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Assessing the EU Emission Trading System's Impact on Economic Growth

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Abstract

This study uses a cross-country panel data set to investigate the effect of the EU ETS on economic growth and the total national level of CO_2 emission. To estimate this we have conducted a growth regression using country fixed effects model for the period 2003-2012. The results show that, during its first two phases, the EU ETS has been effective in reducing the CO_2 emission levels. However, the scheme has so far also been associated with lower economic growth. The results show that the EU ETS has had a negative effect on economic growth and has had a negative impact on total national CO_2 emissions. However, it is possible that a large share of the downturn in economic growth and the reduction in CO_2 emissions during Phase II has to be attributed to the financial crisis of 2007-2008 and the subsequent Euro crisis. Future research should account for these confounding factors as an extensive investigation on how the EU ETS impacts macroeconomic factors is needed to provide policy makers with complete information that could influence potential changes to the system.

Key words: EU ETS, emission trading system, economic growth, EU, CO_2
JEL Classification:

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Index of abbreviations

CDM – Clean Development Mechanism
CER – Certified Emission Reduction
CPI – Corruption Perception Index
DID – Difference-in-difference
EEA-EFTA – European Economic Area – European Free Trade Association
ERU – Emission Reduction Unit
EU25 – Denotes the 25 members of the EU as of 2005. See Appendix 1.
EU ETS – European Union Emission Trading System
FE – Fixed Effects
GDP – Gross Domestic Product
HICP – Harmonised Indices of Consumer Prices
JI – Joint Implementation mechanism
MRW – Mankiw, Romer and Wiel[1]
R&D – Research and Development
RGGI – Regional Greenhouse Gas Initiative

[1] Used to refer to their definition of the neoclassical growth model

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1. Introduction

One of the most important focus points of political discussions today is the global climate change affecting the earth’s inhabitants as well as the planet itself. The increased public awareness of the problem, and the many reports on the impact of the changing climate, puts pressure on the political leaders and legislators around the world to take action to combat the increasing distress our industries and our consumption puts on the world.

In order to combat climate change, legislators have a number of options. However, a growing concern is how production and consumption levels and in extent economic growth, can be maintained or even increased without damaging the environment. In other words, how can we reduce our negative impact on the climate while at the same time maintaining our life standard as well as supporting the growing population of the world and avoid economic losses?

This study assesses the effect of the introduction of the EU Emission Trading System (EU ETS) on the economic growth of the EU25 countries that are subject to the regulation since the launch of the scheme in 2005. A handful other countries have since joined but are excluded from this study in an effort to increase the comparability between the countries.
As a complement to the general regression model used for this study, a difference-in-difference model was used for a robustness check of the baseline regression results. This model includes six countries that joined the EU ETS in Phase II.

In relation to the topic of this study, previous studies suggest that the EU ETS has only had a modest impact on environmental improvements such as reduction in CO_2 emissions with Widerberg and Wråke (2009) suggesting that the reason behind this may be too low prices of emission permits in the early stages of the scheme as well as the possibility that investments in new abatement technology takes long time to show significant reduction in emission levels. CE Delft (2009) focuses on the Dutch industry and finds that the EU ETS have had a small but positive affect on the competitiveness of the industry. This study is one of the very few that focuses on the EU ETS’s impact on the economy and its results suggest that the concern that the EU ETS may harm the economy is not supported by empirical data, at least not for the domestic industry. This raises the question whether the ETS might have a negative economic impact on a higher national level.

This study adds value to the on-going debate concerning the existence and structure of the EU ETS and helps fill a void of economically focused cross-country analyses of the scheme. Most studies on the emission trading system so far have been focused on specific countries or industries while this study takes on a more macroeconomic approach.

The analysis of this study is conducted using Pooled Ordinary Least Squares-regression models (OLS) to estimate the effect of the introduction of the EU ETS on economic growth as well as the emission levels of carbon dioxide (CO_2). Our study consists of empirical cross-country panel data spanning the period 2003-2012, where the two initial years of the time period controls for the difference in economic growth prior to the ETS launch. To account for the commonly agreed on problems of the OLS-regression model such as endogeneity, multicollinearity and heteroskedasticity, appropriate measures have been taken. Carefully introducing the control variables on at the time, while monitoring the change in coefficient estimates for the already introduced control variables, reduces the chance of adding variables that are collinear with other variables. Furthermore, the regressions conducted in this study uses clustered errors that eliminates any heteroskedasticity and autocorrelation. The measures taken to account for the problems with using an OLS-regression model are discussed in detail in the result section. The results of our estimations suggest that the EU ETS has had a negative impact on economic growth and a negative impact on CO_2 emissions.

The rest of the paper is structured as follows. Section two reviews the relevant theoretical and empirical literature focused on the EU ETS as well as other literature we have found to be relevant to our paper. In Section three we provide background information on the EU Emission Trading System where we discuss the reasons behind the introduction, the different phases (trading periods) as well as the output and price developments of the emission permits over the period 2003-2012. Section four presents our data and descriptive statistics followed by Section five which provides the econometric specifications of the current study. Section six presents the empirical results and in Section seven we make concluding remarks.

2. Literature review

2.1 Theoretical background

The threat of climate change is something the general public is, and has become, more aware of as the climate change is showing through increased desertification and hurricane frequency etc. Alongside the increase in awareness, pressure has built on lawmakers to reduce pollution. There are two types of regulation that lawmakers can use. Firstly, the lawmakers can use command and control mechanisms. This is the dominant form of environmental regulation used today. Examples of these are pollution-limits for specific firms/actors, prohibitions against the use of certain products (e.g. DDT) and imposing the use of a given technology (e.g. Catalytic converters in automobiles).

Command and control mechanisms are characterized by limiting the choice for the polluter and for impacting different firms differently; consequently leading to a violation of the equimarginal principle (i.e. the marginal costs differ from one agent to another). This lead to reduced incentive since there is no reason for changing from one technology to another and for reducing pollution in that way. However, command and control mechanisms have the advantages of greater certainty in the results of the regulation as well as reduced monitoring costs.

Secondly, lawmakers can use economic incentive mechanisms. These include fees taxes, and marketable permits and liability. These mechanisms are implemented to account for the cost of the negative externalities of pollution. Market based solutions for reducing pollution such as taxes and permits have the advantage that they reduce the cost of abatement for the polluter and thus create incentive for the polluter to invest in cleaner technology. However, these solutions require a higher degree of monitoring than for example imposing a specific pollution-lowering technology.

The main arguments in favour of market-based solutions are that the costs for pollution abatement are minimized. In contrast to taxation, where a fixed price is set for pollution, tradable emission permits set a fixed amount of pollution and the price is decided by market (and therefore the price will be the equilibrium price for pollution). On the other hand, an advantage of taxation is double dividend. This means that the revenue from one source of taxation can be used to lower the tax-rate on a good with more negative consequences linked to the taxation of that good (Jaeger 2003).

A tradable emission permits system typically works by the regulator setting a top-limit for pollution by issuing a certain number of emission permits, each permit giving the firm the right to emit a given amount of the pollutant in question. If the market price of the permit is higher than the marginal cost of production it is more profitable for the firm to sell an emission permit and chose not to expand the production. On the other hand, if the price of the emission permit falls below the marginal cost of the firm it is more profitable to expand the production, thus the firm would chose to buy additional emission permit on the market. Each agent will pollute until the pollution-cost, the market price of the permits, is equal to the marginal cost of an additional unit of production and thereby satisfying the equimarginal principle and an efficient market.

The implications of introducing a system of tradable emission permits and the potential effects on growth are not extensively studied or discussed in the existing literature. This is most likely due to the fact that emission permits are mainly a microeconomic phenomenon; a concern for one particular market, and GDP growth is a macroeconomic variable. Crettez (2004) theoretically examines what would happen to a laissez-faire market when an environmental regulation was introduced. By using the overlapping generations model he showed that introducing emissions permits on a laissez-faire market had no effect on growth but could possibly have a negative effect on capital accumulation by diverting savings from productive resources to less productive resources. On the other hand, Crettez (2004) showed that the growth rate would be higher in an economy with emission taxes since the revenue from the taxes can be re-invested in growth-promoting programs. Environmental taxes, however, solely introduces a price on emission, thus, it does not per default reduce emission levels.

2.2 Existing literature

The first ten years of the EU ETS has been a bumpy ride. The scheme has been widely debated and subject to close examination by media, academics and lobbyist.

While the EU ETS is far from perfect, it revolutionised the political fight against global climate change and will act as an important contributor to inspiring the design of other emission trading schemes around the world.

Relative to the magnitude of the implementation of the EU ETS, little work has been done in evaluating the economic impacts of the scheme. The lack of literature in the area may well be due to the economic recession that hit Europe in 2008 and the lag in reporting of the data to the Eurostat database and the European Environment Agency by the member countries. Most literature covering the EU ETS that does exist primarily focus on microeconomic and/or environmental aspects.

2.2.1 Literature focused on the EU ETS

In the study ’Impacts on Competitiveness from EU ETS - An analysis of the Dutch industry’ from 2008, de Bruyne, Nelissen, Korteland, Davidson, Faber and Van der Vreede explore how the competitiveness of the Dutch industry have been affected by the introduction of the European Union ETS. The authors argue that the increase in auctioning of permits, proposed for phase 3 of the ETS could, without international agreements on future climate policies, harm the international competitiveness of the Dutch industries. This would come as a result of firms possibly having to see their profits being reduced due to not being able to pass on their costs of the ETS to their consumers. The study estimated the direct costs of the ETS to be approximately 0.2% of the Dutch GDP and found that half of this cost would be possible to pass on to consumers. The authors also underlined that the sectors found to be most at risk to experience loss in competitiveness (such as, aluminium, fertilizer, iron and steel) were in general smaller sectors of the domestic industry.

An underlying goal of the EU ETS is to encourage innovation of low energy intensive technology to allow for reducing emission of pollutants while the production levels remain high. Without technological innovation in this field, production will have to decrease in order for firms to comply with environmental legislation and reduce their emission. The profit maximising nature of firms pushes production levels higher as long as it is profitable, consequently this helps drive technological innovation as firms’ investment in R&D increases.

Calel and Dechezleprêtre (2013) studied the impact of the EU ETS on technological change. Using an extensive data set, including both regulated and non-regulated firms, the EU ETS found to have increased the innovation of low carbon emission intensive technologies by the regulated firms by up to ten percent without affecting patenting in other technologies.

Furthermore the results also showed that the EU ETS had not affected patenting for non-regulated firms, implicating that the effects have been limited to regulated firms.
In 2013, in an attempt to evaluate how effective the European ETS had been during its first two phases in filling its purpose of reducing the carbon dioxide emission level, Laing, Sato, Grubb and Comberti pointed out three specific setbacks of the scheme as the major sources of criticism: over-allocation of permits led to the price crash during fall 2007, the free allocation of permits generated large windfall profits for firms and the scheme became the victim of financial fraud. Laing et al. (2013) reviewed several studies examining how the EU ETS has affected products and prices and found a general consensus among the studies supporting the criticism that the major part of the increased cost imposed on producers by the trading scheme has been passed on to the consumers through for example higher electricity prices.
One important conclusion drawn from the study is that an alarming number of industries have been classified as "at risk of leakage". These industries will receive free allocations still in the third phase of ETS; something that the authors emphasize will lead to the possibility of continuing windfall profits. Furthermore, Laing et al., have found that although some abatement has been made, the initial over-allocation of permits and the recession that hit Europe during the second phase of the ETS have reduced the direct impact of the trading scheme on emissions.

Similarly, Anderson and Di Maria (2011) used data for verified emission in the EU for Phase I of the ETS and compared this with the level of emission estimated for a scenario without the ETS. Through this comparison, Anderson and Di Maria estimated the total level of abatement during the first three years of the EU ETS to be 247 Mt CO_2. Furthermore, Abrell, Ndoye-Faye and Zachmann (2011) used panel data consisting of emission and performance levels for more than 2000 firms operating in the EU to analyse the effectiveness of the EU ETS in order to reduce emission. Abrell et al. (2011) concluded that the scheme had been more effective in reducing emission in its second phase than in the first three years while only having a small effect on the performance of the firms.

2.2.2 Complementary literature

Grossman and Krueger (1994) examined the relationship between environmental quality and economic growth in terms of per capita income. As suggested by the Kuznets curve, the level of emission initially increases as income increases, but once income has reached a certain level, emission levels start to drop as the higher income makes it more feasible to divert resources to emission reduction measures. The results from Grossman and Krueger's study support the theory behind the Kuznets curve, as they found no evidence of a negative relationship of environmental quality and economic growth. On the contrary, they found that initial deterioration of environmental quality coinciding with growth in income is followed by a phase of environmental improvement as per capita income reaches $8,000. However, there might be numerous reasons for the improvement in environmental quality. The pollution haven hypothesis states that the reduction in pollution in industrialized countries is due to production being shifted/outsourced to poorer countries or regions with less strict environmental legislation. Jbara (2007) looks at the relationship between the pollution haven hypothesis and the environmental Kuznets curve in 36 countries in three different years and found no evidence supporting the pollution haven hypothesis.

There is evidence that suggests there is a pollution haven effect caused by the introduction of the EU ETS. The EU ETS increases imports and decreases exports and, since greenhouse gas emissions is a global pollutant; the overall concentration of greenhouse gases does not decrease while the EU is sacrificing potential economic benefits (Wu, 2013).

In a paper by De Gregorio and Lee (2004), one section is dedicated to a cross-country analysis on the determinants of economic growth. The analysis is made using an extended version of the neoclassical growth model[2]. The neoclassical growth model takes into account the convergence hypothesis; countries with an initial income lower than its potential steady-state income will, over time, grow faster than countries with a higher income level. Inspired by previous research in the field that have taken institutions and policy factors such as government corruption, rule of law, inflation, democracy and trade openness to be important to determine long-run per capita income, De Gregorio and Lee (2004) include external economic and political environment and policy variables in their study. This study follows the same approach as the aforementioned study and our framework and variable selection has been influenced by the work of De Gregorio and Lee.

[2] Neoclassical growth model as defined by Barro (1991), Mankiw, Romer, and Weil (1992), Barro and Lee (1994), and Barro and Sala-i-Martin (2004).

3. Background

3.1 Introduction of the EU ETS

In 2005 the European Union launched EU ETS, the EU Emissions Trading System, governed by the 2003 Emission Trading Directive aiming to introduce significant reductions in greenhouse gas emissions with a view to reducing the influence of such emissions on the climate (Directive 2003/87/EC). The directive follows the agreement in 2002, when the 15 EU members countries at the time, accepted joint responsibility of reaching a EU aggregate 8% emission reduction compared to the 1990 level by 2008-2012. The original directive was amended in 2004 to include the use of certified emission reduction (CER) and emission reduction unit (ERU), (Directive 2004/101/EC). Prior to the introduction of the EU ETS, both Denmark and the United Kingdom had adopted their own voluntary emission trading schemes. The UK ETS was created as a pilot for the EU ETS launched in 2002 and has continued to run parallel with the EU ETS (National Audit Office, 2004). Denmark on the other hand launched a greenhouse gas-trading scheme in 2001 that only lasted until 2003 and was solely focused on eight different electricity companies. (Pedersen, 2001)

The introduction of the EU ETS originally covered the power generating sector and the most energy-intensive industrial sectors. As of January 2012, the aviation industry has been brought in under the regulation. However, as a result of a decision made by the EU Commission, only flight routes with both origin and destinations within the EU are subject to the regulation. Transcontinental flights have thus been excluded.

The ETS have prompted the members to divert resources towards monitoring and controlling emission levels from their domestic industries and subsequently reports this data to the EU. All transactions involving emission rights are registered in the Union Registry where every government has their own agency in charge of the national registry (Energimyndigheten 2013).

EU ETS is an emission permit scheme working on the ‘cap and trade’ principle and is the first major system of its kind in the world. Similar trading systems have, since the launch of the EU ETS, been established throughout the world but on smaller regional areas such as the Regional Greenhouse Gas Initiative (RGGI) formed through a cooperation between nine east coast states of the US, the New Zealand Emission Trading Scheme (established in 2008) and the California ETS (established in 2011).

As of today, a universal tax on carbon dioxide has yet to be implemented within the EU. The latest proposition for the implementation for such a tax was made in the 1990's but failed (Pearce 2005). A number of the member states of the European Union have implemented their own domestic tax schemes to battle the levels of CO_2 emissions[3]. The EU ETS is hence, due to the lack of a cross-country tax scheme, the main economic tool used by the EU in its ambition to reduce the emission levels of manmade greenhouse gases. (European Commission 2013).

Initially in phase 1, the EU ETS only covered carbon dioxide emission and only the emission from power generators and energy-intensive industries (EU ETS 2005-2012, European Commission). In phase 2, some member states chose to include nitrous oxide emission but it was not included universally within the system. The different phases, or trading periods, of the EU ETS will be discussed more thoroughly in the next section.

3.2 The different phases of the ETS

The European emission permit scheme, introduced in 2005, is now in its third phase. This study covers the first two phases. Phase II of the scheme was a 'learning by doing' period from 2005 to 2007. These first years of the scheme raised some concerns as an excessive number of permits led to the price of allowances for the first period dropping to zero in the fall of 2007.

During the second trading period (during 2008 to 2012), the EEA-EFTA states: Iceland, Norway and Lichtenstein joined the scheme. In the last year of this period, the EU ETS was extended to, in addition to the power generators and energy-intensive sectors, also include the aviation industry that had previously not been directly affected by the implementation of the permit scheme. As a response to the overestimation leading to issuance of an excessive number of permits in the first trading period, the number of permits issued for the second period had consequently been reduced by 6.5%. However, the unanticipated global financial crisis that began in 2008 led to a sharp decrease in output levels and as a result of that a falling demand for emission permits. The second trading permit thus also resulted in a surplus of permits and credits.

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[3] These countries are Denmark, Finland, France, Ireland, Sweden and the United Kingdom.

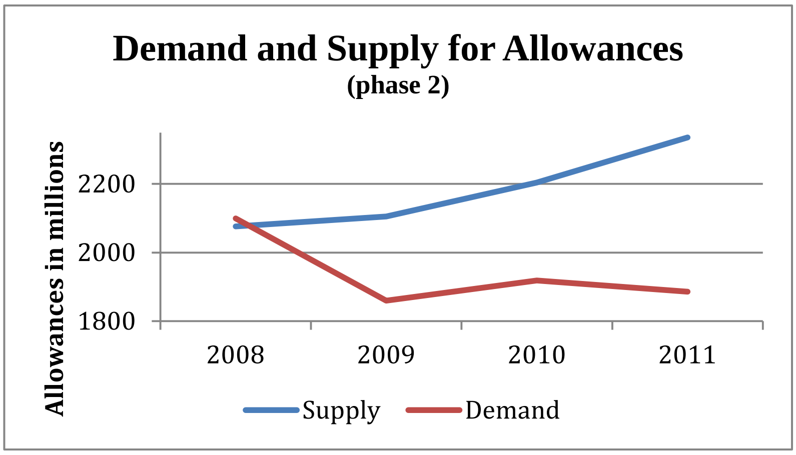

Figure 1 – Graph showing supply and demand of EUAs. Data from European Commission

In Phase II it was made possible for firms having to comply with the EU ETS to buy credits from the Kyoto protocol's mechanisms, the Clean Development Mechanism (CDM) and Joint Implementation (JI) mechanism. As defined in Article 12 of the Kyoto protocol, the CDM allows subjects of the EU ETS to implement emission-reduction project such as installations of renewable energy generators in developing countries and as a reward earn saleable certified emission reduction (CER) units that can be counted towards meeting the Kyoto targets (Article 12, Kyoto Protocol, 1998). Similarly Article 6 of the Kyoto protocol covering the JI mechanism allows an entity subject to emission reduction or limitation commitment to earn emission reduction units (ERU) from an emission-reduction or emission removal project in another Annex B country. As with the CERs the ERUs can also be counted towards meeting the Kyoto targets. This led to an increased demand for such credits and consequently making the EU ETS the principal provider of clean energy investment in developing countries (EU ETS 2005-2012, European Commission).

Furthermore, Phase II saw the inclusion of the aviation industry as per January 1st 2012. In November 2012 the European Commission made a proposal to defer trans-continental flights from the scheme and the European Parliament and Council later approved the proposal.

In 2013 the EU ETS started its third trading period, introducing new reforms to the system including an annual reduction rate of 1.74% in the number of permits issued. During the first two trading periods the main allocation of permits had been a cost-free allocation. As of 2013 this started to shift towards an auctioned based allocation.

The European Union ETS moved into its third trading period, on January 1st 2013 running until December 31st 2020. In accordance with the goals of the Kyoto protocol, the EU member states are to reduce their emissions to 79% of the 2005 level by the year of 2020. The EU commission has also set the goal of reaching 57% of the 2005 level by 2030.

In order to reach the emission targets, a number of changes and reforms to be implemented for Phase II of the ETS have been made. In contrast to the two first phases of the scheme, a EU-wide cap on emissions is in place. Changes in the way of distribution of permits have led to the default being allocation through auctioning and not by free allocation. Furthermore the scheme has been expanded to include other gases and industries, which were not previously subjected to the EU ETS. As evaluations and analyses of the scheme's success so far and whether the targeted emission levels are to be reached, work to investigate further reforms has begun (such as the consultation for revision of the EU Emission Trading System directive for post-2020).

3.3 Price evolution for allowances

The market determines the price of the permits for emission. During phase 1 of the EU ETS, almost all permits were allocated to firms cost-free. If entities gained a surplus or found themselves in need of more permits, firms were allowed to buy and sell permits on the market via an exchange much like the ones for stocks and bonds. Non-compliant firms would face a penalty of €40 per tonne.

The price of permits during phase 1 peaked at around €30 per tonne of CO_2 emitted. Much due to the financial downturn of 2007-2008 and onwards, the price of permits plummeted to zero during the fall of 2007 and remained close to this level until the end of phase 1 on December 31st the same year. Another reason for this was that firms were not allowed to stock up on surplus permits to be used in phase 2 (EU ETS 2005-2012, European Commission).

During phase 2 of the EU ETS, prices became a bit more stable but still came to fluctuate between a top price just shy of €30 per tonne to approximately €12 per tonne. The allocation of permits started to shift towards auctioning and the share of permits allocated cost-free to firms fell to approximately 90% of the total amount. Phase 2 also saw the non-compliance penalty rise from €40 per tonne to €100 per tonne.

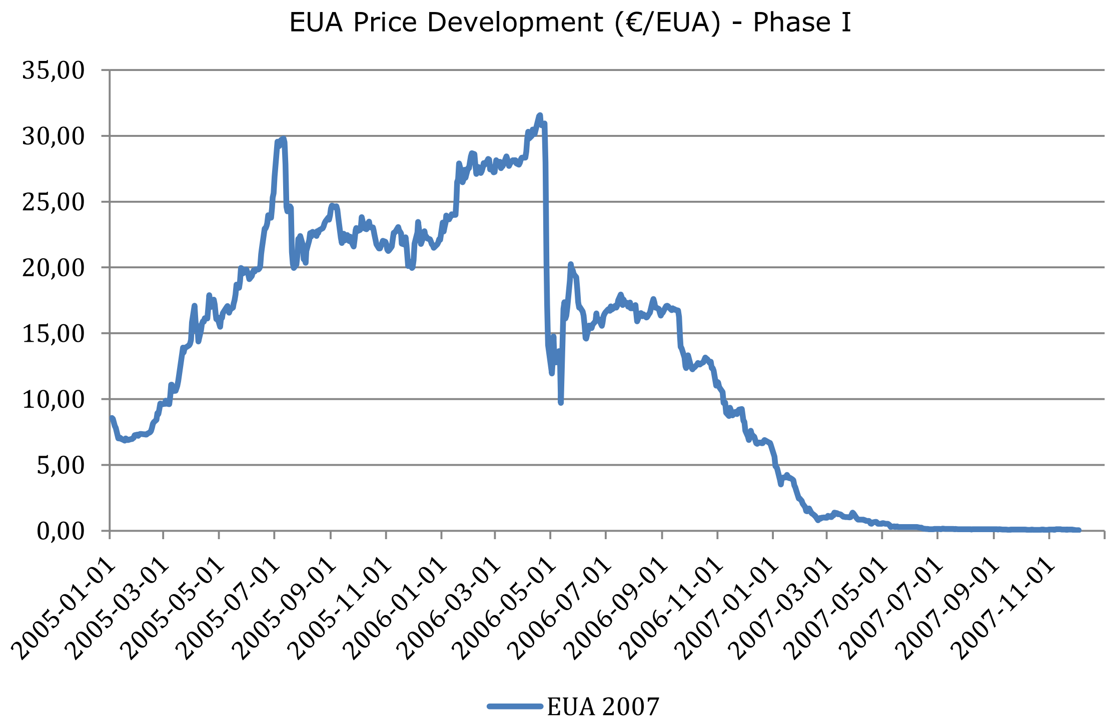

Figure 2a – Price per allowance during Phase I measured in Euros. Source: European Environment Agency

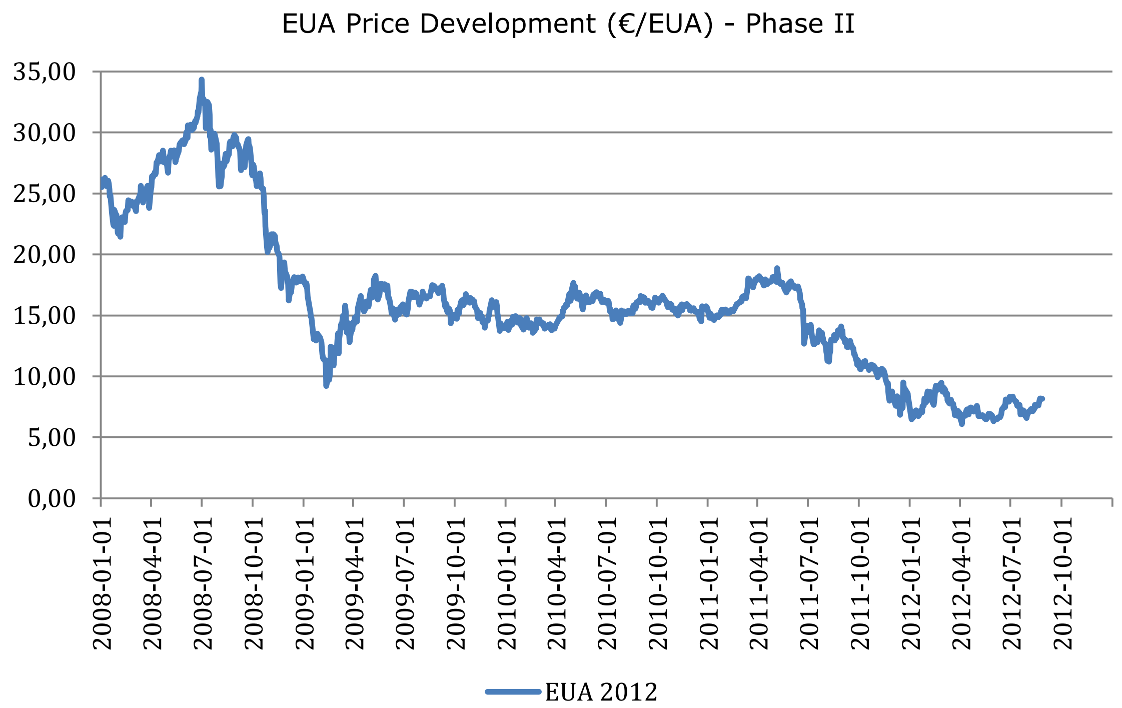

Figure 2b - Price per allowance during Phase II measured in Euros. Source: European Environment Agency

3.4 Production level and CO_2 emission level

Starting in 2003 most EU member states experienced a steady growth in production as a result of extensive economic growth shown below in figure 3.

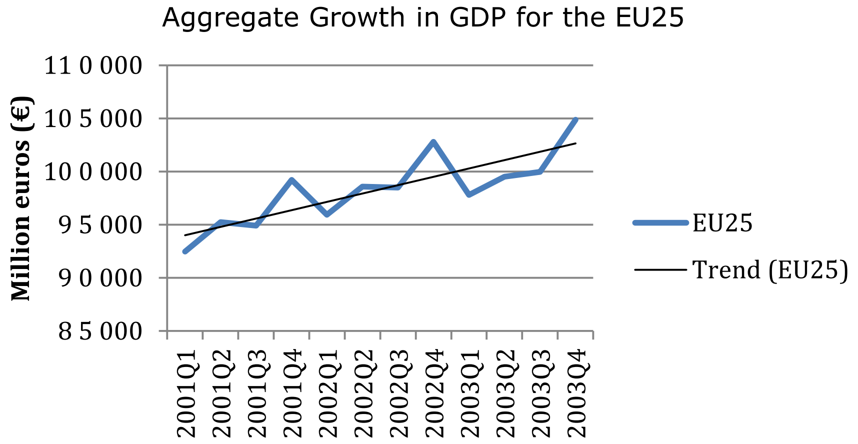

Figure 3 – Aggregate Growth in GDP (current prices) for the EU25. Source: Eurostat

Below, figure 4a shows the annual change in production levels for the manufacturing industries. The graph clearly shows the growth spurt in production levels in the early 2000's. Coinciding with the second phase of the ETS, the financial crisis originating in the US resulted in an economic downturn that, subsequently, reduced production levels sharply.

Figure 4b shows a graph representing the aggregate emission levels of carbon dioxide for the EU25 during 2003 – 2012. The graph indicates a negative trend with annual reductions in emission levels. However, as mentioned in the discussion regarding Figure 4a, the economic downturn in 2008 with the resulting drop in production, is most likely the underlying reason to the increased speed in emission reduction showed in the graph for the same year.

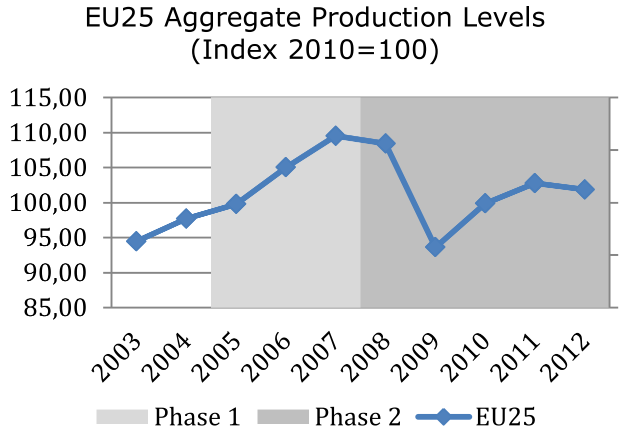

Figure 4a- Aggregate production levels of the manufacturing sector. Data collected from Eurostat Database

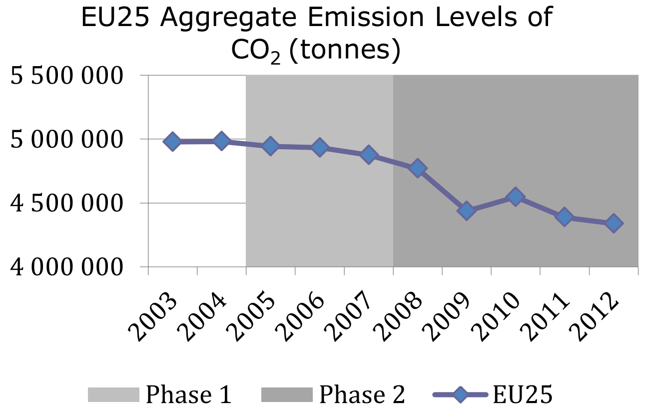

Figure 4b Aggregate total national emission levels of CO_2. Data collected from European Environment Agency

4. Data and Descriptive Statistics

The aim of this paper is to study the effect of the EU ETS on economic growth and CO_2 emissions. We will do this by conducting an analysis that covers the EU25, i.e., the European Union member states including those who joined the cooperation in the 2004 but excluding Croatia, Bulgaria and Romania who became members in 2007.These countries are excluded because they were not part of the first phase of the EU ETS and because environmental and economic data is not easily accessible for years prior to them joining the EU. Similarly, the EEA-EFTA countries Norway, Iceland and Lichtenstein who joined the EU ETS at the start of Phase II in 2008 are also excluded in this study, as they were not affected by the first phase of the ETS. However these countries are included in our diff-in-diff model, which is used to check the robustness of the results from our main regressions.

To allow for estimating the effect on economic growth caused by the introduction of the EU ETS in 2005, the data used for the analysis spans from 2003 to 2012. The economic growth is measured as annual percentage change in real GDP per capita and is collected from Eurostat. Variables that are generally acknowledged as important contributors to GDP growth are included.

The economic data has been collected from the Eurostat database, which is compiled by the European Commission. The economic data includes real GDP, inflation, gross fixed capital formation, government expenditure, total imports, total exports and expenditure on research and development. Most information is based on a mandatory reporting by member states regarding performance of main macroeconomic indicators. All financial data is expressed in millions of Euro to allow for easy comparison and to avoid the need for conversions and calculations in the dataset.
The investment level is measured through gross fixed capital formation as a share of GDP.

The labour participation rate is calculated by dividing the labour force by the entire population aged 15-64. Both labour force and population data are collected from Eurostat.

Following conventional methodology, human capital is measured through a proxy variable of education level. In our model education is measured as the share of the population with an upper secondary level education or higher.

To control for population growth we use fertility rate as well as life expectancy at birth. These variables are obtained from the Eurostat. Fertility rate is measured as the average number of births given per woman and life expectancy is measured as the expected average life-length at birth considering country specific contributors to life quality.

We also include policy related variables such as Rule of Law (RoL), Corruption Perception Index (CPI) and Terms of Trade (ToT). RoL and ToT are part of the World Bank's Worldwide Governance Indices (WGI) and CPI is collected from Transparency International[4]. *Rule of Law* allows us to account for the impact of the quality of contract enforcement and property rights. This is collected through survey-results that reflect the perception to which extent the agents trust and follow the rules of society. *Corruption Perception Index* is used as an indicator for the level of corruption within the decision-making process in a country. Whereas, *Terms of Trade* is used to account for changes in exchange rates due to shocks. This is measured as the capacity to import less export.

The inflation rate data for each country is calculated as the rate of change for Harmonised Index of Consumer Prices (HICP) as regular CPI makes comparison between EU states difficult due to different currencies. Inflation, in combination with government expenditure, is used to measure the effect of governance.
The openness to trade is measured as the value of the export and import divided by the GDP (OECD 2011). This gives us an estimation of how integrated the country is in the international trade. This is not to be confused with the terms of trade that is a measurement of the competitiveness of the economy.

The other dependent variable of interest is the level of CO_2 emission, which is obtained from the European Environment Agency greenhouse gas data viewer. The data shows the total CO_2 emissions for each country. Instead, we use the total national CO_2 emissions due to difference in the specification and division of sectors prior to the introduction of the EU ETS in contrast to the verified emission data for the EU ETS. This will affect our results in the sense that it also covers sectors that aren't covered by the EU ETS. For estimating the effect of the EU ETS on CO_2 emission levels, we control for the share of energy generated from renewable

[4] Transparency International is a non-government organization created in 1993 that work to combat corruption.

sources, total consumption of petroleum fuels and the total import of goods and services. This data is collected from Eurostat.

In the dataset there are some, statistically significant, high correlations between explanatory variables that are worth mentioning (see table 2 for a correlation matrix). Firstly, per capita GDP growth and the proxy for investment level have a high positive correlation. This finding is supported by theory, as increased investment should also increase GDP. Secondly, government expenditure as a share of GDP has a high positive correlation with the fertility rate. This can be explained by higher fertility rates demands a higher rate of government investment in health care. Furthermore, Rule of Law has a high positive correlation with both the fertility rate and life expectancy. These findings are somewhat trickier to explain, as there is no intuitive explanation as to why the Rule of Law coefficient should increase as the fertility rate or life expectancy increases.
Fertility, life expectancy and rule of law (in increasing order) all have high positive correlations with initial GDP per capita. Life expectancy is likely to be high when income is high. The high correlation between rule of law and initial GDP per capita could be explained by rule of law indicating investor confidence. The country benefits from more investments as the rule of law increases. This is supported by a positive, although not strong, correlation between initial per capita GDP and the proxy for the investment level. However the high correlation between fertility and initial GDP per capita is surprising as this indicates a somewhat Malthusian relationship.

5. Econometric Strategy

The empirical framework of econometric estimations of this study follows Solow's neoclassical growth model as defined by Mankiw, Romer & Weil (1992). The MRW model explains long-run economic growth as a function of capital accumulation, human capital and technological progress.[5]

$$Y_{it} = A_{it} K_{it}^{\alpha_K} H_{it}^{\alpha_H} L_{it}^{1-\alpha_K-\alpha_H} \qquad (1)$$

[5] Extending the neoclassical growth model makes it possible to account for the convergence hypothesis stating that a country's initial income level determines its growth rate. A country with a lower initial income level will grow more rapidly than a country with a higher initial income level due to capital accumulation.

Where Y_{it} denotes output of country *i* at time period *t*, *K* is the level of physical capital, *H* is the level of human capital, *L* the level of raw labour and *A* is the level of technological knowledge.

In our model K is expressed as the investment level that is measured as gross fixed capital formation as a share of GDP. L is measured by the labour force participation rate. This provides a measurement for the share of the working-age population that is part of the labour force. H is accounted for through a proxy for the level of education.

The exponents α_K and α_H are output elasticities of physical and human capital with the assumption that α_K, $\alpha_H > 0$ and $\alpha_K + \alpha_H < 1$ implying that there are decreasing returns for both factors and constant returns to scale for the model as a whole.

An increase in the technological knowledge could have different effects on the environmental quality depending on where the increase takes place. However, with an emission cap on emission that the EU ETS and other emission permit schemes impose, the increase would not worsen the environmental quality by increasing emissions but would not necessarily improve it unless the increase in knowledge results in economically feasible innovations for the firms. Hence the effect of EU ETS is linked to increases in innovation and investment. Other control variables that are included are the inflation rate, government expenditure, gross fixed capital formation, labour force participation rate, rule of law, openness to trade and growth rate of technology.

This study is conducted using a balanced panel data set for the 25 EU countries that has been part of the EU ETS since the launch of the program in 2005 (see Appendix 1). The data set consists of proxy variables for measuring human capital, investment level, capital accumulation and technological progress as well as a set of economic and policy related control variables commonly believed to affect economic growth.

The main purpose of the study is to examine what effect the EU Emission Trading Scheme has had on economic growth. The conducted regression analysis estimates the correlation between the response variable, the growth rate in real GDP per capita (i.e. the annual percentage change in real GDP per capita), and the explanatory variables included in the model. The variable of interest is a dummy variable indicating the presence of ETS regulation on the market. This could have a negative effect in our model as an emission cap potentially limits production given the available technology and production methods and thus might slow down economic growth. The emission cap forces firms to divert resources towards investments in energy saving and emission reduction technologies if they are to maintain an unchanged production level. This could potentially impact the profitability of the firm due to resources not being allocated in the most productive way (Crettez 2004). There are also benefits of reduced emissions. An improvement in environmental quality could have positive effects on health, life expectancy and productivity.

Our estimation of the EU ETS's impact on economic growth is conducted using the fixed effects (FE) model as to remove the individual-specific time-invariant characteristics so that we can assess the net effect of the explanatory variables on the response variable. This is estimated by the following model:

$$\% \Delta GDP_{it} = \beta_0 + \beta_1 EU\_ETS + \beta_2 GFCF_{it} + \beta_3 educ_{it} + \beta_4 GDPini_{it} + \beta_5 X_{it} + \tau + \varepsilon_{it} \quad (2)$$

Where *i* is the individual country and *t* signifies the time period. %ΔGDP is the growth rate of the economy and is defined as the annual percentage change in real GDP per capita.
$GFCF_{it}$ is the gross fixed capital formation as a percentage share of GDP and is used as a proxy for the investment level. The variable $educ_{it}$ is the share of the population having attained an upper secondary education or higher and is used as a proxy for human capital.
To account for the difference in starting points among the countries included in the sample, the model includes the variable $GDPini_{it}$ that is the real GDP per capita in the year of 2003.
τ is the country fixed effects.
X_{it} is a set of control variables potentially contributing to economic growth. Included in X_{it} are openness to trade, percentage share of government expenditure in real GDP, inflation rate, fertility rate, life expectancy at birth, total investments in research and development, Rule of Law and Terms of Trade. After controlling for the impact on economic growth from the above-mentioned variables, the sign and significance of β_1 will indicate the effect of the EU ETS on economic growth. A negative sign for β_1 would imply that the EU ETS has had a negative impact on production and thus slowed down the economic growth.

Our estimation of the EU ETS's impact on the national CO_2 emission levels is conducted using a fixed effects model estimated by the following model:

$$co_2\_tot_{it} = \beta_0 + \beta_1 EU\_ETS + \beta_2 fuel\_cons_{it} + \beta_3 rew\_ener_{it} + \beta_4 gdp\_cap_{it} + \beta_5 X_{it} + \tau + \varepsilon_{it} \quad (3)$$

The dependent variable is total CO_2 emissions from the consumption of energy. Where $fuel\_cons_{it}$ is the total consumption of petroleum fuels, rew_ener_{it} is the share of consumed energy generated from renewable sources, gdp_cap is real GDP per capita and τ is the country fixed effects captured by using dummy variables for the different countries. It is a collection of control variables including total imports, total investments in research and development and rule of law. Increasing imports implies that the decrease in domestic production is being made up for by an increase in imports (non-domestic production). An increase in investment in research and development implies an increase in productivity and possible production.

OLS regressions do have some limitations that have to be accounted for. Common problems when using OLS are multicollinearity, endogeneity and heteroskedasticity.
These problems and limitations of the model can be accounted for by taking a number of actions.

Multicollinearity can be caused by a number of reasons such as; inaccurate use of dummy variables, including variables that are computed using other variables in the data set, high correlation between variables. As a result estimations of coefficients may be less precise (i.e. high standard errors), and thus gives a misleading picture of the effect. To address this issue we include our variables one at a time and see how the inclusion affects the model. If the inclusion drastically changes the coefficient of a variable it is a sign of multicollinearity. We use clustered standard errors to account for heteroskedasticity and autocorrelation. Endogeneity occurs when there is a correlation between a variable and the error-term. A common source of endogeneity is omitted variable bias where a possibly correlated variable is included in the error-term. We control for endogeneity stemming from country-specific factors by including country-dummies.

When performing a time-series analysis, a concern is non-stationarity. This occurs when the joint probability distribution changes over time as well as the mean and variance. A consequence of this is that the coefficients in the model will be overestimated (Chang 2003). We address this by performing unit-root tests on all the variables that are included in our models.

6. Results

6.1 Diagnostics

In the early stages of working towards defining our final regression model, dummy variables for the different years covered by our data set were included to account for difference over time. However, the dummy variable for EU ETS works as a measure of time and as a result strong collinearity was found between the two sets of dummy variables. Hence, in order to get a better estimation for the effect of the EU ETS on economic growth, we decided to drop the dummy variables for different years from our regression model.

Using panel data consisting of twenty-five countries, fixed-effects are likely to be present in the model. In order to decide whether the regression should be conducted using fixed or random effects, we performed the Hausman specification test to reveal whether or not the unique errors are correlated with the explanatory variables included in the model. The test was conducted with the null hypothesis being that random effects would be preferred over the alternative that a fixed effects model is to be preferred.

The results from the Hausman specification test suggested *the null hypothesis* should be rejected. Thus our model is estimated using fixed.

In order to address the problem of heteroskedasticity we applied clustered standard errors at country level in the regression models. Using clustered standard errors takes care of heteroskedasticity as well as any potential autocorrelation.

To address the problem with multicollinearity we initially introduced only the most important variables to the regression as well as our variables of interest[6]. We then took on a step-by-step approach by introducing theoretically justified control variables one at the time while monitoring the change in estimated values of previously included variables.

The possible problem of endogeneity (an independent variable is correlated with the error term) is often caused by omitted variable bias. In our model this is dealt with by introducing dummy variables for all but one country. This addresses endogeneity that arises from country-specific factors. However we are unable to account for other time varying factors that may be

[6] Investment level, initial GDP and education are typically always included in growth regression (Levine & Renelt 1992).

omitted from the model and which makes it difficult to indentify causal effects. Another point of concern is reverse causality. For example, in health economics a higher income is associated with better health but better health could lead to an individual being able to work more and thus have a higher income.

To address potential non-stationarity we ran a Harris-Tzavalis test. The results showed that one variable, labour participation rate, was non-stationary. We used the first difference of the variable in question, thus making it stationary.

In addition, we also ran a diff-in-diff model to see whether the impact of the EU ETS on countries included is significantly different from a control group of countries entering the ETS at a later stage such as Norway. The results, however, did not show any statistically significant results from our main model. The results from the diff-in-diff model is thus only presented separately in Appendix and not further discussed.

6.2 Impact on Economic Growth

The results from running our regression model for economic growth (Table 3) suggested that the significant variables in the model were the EU ETS dummy variable, the level of investment, education, initial GDP, government expenditure and openness to trade.

Our variable of interest, EU ETS, is associated with a negative effect on per capita GDP growth. Our estimation implies that the introduction of the EU ETS lowers the growth rate by 0.02 percentage points. We believe there are two possible explanations behind this. Imposing a cap on emission might, as discussed in Section 5.2, reduces production and divert resources from possibly more productive areas towards investments in emission reducing technologies. Another explanation has to do with the fact that the financial crisis that hit the European market in 2007-2008 coincides with Phase II of the EU ETS and thus the estimated impact of the ETS on economic growth might be overstated.

As expected, capital-accumulation is associated with a positive effect on per capita GDP growth. As with capital-accumulation, the neoclassical growth model also predicts that human capital has a positive effect on GDP growth, and consistent with theory education, used as a proxy for human capital, is associated with a positive effect on per capita GDP growth (significant at 10%). Although this could be because of countries with higher growth rates investing more in education and thus it is difficult to identify a causal relationship between human capital and GDP growth.

Initial GDP per capita is associated with a negative effect on per capita GDP growth. This result is supported by the convergence hypothesis, stating that initially poorer countries will grow faster than richer countries as they move towards converging growth paths.

Government expenditure as a percentage share of GDP is negatively associated with growth, possibly implying that resources are less productive when transferred from the private sector to the public sector results in the resources being used less efficiently. This theory is supported by the empirical study conducted by Mitchell (2005) that finds a reduction of the size of the US government would lead to higher incomes and improved competitiveness.

Openness to trade is associated with higher per capita GDP growth, a result that falls in line with expectations as trade between countries allows firms to take advantage of economies of scale, thus reducing the average cost of production (Krugman, 1979).

Initially, labour force participation rate was found to have a negative effect on economic growth. However, we found the variable to be non-stationary. After addressing this fact by using the first difference on the variable it lost its significance.

Rule of law was not found to have a significant effect on GDP growth.

6.3 Impact on CO_2 Emission Levels

The regression results from our model estimating the impact of the EU ETS on total national CO_2 emissions (Table 4) suggest that EU ETS is associated with a negative and statistically significant effect on emission levels. Our results suggest that the introduction of the EU ETS decreases CO_2 emissions by 1.2%.

In addition, petroleum fuel consumption is associated with a positive effect on emission levels.

In order to see whether the EU ETS has been more effective in reducing CO_2 emissions in Phase II compared to Phase I, as suggested by Abrell et al. (2011), we introduced a dummy variable indicating the time period of Phase II in our model. As with the original EU ETS dummy variable, the Phase II dummy is also associated with a negative and statistically significant effect on emission. Furthermore, Phase II is indeed found to have a larger impact on CO_2 emissions than Phase I. Our results suggest that Phase II lowers CO_2 emissions by 6.4%.

GDP per capita is associated with a positive effect on CO_2 emissions. This implies that increased income worsens environmental quality. The reason for this could be that higher income is associated with higher consumption.

Imports are not statistically significant in our model. These results do not support the pollution haven hypothesis and suggests that it is not significantly present in the countries covered by the EU ETS.

As with imports, rule of law is not statistically significant in our model.

7. Conclusions

EU ETS has, according to our estimations, had a negative impact on the economic growth of the EU25 countries during the period 2003-2012. This was expected as a cap and trade system puts a cap on emission level and may thus have a limiting effect on production given the technology available. Furthermore, the EU ETS also had a negative effect on CO_2 emission levels, giving further support to the findings of previous studies

Our results indicate that the introduction of the EU ETS is associated with a significant but very small effect on GDP growth. However, the positive effect of decreased emission outweighs the negative economic consequences associated with the introduction of the EU ETS.

However, care has to be taken when drawing conclusion from the estimation results of this study as the time period covered is relatively short due to the young age of the EU ETS, but more importantly one has to take into account that Phase II of the trading scheme coincided with the severe global financial crisis that hit Europe in 2007-2008 as well as the subsequent Euro crisis. Inarguably this economic turmoil has had a negative impact on production and output levels and parts of the reduction in economic growth and CO_2 emission may be attributed to these crises rather than the EU ETS. It is difficult to identify a causal relationship between the introduction of the EU ETS and economic growth. In order to fully estimate the impact of the EU ETS on economic growth and CO_2 emissions, a larger time span might be needed. A more advanced analysis controlling for these confounding factors and accounting for potential endogenity bias is a natural next step for future research.

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Table 1. Summary Statistics of Variables of interest.

	Obs.	Mean	Std. Dev.	Min	Max
Percentage change in GDP per capita	225	.045	.069	-.191	.316
Gross fixed capital formation (%GDP)	250	.211	.041	.106	.361
Share of population with post-secondary education	250	68.4	14.07	21.9	86.6
Government expenditure (%GDP)	250	.207	.031	.1478	.298
Openness to trade	250	1.16	.557	.480	3.34
Inflation (HCPI)	250	2.76	1.94	-1.7	15.3
Fertility	250	1.55	.236	1.18	2.06
Log life expectancy (at birth	250	4.36	.039	4.26	4.414
Rule of law	250	1.24	.504	.33	2.0
Terms of trade	250	.994	.027	.90	1.08
Diff Labour Participation rate	225	.0019	.007	-.019	.025
Research and development	250	9097.5	15159.6	11.45	79110.4

Table 2. Pair wise correlation Matrix

	Δ%GDP	GFCF/GDP	Educ	G/GDP	Open	Infl	Fertility	Life_exp.	RoL	ToT	Part.rate	Ini GDP	R&D
Δ%GDP	1.000												
GFCF/GDP	0.511*	1.000											
Educ	0.196*	0.145*	1.000										
G/GDP	-0.291*	-0.335*	0.007	1.000									
Open	0.155*	0.038	0.095	-0.25*	1.000								
Infl	0.373*	0.467*	0.164*	-0.25*	0.125*	1.000							
Fertility	-0.120	-0.233*	0.095	0.512*	0.011	-0.21*	1.000						
Life exp.	-0.299*	-0.356*	-0.41*	0.259*	-0.21*	-0.44*	0.380*	1.000					
RoL	-0.185*	-0.331*	-0.034	0.448*	0.133*	-0.32*	0.656*	0.532*	1.000				
ToT	0.056	0.005	-0.17*	-0.001	0.094	-0.006	-0.091	-0.023	0.049	1.000			
Part.rate	0.232*	0.299*	0.002	-0.26*	0.070	0.287*	-0.080	-0.018	-0.061	0.0413	1.000		
Initial GDP per capita	-0.196*	-0.362*	-0.119	0.252	0.280	-0.333	0.588*	0.622*	0.763*	0.116	0.254	1.000	
R&D	-0.154*	-0.279*	0.065	0.173*	-0.39*	-0.20*	0.20*	0.376*	0.303*	-0.063	0.062	0.279	1.000

Table 3: Cross-country growth regression, country fixed effects model

Variables	1	2	3	4
EU ETS	-0.0240***	-0.0253***	-0.0253***	-0.0251***
	(0.00735)	(0.00708)	(0.00723)	(0.00720)
GFCF / GDP	0.985***	0.974***	0.980***	0.982***
	(0.252)	(0.257)	(0.254)	(0.254)
Education	0.00269	0.00283*	0.00287*	0.00289*
	(0.00167)	(0.00139)	(0.00142)	(0.00146)
Initial per capita GDP	-8.75e-06**	-9.41e-06***	-9.44e-06***	-9.56e-06***
	(3.54e-06)	(3.19e-06)	(3.16e-06)	(3.18e-06)
Government expenditure / GDP	-1.456***	-1.487***	-1.509***	-1.510***
	(0.318)	(0.299)	(0.339)	(0.340)
Openness to trade	0.143**	0.146***	0.146***	0.147***
	(0.0521)	(0.0499)	(0.0495)	(0.0495)
Inflation	0.00249	0.00236	0.00246	0.00244
	(0.00217)	(0.00210)	(0.00197)	(0.00198)
Fertility	-0.00578	0.000765	0.00242	0.00319
	(0.0516)	(0.0495)	(0.0473)	(0.0480)
Log life expectancy	-0.477	-0.309	-0.310	-0.284
	(0.377)	(0.365)	(0.369)	(0.370)
Rule of law	-0.0100	-0.0250	-0.0254	-0.0266
	(0.0396)	(0.0491)	(0.0500)	(0.0496)
Terms of trade		0.265	0.267	0.263
		(0.208)	(0.204)	(0.203)
Participation rate (diff)			-0.182	-0.180
			(0.743)	(0.749)
R&D				-4.89e-07
				(9.05e-07)
	(0.0344)	(0.0396)	(0.0397)	(0.0434)
Constant	2.119	1.154	1.158	1.050
	(1.512)	(1.632)	(1.642)	(1.656)
Observations	225	225	225	225
R^2	0.518	0.525	0.525	0.526

* Note: The dependent variable is Growth rate in real per capita GDP. Country-dummies have been included in the regression. Clustered standard errors at country level is included in the parenthesis. ***p<0.01, ** p<0.05, * p<0.1

Table 4: Cross-country regression, Country fixed effects model

Variables	1	2	3
EU ETS	-1.533***	-1.294**	-1.254*
	(0.432)	(0.504)	(0.545)
Phase II	-6.429**	-6.380**	-6.363**
	(2.232)	(2.255)	(2.262)
Fuel consumption	0.00480***	0.00475***	0.00475***
	(0.000314)	(0.000275)	(0.000273)
Share of energy consumption from renewable sources	0.141	0.121	0.117
	(0.435)	(0.434)	(0.439)
Per capita GDP	0.000315**	0.000280**	0.000278**
	(0.000104)	(0.000115)	(0.000116)
Import		-1.95e-05	-1.94e-05
		(1.30e-05)	(1.28e-05)
Rule of law			-0.920
			(1.305)
Constant	12.98	17.77	19.57
	(14.86)	(14.01)	(18.12)
Observations	225	225	225
R^2	0.999	0.999	0.999

Note: The dependent variable is Total CO_2 emissions from consumption of energy. Country-dummies have been included in the regression. Clustered standard errors at country level is included in the parenthesis. ***p<0.01, ** p<0.05, * p<0.1

Table 5: Diff-in-diff model

Variables	1	2	3	4
Treatment	-0.0213	-0.0170	-0.0251	-0.0957
	(0.0607)	(0.0607)	(0.0611)	(0.0721)
EU ETS	-0.0437*	-0.0474	-0.0498	-0.0364
	(0.0255)	(0.0281)	(0.0295)	(0.0333)
Treatment*EU ETS	0.0418	0.0454	0.0476	0.0336
	(0.0258)	(0.0275)	(0.0291)	(0.0321)
GFCF/GDP	0.577***	0.568***	0.562***	0.659***
	(0.177)	(0.180)	(0.175)	(0.189)
Education	0.00164	0.00176	0.00213	0.00206
	(0.00130)	(0.00149)	(0.00163)	(0.00165)
Initial per capita GDP	4.90e-06**	4.97e-06**	5.38e-06**	7.25e-06**
	(2.17e-06)	(2.10e-06)	(2.18e-06)	(3.09e-06)
G/GDP	-2.020***	-2.026***	-2.144***	-2.055***
	(0.401)	(0.406)	(0.447)	(0.407)
Openness	0.0168	0.0170	0.0188	0.0173
	(0.0202)	(0.0203)	(0.0203)	(0.0209)
Inflation	0.00198	0.00210	0.00208	0.00216
	(0.00538)	(0.00538)	(0.00543)	(0.00526)
Fertility	-0.118	-0.117	-0.115	-0.133
	(0.0755)	(0.0777)	(0.0801)	(0.0874)
Log life expectancy	-0.529	-0.531	-0.500	-0.554
	(0.457)	(0.450)	(0.473)	(0.515)
Rule of law	-0.0538	-0.0572	-0.0600	-0.0403
	(0.0451)	(0.0442)	(0.0452)	(0.0419)
Terms of trade		0.0434	0.0571	0.0559
		(0.165)	(0.173)	(0.175)
Participation rate			-0.148	-0.117
			(0.141)	(0.126)
R&D				4.26e-07
				(1.35e-06)
	(0.0500)	(0.0537)	(0.0719)	(0.0635)
Constant	2.613	2.572	2.513	2.707
	(1.862)	(1.899)	(1.968)	(2.186)
Observations	225	225	225	225
R^2	0.403	0.404	0.405	0.430

* Note: The dependent variable is Growth rate in real per capita GDP. Country-dummies have been included in the regression. Clustered standard errors at country level is included in the parenthesis. ***p<0.01, ** p<0.05, * p<0.1

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Appendix

1. Countries included in dataset

EU25 – 25 members of EU as of 2005	IE – Ireland
AT – Austria	IT – Italy
BE – Belgium	LV – Latvia
CY – Cyprus	LT – Lithuania
CZ – Czech Republic	LU – Luxembourg
DK – Denmark	MT – Malta
DE – Germany	NL – Netherlands
EE – Estonia	PL – Poland
ES – Spain	PT – Portugal
FI – Finland	SE – Sweden
FR – France	SI – Slovenia
GR – Greece	SK – Slovakia
HR – Hungary	UK – United Kingdom