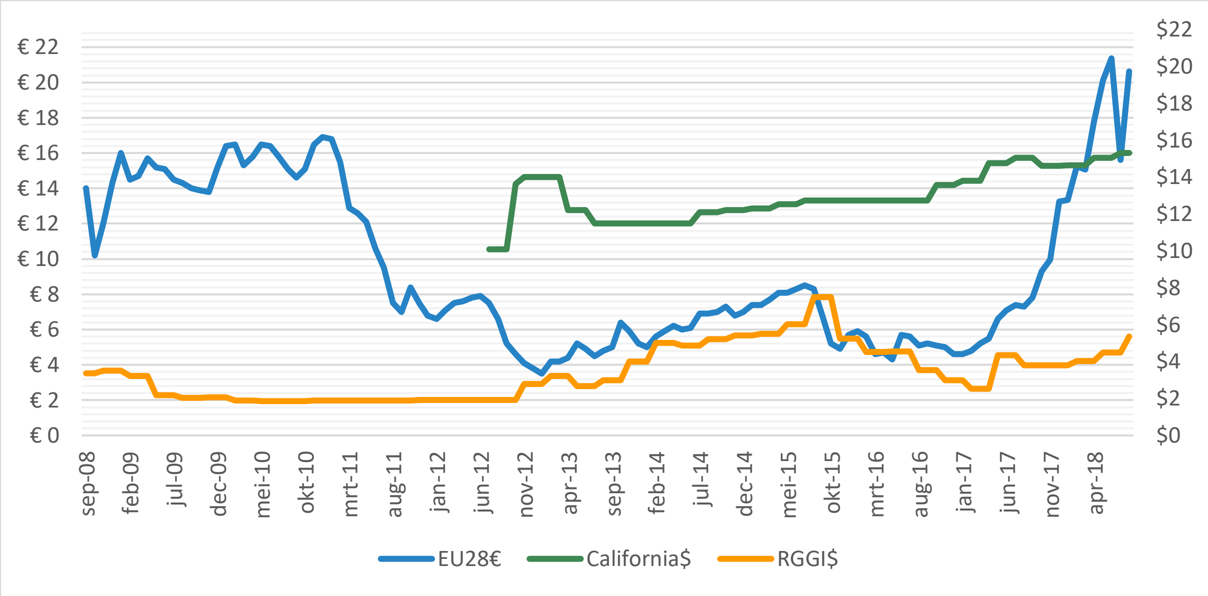


FIGURE 8 CARBON PRICE

The price is a result of the normal play of supply and demand, as stated in the theoretical part. According to the ETS principle, the ceiling in combination with the theory of supply and demand should lead to a certain level of CO_2. The different groups have shown different prices over the years. The question remains to what extent the price actually has a direct effect on the amount of CO_2. When the ceiling is too high, there is little financial pressure from the obligation to buy permits to legally emit CO_2. When the ceiling has a too low maximum, there is a high financial pressure. That is why the price can be seen as a method of providing insight into the extent to which the ceiling matches the current reduction capacities of the market. The development of alternative production methods or improvements takes some time and therefore the price is also a reflection of the expected future innovation capacity. In theory, a direct curtailment of the ceiling has direct consequences for CO_2 emissions. But because companies must anticipate, they have as escape the a possibility to obtain permits from companies that do not need permits anyway. As a result, the price can be seen as a signal when demand for emissions is high or low, relative to the cap. In the end emissions should go down when the cap is stricter than the number of emissions that would follow under the counter-factual. A stricter cap, yields a higher price, because it becomes more costly to reduce emissions.

6. Data

6.1 Collecting the data

For the theoretical framework, various studies and elaborations in the field of emissions trading have been used. These documents are freely accessible through the university library. Also, a large part is publicly accessible on the website of the European Commission and other European bodies. These sources can be found in the relevant sections and can be found in an extended version in the references list.

Information about the European Union is widely available from the European statistical office Eurostat. For example, data are available here on the size of the gross domestic product and the size of the population. Information is kept up to date per country, but also for the total of the European Union. The European Environment Agency (EEA), together with Eurostat, provides data on the amount of CO_2 per sector per year if necessary. In addition, the EEA also provides annual reports on the status of greenhouse gases via an interactive dashboard. The European Commission, in its role as the principal, can provide other information on the EU ETS itself and policies that may affect greenhouse gas figures at the European level.

Since January 31, 2020, the United Kingdom is no longer part of the European Union, but of course, still appears in many datasets over the past few years. Because it is maybe not always clear whether EU 27 or EU 28 is used in some sets, the data of the EU 28 group is chosen if possible. Given it is more likely that data compiled in the past include the EU 28 and not yet the EU 27.

In the United States the development of different gases is tracked uniformly only at the federal level. This tracking is done per sector per year by the United States Environmental Protection Agency (EPA). For more detail in the data, there is a dependence on the reporting of individual states. Each state in RGGI and California reports every year or once every few years a greenhouse gas inventory which states noting the number of gases per sector per year. It differed from when tracking started, varying between 1990 and 2004. In the absence of individual years, attempts have been made to obtain this by contacting the agencies in charge of implementation. This direct contacting is the case for the states: New Jersey, New Hampshire, Maine, Maryland, and Rhode Island. Also, the way of breakdown by category is not always the same or sufficiently explained to be able to equate this to each other manually. The same method of data collection was used for the control group. Since it was already expected that information would not be visible at a detailed level for every state, one of the criteria for forming the control group is the amount of information available. In practice, there appears to be very little detail-level information available for these states, making this criterion no longer relevant. The control group is now formed by geographic spreading and size of the states. For an overview of the information gathering at a detailed level of the states, see Appendix 3.

Uniformity and additional information can be achieved by looking at the Facility Level Information on GreenHouse gases Tool (FLIGHT) prepared by EPA. FLIGHT provides information about greenhouse gas emissions from extensive facilities in the United States. A facility is considered extensive if the emissions exceed 25 kilotons CO_2 eq. annually. This tool keeps an overview of different types of installations and can be found in detail with the name of the company. In some exceptional cases over 2017 and 2018, facilities no longer appear in the list. Whether this is a lack of reporting, no longer using the installation or for any other reason is not known. The FLIGHT facilities are required to report annual data about greenhouse gas emissions to EPA as part of the Greenhouse Gas Reporting Program. This reporting means that there is a uniform image of the bigger facilities, which in some cases fall under an ETS and in case of the control group do not fall under ETS. (Environmental Protection Agency, 2019)

The United States Bureau of Economic Analysis can provide data on the size of the economy. It is possible to overcome the effect of inflation with a multi-year comparison. The advantage of calculating back to a compensated base year is that inflation does not play an obscuring role in the comparison. The values are calculated back to a central year, in this case to the value of 2012. Eurostat calculates back to the value of 2010. The United States Census Bureau has figures available on the population by state. The difference between the two years is compensated in the data. (GDP and Personal Income, 2020) (United States Census Bureau, 2020)

Historical values for the permit prices for the EU ETS have been retrieved from the websites of the Netherlands Central Bureau of Statistics (CBS, 2020) supplemented with the most recent data available by EMBER (Sandbag Climate Campaign CIC, 2020). The organisation behind RGGI has an overview of the prices on its website (The Regional Greenhouse Gas Initiative, 2020). California has set up a separate dashboard for this. (Climate Policy Initiative, 2020) (California Air Resources Board, 2020)

In order to select the data, the series must be as complete as possible from 1990, the base year when talking about climate policy. In most cases, the reports are one to two years behind the current year. In the dataset, therefore, the same number of values is not known for the different states for every factor. The focus on data collection is starting just before 2005 to 2019. This period makes it possible to view the trend as it was before the introduction of the policy tool, for EU ETS in 2005, and view the trend after the introduction of the policy instrument.

6.2 The available data

Group	No.	Level of total CO_2 emissions				Level of ETS CO_2 emissions			
	States	Years	Total	Present	Missing	Years	Total	Present	Missing
EU	28	'90-'19	30	30	0	'05-'19	420	409	11
RGGI	10	'05-'18	144	130	14	'10-'19	100	100	0
California	1	'90-'18	30	29	1	'10-'19	10	10	0
Control	20	'90-'18	580	135	445	'10-'19	200	200	0

TABLE 3 – RESEARCH GROUPS

There are four research groups in this study, each with its underlying number of states. An exception to this is the state of California. Individual data is available for all states on; the size of the population, the size of the economy, amount of CO_2 and the amount of CO_2 that can be allocated under ETS regulation. All information is available for the first two variables mentioned. Information regarding CO_2 is not always fully available. The available values vary over time, starting in 1990 and ending in 2019. For some variables, not all data is still available. Therefore the start or end year may differ. The number of missing values in the series is indicated in the missing column. Overall this means that the number of observations may vary per exercise.

6.3 The control group

It appears that forming a control group is much more complicated than expected. In this group of 20 states, only a few cases keep an inventory report, and in those cases where this the case, data is sometimes available with a considerable interval. This interval can be seen in the high score on missing values on the total level of CO_2 emissions, since there is a uniform way of registering the CO_2 emission allocated ETS result in no missing values. As a result, it is not always possible to obtain the necessary data from the pre-intervention period, respectively 2005, 2009 and 2012. A comparison of DID is therefore also more difficult to make.

The Kaya Identity is relevant again to see if the control group has the correct properties. This identity indicates various factors that influence the CO_2 level. These are population and GDP per capita. The Kaya identity also mentions the energy intensity of the GDP and carbon footprint of energy, both of which can be influenced by the ETS policy, so that checking the groups for these values is not the correct handling.

The first factor for analysing, the control group, we looked at the size of the population, and specifically at the development over the past period. As can be seen from the theoretical framework, a rapidly growing population can have a negative effect on CO_2 emissions, as mentioned in paragraph 3.4. Figure 9 shows the historical values of population growth for all four groups. All groups show an even low to a limited annual population growth of between 0.0% and 1.5% per year. This ratio is a typical value for developed economies such as the industrialised 7 (G7) partnership, with values ranging from -0.1% for Japan to + 1.0% for Canada measured over the period 2011 - 2016. The United States also make part of the G7 and come here in total on an average of + 0.8% per year. The RGGI group is slightly below that. (World Population Review, 2020) (Statistics Canada, 2017)

For the second factor, we looked at developments in the GDP per capita. Because a higher GDP per capita does not immediately have to lead to considerable pressure on the CO_2 level, a relative change from year to year is also visible in figure 10. At first glance, the observations show a similar movement, with an apparent dip in 2009 at the time of the economic crisis.

In general, when looking at figure 9 and figure 10, the conclusion can be drawn that the control group shows sufficient similarities with the states and countries to be examined to be able to designate the control group as such.

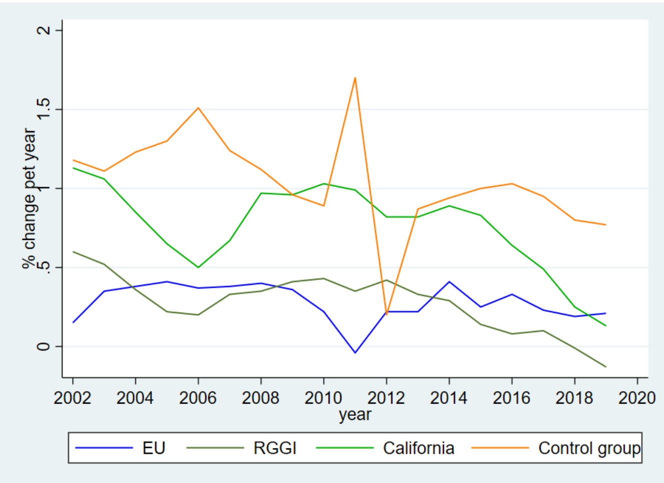


FIGURE 9 – POPULATION DEVELOPMENT

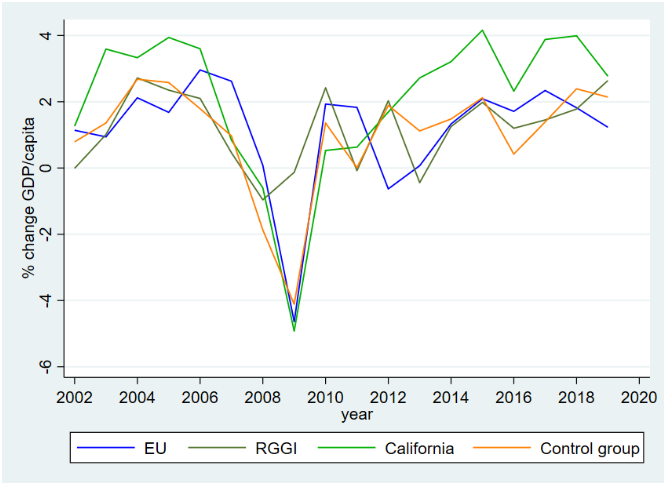


FIGURE 10 – GDP PER CAPITA DEVELOPMENT

6.4 Validity

Validity is the degree to which a test measures what it should measure. When talking about CO_2, uniformity is created in the unit in which results must be expressed. The effects of the policy are mainly investigated in terms of its impact on the amount of CO_2 equivalent. This is a logical choice because the policy instrument also targets a decreasing amount of this measure.

As indicated in the description of the method of data collection, there is a change in the number of countries participating in the EU ETS system. In almost most cases, it is possible to choose the data belonging to the EU 28 countries. It is more likely that data that is not known and has been published in the past still interpreted the EU 28 and not the future EU 27.

6.5 Reliability

The reliability is high because historical data has been used for almost all data. These are generally widely available and will in almost all cases lead to a reproducible study. Since there is no experimental research, it does not mean that there could be no measurement errors. Because the information required for the data set does not come from a central point, but is collected through different routes, it is possible that a small shortcoming could arise in the uniformity in which data is kept. For example, when looking at the three most common greenhouse gases CO_2, CH_4, N_2O, the changes in different assessment methods for global warming potential are present but can be called minimal and so are the effects on the results. To avoid errors in the dataset, due to the use of rounded numbers, the figures are included in the smallest unit possible. These are only converted later to larger units, such as is the case with CO_2 equivalent, from tons to megatons.

7. Descriptive statistics

7.1 The European Union

The first part of the analysis examines the changes that may be seen over time. It tries to investigate whether there is a suggestive correlation due to the introduction of the EU ETS system and the CO_2 equivalent levels.

When looking at figure 11 where the total amount of CO_2 is displayed, the first years of the graph show a slight increase of approximately 100 megatons of CO_2. There was a substantial decline from 2007 to 2008, coinciding with the introduction of ETS phase 2. A small increase can still be seen in 2010, after which the decline continues to a new balance, which will start in 2014 and lasts at least three years. The figures for 2019 do not yet appear in all reports, and statements in the news fluctuate between a decrease of 2% or 2.5%. A decline is therefore visible.

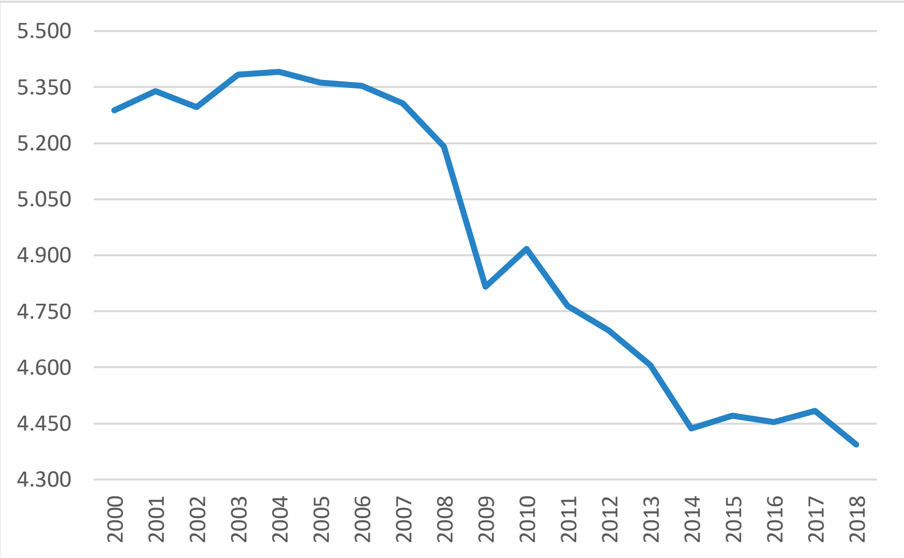


FIGURE 11 TOTAL CO_2 (MEGATONS)

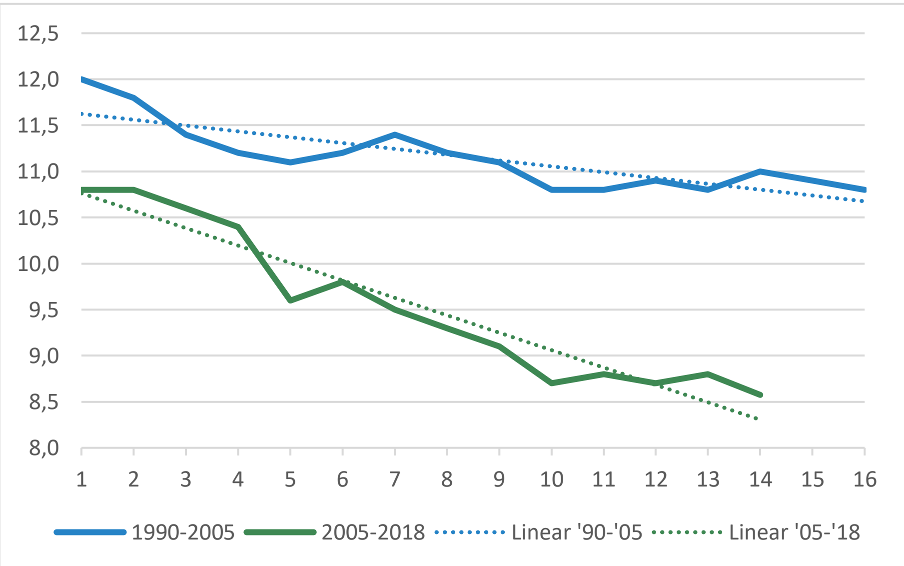


FIGURE 12 CHANGES CO_2 PER CAPITA OVER TIME (TONS)

If the known data on total emissions were to be divided into the two periods, the following trend lines emerge as shown in figure 12. From this figure it is clear that the trend shows a stronger decrease in the period of operation of ETS than in the period before the start of EU ETS. The more substantial decline during the second period could also be attributed to the increased awareness of CO_2 reduction and related measures affecting the whole economy.

The sharp decrease seen in figure 10 in the years 2008-2009, is not entirely due to the start of phase 2 of ETS. This is clearly visible in the also sharp decrease in GDP in figure 13. The financial and economic crisis that was at its most severe around that time had a strong depressing effect on the GDP and therefore also on the total CO_2 emissions. The graph in figure 13 shows the relative changes over time, with base year 2000 = 100%. Here too it is clearly visible that a change in the trend is visible from around 2007. From apparently a constant trend to a decreasing trend. The one-off dip in the line as a result of economic decline has little disruptive effect with the drawing of an imaginary trend line.

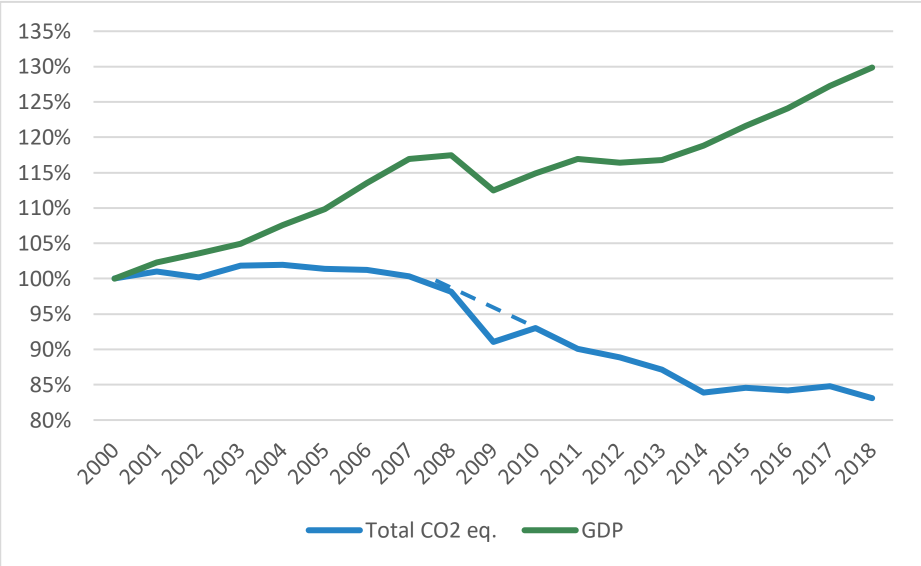


FIGURE 13 RELATIVE CHANGES YEAR 2000 = 100%

The book by (Hintermann & Gronwald, 2015) also examines the question of whether EU ETS contributes to the limitation and reduction of emissions. They looked at the periods 2005 - 2007 and 2008 - 2012. The authors note that there is an increase in GDP and at the same time a decrease in the amount of emission. The financial and economic crisis spanned much of the period under review. It was therefore not clear at the time of writing whether there were any after-effects of this decline. *''The remarkably low price of around 4 euros is seen as counter-proof of the system's good functioning. Meanwhile, the price has risen again, so it makes this argumentation less strong''.* The lack of causality, as Hintermann & Gronwald state, is also endorsed in the article by (Liu & Hao, 2018). Their research shows that no direct causality can be established between emissions, energy consumption and GDP per capita.

As described in the theoretical framework, economic development can not be considered as the most sufficient factor for growing CO_2 emissions. For this reason, figure 13 should be seen as indicative. As all the descriptive statistics are in relation to the conclusion.

Maybe saying much more is a comparison between the total amount of CO_2 and those of the installations that fall under the ETS regime. As shown in figure 4, only barely 40 percent of total emissions fall under the ETS regime. Besides the general effort sharing legislation regarding total emissions. Figure 14 shows the partition tot EU ETS, whereby 2005 was taken as the base year at the start of the EU ETS. If for this graph, the actual emissions were shown instead of relative changes, this would reduce readability. It now appears that the sharp decrease, as shown in figure 11, was caused to a greater extent by the installations that fall under ETS, and less by the other installations. The reduction in 2008 – 2009 for ETS is proportionally more significant at 14.5% than the reduction of 9.3% for the total amount. It is unclear why under the given economic circumstances, this difference occurs so strongly in a short time. After this, it seems that the reduction will again hold the same decreasing trend for a few years, which would suggest that ETS offers little added value at that time. Where in figure 13 a new plateau appeared to emerge from 2014, figure 14 shows that the non-ETS installations cause the primary reason for this. The relative difference, therefore, increases further.

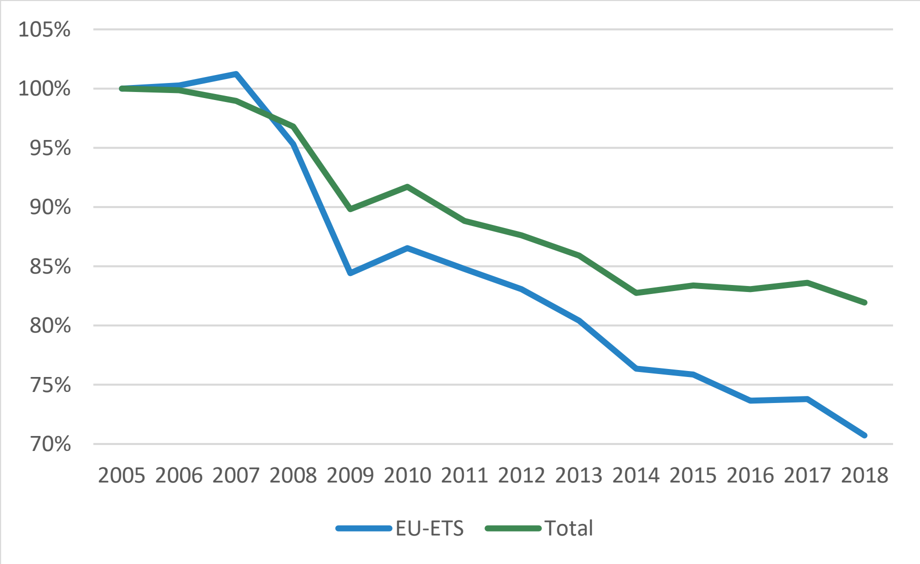


FIGURE 14 CHANGES OF ETS INSTALLATIONS RELATIVE TO THE TOTAL

7.2 The EU and other states

The second part of the descriptive analysis tries to investigate the hypothesis based on a kind of differences-in-differences analysis. This analysis will be a comparison between different groups; EU, RGGI, California and the control group. When only looking at the amount of CO_2, conclusions may be drawn that are not entirely correct. That is why the research also consider the population. All four groups have each their properties concerning the ETS system, the earlier stated hypothesis is that there are different outcomes for each group. A more extensive system, in the concept of percentage of the total CO_2 emissions, is expected to show a more significant decrease in the total amount of CO_2 level.

It may be interesting to start by looking at the developments in the field of greenhouse gases at a total level over the past few years. The figure below shows a analysis of the total amount of CO_2 for the EU, RGGI, California and the Control group. In this case, the control group has a size of 4 states instead of a total of 20. This is because there is information available from the inventory reports, running from 2005 to 2015 only for those 4. The States are Iowa, Minnesota, North Carolina and Washington. Only two of these states have information available per year since 1990. Not enough information is available from the other 16 states to obtain sufficient observations. The dashed lines indicate the introduction of ETS in 2009 for RGGI and the introduction of ETS in 2012 for California. Introduction of ETS in the EU was in 2005, due to a lack of information about the control group, only the values for post-intervention are shown here. The period before 2005 has already been further investigated in paragraph 7.1, considering the internal EU analysis. Because the EU is much larger, for some figures, relative values have been used instead of absolute ones. There are also several years in which ETS was introduced and, therefore, also several vertical lines in the following graphs. Thus, the trend lines show a turning point for the regions concerned but not for the control group.

Figure 15 shows the values for the total of all four research groups. As indicated, the control group for the total CO_2 level only concerns a minimal number of underlying observations. This is also reflected in the accountability table 5. It also mentions the absolute values that underlie the relative values. It is striking in figure 15 that the EU and RGGI show a more substantial decline than the other two groups. The speed in this seems to differ slightly over the years. The decrease for RGGI is fading just after the point of intervention with ETS. Where no clear difference can be observed for California, this also applies to the control group. The general picture is a declining trend for all groups.

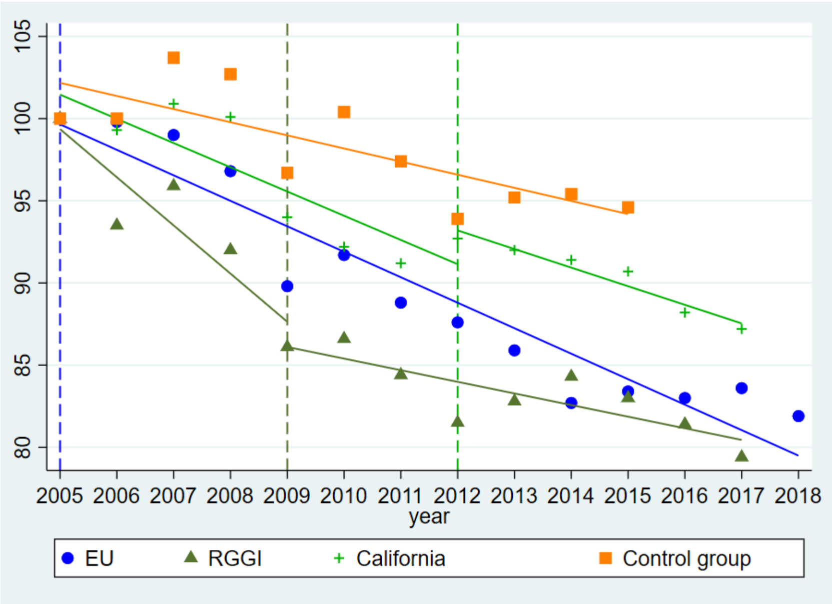


FIGURE 15 – DIF-DIF ANALYSIS ON TOTAL AMOUNT OF CO_2 EQUIVALENT

TABLE 5 – SUMMARY OF DIF-DIF ANALYSIS

	Years	States	Obs.	Mean	Std. Dev.	Min	Max
EU	14	28	392	4803.53	350.65	4393.5	5362.0
RGGI	13	10	123	614.18	44.83	560.2	706.1
California	13	1	12	456.59	22.85	424.1	490.9
Control	11	4	44	570.20	18.61	545.5	602.2

When considering the size of the population, the analysis would look like shown in figure 16. The values for the control group are much higher that they are shown on the secondary y-axis. The observations showed concern the total average of each group. A possible explanation for the substantial decrease that is now visible to the control group is also the more robust population growth that was visible in figure 9. As a result, the share of CO_2 per capita decreases more sharply. A weaker decline for the RGGI can be seen after implementation and a continuation of the trend at California. The EU has now a more stable decrease compared to the other groups. A decline in the population in some countries of the EU will partly offset the strong effect as was visible in figure 15.

TABLE 6 – SUMMARY OF FIGURE 15

	Years	States	Obs.	Mean	Std. Dev.	Min	Max
EU	14	28	392	9.53	0.79	8.6	10.8
RGGI	13	10	123	12.41	1.07	11.1	14.5
California	13	1	12	12.18	0.99	10.8	13.6
Control	11	4	44	23.33	1.51	21.3	25.4

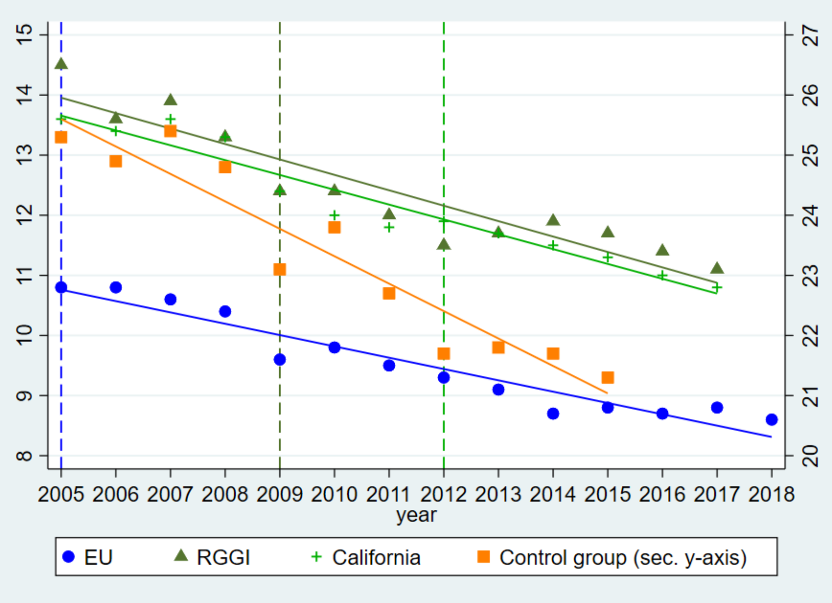


FIGURE 16 – DIF-DIF ANALYSIS ON TOTAL AMOUNT OF CO_2 PER CAPITA

The influence of economic developments on total CO_2 emissions are challenging to determine and theoretical hard to discover, as stated in the theoretical framework. As outlined in the theoretical framework, a growing economy does not immediately mean that the amount of CO_2 has to increase. However, it can be made clear how much CO_2 is released for adding 1 million in value to the GDP. This makes it possible to observe a trend, although it is not known where the economy is on the environmental Kuznets curve. Figure 17 shows the amount of CO_2 that are polluted to be able to add 1 million in value to GDP. The values for RGGI and California are so much lower that they are shown on the secondary y-axis. To see more details in the figures, the same values are also shown as relative numbers compared tot 2005 in figure 18. The observations showed concern the total average of each group. The decrease in the EU is globally in line with the control group.

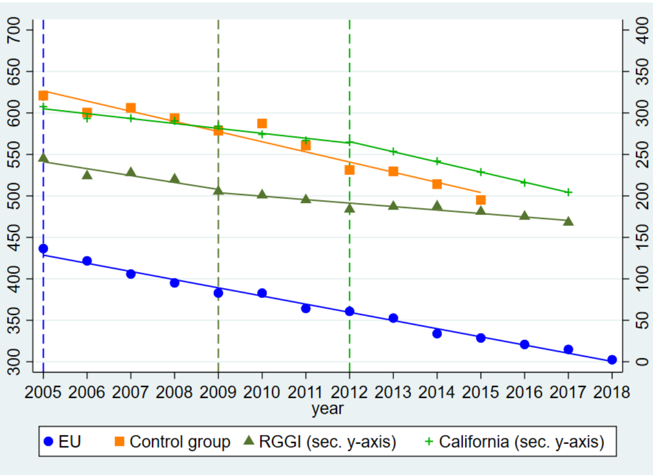


FIGURE 17 DIF-DIF ANALYSIS ON TONS CO_2/MILLION GDP

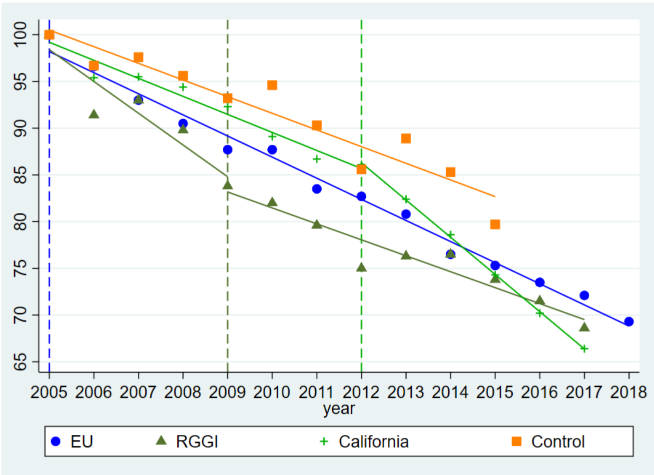


FIGURE 18 DIF-DIF ANALYSIS ON RELATIVE TONS CO_2/MILLION GDP

TABLE 7 – SUMMARY OF FIGURE 18

	Years	States	Obs.	Mean	Std. Dev.	Min	Max
EU	14	28	392	364.55	39.95	302.5	436.5
RGGI	13	10	123	251.74	27.95	211.5	308.4
California	13	1	12	263.02	31.08	204.4	307.6
Control	11	4	44	565.28	39.84	495.1	621.0

The ETS policy instrument is aimed at promoting a decrease at the largest installations. Therefore it is necessary to zoom in further on a more specific level. Because, as written in the theoretical framework, the scope and thus, the size of the system for each group is different. For example, the ETS system in California also includes the transport sector, but this is not the case in the EU. It is estimated that this already gives a difference in scope of 30 percent.

In order to enable this further level of detail, the FLIGHT tool is used for data on the American states. This tool specifically keeps track of the values for the large installations, the disadvantage is that this only started in 2010. This late start means that it is not possible to have a complete historical series for a difference-in-difference analysis. The advantage is that data is now available for the entire control group of 20 states, which improves reliability.

The values for Figure 19 are shown as relative values compared to 2010 because the values are much lower in absolute terms for RGGI and California, due to the small size of the area. The figure shows per group a total average amount of CO_2 for the ETS installations, potential (industrial) ETS installations in case of the RGGI and control group. The figure shows that the most substantial decrease can be seen at RGGI and for California after implementation of ETS. Furthermore, the California trendline after implementation shows a more substantial decline than the EU and the control group, which is strikingly similar to each other.

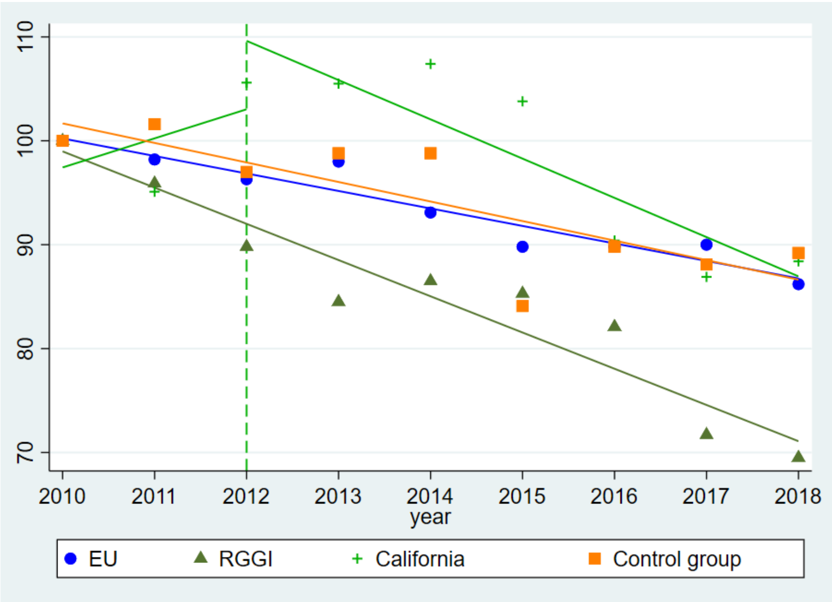


FIGURE 19 DIF-DIF ANALYSIS ON RELATIVE TOTAL AMOUNT OF ETS CO_2

TABLE 8 – SUMMARY OF FIGURE 20, ABSOLUTE VALUES

	Years	States	Obs.	Mean	Std. Dev.	Min	Max
EU	9	28	252	1800,42	83,94	1655,3	1919,5
RGGI	9	10	90	139,44	15,43	113,8	163,9
California	9	1	9	107,93	8,39	95,6	118,1
Control	9	20	180	1577,06	79,53	1458,6	1681,4

Figure 20 shows the values when the size of the population is also included in the amount of ETS CO_2, we see the emissions per capita. The results show that the strongest decrease can be seen at the control group. The value for emission tons per capita is also higher here than for the other groups. These are shown on the y-axis to ensure legibility. All groups where a form of ETS is present show an almost equal parallel decrease. Where figure 16 dealt with the total CO_2 tons per capita, the strong decrease was visible for the control group both there and here as well. Where this was only visible up to and including 2015 in figure 15, this trend therefore seems to continue at, in the case of the control group, potential ETS level. It should be noted here that high emissions per capita should also be easier to reduce. In addition, the decrease as the difference between the maximum value and the minimum value for RGGI is the largest with -30.3% and not for the control group, here only -17.2%. The figure does not give a completely accurate picture according to the growth of dif-dif. This is because it is not clear what the trend for intervention is for all groups.

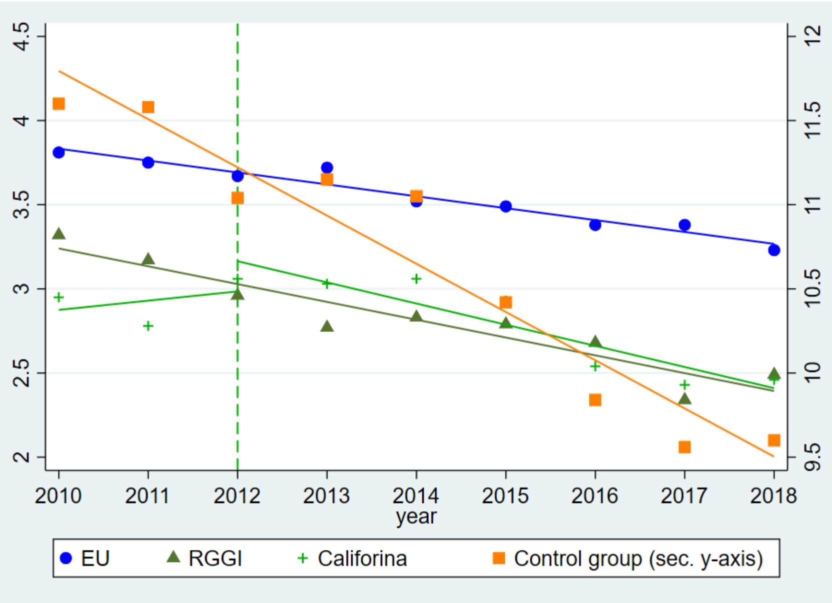


FIGURE 20 DIF-DIF ANALYSIS ETS TONS CO_2/CAPITA

TABLE 10 – SUMMARY OF FIGURE 21

	Years	States	Obs.	Mean	Std. Dev.	Min	Max
EU	9	28	252	3,55	0,19	3,2	3,8
RGGI	9	10	90	2,82	0,29	2,3	3,3
California	9	1	9	2,81	0,25	2,4	3,1
Control	9	20	180	10,65	0,73	9,6	11,6

When considering for the size of the economy, the analysis would look like figure 21. The strongest decrease that was visible for the control group at ton/capita is less noticeable here, but still present. Together with the EU, this is the least significant decrease. Here too, California again shows a noticeable change after the moment of implementation. The values for RGGI and California are much lower, that they are shown on the secondary y-axis.

TABLE 12 – SUMMARY OF FIGURE 22

	Years	States	Obs.	Mean	Std. Dev.	Min	Max
EU	9	28	252	133,81	11,43	114,0	149,4
RGGI	9	10	90	55,62	7,25	44,42	67,75
California	9	1	9	58,73	8,73	44,93	68,17
Control	9	20	180	270,05	26,9	228,5	306,8

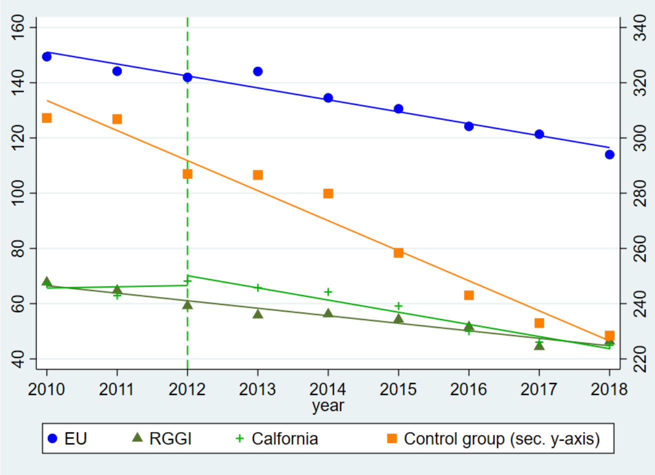


FIGURE 21 DIF-DIF ANALYSIS ETS TONS CO_2/MILLION GDP

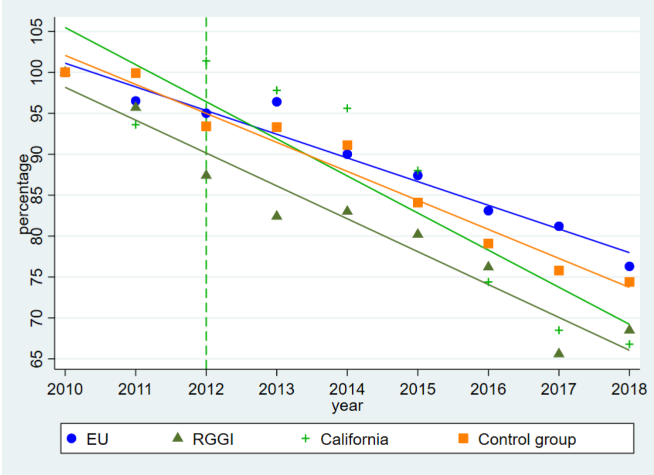


FIGURE 22 DIF-DIF ANALYSIS ETS TONS CO_2/MILLION GDP

7.3 Summary

As indicated earlier, the descriptive statistics alone are not sufficient to draw firm conclusions about the relationship between emissions and the presence of an ETS price. However, this can be seen as indicative of a possible relationship. When looking only at the EU figures, there seem to be more indications favouring an ETS presence. Figures 11,12,13, for example, show an apparent decrease in CO_2 in the period of the presence of ETS. But a more precise picture emerges, whereby in figure 14 a distinction is made in CO_2 levels between ETS-effected installations and the entire economy.

International comparisons between the different regions show little evidence that having an ETS in a region causes a bigger decrease in CO_2. CO_2 per capita expressed shows a stronger decrease in the control group. And expressed concerning GDP, the differences are not substantial. Zooming in on the level of (potential) ETS installations, the differences between them become more remarkable, as there is, after all, inequality in the size of the ETS system. At this level, a clear benefit is visible for the control group. The more substantial visible decrease is indeed present. As a major side note, the overall level of CO_2 emissions is higher, and that reductions are therefore easier to achieve. CO_2 emissions converted to relative values; this sharp decrease is no longer present.

8. Regression

8.1 Statistical analysis

Because the price can be seen as an expression of the system and creates the possibility of trading, it is interesting to investigate whether there is a relationship between the price, caused by supply and demand combined with the ceiling, in relation to the CO_2 emissions. In the following regressions, this possible relationship with each other is examined. As indicated earlier in chapter 5, the descriptive statistics from chapter 7 are purely indicative and illustrative. It has too little factual value to be able to demonstrate a clear relationship. From this imaging and indicative perspective, it can help to understand the context and the regression better.

8.2 Emission per capita

Firstly, we start with a regression that includes emission per capita and the ETS price. This shows the effect in the CO_2 levels if the price of a permit ETS increases by 1 euro. To substantiate the hypothesis, negative values would therefore be expected here, since there would be a negative relationship between price and CO_2. With each version of the regression 1 t/m 6, this is continuously expanded a little further. For example, country fixed effects and year fixed effects are taken into account and adjustments are made for the economy's size. As indicated in the theoretical framework, there is only a limited direct effect in the short term in implementing the ETS price and additional measures. In the short term, there is an elastic relationship, but limited. For this reason, it is assumed that the CO_2 values with a one-year delay may give a better picture in the regression; this can be seen in regression 5 and 6. A further delay in the display of CO_2 would result in a lower amount of available data, resulting in lower reliability.

	ETS Price (1)	Fe Robust (2)	Year (3)	GDP (4)	Lagged (5)	Lagged (6)
Emission per capita						
Coefficient ETS Price	0.019833*** (0.00)	0.019512*** (0.01)	-0.003658 (0.81)	-0.003666 (0.81)	-0.021990 (0.38)	-0.028836 (0.40)
st. dv ETS Price	0.005143	0.007272	0.015454	0.015462	0.024515	0.012270
Coefficient GDP				1.03e-06 (0.32)		9.68e-07 (0.41)
st. dv GDP				1.03e-06		1.15e-06
County fixed effects		x	x	x		x
Year fixed effect			x	x		x
Obeservations	516	516	516	516	490	490

TABLE 13 – REGRESSION RESULTS

1: Only ETS Price
2: ETS Price, fe robust
3: ETS Price, fe robust, i.year
4: ETS Price, GDP, fe robust, i.year
5: Only ETS Price, emissions lagged 1 year
6: ETS Price, GDP, fe robust, i.year, emissions lagged 1 year

The results of this first regression show the following picture. The most straightforward regression, where only the ETS price is considered, gives a very high significance of 0.00. This significance level diappears when the CO_2 data is displayed with a delay of 1 year in regression 5. The significance of regrission 1 is somewhat surprising because it is precisely by disregarding factors of influence that it would be expected that there would be no significance. An increase in the ETS price results in an increase of 0.02 tons of CO_2 per capita. Taking into account the country fixed effects, a significant effect is still visible, although the coefficient is still not very outspoken. Contrary to the hypothesis, there is a positive relationship till regression 2.

When logically, the year-fixed effect is also taken into account and is additionally corrected for the economy's size, the coefficient changes to a negative value, although with a deficient significance level. An increase in the ETS price results in a decrease of 0.0036 tons of CO_2 per capita. This effect becomes stronger in regression 5 and 6. The economy's (GDP) coefficient is so small because it is expressed in units of a million. Taking this into account, the coefficient cause a small increase if GDP grows with one million. So there would be a positive relationship here. Regression 6 provides a higher significance level than regression 4 for the ETS price coefficient, but not for the economy's size. Still both are not yet sufficient enough. It is striking that the coefficient on ETS has a stronger negative value than regression 4, just in line with the hypothesis.

8.3 Emissions per GDP

A second regression takes place between the emission per GDP and the ETS price. Here, too, a regression is being expanded further and further, as in 8.2. One difference to note is that the correction is not made for the size of the economy but for the population's size. After all, a growing population provides more numerous opportunities for the economy to grow.

	ETS Price (1)	Fe Robust (2)	Year (3)	Population (4)	Lagged (5)	Lagged (6)
Emission per GDP						
Coeffcient ETS Price	0.919377*** (0.01)	0.882906** (0.04)	-0.457164 (0.35)	-0.456242 (0.36)	2.857285** (0.02)	3.199107*** (0.01)
st. dv ETS Price	0.359139	0.424061	0.485837	0.491366	1.191479	1.223567
Coeffiecient population				0.000014* (0.07)		0.000016* (0.08)
st. dv population				7.63e-06		8.86e-06
County fixed effects		x	x	x		x
Year fixed effect			x	x		x
Obeservations	516	516	516	516	490	490

TABLE 14 – REGRESSION RESULTS

1: Only ETS Price
2: ETS Price, fe robust,
3: ETS Price, fe robust, i.year
4: ETS Price, population, fe robust, i.year
5: Only ETS Price, emissions lagged 1 year
6: ETS Price, GDP, fe robust, i.year, emissions lagged 1 year

The result of the second regression shows the following picture. As seen in 8.2, where a direct positive relation was very significant, it also appears here in regressions 1 and 5. Based on the hypothesis, a negative relationship should also be expected here. The regression 1 coefficient and significance decrease slightly when the country fixed effects are also taken into account. Regression 1 and 2 shows that when the price increases by 1 euro, there is an increase of about 0.9 tons of CO_2 per million GDP. The significance disappeared completely when the year fixed effect and the population are also considered. Again, just as was visible in 8.2, a change from slope from positive to negative is visible when more factors are taken into account. The difference is also more pronounced. Here now an increase of 1 euro causes a decrease of approximately 0.45 tons per million GDP. The delayed representation of the CO_2 values results in a very strong positive ETS price coefficient in regression 5 and 6, still with a good amount of significance. This again contradicts the hypothesis. The results found in the variable population are still minimal but significant to a certain extent. The increase of 1 person in the population causes an increase of an average of 0.000015 tons of CO_2 per million GDP.

Conclusion

In this chapter, a conclusion will be formed, which aims to answer the main question: *To what extent has an emission trading system made an effective contribution to the reduction of CO_2 emissions?*

Starting with the theoretical background of emission trading systems, also known as cap-and-trade, will be discussed. We have seen that the European Union has set itself specific goals in terms of preventing climate change. This goal requires a substantial reduction in CO_2 emissions, and the ultimate goal is to be fully CO_2 neutral by 2050. CO_2 emissions are seen as a negative externality, an unpriced effect of an action. It imposes costs on people who did not create the externality. Due to the absence of pricing-in this externality, the private marginal costs were calculated too low in case of this non-regulation. There are two ways of overcoming the problem of not including the externality in the private marginal costs: a market-based regulation or command-and-control regulation. Various countries or regions focus on ETS as policy instrument, which can be described as a market-based solution. ETS is a cap-and-trade instrument which consists of two parts. The cap on greenhouse gas emissions is a limit on pollution whereby the cap gets stricter over time. The trade part is a market for businesses to buy and sell allowances that let them emit only a certain amount, as supply and demand set the price. Trading gives businesses a strong incentive to save money by cutting emissions in the most cost-effective ways.

In any case, tackling the climate problem is difficult because, for example, efficiency measures can lead to downward pressure on future fossil prices. This causes increased incentive to produce more at current prices. Also, the price-depressing effect due to the higher efficiency makes it possible to use more fossil energy at the same cost. A cap-and-trade system should be able to address some of these concerns, for example, by setting a limit to the total emission of CO_2. It is essential to realize that it always involves a combination of measures. This mixture of measures has the common goal of reducing emissions, but it is more challenging to determine the individual effect of measures. So it will be hard to determine the effective contribution of ETS. The EU has great ambitions in terms of climate goals. It intends to achieve these goals, partly by focusing on the EU ETS policy instrument. It is an extensive policy instrument, which serves as a worldwide example of intergovernmental cooperation in the field of preventing climate change. In addition, the EU is also focusing on other policy measures, but more room has been left for customization at the individual member states. In the United States, there is much more room at the individual level of the states. This creates a variety of objectives and measures. The result is that it also offers opportunities for a representable control group with the same basis because some states do have an ETS policy. And opportunities to compare groups of different ETS systems with each other given the divergent permit prices.

The descriptive statistics chapter looks at indicative expressions of a possible relationship between price and CO_2 emissions. As stated, the descriptive statistics alone are not sufficient to draw firm conclusions. Figures 11,12,13 and 14 seem to be in favour of the presence of ETS. The international comparisons in descriptive statistics do not provide an unambiguous picture of whether the presence of an ETS results in a more imposing CO_2 reduction. In some of the graphs, an advantage is visible for regions with ETS, but there are also advantages for the control group in other graphs. So the descriptive statistics can not give any predictive answer to the research question.

Chapter 8 searches for evidence for an ETS system's intended functioning based on statistical analysis, inconclusive results emerge that would support the hypothesis. There is a high significance when not expected, in case of a positive relationship between the price and the amount of CO_2. And a low significance when taken more influences into account, but then there occurs a small negative relationship as stated in the hypothesis comparing CO_2 per capita. Also, the ETS coefficients are not sufficient enough so that, taking the standard deviation into account, a reasonably strong result remains. In case of the regression with CO_2 per GDP there appears a strong en significant relationship taking more influences and the time lagged into account. This apparently contradictory result shows a predominantly positive relationship between price and CO_2 based on the significance of paragraph 8.3.

Based on the descripted economic theory, the conduct of an emissions trading system would be a good policy instrument for the purpose at hand. The descriptive statistics show no indication in favour of ETS for the EU only. Especially, there is not sufficient indication from the descriptive statistics when there is an international comparison, including the control group. This same picture is maintained by the results that follow from chapter 8.2, but are revoked by the results of the subsequent paragraph. There are more indications of a causal positive relationship based on the simple regressions that do not include all factors of influence. The hypothesis that the policy instrument ETS does make an effective contribution to the reduction of CO_2 equivalent is therefore not statistically significant supported by the results found. The research has not been able to conclusively demonstrate the desired negative causal relationship.

Discussion

It has turned out that the policy area of climate change and the associated reduction of CO_2 equivalents is a complicated environment. Many factors play a significant role in this. This research has attempted to identify the major factors of influence and to take this into account in the results. It is complicated to draw a more firm conclusion due to the lack of sufficiently unambiguous results. A limitation is the amount of data available, which means that there may be too much slack in the results. Ideally, use should be made of a study that compares even more systems. Or where more historical data is available to be able to apply pure difference-in-differences. It has proven particularly difficult to set up a thorough control group. It is difficult to provide insight into many factors, as described in chapter 3, there are also many small factors of influence. Due to the high complexity and mutual influence of individual CO_2 measures on each other, it is difficult to determine the effect per measure. Therefore, it hasn't proved easy to draw an unambiguous conclusion in this research into an emission trading system's functioning. This is unfortunate as the system has great potential, according to economic theory. And the lack of clear evidence makes the system more sensitive to criticism.

The biggest reason why it is probably difficult to draw a clear conclusion is because of the delay in taking measures. The short-and long-run effects mentioned earlier in the research probably played a more important role in the results found than initially thought, and this may therefore have been insufficiently taken into account in the research design. It is difficult to determine how quickly, on average, the CO_2 reducing measures are taken and affect. Table 13 showed that with a 1-year delay there is a better connection with the hypothesis, but in table 14 the opposite was visible. If in both cases there had been a better fit with the hypothesis, this was at least an indication that the delay has a better representation of reality. A longer delay was not possible due to a lack of sufficient data, so there are still possibilities in a follow-up study. A study of how long the average abatement time is could therefore be a good suggestion. It is of added value for a similar design of this research when this is exactly known. This can then be used to better demonstrate how the relationship between price and CO_2 quantity relates to each other.

Despite the lack of clear proof of functioning, a trend is visible worldwide. More and more countries are preparing for, or have recently started implementing and executing an ETS system. This trend is unlikely to happen if there were no confidence in the policy instrument. With the unique combination between market forces, the formation of a price, and the regulated reduction by means of an annual reduction cap, there is serious potential, especially if there were large-scale links between different regions. Despite the fact that there is no statistically conclusive evidence for this. Conversely, it cannot be stated that the lack of support for the hypothesis should be seen as a claim that having an ETS increases the amount of CO_2. The multi-year CO_2 trend is already downwards, and there are no reasons to assume that there will be a slowdown when limits are set on the amount of CO_2 in combination with pricing on this. The most recent development is that the price for ETS permits has risen sharply, which may lead to clearer results in a follow-up study.

Given the trend of an increasing number of ETS regions combined with a more extended period in which the current ETS regions are operational, it is worth repeating this study in a few years. Hopefully, as a result of more data, it should be possible to draw a firmer conclusion in favour of ETS. Based on the current research, no policy implications can be stated for the time being.

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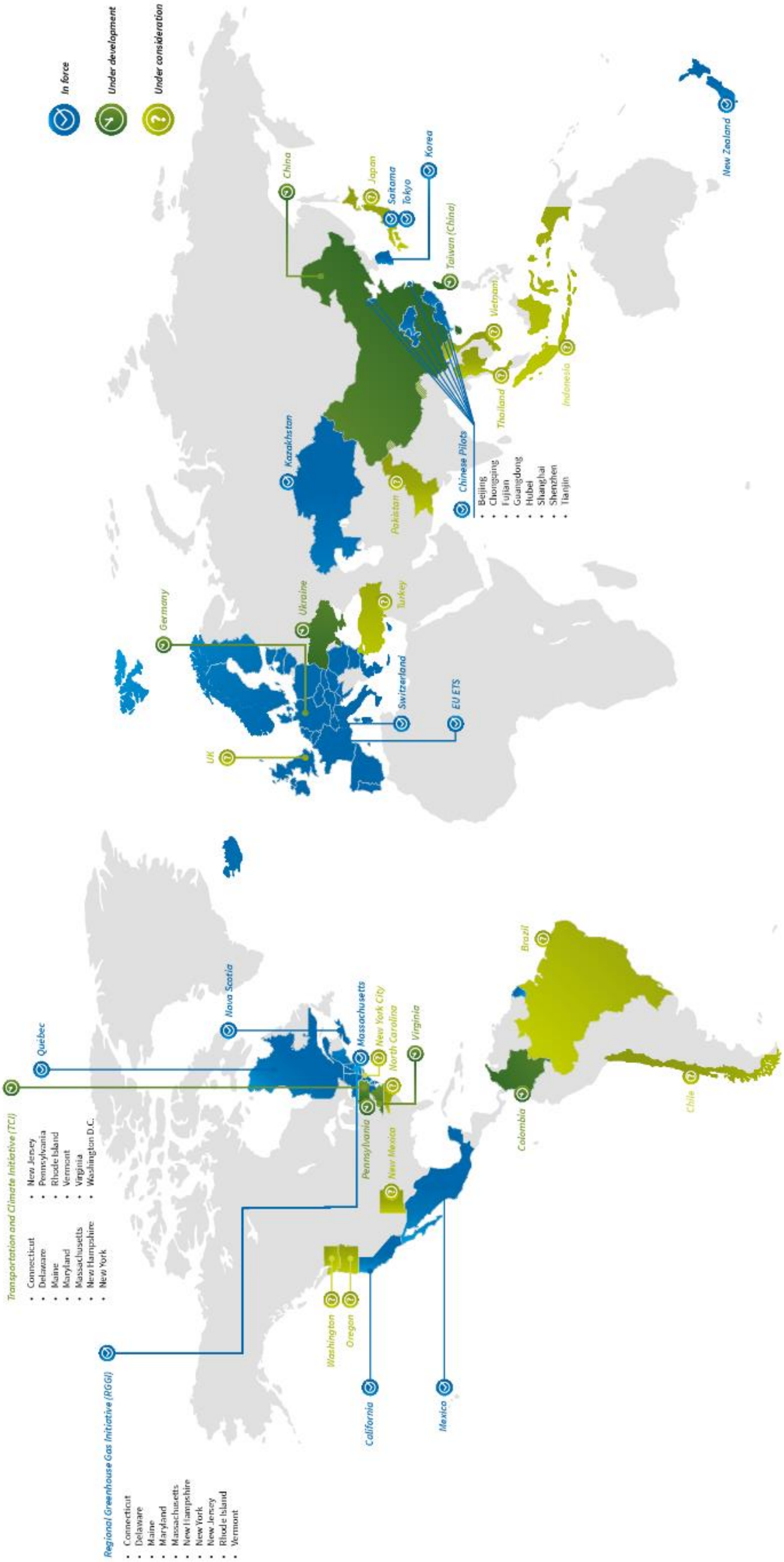
Appendix

1. Map of ETS worldwide

(International Carbon Action Partnership, 2020)



2. Map of control group states

(Map of USA with state names, 2010)

3. Information sources individual states

Information from the individual states is found at the following of its agencies and is published in annual reports or online dashboards. No reports are kept for the missing states in this list.

- California – Air Resources Board (California State, 2020)
- Colorado – Department of Public Health & Environment (Colorado State, 2020)
- Connecticut – Department of Energy and Environmental Protection (Connecticut State, 2020)
- Delaware – Department of Natural Resources and Environmental Control (Delaware State, 2020)
- Iowa – Department of Natural Resources (Iowa State, 2020)
- Maine – Department of Environmental Protection (Maine State, 2020)
- Maryland – Department of the Environment (Maryland State, 2020)
- Massachusetts – Department of Environmental Protection (Massachusetts State, 2020)
- Minnesota – Pollution Control Agency (Minnesota State, 2020)
- New Hampshire – Department of Environmental Services (only email)
- New Jersey – Department of Environmental Protection (New Jersey State, 2020)
- New Mexico – Environmental Department (New Mexico State, 2020)
- New York – Energy Research and Development Authority (New York State, 2020)
- Nevada – Division of Environmental Protection (Nevada State, 2020)
- North Carolina – Department of Environmental Quality (North Carolina State, 2020)
- Pennsylvania – Department of Environmental Protection (Pennsylvania State, 2020)
- Rhode Island – Department of Environmental Management (Rhode Island State, 2020)
- Vermont – Department of Environmental Conservation (Vermont State, 2020)
- Washington – Department of Ecology (Washington State, 2020)

4. Structure of the datasheet

	2010	2011	2012	2013	2014	2015	2016	2017
Connecticut								
Total State (Mtons)	42,79	41,45	40,77	41,70	41,21	42,72	40,51	39,97
FLIGHT (tons)	10.307.079	9.101.744	9.301.032	9.277.643	9.164.454	9.907.368	9.393.677	8.606.610
Δ FLIGHT		-11,7%	2,2%	-0,3%	-1,2%	8,1%	-5,2%	-8,4%
No. FLIGHT facilities	46	53	54	52	53	48	45	45
GDP (million$)	247.461	242.020	243.801	241.081	237.784	242.911	242.794	243.683
Δ GDP		-2,2%	0,7%	-1,1%	-1,4%	2,2%	0,0%	0,4%
T/million FLIGHT	41,65	37,61	38,15	38,48	38,54	40,79	38,69	35,32
Population	3,527	3,588	3,595	3,595	3,595	3,587	3,578	3,573
Δ population		1,7%	0,2%	0,0%	0,0%	-0,2%	-0,3%	-0,1%
T/capita FLIGHT	2,92	2,54	2,59	2,58	2,55	2,76	2,63	2,41
T/million/capita	147	135	137	138	139	146	138	126

Country	Year	Population	GDP	ETS_CO2	emission_cap	emission_GDP	dummy_ets	ets_prijs
Austria	2004	8142573	271221	0			0	
Austria	2005	8201359	277307	33373155	4,07	120,35	1	8,37
Austria	2006	8254298	286886	32384372	3,92	112,88	1	22,95
Austria	2007	8282984	297579	31751260	3,83	106,70	1	17,30
Austria	2008	8307989	301925	32078974	3,86	106,25	1	24,10
Austria	2009	8335003	290559	27359833	3,28	94,16	1	14,00
Austria	2010	8351643	295897	30919711	3,70	104,49	1	14,00
Austria	2011	8375164	304545	30599418	3,65	100,48	1	14,60
Austria	2012	8408121	306617	28387060	3,38	92,58	1	7,00