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An Analytical Study Of Effect Of The Carbon Tax On The Economy And Emissions In Sweden

Author[1]
Nagina Kumari
Research Scholar
Department of Accountancy & Law
Faculty of Commerce
Dayalbagh Educational Institute (Deemed to be University) Dayalbagh Agra
Uttar Pradesh
Email: kumarinagina30@gmail.com
Author[2]
Dr.Rakesh Kumar
Assistant Professor
Department of Accountancy & Law
Faculty of Commerce
Dayalbagh Educational Institute (Deemed to be University) Dayalbagh Agra
Uttar Pradesh
Email Id:rakeshyadav301@gmail.com

Abstract

This paper investigates the effects of the introduction of the carbon tax in Sweden. In order todo this, a time series analysis was carried out, and the VECM model was used. The variables included in the model are the CO2 emissions, the carbon tax rate, the GDP per capita, the consumer price index and the energy consumption. The main finding from the results is in line with the previous works and the theoretical assumptions. Therefore, in the long-run, an increase in the carbon tax is significantly correlated with a reduction in carbon dioxide emissions. This implies that the carbon tax is an effective policy for reducing emissions. Moreover, according to the results, an increase in the GDP per capita and in the consumer price index are significantly correlated with a growth the carbon dioxide emissions, while energy consumption is not a significant determinant of CO2 emissions.

Keywords :Carbon tax, Carbon emission, Carbon tax effect.

1. Introduction

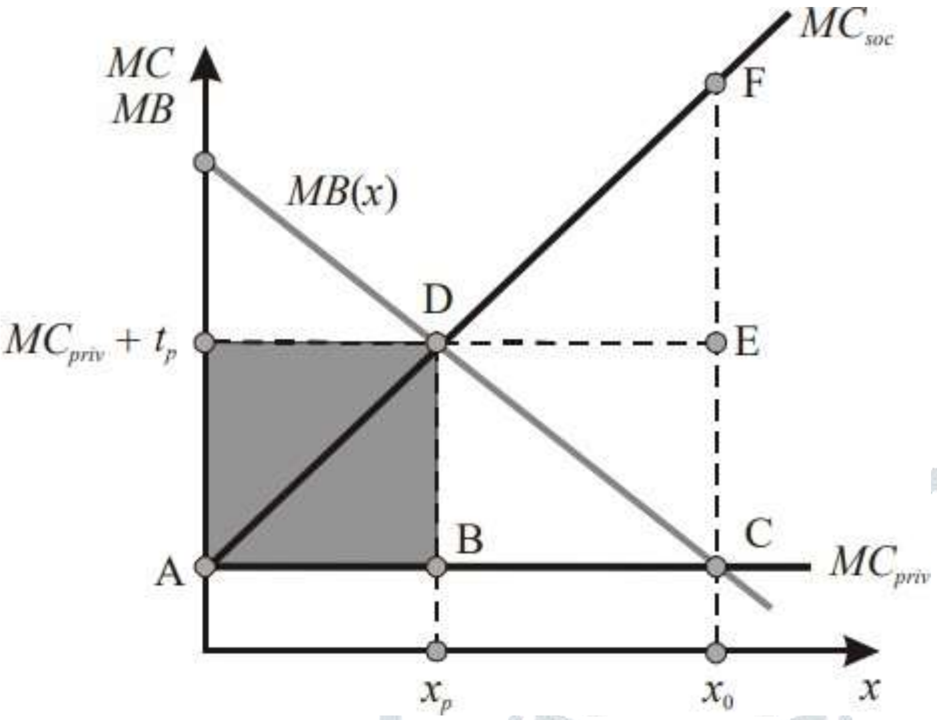
The recent report by the Intergovernmental Panel on Climate Change (IPCC) has stressed the fact that nations around the World have to undertake all the necessary steps to ensure that the global warming is limited to 1.5 degrees Celsius, and have to do it in the shortest time possible (Plumer and Zhong, 2022). Nearly all scientific papers forecast a hotter future, where migrations will increase, heat waves will be the norm and sea-level rise will become a real danger for those living along the coast (Plumer and Fountain, 2021).As a result of these scenarios, environmental economists have been studying what policies would be effective to reduce and limit carbon dioxide (CO2) emissions, with the ultimate goal of reaching net-zero emissions by 2050.

One of the most consequential policies put in place is the carbon tax, which is "an excise tax on the producers of raw fossil fuels based on the relative carbon content of those fuels" (OECD, 2008).The Carbon Tax is a recurrent topic in politics and academia, an issue of shark debate in most countries. The idea of implementing it is often controversial, and it is a highly divisive topic. One side is represented by those who believe it is an unfair tax that hurts the economy and businesses. The opposite side is supported by those who think that it is the best way to fight one of humanity's biggest challenges: climate change. Unfortunately, as politics has become more and more divisive, a more comprehensive evaluation of the economic and environmental impacts of the carbon tax is required. Therefore, the research question of this thesis is to investigate what are the effects of the carbon tax on the economy and on the emissions in Sweden.In order to do this, I have collected the relevant data and analyzed variables such as the CO2 emissions per capita, the consumer price index (CPI), the energy consumption, the gross domestic product (GDP) per capita and the rate of the carbon tax,from its early implementation until now.

2.1 Economic theory

Every time there is a discussion about environmental taxes, it is necessary to begin with the work of the British economist Pigou. With the term Pigovian tax, we mean a contribution paid by either an individual or a business as a result of their negative externalities on the society. Therefore,according to Pigou, the "optimal tax on emissions has to be set equal to themarginal environmental damage" (Schöb, 2003).
The graph below shows how a Pigovian tax works. MC stands for marginal cost, which canbe either private or social. Similarly, MB stands for the marginal benefit of consumption. $x0$ is the market equilibrium. The Pareto efficiency, which occurs "when resources are soallocated that it is not possible to make anyone better off without making someone else worse off" (OECD, 2022),is located at the intersection between the private marginal cost and theline representing the marginal benefit MB.

Figure 1: graph of the Pigovain tax (Schöb, 2003)



A carbon tax, which is a specific type of Pigovian tax, is a policy that "controls climate modification by placing a per-unit emission tax on all carbon-emitting sources" (Tietenberg and Lewis, 2012). The main objective is to "mitigate the negative externalities created bygreenhouse gas emissions" (Kennedy, 2021).

2.2 The theory behind the correct design

Designing a tax on carbon is part of a pollution policy (Perman, Ma, Common and Mac Gilvray, 2003). When introducing a policy of this kind, an environmental economist has toset a target level and evaluate what the most effective way to reach that set goal is. The targets to achieve may be aimed at economic efficiency or at reaching sustainable developments. To do this, economists use the partial equilibrium, by "looking at a single activity in isolation from the rest of the system in which the activity is embedded" (Perman, Ma, Common and Mac Gilvray, 2003).Sterner and Coria (2013) illustrate the main criteria for selection of a pollution control instrument. Some of them include, for example, the dynamicefficiency, the cost-effectiveness, the dependability and the long-run effects.

The correct rate for an environmental tax is also subject to multiple dilemmas amongscholars. As a result of the fact that burning carbon to produce electricity is dangerous forhumans and for the Earth, the optimal level of human-induced greenhouse gas emissions iszero, but this is not realistic for the time being, as it is not economically feasible. Therefore,in order to set an environmental tax, there are always some sorts of trade-offs to put in place. In order to construct an economic model to evaluate the impact of a carbon tax, Perman et al. (2003) describe it as a typical top-down model, "constructed around a set of aggregateeconomic variables", that in this study are the GDP per capita, the CO2 emissions per capita,the consumer price index and the energy consumption. In order to analyze the relationshipsbetween these variables, an econometrical study is required; in this case, it is using time- series data. The writers continue by saying that often the "carbon tax is taken an exogenous shock, and the model is solved for equilibrium before and after the shock."

The economic theory suggests that a carbon tax is really effective if it achieves the three following objectives: the decrease in the production of carbon-intensive goods and service, the reduction of the carbon footprint and "incentivizes a reduction in the carbon intensity of energy" (Ecofys,2018).As Harrison and Kriström (1997) state, when implementing a carbon tax, four possible design issues should be taken into account. The first one is about the scope. "Which sectors should be involved?", "should there be some exceptions?" are questions that should be investigated. For instance, at the beginning of the introduction of the tax, the Swedish Government excluded some energy-intensive firms, as they could have been hurt in competitiveness.

The second design issue is about the equity effects of the tax. Because most studies claim that the tax is regressive, it is fundamental to analyze this issue correctly.

The third one is that an additional policy issue is linked with the possibility of the double dividend, which will be explained in the next paragraph. Finally, the last issue is to understand whether the carbon tax is the an effective way to reduce emissions. For instance, as Harrison and Kriström (1997) point out, an increase in the tax may" result in substitution in production and consumption that result in increases in emissions and other pollutants." Having said that, it has been shown in multiple studies the positive effects of the carbon tax, and its mechanisms are observed with great interest by many governments worldwide. Today the carbon tax has been adopted in 42 countries around the World (including all EU member states),and several other countries, such as Indonesia and Brazil, are planning to implement it (Carbon Prices Around the World, 2021). As of October 2021, carbon taxes around the World covered around 22% of the World's emissions.

2.3 Double dividend hypothesis and the Porter Hypothesis

Most scholars believe that, economically, the carbon tax can be beneficial thanks to the double dividend hypothesis. This happens when the revenues generated from an environmental tax are invested to offset likely negative outcomes of that levy or to reduce other taxes. It is called double dividend because an environmental tax can have two benefits: the improvement of an environmental situation and an efficiency gain to the economy (Holland, 2016). The ultimate goal of a Double Dividend is to have a larger welfare gain after the introduction of a tax (Jaeger, 2013).As a consequence of this, a carbon tax can improve both the environment and non-environmental welfare (Schöb, 2003).

A similar approach is the revenue-neutral tax. In this case, all the revenues generated from the levy are redistributed among the population in the form of an income/corporate tax reduction. (Murray and Rivers, 2015). Therefore, the peculiar revenue-neutral carbon tax reaches both the goal of CO_2 emissions reductions and a decrease in the general taxation, while at the same time being extremely popular among voters (Institute, 2022).

Another relatable concept to consider when discussing this issue is the Porter Hypothesis, which states that the introduction of an environmental levy does not necessarily lead to a loss of competitiveness for companies (Porter and Linde, 1995). This is due to the main fact that environmental regulations tend to foster innovation, higher expenditures in research and development (R&D) and efficiency, which ultimately lead to a more sustainable business environment, from the firm to the whole supply chain.Both the double dividend and the Porter hypothesis are crucial theoretical aspects in explaining why the implementation of thetax may actually bring positive effects.

2.4 Background of the carbon tax in Sweden

Sweden, in 1991, became the second Nation in the World, after Finland, to adopt a countrywide carbon tax (Tax Foundation, 2020). It taxes emissions coming from buildings, industries, agriculture and the transportation sector. However, it is important to note that there are multiple exceptions, and the tax covers only around 40% of all the emissions in Sweden (Tax Foundation,2020) The Swedish carbon tax is not the only environmental tax present in the Country; Sweden also enforces, among others, a tax on air travel, a tax on diesel, a congestion tax in Stockholm and Gothenburg and an energy tax (Statistiska centralbyrån, 2020). This energy tax was introduced long before the carbon tax, in 1974. It has been adopted mainly for fiscal purposes, rather than for environmental reasons or for changing consumers' behaviors (Ecofys, 2018). The energy tax, despite being lowered after the introduction of the carbon tax, still exists, mainly on electrical power, fuels or gasoline (Tax Foundation, 2020). The introduction of the carbon tax was part of a larger tax reform in the 1990s, that decreased certain taxes and introduced others.

In addition to this, as part of the European Union, Sweden is a member, along with other 30 countries, of the European Union Emissions Trading System (EU ETS), a cap and trade scheme with the ultimate goal of limiting emissions (European Commissions, 2022). The Swedish industries affected by the EU ETS are exempted from the national carbon tax, so toavoid bureaucratic issues and being taxed twice (Tax Foundation, 2020). Today, 95% of the carbon emissions in Sweden are taxed either by the domestic carbon tax or the EU ETS(Government Offices of Sweden, 2022).In 2019, the Swedish government was able to collectaround 22 billion SEK thanks to the carbon tax, a figure that comprises 1% of the total tax revenues in the Country (Tax Foundation, 2020).At 126 $ per metric ton of CO_2, it is the most expensive carbon tax rate in the World, and it has been steadily growing over the years. A notable increase in the carbon tax rate happened between 2001 and 2004, and with the additional revenues, income taxes were cut (Ecofys, 2018).

It should not come as a surprise that the Swedish carbon tax is the most expensive worldwide. The Country has shown over the years incredible environmental milestones. It is leading by a wide margin the other EU countries when it comes to the share of electricity coming from renewable sources (European Commission, 2022), it ranks second in the World, after Norway, for the number of electric vehicles per capita (Holland, 2022) and in the Europe Sustainable Development Report(Larson, 2022), and it will be a carbon-neutral Country in 2045 (sweden.se, 2022).CO_2 emissions in Sweden, on a per capita basis, topped in 1976, when every Swede was responsible for emitting 11,1 tons of carbon dioxide. In 2016, the figure was only 4,5 tons, less than half (Sweden CO_2 Emissions - Worldometer, 2022). It is important to note, given the research question of this thesis, that the reduction in emissions started before the introduction of the tax.In Sweden, the carbon tax has advocates and critics. On one side, several voices claim that the tax rate should be raised, so to foster the growth of non-fossil fuel sources of energy. Moreover, to be really effective, fewer exemptions should be given. Many, on the other side, claim that the rate is too high, and that it hurts businesses. Some economists have claimed that the best rate should be around three times cheaper than the one it exists today. The majority of political parties and voters support the tax, in one way or another (Ecofys, 2018).

2.5 Literature review

Several studies have been made to verify the environmental as well as the economic effectsof the carbon tax. Among the scholars that support the levy, there are Hu, Dong and Zhou (2021), suggesting that the carbon tax is an excellent tool to curb emissions. What stands out the most from their research is the double effect that the tax generates; not only a reduction inemissions, but also economic benefits. This is due to the fact that the revenues generatedfrom the tax can all be spent in other effective ways, such as a reduction in corporate taxation, that ultimately leads to an increase in occupation. This theory corresponds to the double dividend hypothesis explained before.Moreover, the three economists have documented that the carbon tax is the best instrument to fight emissions, as the tax is linked with a reduction of energy consumption, as well as a great decline in air pollution.

Studies in the UK offer similar findings: after the introduction of the tax, there has been a relevant decline in the emissions, and a sharp increase in the share of electricity coming from renewable energies (Gugler, Haxhimusa and Liebensteiner, 2020).

The Canadian province of British Columbia has often been studied, as it was the firstgovernment in North America to fully adopted a carbon tax. The Case of British Columbia has been widely accepted as one of the best implementations of the tax worldwide (Bernard, Kichian and Islam,2018). Besides being revenue-neutral, it also did not impact the growth of the gross domestic product. Runst and Höhle (2022), after studying the effectiveness of the carbon tax in Germany, found positive results. The tax has clearly reduced the emissions and,when it comes to road transport, it was one of the main drivers for a higher fuel efficiency as well as engine technology. The reduction in emissions from cars, after the introduction of the levy, is estimated at around 250 kg on a per capita basis.In contrast to the previous analysis, other papers jump to different conclusions. Some examples include the research conducted in Brazil, where the introduction of the tax is linked with a net welfare loss, and tend to impact more negatively on lower-income citizens (Moz-Christofoletti and Pereda, 2021).

The same idea has been expressed by Wang et al.(2016), that emphasize the fact that the taxis regressive in developed countries, while for developing countries there is not a coherent conclusion on whether it is progressive or not. The authors stress multiple times the fact that to really measure the effectiveness of a carbon tax, what matters the most is its design. Infact, a carbon tax may give different socio-economical and environmental outcomes based on how it is designed and intended.To mitigate some of the negative consequences, the scholars propose, among others, taxing energy consumption only for middle-class and higher-earners individuals, so as to allow "tax-free energy allowance" for those in need the most. Other solutions may include the reduction of certain taxes,such as income tax or the value-added tax (VAT) to alleviate the effects of the distortion of the carbon tax, as well as an increase in welfare programmes and social benefits.Vera and Sauma (2015) have noticed how an introduction of a carbon tax in Chile may be advantageous when it comes to the reduction of CO_2 emissions. However, they also find that policies aimed at energy efficiency could reduceemissions by a more considerable margin.Moreover, unlike the introduction of a carbon tax, which is often associated with a growth in the marginal cost of power production, an increase in energy efficiency decreases energy prices.A comprehensive study has been analyzed by Lin and Li (2011). They, again, support the idea that taxing carbon is an effective way to cut emissions and foster investments in renewable energies.However, on the economic side, the tax is linked with an increase in prices, which may hurt the economic growth and it is a heavy hit for firms.Dissou and Siddiqui (2014) disagree with the above-mentioned views shared by some scholars. In fact, they provide evidence that the carbon tax can be progressive because it reduces inequalities,as it changes factor prices. However, it is important to highlight that they also accept the idea that the carbon tax is regressive in certain instances. For example,the changes in commodity prices due to the tax increase income inequality.

In addition to this, a paper by Callan et al. (2009) suggests that the carbon tax is regressive, and that it tends to hit lower-income individuals, although not by a remarkable margin.

In conclusion, what the literature review seems to suggest is that, on the environmental side, the carbon tax is an excellent tool to fight CO2 emissions.On the contrary, economically, scholars are split. However, most of them agree on the fact that, if well-designed, a carbontax may improve the economy or, at least, not damage it.

In order to do that, policymakers should adopt the tax reflecting on two main aspects.

Firstly, when designing an effective carbon tax, the likely inequality issues that may arise should be taken into consideration. Secondly, a carbon tax is well-designed if it is linked to governmental compensation plans, in order to mitigate eventual economic contractions (Meng, Siriwardana andMcNeill, 2012).

2.6 Effects of the carbon tax in Sweden

There are not many previous works analyzing the impacts of the tax in Sweden, the Country studied in this work.One of the most comprehensive has been written by Khastar, Aslani andNejati, (2020), analyzing the welfare effect of the tax in Finland. Sweden's eastern Neighbor has extremely similar societal,economic and cultural connections, and therefore the findings may be very similar to the ones in Sweden. Moreover, Finland adopted the carbon tax in1990, just one year before Sweden.In the paper by Khastar et al. (2020), the main conclusion is that the tax ultimately generates a rise in prices for consumers, as a result of higher costsfor fuels and electricity. A carbon tax rate of 150 $ is assumed to generate a welfare decline of 3.5 million dollars. On the other side, 150 $ as a tax rate allowed emissions to decline by30%, compared with no taxation on carbon at all. Another study was carried out by Andersson (2019). The main results are that the carbon tax in Sweden has been extremelysuccessful. His focus has been mainly on the transportation sector,and he found a 6%reduction in the emissions, on an average year, thanks to the tax. Moreover, he observed thatconsumers respond more strongly to a change in the rate of the carbon tax rather than changes in petrol prices.The report by Ecofys (2018) observed the following results after the beginning of the implementation of the tax. The residential energy emissions decreased by80%, fuel oil is, nowadays, virtually non-existent, heating based on electricity increased by 16% and industrial emissions declined by 10% (while the production went up by a third).

An opposite view is held by Shmelev and Speck (2018). In their paper, they argue that the carbon tax has not been enough to reduce emissions in Sweden, but it is thanks to the additional energy tax that this was possible. Moreover, they add that it is primarily the change in the price of oil and the rise of innovation in nuclear and hydroelectric energy the reason for the change in the "patterns of energy use".Again, even according to the study by Ecofys (2018), among the side effects of the carbon tax there is the possibility of reducing some taxes as a result of the revenues earned. Finally, interestingly, no studies have concluded that the level of innovation in Sweden has declined since the introduction of the tax (OECD, 2020).

3. Methodology

The aim of the current study is to explore how the carbon tax influences the CO2 emissions in Sweden, during the period 1985-2021. This chapter provides an insight into key research tools and techniques that are used to explore and find relevant findings, with the ultimate goal of answering the research question. The chapter is divided into several sub-sections.

3.1 Data

The linear model can be defined as follows:

$$co2em = f\ (GDPpc,\ Carbon\ Tax,\ CPI,\ energy) \quad (1)$$

In the above model, "co2em" represents CO2 per capita emission, "GDPpc is GDP per capita,"Carbon Tax" represents the taxes on carbon emission, "CPI" is consumer price index, and"energy" represents the energy consumption. Every variable is endogenous in the VEC model.The linear model represented in equation 1 can now be converted into log form, as it allows more precise and suitable results, and leads to more accurate findings (Shahbaz et al., 2012).

Therefore, the log-linear function can be re-written as follow:

$$\text{In}\ (co2em) = \alpha + \beta 1(lnGDPpc) + \beta 2\ln(CarbonTax) + \beta 3\ln(CPI) + \beta 4\ln(energy) + \varepsilon T \quad (2)$$

In equation 2, "ln" stands for the natural log of the respective variables, α is the intercept ,1, $\beta 2$, $\beta 3$ and $\beta 4$ are the coefficients of the variables, and εT is the error term.

The variables are collected annually from 1985 until 2021. Because we are dealing with a time period of 36 years, the data were, as above-mentioned, transformed into log form, in order to account for the likely presence of heteroskedasticity, as well as for a better interpretation of the findings. The number of variables has been carefully selected, since, as suggested by the literature, there should be a correct proportion and balance between the number of coefficients in the model compared to the overall size of the sample (Stock & Watson, 2020). While gathering the data, only the most reliable sources were used, to ensure the maximum correctness of the whole analysis.

In Table 1, we can observe a summary of the variables present in the model, alongside thesource from where they were collected and their unit.

Variable	Source	Unit
CO2 emissions per capita= logco2em	Our World in Data	ton
GDP per capita= log GDPpc	OECD	US Dollar
Carbon tax rate= logCarbonTax	Skatteverket	kr/ton
Consumer price index= logCPI	Statistiska centralbyrån	year 1949=100
Energy consumption= logenergy	Our World in Data kWh	kWh

The following is a brief description of the variables, followed by a graph showing the trend for each of them.

CO2 emissions per capita:According to the OECD (2012), "carbon dioxide (CO2) is a colourless, odourless and non-poisonous gas formed by combustion of carbon and in the respiration of living organisms and is considered a greenhouse gas. Emissions means the release of greenhouse gases and/or their precursors into the atmosphere".CO2 emissions are so important as they represent the main driver of climate change.The sources of the data isthe website "Our World in Data", and they are calculated on a per capita level.The data that I collected show a clear decline in the emissions, with a noticeable higher rate of decrease since 2011.In 2021, In 2021, Swedes emitted 3.826 tons of CO2 per each inhabitant, between Croatia and Chile and below most OECD countries (Worldometer , 2022).

GDP per capita:According to the OECD (2022), the gross domestic product "is the standard measure of the value added created through the production of goods and services in a country during a certain period". Therefore, the GDP is a good indicator to show the Country"s economic activity. There are two types of measurement for the GDP: the nominal and the real. The latter is more accurate, as it is adjusted for inflation of deflation, a well as being adjusted for the fluctuation of the US Dollar (Investopedia, 2022). In order to account for the maximum accuracy of the data,the values collected are referred to the GDP real.

The GDP per capita is simply equal to the GDP divided by the population in that particular year.By dividing the value by the population, hence obtaining the GDP per capita, we can get a clearer idea of the standard of living of the population every year.This variable is included in the model since several previous studies mention how the wealth of a Nation is often linked with its environmental performance. Moreover, generally speaking, the GDP tends to be a very frequent variable adopted in most papers, as it is the most important economic indicator of a Country (OECD, 2022). The data are collected in US Dollars from the OECD database.In the dataset, the Swedish GDP per capita has always almost been growing every year. There are two noticeable exceptions, that are linked to an economic crisis. From the graph of figure 2, it is clear to notice the economic downturn in 2009 and 2011 due to the global financial crisis. In the early „90s, the GDP per capita has been almost stationary, as a result of the Swedish financial crisis. However, after 1994, the economy began growing again.Today, Sweden is ranked 10th among OECD co countries with the highest GDP per capita, between Belgium and Australia (OECD, 2022).

Carbon tax rate: As the thesis is mainly about the role of thia tax on the emissions, it was necessary to adopt it as a variable**.** The data collected for the carbon tax come from theSwedish Tax Agency (Skatteverket), and are measured in Swedish kronor (SEK) per ton. In the data collected, the tax has grown considerably since its introduction, but at different rates.Moreover,in certain years the tax was stable or slightly larger as it was adjusted for inflation.The biggest increase in the tax occurred in the year 2001 and, to a lesser extent, in 1991. What is positive is that the tax is always increasing, a clear sign that policymakers believe in the positive outcome of this policy.

Consumer price index: It “measures changes over time in the general level of prices of goods and services that a reference population acquires, uses or pays for consumption” (OECD, 2013). The data from these variables are collected mainly to verify the correlation with the carbon tax and the CO2 emissions. For instance, the rise in prices may result in the need, from businesses and firms,to adopt less environmental-friendly methods. This has been shown in China, where an increase of prices in the agricultural field resulted in a growth in carbon dioxide emissions (Pang et al.,2021).

The data are collected by the online database of Statistiska Centralbyrån, the Swedish statistical governmental agency, and the level of prices in 1949 is the base price. In the dataset, CPI experiences a positive trend, with the largest increases occurring between 1985 and 1994. In general, the level of prices greatly increased over time, from 100 of 1949, the base year, until 1960 for 2021.

Energy consumption: In 2019, more than a third of all CO2 emissions in Sweden were coming from the energy sector. This figure is in line with the rest of the World (Statista, 2019). Therefore, inserting energy consumption as a part of this model might be the right choice to make. In addition to this, this variable is present in most previous papers related to the same topic.The data from this variable include the sum of all energy uses, therefore also electricity,transportation and heating. The variable is measured kilowatt-hours per person.Based on the data collected, the energy consumption has decreased from 1985 until 2020, however,the decline has not been constant over the years. From 2014 until 2020, the level of energy consumption has been virtually the same.Two other variables have been considered to be added to the study. However, for different reasons,they were discarded.

The first one was the share of the Swedish population living in urban areas. I decided to discard this variable for three main reasons. The first one is that the share is virtually constant over time. Moreover, Sweden is already an extremely urbanized Country, therefore it was notworth it to insert this variable in the model. In 2021, 88,2% of the population was living in an urban area (Macrotrends, 2022). Secondly, the literature suggests that the urban population is positively correlated with emissions, but mostly in developing countries, such as China. In Western Europe,the pattern of emissions between a rural citizen and an urban one tends to be similar (Gill and Moeller, 2018). Finally, inserting the variable in the project generated multi collinearity problems. Secondly, another interesting variable to add would have been the share of the trade as a percentage of the GDP. The impact of trade on the emissions has already been studied by Sharma (2011) and several studies found out a positive relation between the emissions and this variable. However, the lack of sufficient data was the main reason why this variable is not part of the analysis.

3.2 Descriptive statistics

Table 2 is a description of the variables used in the model and, for each of them, their mean, their standard deviation, as well as their minimum and maximum value.

Table 2: descriptive statistics:

Variable	Mean	Std. Dev	Min Max	Max
Co2em	5.88625	1.037402	3.826	7.462
GDPpc	34612.27	13421.88	15929	60393
Carbon Tax	1614.861	1069.556	0	2976
CPI	1515	295.3596	854	1930
energy	69630.97	6827.616	60156	83600

3.3 Econometric specification

In order to perform the econometric model, the software STATA 17.0 was used.Since the study focuses on the examination of one to one causal relationship among per capita carbon emission and other factors, it is fundamental to choose the appropriate specification of the model. Some of them include the vector error correction model (VECM), the vector autoregressive model (VAR) and the autoregressive distributed lag model (ARDL). The selection of these models depends on the unit root of the variables and on the existence of co- integration between the considered variables.Because of the outcome of the unit root test and Johansen test for co-integration estimated as a result VECM is the model used in this study.

The Vector Error Correction Model enjoys different advantages: Firstly, it allows to investigate both the short-run and the long-run relationships among the variables in the model. Secondly,VECM is one of the time series modeling techniques that can directly predict the level at which a variable can be returned to equilibrium following a shock to other variables (Usman et al., 2017).Finally, the VECM model is a specialized version of vector autoregression that works with variables that are integrated of order one, co-integrated, and have a long-run relationship. Using the variables included in this study,the equations for the VECM can be written as follows:

$$\Delta lco2em_t = \alpha + \sum_{i=1}^{k-1} \gamma_i \Delta lnco2em_{t-1} + \sum_{j=1}^{k-1} \beta_j \Delta lGDPpc_{t-1} + \sum_{m=1}^{k-1} \mu_m \Delta lCarbonTax_{t-1} + \sum_{n=1}^{k-1} \tau_n \Delta lCPI_{t-1} + \sum_{q=1}^{k-1} \varphi_q \Delta lnenergy_{t-1} + \lambda_1 ECT_{t-1} + u_{1t} \quad (5)$$

$$\Delta lGDPpc_t = \theta + \sum_{i=1}^{k-1} \gamma_i \Delta lnco2em_{t-1} + \sum_{j=1}^{k-1} \beta_j \Delta lGDPpc_{t-1} + \sum_{m=1}^{k-1} \mu_m \Delta lCarbonTax_{t-1} + \sum_{n=1}^{k-1} \tau_n \Delta lCPI_{t-1} + \sum_{q=1}^{k-1} \varphi_q \Delta lnenergy_{t-1} + \lambda_2 ECT_{t-1} + u_{2t} \quad (6)$$

$$\Delta lCarbonTax_t = \delta + \sum_{i=1}^{k-1} \gamma_i \Delta lnco2em_{t-1} + \sum_{j=1}^{k-1} \beta_j \Delta lGDPpc_{t-1} + \sum_{m=1}^{k-1} \mu_m \Delta lCarbonTax_{t-1} + \sum_{n=1}^{k-1} \tau_n \Delta lCPI_{t-1} + \sum_{q=1}^{k-1} \varphi_q \Delta lnenergy_{t-1} + \lambda_3 ECT_{t-1} + u_{3t} \quad (7)$$

$$\Delta lCPI_t = \vartheta + \sum_{i=1}^{k-1} \gamma_i \Delta lnco2em_{t-1} + \sum_{j=1}^{k-1} \beta_j \Delta lGDPpc_{t-1} + \sum_{m=1}^{k-1} \mu_m \Delta lCarbonTax_{t-1} + \sum_{n=1}^{k-1} \tau_n \Delta lCPI_{t-1} + \sum_{q=1}^{k-1} \varphi_q \Delta lnenergy_{t-1} + \lambda_4 ECT_{t-1} + u_{4t} \quad (8)$$

$$\Delta lenergy_t = \omega + \sum_{i=1}^{k-1} \gamma_i \Delta lnco2em_{t-1} + \sum_{j=1}^{k-1} \beta_j \Delta lGDPpc_{t-1} + \sum_{m=1}^{k-1} \mu_m \Delta lCarbonTax_{t-1} + \sum_{n=1}^{k-1} \tau_n \Delta lCPI_{t-1} + \sum_{q=1}^{k-1} \varphi_q \Delta lnenergy_{t-1} + \lambda_5 ECT_{t-1} + u_{5t} \quad (9)$$

In the equations above, λ represents the coefficient for the error correction term (hence the acronym ETC); $ECTt-1$ is the lagged error correction term; ω, P, δ, θ, α are the constantterms; Δis the first difference of all the variables included in the model; γi, , μm, rn and φq are the short run coefficient in the long-run equilibrium; uit are the stochastic error terms and k is the optimal lag length. The variables are in log form.In order to develop the VECM, it is necessary to perform some pre-estimation steps that are the unit root test (test for stationarity), the test for lag selection (optimal number of lags) and the test for cointegration (establishment of long-term relationship).

3.4 Eventual problems with the method

The first issue that may arise from this analysis is the time frame. Clearly, the longer the time, the more accurate the research is. Unfortunately, due to the fact that the carbon tax has been introduced recently, it was not possible to collect earlier data.

In order to obtain more accurate results, it could have been better to gather quarterly data, in order to have more detailed information, as well as more observations. However, these data were not available online. Therefore, the small sample size in the dataset is a limitation totake into account. As above-mentioned, the relatively high number of lags increases the number of parameters in contrast with the total number of observations, hence decreasing the accuracy of the results. This is because the literature suggests that the number of parameters should be less than the number of data points. In general, when it comes to the model chosen for the analysis, the risk of having too many parameters is that it may be outside the range of data, hence giving unreliable results.

This model has five variables and four number of lags. This means that there are 21 coefficients, the result of (5*4)+1, which is the intercept. This number should then bemultiplied by the 5 equations in the model. Estimating many coefficients may lead to biased and unreliable results,and "the number of coefficients therefore should be small relative to thesample size, so the number of VAR variables should be few" (Stock & Watson, 2020).

This is a limitation of the study to keep into account. Changing the data or the number of dimensions and adding or removing variables are solutions that were not feasible, as theygave even less reliable results or issues with stationarity.

3.5 Unit root test

As I am dealing with a time-series analysis, the first step to undertake is the unit root test. This test is fundamental, as the choice of the model directly depends on the presence or absence of unit root.The reason why it is crucial to check the stationary is due to the fact that if variables are not stationary, there is the risk of a spurious regression (Baumohl and Lyocsa, 2009).In time series, with the term stationary, we mean the situation in which "mean and variance are constant over time" (Pulina, n.d.). The specific test used is the Augmented Dickey-Fuller (ADF),as it is by far the most common statistical approach used in the previous studies, but other unit root tests include the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test, the Phillips-Perron test and the ADF-GLS test.

The unit root exists in time series of the value of α-1 in the given equation:

$$Yt = \alpha Yt-1 + \beta Xe + \varepsilon t \quad (10)$$

Where Yt is the value of time series at time t, Xe is an exogenous variable and εt is the error term with mean equal to zero . Therefore, if α is equal to 1, it means that it exists unit root in the dataset.The Augmented Dickey Fuller Test evolved based on the above DF test and expands the DF test to include higher order regressive process in the model (Gujarati, 2003). The ADF test allows to incorporate additional lags which take into consideration the possibility of serial correlation in the series. The ADF test equation with p lags can be written as follows, where $Yt-1$ represents the first lag of time series and $\Delta Yt-1$ represent the first difference of the time series at $(t-1)$ period (Prabhakaran, 2022).

$Yt = c + \beta t + \alpha Yt-1 + \emptyset 1 \Delta Yt-1 + \emptyset 2 Yt-2 \ldots + \emptyset p \Delta Yt-p + et$

(11)

The Augmented Dickey-Fuller generalized test equation is expressed in three different ways (Gujarati et al., 2021). The first equation (12), it is constant with trend. In the secondequation,(13) is constant without a trend, and in the last one, it has neither a constant nor atrend (14).

$\Delta yt = \alpha + \beta t + \theta yt-1 + \Sigma\, \delta I \Delta yt-1 + \varepsilon t k i=1$ (12)

$\Delta yt = \alpha + \theta yt-1 + \Sigma\, \delta I \Delta yt-1 + \varepsilon t k i=1(13)\Delta yt = \theta yt-1$
$+ \Sigma\, \delta I \Delta yt-1 + \varepsilon t k i=1$ (14)

In equations 12, 13 and 14, α is the intercept, namely the drift; β is the coefficient for the time trend; t is the time; y is “the coefficient presenting process root” (RTC Lab, 2020) and εt is the white noise error term.

As above-mentioned, the ADF test, in equation (11), allows incorporating the lagged values of the variables. Consequentially, in order to correctly carry out the test, it is important to choose an appropriate procedure for choosing the lags.

The results from the ADF test can give different outcomes. If the variables included in the model are stationary at level, a simple regression is needed. If the variables are stationary at level, after first difference or mixed, it will be necessary to adopt the ARDL model. Finally, if the variables are stationary at first difference, it is necessary to proceed with either VECM or VAR.Integrated at order zero, written as I (0), means that the series “does not have a stochastic trendand is stationary”. On the other hand, a series integrated of order once, written as I (1), means that”the series has a random walk trend” (Gujarati et al., 2021).For carrying out the ADF test, I did not include the trend term, and the constant term has not been suppressed. The drift term has not been included in the regression, as the series do not exhibita drift.Now it is possible to focus on the results.

From Table 3, we see that the variables are not stationary at level, as their associated t statistics are smaller, in absolute value, than the critical values. Here, we do not reject the nullhypothesis of having unit root. For this reason, the next step is to verify if the variables are stationary at first difference (Table 3).

Table 3: Augmented Dickey-Fuller test in level

Variable	Test statistic	1% critical value	5% critical value	10% critical value	p value	Test Results
logco2em	-1.926	-4.352	-3.588	-3.233	0.6409	Non-Stationary
logGDPpc	-1.073	-3.730	-2.992	-2.626	0.7257	Non-Stationary
logCarbonTax	-1.277	-3.736	-2.994	-2.628	0.6396	Non-Stationary
logCPI	-0.635	-3.736	-2.994	-2.628	0.8630	Non-Stationary
logenergy	-0.954	-3.730	-2.992	-2.626	0.7698	Non-Stationary

In the case of Table 4, we can compare the critical values with the first difference of the variables, and we can safely conclude that the variables are stationary at first difference I(1). We can then reject the null hypothesis, namely that there is unit root in the sample.

Table 4 Augmented Dickey-Fuller test at first differences

Variable	Test statistic	1% critical value	5% critical value	10% critical value	p value	Test Results
logco2em	-3.799	-3.736	-2.994	-2.628	0.0029	Stationary
logGDPpc	-5.574	-3.736	-2.994	-2.628	0.0000	Stationary
logCarbonTax	-2.619	-2.492	-1.711	-1.318	0.0075	Stationary
logCPI	-4.700	-3.736	-2.994	-2.628	0.0001	Stationary
logenergy	-6.156	-3.736	-2.994	-2.628	0.0000	Stationary

3.6 Lag length Selection Criterion

The unit root analysis confirmed that both linear regression and ARDL approaches are notsuitable for this study, therefore, we need to focus on either the VAR or VECM.

Following the ADF test, it is necessary to compute the lag-order selection model, in order to quantify what is the optimal number of lags in the model. The existence of lags in an analysis is due to the fact that a change in one variable does not instantaneously change the other variable,but some time is required. This procedure is crucial because a too-high number oflags would mean a higher standard errors for the coefficients, a loss of a degree of freedomand, in general, a more uncertain model; too low, on the other hand, would result in a misspecified model, in a loss of information and in specification errors.

Table 5 below provides a summary overview of the results from the lag selection. The first column in the table (Lag) is the number of lags used for model estimation; the second column (LL) is the log-likelihood; the third column (LR) is the likelihood ratio test statistic; the fourth column (df) is the degrees of freedom; the fifth column (P) is the p-value for the likelihood ratio test; the sixth column (FPE) is the Final Prediction Error (FPE) of the model; the seventh column (AIC) is the Akaike Information Criterion (AIC); the eighth column (HQIC) is the Hannan-Quinn Information Criterion (HQIC) and finally the ninth column (SBIC) is the Schwarz Bayesian Information Criterion (SBIC). All these tests suggest that four is the optimal number of lags.

Table 5: results of VAR selection order criteria

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	166.352				2.8e-12	-12.4117	-12.342	-12.1697
1	277.87	233.04	25	0.000	3.8e-15	-19.0669	-18.6489	-17.6153
2	320.595	85.449	25	0.000	1.2e-15	-20.4303	-19.664	-17.769
3	373.17	105.15	25	0.000	3.le-16	-22.5515	-21.4368	-18.6804
4	484.561	222.78*	25	0.000	3.3e-18*	-29.197*	-27.7339*	-24.1162*

Note: * represents the optimal lag based on the specific criterion.

3.7 Johansen test for cointegration

If series are integrated of order one, i.e., stationary at first difference, it is necessary to perform a cointegration test, in order to establish a long-term relationship between the variables. Testing for cointegration is also required so that it is possible to choose either the VECM or the VAR model.We select the VECM when the variables are co-integrated, while we opt for the VAR when no cointegration has been found. This means that, in case of no cointegrating, only the short-run model (VAR) will need to be constructed. On the other hand, should the variables be cointegrating, it will be necessary to construct both the short- run (VAR) and the long-run (VECM) model. Variables are cointegrated when they share a long-run relationship (Gujarati, 2003). Therefore, in order to verify this relationship among the collected variables, it is necessary to undertake a cointegration test.

There are two different methods to test for cointegration: the Engle-Granger and the Johansen test for cointegration. The former is primarily suitable for a model with only two variables (Corporate Finance Institute, 2022), therefore the test used is the Johansen test. Moreover, this is the test adopted the most in previous similar works. In general, the Johansen co- integration test allows for the estimation of all co-integrating vectors in the presence of two variables. The Johansen test for cointegration can also be seen "as a multivariate generalization of the augmented Dickey-Fuller test (Winarno et al., 2021), and it is a likelihood-ratio test.the estimation of all co-integrating vectors in the presence of two variables. The Johansen test for cointegration can also be seen "as a multivariate generalization of the augmented Dickey-Fuller test (Winarno et al., 2021), and it is a likelihood-ratio test.

The Johansen test for cointegration encompasses two different tests: the trace test and the maximum eigenvalue test.

The best way to interpret the results from Table 6 and 7 is to read the results starting from the first raw. In the case of Table 6, the first raw corresponds to 0 as a rank. The trace statistics (86.9026)is larger than the critical value, (68.52), so this means no cointegration. Now, moving to the second raw, we can notice that, because the trace statistic is bigger than the 5% critical value, we cannot reject the null hypothesis. Therefore, the results suggest that the rankis one, meaning there is one cointegrated equation.

Table 6: results of the Johansen tests for cointegration (Trace Statistics)

Maximum rank	Parameters	Eigen value	Trace statistics	Critical value 5%
0	30		86.9026	68.52
1	39	0.75780	47.1993*	47.21
2	46	0.59589	21.8294	29.68
3	51	0.36058	9.3080	15.41
4	54	0.21132	2.6611	3.76
5	55	0.09066		

Note: * indicates the selected rank

As can be visible from Table 7 below, at the row corresponding to the maximum rank of 1, the maximum statistics value is lower than the critical value at 5%. This means that we have to accept the null hypothesis and, consequentially, we have to reject the alternative hypothesis, which states that there is a $r_0 + 1$cointegrating vector. Therefore, both tests (trace and eigenvalue) propose that there is one cointegrating equation.

Table 7: results of the Johansen tests for cointegration (Maximum Eigenvalue)

Maximum rank	Parameters	Eigen value	Maximum	Critical value 5%
0	30		39.7033	33.46
1	39	0.75780	25.3699	27.07
2	46	0.59589	12.5214	29.97
3	51	0.36058	6.6470	14.07
4	54	0.21132	2.6611	3.76
5	55	0.09066		

As the series are cointegrating, we can say that they show a long-run relationship. This means that it is possible to estimate both the short-run and the long-run models, and, to estimate this, the VECM will be required.The tests carried out, the ADF test and the Johansen co- integration test., were necessary in order to verify the accuracy and the suitability of the vector error correction model.

4. Results

This section presents the findings from the estimation. Firstly, a correlation matrix has been added to analyze the relationships between the variables. Secondly, the results (presented in their respective tables) from the short-run and the long-run estimates have been analyzed. Finally, I have included post-estimation tests, namely the Granger Causality test, the Impulse Response Function, the Normality Test and the Stability Test.

4.1 Correlation Matrix

The correlation matrix is a specific type of statistical tool used to verify the degree of association between two variables and to ascertain the relationship between them.

In the table 8 below, it is possible to observe an overview of the correlation matrix. As a rule of thumb,a value higher than 0.50 indicates that "the variables are strongly positively or negatively correlated" (Ghazouani, 2021). The asterisk next to the value indicates a significance level of 1 %.

Table 8: correlation matrix

Variable	logCarbonTax	logGDPpc	logco2em	logCPI	logenergy
logCarbonTax	1.0000				
logGDPpc	0.9521* 0.0000	1.0000			
logco2em	-0.8158* 0.0000	-0.9075* 0.0000	1.0000		
logCPI	0.9472* 0.0000	0.9191* 0.000	-0.7842* 0.000	1.0000	
logenergy	-0.8077* 0.0000	-0.9125* 0.0000	0.8908* 0.000	-0.8834* 0.000	1.0000

Note: * one percent significant level

From Table 8, what is extremely interesting to notice is the high positive correlation between the carbon tax and the GDP per capita and the CPI, showing that the carbon levy moves inthe same direction as the two above-mentioned variables. On the other hand, there is a negative correlation between carbon tax and the emissions, at -0.8158. High positive correlation is also recorded between CPI and the GDP per capita.

In general, it is possible to draw the conclusion that the carbon tax, the GDP per capita and the CPI have a negative degree of association with the CO2 emissions, while the energy consumption has a positive one.In all instances, the correlations are statistically significant at 1% level.

4.2 VECM estimation results

4.2.1 VECM short-run estimates

As mentioned in the previous chapters, one of the advantages of the VECM is that it allows to investigate both the results from short-run and the long-run.The short-run estimates from the VECM model are explained in table 9 below.In the table, it is possible to see the coefficientof the variables at the different lagged values (L1,L2D, L3D etc.), together with their standard errors, the z test (which is obtained by dividing the coefficient and the respective standard error) and p values. The VECM short-run estimates show the different variables of interest and their respecting regressors, but, for this work, I have I included only logco2e, asit is the most crucial variable in the study, and for providing more clarity.ce1 stands for the cointegration equation 1, and each of the variables is shown with its corresponding lags.

We can see that, when it comes to the logCarbonTax, its first lag has a positive impact on the CO2 emissions at ten percent significant level in the short-term. On the other hand, the other lags of logCarbonTax are insignificant (in fact, their p values are 0.861 for lag two and 0.492 for lag three).In the short-run, a positive relationship is also found between the carbonemissions and the GDP per capita at lag three, but this is not statistically significant.

Moving to the following variable, the log for the Consumer Price Index, we can notice that at lag three, logCPI is statistically significant in the short-run.On the other hand, logGDPpc and logenergy do not have any significant impact on logco2em regardless of the lag, as a result ofthe value of their p value.

4.2.2 VECM long-run estimates

As mentioned above, the solution from the Johansen cointegration test has resulted in one cointegrating equation. This implies that the series are related and can be combined in a linearfashion, and it means that, even if there are shocks in the short-term that might affect themovement of the individual series, the series will eventually converge in the long-run.

As the finding from the Johansen test for cointegration implied that there is one co- integrating equation, we opted for the Vector Error Correction Model, that allows, unlike the VAR, to estimate the long-run results. Hence, the outcomes of the results in the long-run can be observed. It is essential to highlight that, as a result of the normalization of the coefficient of the model, the sign of the same coefficient should be interpreted with the opposite sign. This is due to the fact that the Johansen Normalization equation is in implicit form.

As already mentioned for the table related with the short-term results, it is possible to observethe variables alongside their coefficient, standard errors and p values.

To begin with, what the results indicate are that the variables locco2em, logGDPpc, logCarbonTax and logCPI are significant at 1%. On the other hand, logenergy does not havea significant impact on the long-run relationship.The following is the interpretation for eachvariable.The results show that a 1% increase in the carbon tax is significantly correlated with a reduction in emissions by 2,27%. This is in line with the theoretical assumptions written inthe theoretical part, that state that a carbon tax is a viable, feasible and effective way ofreducing emissions, and the results show how beneficial a carbon tax may be for the environment. The decrease in emissions is not outstanding, as firms may continue to polluteas long as it is economically convenient, but nevertheless, it still remains an efficient policy. This does not mean that the carbon tax should be the only tool to implement to mitigate thedevasting impact of climate change, but it should still be on top of the priority forgovernments around the world. In the longrun,in order to reach the objective of zero netemissions by 2050, the best approach is to constantly raise the carbon tax every year. This isan effective way to reduce emissions, and it also gives firms and businesses the right time to adjust and adapt to a carbon-free future. A similar approach has been suggested by Doğan etal. (2022), by investigating what would happen to G7 countries incase of an increase inenvironmental taxes. Their findings are that a stricter environmental levy could successfully allow companies to switch to greener business operations and methods, without damaging theeconomy.It might be pointed out that the reduction in emissions is not remarkably high. Thiscould be explained by four reasons. The first one is that the Swedish carbon tax rate isalready the highest in the World, which means that the marginal reduction is lower than othercarbon tax policies around the World. Secondly, even if the carbon tax would increase by asignificant margin (for example tenfold), the emissions would not reach zero, as there are other drivers for emissions. Thirdly, a very high tax rate from a carbon levy does not necessarily mean that emissions could be reduced further. In fact, it is not implied that the revenues generated from the tax are fully redistributed in environmental governmental policies to fight global warming, and firms can keep polluting. Finally, several industries are exempted from the payment of the tax, and can still keep on polluting until new regulations are introduced by policymakers. Therefore, if policy-makers will decide to improve and upgrade the regulations regarding the levy, for example reducing or completely eliminating the exemptions, there is a high possibility that the carbon tax will be able to be even more effective in reducing the emissions than it is today.On the other hand, we can see that there is a positive relationship between the GDP per capita and the emissions. In fact, a 1% increasein the GDP per capita affects the CO_2 emissions by a growth of 11,2%. This is a result that comes up against the theory behind the Environmental Kuznets Curve (EKC), named afterthe American economist Simon Kuznets. The theory suggests that environmental degradation increases when a Country is developing, but, as the GDP grows, the environmental levels improve over time (Perman and Stern, 2003). However, the EKC has

been subjected to multiple studies that have criticized it to various degrees. Some scholars claim that it does not simply exist in the real world (Perman and Stern, 2003), while Cole, Rayner and Bates (1997) state that it is applicable only to local air pollutants. Therefore, inthe long-run, logGDPpc and logCarbonTax have asymmetric effects on logco2em, ceteris paribus. The majority of scholars agree with the results from this analysis, i.e. the economic growth is a leading cause for CO2 emissions (Moyer, Woolley, Glotter and Weisbach, 2013). The fact that the increase in the GDP is responsible for global warming has been observed in every region of the Earth except for Latin America (Acheampong, 2018).

This does not mean that economic growth will always be an obstacle for reaching net neutrality. In fact, several economists suggest that, due to technological innovations, a shift from an industrial to a service-based economy and a slower population growth, it may be possible to reach the environmental objectives without sacrificing the economic development (Begum, Sohag, Abdullah and Jaafar, 2015).

It will be necessary to perform additional studies in the future regarding the correlation between emissions and the growth of the gross domestic product, and finally draw to a shared conclusion among all the economists. In fact, the perceived and likely decline in the economic output is one of the reasons that prevent voters, and consequentially politicians, from implementing bold actions in favor of the climate.

In addition to this, an increase of 1% in the consumer price index is significantly correlated with a reduction in the emissions on a per capita basis by 25,4%. An explanation of this maybe that when the level of prices rises, the population tends to limit consumption, hencereducing the emissions.This is the phenomenon that periodically occurs when there is an increase in oil or gas prices, in which households simply decide to drive less. For these reasons, several environmental economists have claimed that higher fuel prices are actuallybeneficial for the environment (Frankel, 2021). In fact, higher fuels prices mean higher costs for businesses, hence higher prices for consumers,which leads to a reduction in consumers‟purchasing power, that, ultimately lead to a reduction in the emissions. A similar finding isbacked up by a study Wang et al. (2017) on the effects of an implementation of agovernmental carbon tax. What they have noticed is that the prices tend to grow as effects ofthe new environmental levy. As a consequence of this, consumers reduce their spending;factories produce fewer products, and, because of all these factors combined, the overall emissions decrease. However, the authors believe that higher environmental regulations mayalso be proven to be effective in reducing the emissions without increasing the prices, ascompanies and businesses would be required to produce and manufacture goods moreefficiently from an environmental standpoint. The value of the coefficient is remarkably high,at 25.41. The explanation may rely on the fact that the value for log of the cpi is relativelylow, as well as the difference between its maximum and minimum value. Consequentially, aslight increase of 1% generates notable changes in the dependent variable.

Finally, in the normalization report of Johansen, the variable logenergy is not significant, therefore,it does not contribute to the change of the dependent variable. There are different explanations for this finding. One of them can be attributed to the different structure of the energy consumption in Sweden, that over the years has constantly increased the share of electricity coming from non-fossil fuels. The share of energy, consumed in Sweden, coming from nuclear power and renewable energy increased from 55,2% in 1985 to 71,1% in 2020 (Ritchie, Roser and Rosado, 2022). The largest increase is represented by the energy consumption coming from wind turbines, which increased from virtually zero in 1991 to 11,3% in 2020; on the contrary, oil decreased from 31,1% of the total consumption to 24,7% of today. The fact that the increase of energy consumption is statistically insignificant is backed up by several other papers. For example, there has not been established a clear nexus between the energy consumption with the emissions in Sub-Saharian Africa and in Latin America (Acheampong, 2018). Generally speaking, as the population of the world keeps increasing, topping 8 billion humans in 2022, it will be necessary to foster the investments in technologies related with renewable energies and nuclear power as a viable option to reduce the emissions. In fact, it is unrealistic and politically unfeasible to expect a decline in energy consumption, as the world‟s population keeps increasing. Several papers point out a similar idea: it is not the increase in energy consumption that causes more CO2 emissions, but it isthe sources of energy that greatly contribute to environmental degradation. This means that if a Country like Sweden, that produces most of its energy from non-fossil fuel sources, does not jeopardize its environmental achievement in case of higher energy production, unlike countries that mostly rely on coal and oil for producing energy, such as India and Indonesia. (Khan et al., 2020).

5. Conclusions, policy implications and limitations

The last section of this work is composed of three paragraphs. The conclusions, the policy implications and a description of the main limitations and suggestions for further research.

5.1 Conclusions

In this study, the research question was to investigate what are the effects of the introduction of a carbon tax in Sweden. According to the regression made, the main finding is that, in the long run, a percentage increase in the rate of the carbon tax significantly reduces CO2 emissions. This is the result that we were expecting, based on the previous literature. This finding also highlights once again how crucial is this policy for the fight against climate change, as it is an effective measure. On the other hand, the gross domestic product at a per capita basis and the emissions are negatively correlated, which means that an increase in the GDP per capita is significantly correlated with an increase in emissions.In addition to this is that the consumer price index and the emissions are positively correlated, while the energy consumption is not statistically significant.

5.2 Policy implications

As mentioned in the introduction part, the World is heading toward a hotter future, and the devastating impact of global warming will greatly affect the World‟s economy and our lifestyle. Our planet will experience major floodings, heat waves, wildfires, changes in precipitation patterns, more droughts and stronger hurricanes (Nasa, 2022) Therefore, it is necessary that policymakers adopt well-designed and effective solutions to mitigate these adverse effects and start imaging a future without carbon. Several policies have been designed to fight climate change, such as the carbon tax, cap-and-trade program, tax incentives for fostering renewable energies, consumer incentives etc.Every policy that has as an objective the reduction of carbon dioxide emissions should be welcome.However, the recommendation for policymakers, based on the content of this work, is to adopt a carbon tax, as it is a significantly effective way to reduce emissions. Even countries that have already implemented the tax, such as Sweden, should consider raising it.

5.3 Limitations and suggestions for further research

One limitation of the thesis has been the fact that many exceptions exist; in fact, not allindustries and firms are subject to the carbon tax. In addition to this, the tax covers only 40% of the emissions in Sweden. Therefore, it is hard to quantify precisely the effects of the levy, as its application is limited.

Similarly, there are two different schemes in use: the Swedish carbon tax and the European ETS scheme. Again, due to these reasons, this analysis may give only partial results.

Finally, the energy tax used in Sweden shares certain similarities with the carbon tax, and that might be an obstacle to the accuracy of the results.A suggestion for further research would be analyzing multiple countries that have adopted the tax, not only Sweden, in order to assess the effects of the carbon tax in a more comprehensive way. In this manner, it would be possible to verify whether the effects of the tax on the environment vary and so if the carbon tax can be applicable in other countries.

In addition to this, it may be interesting to analyze the impact of the tax by industry with micro level data, so to verify, for instance, how different sectors and industries react to the levy. Finally, this thesis has chiefly investigated the correlation between the different variables. However, it may also be interesting to analyze the causal effects between them.

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