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Emission Trading Systems and Forestry: Understanding the Case of New Zealand and Applications for Sweden through the EU ETS

By

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Abstract

Forest carbon sinks are becoming increasingly important as a climate change mitigation tool. To date, New Zealand is the only country that has fully incorporated forestry into its emission trading framework. This study seeks to understand if and how that has impacted forest management practices and carbon sink enhancement. Furthermore, this study seeks to understand to what extent the practices in New Zealand could be useful for improving Sweden's forest carbon sinks by studying the European Emission Trading System. As Sweden is one of the most forested countries in Europe, understanding global, regional and national policy development related to forestry is essential to enhance Sweden's carbon sinks and reach national climate targets. This study uses quantitative regression analysis and descriptive statistics to study the relationship between the price of New Zealand carbon units and forest management practices. Findings from the research demonstrates some relation between carbon sink enhancement and price of NZU. Therefore, if New Zealand's emission trading system had been applied solely to the case of Sweden it is possible that it would enhance Sweden's carbon sinks. However, on an EU level, as the region consists of multiple member states which are vastly different, another type of study would have to be conducted.

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List of Abbreviations

AFOLU Agriculture, forest land and other land use

A/R Afforestation and Reforestation

CDM Clean Development Mechanism

CO2 Carbon Dioxide

CO2 eq Carbon Dioxide equivalent

CPI Carbon Pricing Initiative

ETS Emission Trading System (Scheme)

EUA European Union Allowance

GHG Greenhouse Gas

IPCC Intergovernmental Panel on Climate Change

JI Joint Implementation

LULUCF Land Use, Land Use Change and Forestry

NZU New Zealand Unit

UNFCCC United Nations Framework Convention on Climate Change

Introduction

1.1 Research Problem

Since the 19th century the average global temperature has risen by 1.1 degrees Celsius which has caused intensified and more frequent natural disasters (Nasa, 2022). The 2015 Paris Agreement set a cap to keep global warming below 2 degrees, preferably 1.5, to mitigate the worst effects of climate change (IPCC, 2022). In order to keep global warming below 2 degrees, stabilizing the carbon dioxide content in the atmosphere is of immense importance. Therefore, policies targeted towards reducing fossil fuels as well as removing carbon dioxide from the atmosphere have become increasingly relevant.

One sector that is becoming of increasing interest for emission reduction is the forestry sector as it performs carbon removing activities by storing carbon, which is referred to as a carbon sink. A carbon sink is anything that absorbs more carbon dioxide that it emits, and the largest carbon sinks are forests, oceans and soils (ClientEarth, 2020). Forest carbon sinks are created through carbon sequestration, meaning the process of binding and storing carbon dioxide in biomass (Kirby & Potvin, 2007). Protecting carbon sinks around the world has been highlighted as an important tool to mitigate climate change in both domestic and international policy. The United Nations' Sustainable Development Goal (SDG) 15, 'Life on Land', deals with forest management and land degradation in order to promote sustainable use of terrestrial ecosystems. Target 15.2 was specifically aimed towards forest management and stated that "by 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally", however, this target was not achieved (UN, 2022, p. 22). Afforestation and reforestation (A/R) is defined as activities where trees are planted in areas that have not been or not recently been forested (Carver et al., 2021). Deforestation refers to the process of removing forests for the purpose of other land use (OECD, 2021; Carver et al., 2022). Although there are many initiatives to enhance sustainable forest management, the world's current trajectory will not enable SDG 15 to be achieved in line with the Paris Agreement (UNEP, 2022).

The Intergovernmental Panel on Climate Change (IPCC) stated in their 6th report (2022) that agriculture, forest and other land use (AFOLU) accounted for 13-21% of human-caused greenhouse gas emissions in the period 2010-2019, where deforestation stood for 45% of AFLOU emissions (IPCC, 2022). However, A/R and properly managed forests have the potential to decrease emissions through carbon sequestration and carbon sink enhancement. Therefore, rethinking how the value of forests is incorporated into economic and policy decisions is essential for climate change mitigation and ecosystem preservation (IPCC, 2022; Carver et al., 2022; Hanley & Barbier, 2009).

As the time for decreasing emissions and reaching international agreements such as the Paris Agreement is expiring, carbon sink enhancement is becoming increasingly important in policy decisions. One of the commitments by signatories of the Paris Agreement is to submit national climate action plans, known as nationally determined contributions (NDCs), that communicate actions the country will take to fulfill the agreement (UN, 2015). In 157 countries' NDCs, after reduction of greenhouse gas (GHG) emissions, forests were the most referenced sector for mitigation measures (Shrestha et al., 2021). The majority of the countries' NDCs referred to forest management, restoration, afforestation and protection of natural forests as key instruments to achieving their emission and policy targets (Shrestha et al., 2021). The large interest in forestry seen in international agreements and national targets calls for new and creative solutions for forest management and carbon sink enhancement to enable a sustainable transition.

New ways to decrease GHG emissions have developed globally where carbon pricing initiatives (CPIs) are becoming of increasing interest (World Bank, 2022). CPIs are a way to incorporate negative externalities arising from GHG emissions by placing a price on carbon dioxide (CO2) emissions (Prokofieva, 2016). According to the World Bank (2022) 68 carbon pricing instruments are in operation, including both carbon taxes and emission trading systems (ETS). In 2020, 34 ETS frameworks were in place on a national, subnational and regional level. Out of 34 ETS in operation, the first and largest is the European Union Emission Trading System (EU ETS) which was established in 2005 (European Commission, 2015). It covers around 40% of EU emissions and includes all member states as well as Iceland, Liechtenstein and Norway (European Commission, n.dc). The EU ETS framework covers the main polluting industries in the EU which includes power stations, intensive heavy industry and civil aviation (Appunn & Wettengel, 2023). The most extensive ETS framework with regards to the number of covered sectors in the economy, is New Zealand's ETS (NZ ETS). This study seeks to understand if emission trading systems are a good medium for carbon sink enhancement which makes New Zealand's ETS particularly interesting as it is the only ETS that has included forestry.

Previous research on carbon sink enhancement mainly concerns different methods of forest management practices to enhance carbon sinks rather than effects from market CPIs (Bernal et al., 2018; Prokofieva, 2016; Lefebvre et al., 2021; Toochi, 2018). Moreover, there is not an extensive body of literature discussing CPIs in relation to carbon sinks and forestry. The literature concerning risks and opportunities for sustainable forest management arising from emission trading is especially limited. This study contributes to the body of literature by studying the relationship between forest management practices and price of carbon units in New Zealand through quantitative analysis. In addition, it contributes to the discussion on carbon sink enhancement in Sweden by studying the case of the EU ETS.

1.2 Research Questions, Aim and Scope

To what extent can the EU ETS be a framework that contributes to carbon sinks enhancement? Can carbon pricing initiatives such as ETS frameworks be used to mitigate climate change? These are some questions that arise when studying the topic of emission trading and carbon sinks. One of the most forested countries in the EU is Sweden, making it an interesting case to study. This study therefore aims to explore lessons learned from New Zealand's broader ETS, and to investigate if including forestry in the New Zealand ETS has had any impacts on deforestation, A/R and carbon sequestration. The research questions then becomes:

Has including forestry in the NZ ETS had a significant impact on forest management?

Sub-research question

To what extent are these findings relevant for the EU ETS and carbon sink enhancement in Sweden?

As mentioned, New Zealand's ETS is of specific interest as it is the only emission trading framework that covers the forest sector (Carver et al, 2022). It does so by having landowners pay for emissions related to deforestation activities and receive economic compensation for carbon sink enhancement through A/R and sustainable forest management (Carver et al, 2022). The NZ ETS has been active since 2008 with spot prices being recorded from 2009 (Ministry for the Environment, 2022). The units traded under the system are called New Zealand Units (NZU) (Ministry for the Environment, 2022).

As the second most forested county in the EU, Sweden's carbon sinks are an interesting case to compare with the findings from New Zealand Eurostat, 2022). Sweden's land area consists of 63% forest out of which 84% is categorized as productive forest land, meaning it can be used in industry and production (SCB, 2022). According to Skogsindustrierna (2022), the Swedish organization for the forest industry, the forest sector accounts for 9-12% of the total Swedish industry exports, employment and economic gain. The health of the forest is therefore essential to Sweden's economy. Furthermore, because of the large share of forest area in Sweden, policy decisions regarding forest management have a large effect on Sweden's economy. In the potential case of forestry being included in the EU ETS, Sweden would be one of the most affected member states. On the other hand, the state of the carbon sinks in Sweden have a large impact on climate targets set by the EU.

This study will use a quantitative approach to study the previously stated research and sub research question. Descriptive statistics will be complemented by a regression analysis to understand the relationship between forest management practices and price of NZUs. The findings from the case of New Zealand will then be analyzed to understand what implications including forestry in the EU ETS could have on carbon sinks in Sweden.

1.3 Outline of the Thesis

After the introduction, a subsequent section on background information will follow that includes relevant context, theory on carbon pricing initiatives and previous research. Section three will present the data and section four will discuss the methods used for this research. Findings will be presented and discussed in section 5 followed by a conclusion in section six.

2 Background

2.1 Context

2.1.1 Forests as a tool for climate change mitigation

CO_2 is sequestered by trees through the process of photosynthesis where around 80% is stored above ground in their trunk and branches and 20% is stored below ground in their root system as carbon (Kirby & Potvin, 2007). The sequestered carbon that is stored in a tree's biomass above and below ground, is what makes forests a carbon sink. The sink is effective over the duration of the tree's life; if the tree burns down or decomposes, the once stored carbon is released back into the atmosphere as CO_2 (Adams & Turner, 2012). As both trees and soils store large amounts of carbon, forests are a substantial and important carbon sink and therefore subject to many national and international climate change mitigation plans (Jablinski & Stempski, 2018).

A forest's ability to sequester and store carbon depends on how the forest is managed. Forest management includes time elapsed between rotation cycles, which is the time it takes for a planted tree to be harvested, the extent and age of trees being harvested, the upholding of biodiversity levels among species and land area as well as properly calculated carbon fluctuations: emitted minus sequestered carbon (Harris et al., 2021; Bernal et al., 2018). Properly managed forests, meaning managed with sustainability in mind, are almost always net-carbon sinks (Harris et al., 2021). Apart from carbon sequestration, forests provide multiple relevant ecosystem services such as climate regulation, protection of biodiversity and soil as well as providing food and acting as a natural resource (Benal et al, 2018). Enhancing forests is thus a natural way to reduce GHG emissions and increase the quality of ecosystems.

Recognizing the necessary ecosystem services a tree provides, meaning "the benefits people obtain from ecosystems" (Millenium ecosystem assessment, 2005, p.5), is essential to foster sustainable forest management practices. In order for policy measures on carbon sink enhancement to have an effect, an understanding for the biological functions of a tree and forest are of absolute importance. Research on different forest management practicies that enhance carbon sinks, such as length of rotation cycles and the sequestration capability of different species, is the foundation on which impactful climate policy implementations lay.

2.1.2 The Kyoto Protocol

The Kyoto Protocol is a commitment by developed nations, adopted 1997, to reduce their emissions and make way for sustainable development (UNFCCC, 1997). The Paris Agreement superseded the Kyoto Protocol in 2015 to include developing nations as well, however the Kyoto Protocol technically still remains in force (UN, 2015). Both frameworks are active under the United Nations Framework Convention for Climate Change (UNFCCC). Part of the commitment to the Kyoto Protocol includes enhancing sustainable forest management, afforestation and reforestation in order to protect and enhance carbon sinks (UNFCCC, 1997).

The target for the initial period of the Kyoto Protocol, 2008-2012, was to reduce signing parties' overall emissions by 5% compared to 1990 levels (UNFCCC, 1997). The EU-15 exceeded this target and pledged a reduction of 8% (European Commission, 2004). The Kyoto Protocol was amended in 2012 by the Doha Amendment which increased the commitment to 18% compared to 1990 levels for the period 2013-2020 (UN, 2012). The EU delivered on its commitments to the Kyoto Protocol in both periods, however, is off track to reach its latest goal of a 55% reduction of GHG by 2030 enforced by the Paris Agreement (European Environment Agency, 2022).

The targets set by signing parties under the Kyoto Protocol were translated into levels of allowed emissions units where national measures are the primary tool to achieve set targets. However, the Kyoto Protocol provides additional elements in the form of flexible market measures to enable a successful decrease in emissions (UNFCCC, n.d). These mechanisms include the clean development mechanism (CDM), joint implementation (JI) and emissions trading which together are known as the carbon market (UNFCCC, n.d). Emission trading allows countries with excess emission units to trade said units with countries above their targets (UNFCCC, n.d). CDM allows signing parties to implement emission reduction projects in developing countries, outside the Kyoto Protocol. These projects in turn provide emission reduction credits within the emission trading framework (UNFCCC, n.d). Similar to the CDM mechanism JI provides emission reduction credits and does so by allowing emission reduction projects among signing parties. The Kyoto Protocol thus gave rise to many of the emission trading systems in existence today that aim to contribute to delivering on the Paris Agreement (UNFCCC, n.d). Both the Kyoto Protocol and the Paris Agreement realize the importance of carbon sinks and the forest sector, however, have not pushed for an inclusion of forestry into emission trading frameworks.

2.2 Theoretical framework

The following section will discuss the theory behind carbon pricing as an economic tool for emission reduction through a neoclassical microeconomic perspective as well as how it has been implemented in the case of the EU and New Zealand.

Carbon pricing aims to correct market failure arising from economic activity such as the depletion of public goods (Cramton et al., 2017). Public goods are often subject to the free rider problem which, in the case of carbon mitigation, refers to the reluctance of one actor (country or firm) to move ahead on climate policy, as the first mover often has to bear additional costs (Cramton et al, 2017). Apart from depleting common goods, the existence of a free rider problem results in a continuous creation of negative socio-economic externalities (Cramton et al., 2017). Negative externalities occur when the production or consumption of a good result in a monetary or non-monetary cost for a third party (Cowen & Tabarrok, 2018). CO2 emissions are a negative externality that cause air pollution and global warming, for example, resulting in increased health costs for society and a depletion of ecosystems. Carbon pricing includes two instruments, carbon tax and emission trading, which aim to correct some of the issues arising from public goods and negative externalities by assigning a price to CO2 emissions.

Parry et al. (2022) highlight differences between the two carbon pricing initiatives in existence, emission trading and carbon tax. They argue that a carbon tax is more feasible from an administrative perspective as there is more control over the price of carbon while emission trading, due to the price being determined by the market, is more volatile. This in turn implies that fiscal revenues from a carbon tax are more stable over time as opposed to emission trading. Parry et al. (2022) states that a carbon tax, although beneficial from a stability perspective, is difficult to implement on a regional level such as within the EU due to limitations in the Union's legislative framework. Therefore, it is unlikely that a carbon tax could be enforced within the Union instead an ETS framework is more feasible (Parry et al., 2022). In accordance with Parry et al. (2022) Cramton et al. (2017) supports the idea of wide collaboration on carbon pricing. He states that a global price for carbon would be ideal as the climate crisis is of global concern, hoping that a global price would enhance cooperation. However, similar to Parry et al. (2022) he states that it is not feasible from a legislative perspective.

According to Parry et al. (2022) emission trading is a natural instrument for carbon pricing as it tends to be widely accepted by firms due a more gradual approach. Emission trading systems often removes some of the burden placed on firms through a cap-and-trade approach and freely allocated allowances, which are reduced over time, as opposed to a carbon tax that can cause large costs instantaneously (Henríques, 2021). Henríques (2021) highlights additional benefits from emission trading in the form of new strategies that develop as a result of firms having to manage new environmental costs related to their operations. He argues that new management strategies have the potential to promote investments in renewable energy and green technology which contributes positively to a sustainable transition.

Carbon pricing is considered a cost-effective way to enhance a sustainable transition by raising the price of GHG emissions (Parry et al, 2022; Henríquez, 2021). Benefits of carbon pricing include emission reduction, clean energy investment through the development of green technology, and fiscal revenue, which can be used to increase welfare (Parry et al, 2022). For many countries, increased public health from reduced air pollution outweighs the costs of establishing a carbon pricing initiative (Cramton et al, 2022). Revenues from carbon pricing, especially ETS, are more likely to be earmarked for environmental purposes, creating a positive spiral for society when emission units increase in price (Parry et al., 2022). For example in the EU ETS framework part of the revenues are reserved for investments in low carbon technology, energy efficiency and climate change adaptation projects as well as carbon sink enhancement (European Environment Agency, 2023).

Carbon pricing with regards to forestry is feasible according to Parry et al. (2022), however, not in the form of pure carbon tax or ETS. Instead the scholars favor a fee-based scheme where landowners are economically penalized for reducing the carbon sink through deforestation and rewarded for increasing the carbon sink, through A/R or sustainable forest management. What Parry et al. (2022) presents as a fee-based scheme is very similar to how New Zealand treats forestry in their ETS (Gren & Akilu, 2016). An alternative to a fee-based scheme are offset markets where instead of cutting their own emissions firms pay other actors for carbon sequestration projects elsewhere (Parry et al., 2022). However, according to Parry et al. (2022) offsetting programs are difficult by nature due to lack of permanence of the projects and additionality.

The theory behind carbon pricing and especially emission trading is that it is a cost-effective way to reduce emissions by promoting sustainable behavior and investments. As forestry is implemented in New Zealand's ETS it would therefore be expected that emissions from forest management which arise due to deforestation, would have a negative relationship with the price of NZU. On the other hand, as landowners are economically rewarded for carbon sink enhancement, carbon sequestration should instead have a positive relationship with NZU.

2.2.1 European Union Emission Trading System, EU ETS

In 2005 the European Union established an ETS to decrease carbon emissions in the Union (EU, 2015). Emissions in the EU ETS are traded through units, where one unit corresponds to one tonne of CO2 equivalents (CO2 eq) which are other GHG emissions that are translated into their equivalent in CO2 emissions. These units are called European Union Allowances (EUAs) and auctioned on the European Energy Exchange (EEX). The system acts through a cap-and-trade approach where a specific amount of carbon is allowed to be emitted in the Union. The amount of carbon is thereafter translated into units. The program is divided into different phases where the yearly cap is decreased at different rates, resulting in less supply of available units for trade (European Commission, n.dc).

Phase 1, the pilot phase was active between 2005-2007, phase 2 from 2008-2012, phase 3 from 2013-2020 (EU, 2015). The current phase, phase 4, came into effect in 2021 and is set to 2030 (European Commission, n.dc). The target price for EUAs has been around €30 per tonne of CO2 in order to reach emission reduction targets, but with an historic average well below, around €10 per tonne of CO2 before 2018 (Joltreau & Sommerfeld, 2018). Since 2018, the price has surged and increased steadily as seen in Figure 1 (Hodgson & Sheppard, 2023).

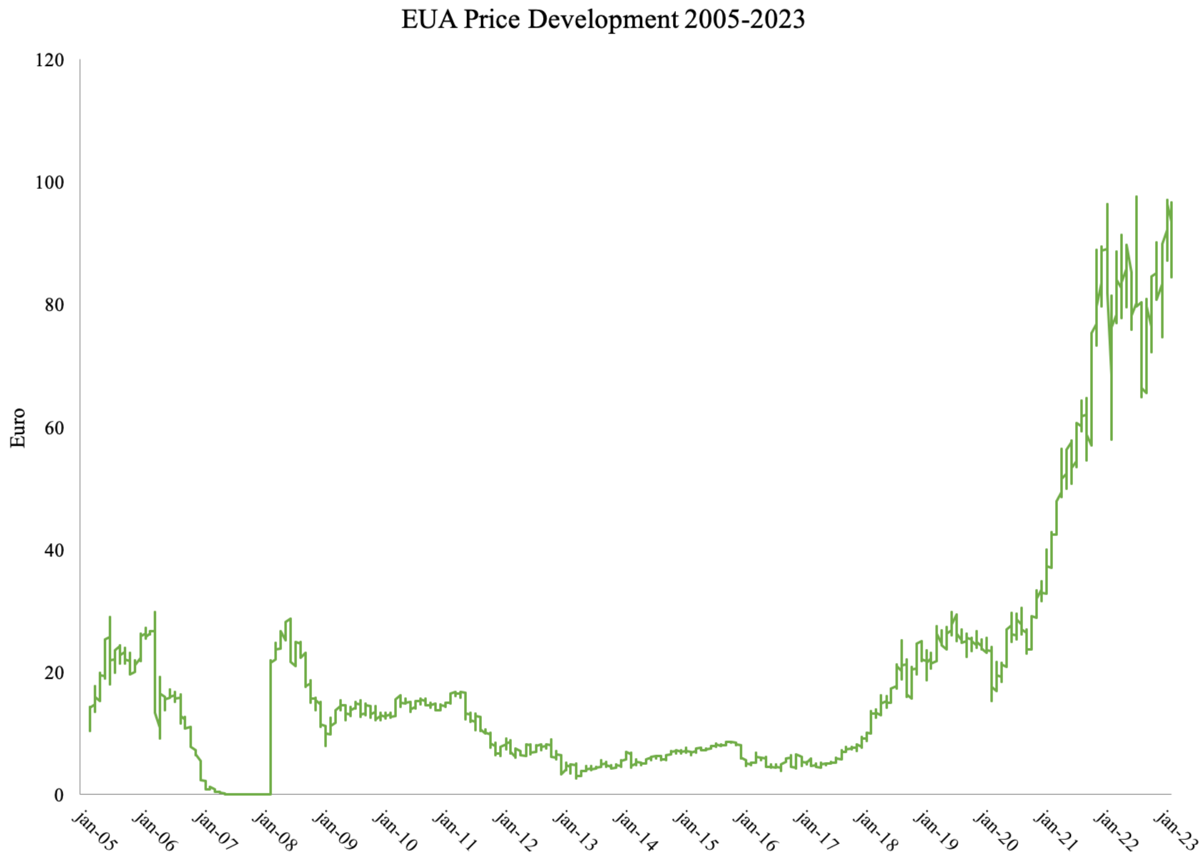

Figure 1**:** Average spot price of EUA over time
Source: Based on data from the European Energy Exchange (EEX), not adjusted for inflation

The ETS framework includes the main polluting industries in the EU which consist of power stations, intensive heavy industry and civil aviation (Appunn & Wettengel, 2023). Together, these industries encompass around 40% of total EU emissions which are subject to the yearly decreasing emission cap (Appunn & Wettengel, 2023). Since the implementation of the system, emissions have been reduced by 42.8% within the covered sectors (Henríques, 2021). The EUAs are first distributed to member states by the European Commision and then traded on the EEX; the price of EUAs is thereby determined on the secondary market. As with any other financial market, the price of the EUAs, and value of carbon, increases and decreases depending on supply and demand for carbon units.

Units enter the market through auctioning and free allocation distributed by the European Commission (European Commission, n.db). Auctioning is the preferred method as it is more transparent and incorporates the market platform, ensuring that the polluter, the firm, pays, as opposed to freely allocated units which are not acquired through auctioning but handed out (European Commission, n.da). Phase 3 was the first phase where auctioning was the default method for allocating allowances and accounted for around 57% of the total amount of allocations, the same holds true for phase 4 (European Commission, n.da). 25 EU member states as well as Norway, Iceland and Liechtenstein, participate in the trade via the EEX (European Commission, n.dc). To ensure a high price of EUAs free allocation has decreased since the implementation of the system, especially during its third phase (2013-2020), however it is still present in heavy industry and the majority of free allocation permits are allocated towards aviation.

Phase 4 (2021-2030) is part of a new policy framework introduced by the EU called ‘Fit for 55’ which aims to reduce emissions in the EU by 55% before 2030 (European Council, 2023). As part of the Fit for 55 package phase 4 will be expanded to cover maritime emissions by 2026. Furthermore, the emission cap for annual emissions will be reduced at an increasing rate during phase 4, decreasing by 2.2% annually during 2021-2023, 4.3% throughout 2023-2027 and 4.4% until 2030 (European Council, 2023). In addition, a new emission trading system, parallel to the current EU ETS, will be initiated in 2026 where buildings, road transport and fuel for additional sectors will be traded (European Council, 2023). As the system continues to broaden and develop, understanding how the land use, land use change and forestry sector (LULUCF), which is not included in the current ETS nor the new emission trading framework, is managed is important as it is part of the overall targets of Fit for 55.

Forest emissions and sequestration are managed under the LULUCF sector in the EU (European Environment Agency, 2022). As previously stated, this sector is not included in the EU ETS, but instead managed separately with regards to targets and accounting. Forestry is an important sector for the EU to meet climate targets to reach carbon neutrality by 2050, yet the carbon sink has been decreasing over the past 10 years, a trend that continues to be negative (European Environment Agency, 2022). Before 2020 there were no specific carbon targets covering the LULUCF sector, however, this was amended by Regulation (EU) 2018/841 which set the first targets for the period 2021-2030 (European Environment Agency, 2022). The regulation implies a net removal of 310 $MtCO_2$ eq by 2030 and is made up by individual commitments by each member state, where Sweden has committed to a 40% emission reduction compared to 2005 levels (Government Offices of Sweden, 2019). In addition to these commitments Sweden's forests are also targeted by a national carbon tax which includes the fossil fuels used in the forest industry (Government offices of Sweden, 2019). Additional targets set for the LULUCF sector in the EU is climate neutrality by 2035 which implies that sequestration from the sector also has to cover emissions from agriculture (European Environment Agency, 2022). These new targets for the sector are projected to increase the carbon sink by 3% between 2021-2040, which according to the European Environment Agency (2022) is not sufficient to reach the EU targets of carbon neutrality.

The complex and expanding framework of the EU's climate ambitions underline the importance of research in the field of emission trading and how it can be optimized as a tool to climate goals. Although forestry is not included in the current EU ETS framework, it is present in multiple areas of the Fit for 55 initiative where carbon removal is becoming of increasing importance in EUs climate policy.

2.2.2 New Zealand Emission Trading System, NZ ETS

As previously mentioned New Zealand's emission trading system (NZ ETS), implemented in 2008, is the most extensive ETS, covering energy, industry, buildings, transport, domestic aviation and forestry (Ministry for the Environment, 2023). It is the only ETS framework that covers the forest industry in a way that makes forest owners compensate for releasing CO_2 into the atmosphere through deforestation, and get compensated for carbon sink enhancement (Carver et al., 2022). Figure 2 demonstrates the price development of NZUs since the implementation of the system. As seen in the Figure prices have increased substantially in recent years.

Figure 2: Average spot price of NZU over time
Source: Based on data from the International Carbon Action Partnership (ICAP), not adjusted for inflation

The framework manages forestry under article 3.3 of the Kyoto Protocol which considers changes to forested areas relative to the 1990 baseline (Adams & Turner, 2012). As a result, forested land is divided into pre-1990 forest land and post-1989 forest land. Entry to the NZ ETS is compulsory for any pre-1990 forest over 50 hectares for tracking purposes (Adams & Turner, 2012). Pre-1990 forest managers are not obliged to surrender credits for harvesting, unless it is permanent, and cannot claim credits for sequestration (Adams & Turner, 2012). In comparison, entry is optional for post-1989 forest land but partaking landowners can claim credits for sequestration and are obliged to surrender credits for harvesting and deforestation (Adams & Turner, 2012). The purpose of including forestry in the ETS was to increase afforestation and improve sustainable forest management to enhance forest carbon sinks (Jablonski & Stempski, 2018).

Comparing the EU and New Zealand, there are similarities in the share of land area covered by forest with 39% (Eurostat, 2023) and 38% (Ministry of Primary Industries, n.d) respectively. Furthermore, both the EU and the NZ ETS have seen a sharp increase in the price of carbon units in recent years (World Bank, 2022). However, as stated previously in this study, the forest management strategy differs between the two regions. The EU manages LULUCF emissions outside an ETS framework with individual targets for each member state, while New Zealand has incorporated the sector into their framework. According to the Ministry for the Environment in New Zealand (2022), net emissions from the LULUCF sector are projected to decrease by 2050 while the European Environment Agency (2022) projects that, without fulfilling the new policy measures, the current trend of increasing emissions in the sector will remain.

2.3 Previous Research

The literature covered in this research provides an insight to the discussion on the topics of carbon sink enhancement, carbon pricing as well as how forestry is considered in relation to ETS. As this research aims to uncover how forest management practices in New Zealand have been influenced by the NZ ETS as well as how it translates onto the case of the EU ETS and Sweden, previous research provides the general trends on the topic.

2.3.1 Carbon pricing initiative, CPIs

The potential of using carbon sequestration and carbon sinks as a mitigation tool for climate change depends on the magnitude of carbon sink enhancement as well as the cost of performing carbon sequestering activities compared to other measures, such as fossil fuel reductions. There is a consensus among scholars that the marginal costs of carbon sink enhancement are lower than the marginal costs of fossil fuel reduction (Gren & Aklilu, 2016; Pahn et al., 2014; Lucatello, 2021). Therefore, carbon sink enhancement is seen as a cost-effective climate change mitigation strategy.

The literature identifies four main areas of difficulty regarding policy implementation for carbon sink enhancement; heterogeneity, uncertainty, additionality and permanence (Gren & Aklilu, 2016; Naturvårdsverket 2022). Heterogeneity refers to regional differences regarding sequestration capability (Gren & Aklilu, 2016; Bernal et al., 2018). Uncertainty concerns differences in weather conditions affecting yearly biomass growth as well as different methodologies for quantifying and monitoring sequestration ability (Gren & Akiliu, 2016; Lefbvre et al., 2021). Additionality deals with the difficulty in assessing whether the project or outcome would be achieved even without the policy implementation in question; stated in another way, is the policy cost-efficient? (Gren & Aklilu, 2016; Gong et al., 2022). The scholars also discuss difficulties with assessing the permanence of carbon sinks, which is important as carbon sinks only exist as long as the forest is not degraded due to natural disasters or deforestation. Another issue concerning permanence is how harvested wood products are utilized. Harvested wood products also act as a carbon sink, however the lifespan of such products varies greatly, for example a house built out of wood stores carbon longer than a biomass used for heating in the form of bioenergy (Gong et al., 2022). All four areas identified by the scholars face the same dilemma of predictability stemming from a nature-based solution. In order to overcome some of these issues, carbon pricing initiatives provide frameworks for standardized GHG accounting and reporting.

CPIs have increased worldwide as a mitigation mechanism for GHG reduction. The price of carbon on many markets shows an increasing trend where the price of offsets doubled between 2020-2021 due to enhanced interest in carbon removal (World Bank, 2022). Offsetting is the process of compensating GHG emissions by investing in projects that remove an equivalent amount of emissions elsewhere, an example of an offsetting project is afforestation (Shrestha et al., 2021). Apart from offsets, the World Bank (2022) and Keenor et al. (2021) believe a continuous increase in the carbon price is inevitable. However, these scholars emphasize that CPIs alone are not sufficient to reach net-zero targets set out by policy makers. The World Bank (2022) has a similar reasoning: although there is an increase in carbon prices, these prices must rise considerably in order to reach the goals set out by the Paris Agreement. Keenor et al. (2021) therefore highlights the importance of incentivising carbon sequestering activities.

In their study Keenor et al. (2021) suggest an implementation of a minimum price for carbon units as a means to ensure adequate economic incentives for carbon sequestration. Most ETS do not currently have a price floor for carbon units which, historically, has resulted in low prices

(Joltreau & Sommerfeld, 2018). Keenor et al. (2021) further highlight the importance of a price floor in order to encourage firms to decrease their own emissions instead of buying cheap carbon units and banking them or purchasing offsets. If price floors were introduced, the price to offset carbon would also increase, further pressuring firms to reduce their emissions (Keenor et al., 2021). In such a scenario, Keenor et al. (2021) favor including sequestration credits into ETS.

Apart from lacking a price floor, some scholars identify high levels of free allocation, meaning units that are distributed rather than purchased on the market, and over-allocation, too much supply of units, as reasons behind historically low prices of carbon units (Joltreau and Sommerfeld, 2018). Parry et al. (2022) argues that a carbon unit price of around €45 per tonne would contribute to a CO2 emission reduction by around 15-35% compared to the business-as-usual levels by 2030 for the Group of Twenty (G20). However, for a long period the price of EU ETS never rose above €10 and Hernandez (2021) confirms that New Zealand has had periods of low prices, which can be observed in Figure 2. For the case of the EU Joltreau and Sommerfeld (2018) state that low prices can be due to freely allocated permits being based on historical emissions which might not accurately represent the level of current-day emissions. This in turn creates an overallocation of free emission rights. In addition, they highlight that the low prices of carbon units has caused many firms to bank their units or purchase units for future use, resulting in a negative spiral of through an inactive market. However, as the EU ETS continues to develop, fewer freely allocated allowances are distributed and from Figure 1 it is clear that prices have increased (European Commission, n.da).

2.3.3 Forestry within ETSs

New Zealand is the only ETS mechanism that incorporates the forest industry. There seems to be consensus among scholars that the NZ ETS system has contributed to limiting deforestation, although the impact on afforestation is more inconsistent (Carver et al., 2022; Shrestha et al., 2021; Adams & Turner, 2012; Rontard & Hernandez, 2021). A positive position towards the NZ ETS framework among scholars seems to have become established in recent years. Earlier scholars such as Evison (2017) concluded that NZ ETS does not positively influence investments in afforestation, conversely, in some cases the mechanism has encouraged deforestation. In response to Evison (2017), Carver et al. (2022) argue that since Evison's (2017) findings, policy and the NZ ETS has developed and matured. Carver et al. (2022) find in their study that NZ ETS has impacted the decision making of forest managers in New Zealand. They conclude that, since 2016 when emission prices rose together with policy reforms, there has been a marked increase in afforestation together with a decrease in deforestation. They further highlight that emission pricing has disrupted an established negative correlation between timber prices and afforestation. Rontard and Hernandez (2021) are in agreement with Carver et al.'s (2022) findings on deforestation, however, state that NZ ETS has had a small impact on afforestation. The scholars reason that this could be due to the lagged effects on carbon removing activities. However, Carver et al. (2022) and Rontard and Hernandez (2021) agree that overall the NZ ETS has been beneficial for sustainable forest management. Another study by Shrestha et al. (2021) found, through interviews with industry experts, that respondents representing New Zealand had a positive perception of including forestry in the NZ ETS. In conclusion, there seems to be a positive trend in the literature regarding the inclusion of forestry in the NZ ETS and its effects on forest management and thereby carbon sequestration.

Very little research has been done on the topic of potential effects of including forestry in the EU ETS. In Shrestha et al.'s (2021) study the scholars found a larger concern among EU representatives regarding integrating forest into the EU ETS mechanism compared to the sentiment among representatives from New Zealand. The main concerns surrounded offshoring carbon intensive industry, how to standardize forest accounting among member states and trusting the permanence of carbon sinks (Shrestha et al., 2021). Furthermore, the EU representatives were also conflicted about what effects a low carbon price could have on forest management practices. Early studies on the EU ETS by Dutschke et al. (2005) argued that A/R activities should be included in the EU ETS as they believed that including forestry would have a positive effect through increased sequestration. The topic of forestry in the ETS is not unknown, rather unexplored.

As stated by Shrestha et al., 2021 a large concern with including forestry into the EU ETS mechanism regards the difficulty of uniformity in the methods and quantification of sequestration for all member states. Arthur Runge-Metzger, the director at the European Commission Department for Climate Change, stated in an interview in 2020 that “If the standard is good enough and one can be sure that a tonne is a tonne, then we might be able to recognise (forest credits) like an emission allowance under the ETS" (Simon, 2020). Carbon removals are only partly accounted for by the EU and not all member states conform to the same methodology, making comparisons difficult (Simon, 2020). In comparison, the NZ ETS system only includes one country therefore does not face such issues.

The EU has taken steps towards carbon sink enhancement through a new certification system for carbon removals (European Commission, 2022). According to the European Commission (2022) one of the main goals of the proposal is to develop the EU's ability to quantify, verify and monitor carbon removals. According to Runge-Metzger this is a necessary step for a potential future inclusion of carbon removals into the EU ETS (European Commission, 2022; Simon, 2020). Another important goal of the proposal is to encourage farmers and forest owners to adopt sustainable and effective carbon removal solutions. This means that forests have to be managed in a manner that ensures long-term carbon storage thereby decreasing the issues with permanence (European Commission 2022).

Sweden's Environmental Protection Agency (Naturvårdsverket) produced a report in 2022 on how to enhance carbon sinks in Sweden. The researchers propose different economic instruments of control: economic compensation for sustainable forest management practices, integration of reverse auctioning and emission trading. Economic compensation could for example come in the form of a government grant for carbon sink enhancement (Gong et al., 2022). Reverse auctioning with regards to carbon sink enhancement implies that the buyer, for example a government actor or private firm, puts up a request for carbon sequestration and forest owners, the sellers of the service, place bids for the amount they are willing to be paid for storing said carbon; the winner of the auction is the seller who places the lowest bid (Gong et al., 2022). In their conclusions they advise the Swedish government to make necessary infrastructure investments to enable future opportunities for reverse auctioning and emission trading of forest carbon credits on the Swedish market (Gong et al., 2022).

The body of literature studying the effects of including forestry into the EU ETS is not extensive. However, scholars seem to be in agreement on the difficulties surrounding policy implementation on carbon sink enhancement. These issues mainly arise from the nature of quantifying a natural resource. The EU's new certification framework for carbon removals is seen as a step towards standardizing carbon removal quantification. In addition, policymakers in the EU and Sweden seem open towards the potential of future inclusion of forestry in the ETS framework. With regards to New Zealand's ETS, the general consensus among scholars seems to be positive towards the role of forestry in the ETS. The theory, and previous research on carbon pricing, presented in this study displays the complexity of carbon sinks and emission trading, yet, overall, there seems to be a rising interest in the topic which can be observed through a growing body of research.

This study aims to contribute to the literature on forestry and emission trading. Few studies have investigated the relationship between the price of NZUs and the subsequent effect on emissions from forest management practices. Therefore, this study contributes with a quantitative analysis on how forest management has been impacted by the price of NZU. Moreover, this research aims to add to the discussion on carbon sink enhancement in Sweden and the EU.

3 Data

3.1 Source Material

The data used in this research is publicly available secondary data from New Zealand's GHG inventory (Ministry for the Environment, 2022), the Swedish Environmental Protection Agency (Naturvårdsverket, 2022) and the International Carbon Action Partnership (ICAP, 2023). Both New Zealand's GHG inventory and the Swedish Environmental Protection Agency provide emission data from 1990 and since both countries are signatories of the Kyoto Protocol, the accounting of emissions is similar, although New Zealand's data is available at a more detailed level. This study will focus on the LULUCF category within the emission inventory, more specifically on forestry and forest carbon sequestration. ICAP (2023) is an international forum that provides technical knowledge-sharing for governments and public agents that have, or plan to, implement emissions trading systems. ICAP provides daily pricing of carbon units in USD and Euro. For this study, the price of NZU is collected in Euro as it enables comparison with

EUAs. The price of NZUs is thereafter adjusted for inflation using New Zealand inflation rate (ICAP, 2023; World Bank, 2023).

The NZ ETS was implemented in 2008 and recorded spot prices can be observed from 2009. New Zealand national GHG inventory's latest publication was in 2022 which provided data for the period 1990-2020. Aligning the data sets enables regression analysis for the period 2009-2020 which will be used for this research.

3.2 Variables

The dependent variables used in this research aim to reflect areas of forest management practices: deforestation, A/R and carbon sink change. These variables are controlled by the landowner, meaning it is possible to study if they are influenced by the price of NZU, the explanatory variable.

Dependent variable

Three different models will be used in this study allowing for three different dependent variables. The dependent variables used in the regression analysis are: annual emissions from deforestation, named *Deforestation*; emissions from afforestation and reforestation, named *AR,* and emissions from changes in the remaining forest carbon sink, named *CSC*. The dependent variables are all discrete and expressed in tonnes of CO2 eq and cover the period 1990-2020 with the years 2009-2020 being utilized in this study. *Deforestation* will be studied in its logarithmic form, but since *AR* and *CSC* are expressed in negative numbers, due to sequestering CO2 rather than emitting, they will be kept in their original form to easier observe trends. The data is gathered from New Zealand's national GHG inventory published in 2022.

Explanatory variable

The explanatory variable is the annual average spot price of New Zealand carbon units called *NZU*, expressed in Euro for the period 2009-2023 and is therefore also a discrete variable. The data is gathered from ICAP (2023) in Euro, nominal values, and calculated into yearly averages for the period 2009-2020. The yearly averages have in turn been adjusted for inflation using New

Zealand's inflation rate from the World Bank (2022). The variable *NZU* is expressed in its logarithmic form for the regressions.

Control Variables

The study uses two discrete control variables, New Zealand gross domestic product, *GDP* in current USD from the World Bank (2023) and New Zealand's net greenhouse gas emissions, *GHG*, in tonnes of CO2 eq, excluding the LULUCF category from New Zealand's GHG inventory (Ministry for the Environment, 2022). *GDP* is included as the forest industry is thought to be impacted by the state of the economy. *GHG* is included as an environmental instrument to study natural shocks that might influence overall GHG emissions as well as emissions from forestry. These variables will be expressed in their logarithmic form. Year will be included as a control variable to capture existing trends for the dependent variables over time. All control variables will be studied for the period 2009-2020.

3.3 Validity and reliability

The data used for this research is mainly public government data coming from sources that can be considered reliable. However, as the data is not primary but collected by multiple agents and then compiled, it is less reliable than the primary data itself. A benefit with the government data is that both Sweden, via the EU, and New Zealand are signatories of the Kyoto Protocol which make them obliged to disclose data on their forestry activities under the LULUCF category. This in turn makes the data comparable. Although the data is comparable under the LULUCF sector, as New Zealand has included forestry into its ETS, the data provided is more detailed. For example, New Zealand discloses data on pre 1990 and post 1989 forest, which the EU does not. However, these slight differences can be a useful source of information on how to perform carbon accounting in the case that forestry were to be included in the EU ETS. Data from the whole GHG inventory provides additional benefits as it enables an understanding of what is included in the different sectors, this is true for both New Zealand and the EU. Understanding what is included in the different categorisations of the GHG inventory is necessary to ensure exogeneity among the variables. This study has collected data in a way that there is no overlap in emission accounting and can be therefore considered sufficient to answer the research question on how forest management in New Zealand's ETS have developed.

4 Methods

4.1 Analytical approach

The data is first analyzed through descriptive statistics to study the trends over time on an observational level. The descriptive statistics section will study Sweden's forest carbon sequestration and forest growth as well as New Zealand's forest management practices in relation to NZU price development. Thereafter a regression analysis in Stata will be conducted through a linear OLS regression analysis which has the following general form:

$$Y_i = \beta_1 + \beta_2(t)_{t,2} + \beta_3 x_{t,3} + \dots + \beta_k x_{t,k} + \varepsilon_t \quad t = [1, T]$$

where Y is the dependent variable, $X_{t,2}, X_{t,3}, \dots, X_{t,k}$ are explanatory variables, β_1 is the intercept, $\beta_2, \beta_3, \dots, \beta_k$ are coefficients and thus represent increase or decrease in the dependent variable when $X_{t,k}$ increases with one unit, all other X held constant, and ε_t is the error term. As the data is a time series T denotes time in years (Greene, 2012).

Forest carbon emissions could potentially be highly correlated with the different forest management activities included in this study. Therefore, three different dependent variables and thus models are being regressed to complement the descriptive statistics. A two step regression will be performed, with the models first beeing regressed in their simple form to study the initial relationship and subsequently with control variables to evaluate the robustness of the initial model. The linear regression models in their simple form look as follows:

Model 1A: $\Delta(Deforestation) = \beta_1 + \beta_2\Delta(NZU)_{t-n} + \beta_3\Delta(year)_t + \varepsilon_{t-n}$

Model 2A: $\Delta(AR) = \beta_1 + \beta_2\Delta(NZU)_{t-n} + \beta_3\Delta(year)_t + \varepsilon_{t-n}$

Model 3A: $\Delta(CSC) = \beta_1 + \beta_2\Delta(NZU)_{t-n} + \beta_3\Delta(year)_t + \varepsilon_{t-n}$

Where β_1 is the intercept of the dependent variable, β_2/β_3 are the logarithmic rate of change for *Deforestation* and the rate of change for *AR & CSC.* The models will also be subject to time lags, *t-n*, where *n* denotes the number lags in years. Moreover, the models are initially tested without a time lag to see whether the effects of the price response can be observed within the same year. Due to the short time span of the study, the models will be regressed with up to two year lags to ensure an adequate amount of observations. The control variable *Year* will not be lagged as that increases the risk of multicollinearity. Instead *Year* will be interpreted as the general trend.

Models with control variables:

Model 1B:

$$\Delta(Deforestation) = \beta_1 + \beta_2\Delta(NZU)_{t-n} + \beta_2\Delta(GDP)_{t-n} + \beta_3\Delta(GHG)_{t-n} + \beta_4(year)_t + \varepsilon_{t-n}$$

Model 2B:

$$\Delta(AR) = \beta_1 + \beta_2\Delta(NZU)_{t-n} + \beta_2\Delta(GDP)_{t-n} + \beta_3\Delta(GHG)_{t-n} + \beta_4(year)_t + \varepsilon_{t-n}$$

Model 3B:

$$\Delta(CSC) = \beta_1 + \beta_2\Delta(NZU)_{t-n} + \beta_2\Delta(GDP)_{t-n} + \beta_3\Delta(GHG)_{t-n} + \beta_4(year)_t + \varepsilon_{t-n}$$

Deforestation, *NZU* and the explanatory variables will be included in the regression with their logarithmic form to increase the stability of the variables, making Model 1A and Model 1B a log-log model. A log-log model implies that a 1% increase in the explanatory variable, all other variables held constant, corresponds to a percent increase in the dependent variable determined by the coefficient β (University of Virginia Library, 2018). As the variables *AR* and *CSC* are negative values and not logged, the regressions on Model 2A, Model 2B, Model 3A and Model 3B will be lin-log regressions meaning a 1% increase in the explanatory variable, all other variables held constant, corresponds to a β unit increase in the dependent variable (University of Virginia Library, 2018). Forest activities can be assumed to have lagged time effects which makes it necessary to include lagged explanatory variables.

4.2 Robustness tests

The regressions will be subject to a few tests that ensure that the models follow Gauss-Markov assumptions meaning that a robust and valid statistical significance exists. Violations of the Gauss-Markov assumptions can result in inflated and inaccurate coefficients and p-values (Reed College, n.d).

4.2.1 Multicollinearity

The regressions will be tested for multicollinearity through a Variance Inflation Factor test (VIF) to ensure that the explanatory variables are not correlated. If the VIF factor is greater than four the variables are considered highly correlated and if the VIF is above 10 there exists serious multicollinearity that has to be corrected (Pennsylvania State University, 2018). As presented in Table 1 there does not seem to be any multicollinearity in the models.

Table 1: VIF test

Variable (ln)	VIF	I/VIF
GHG	2.07	0.415
GDP	1.87	0.442
NZU	1.23	0.902

4.2.2 Heteroskedasticity

To determine whether robust standard errors need to be used in the model, the Breusch-Pagan test for heteroskedasticity will be conducted. Heteroskedasticity implies nonlinearity of the variances in the residuals across the observations and can lead to misspecifications of the coefficients (Breusch & Pagan, 1979). According to White (1980) if the models are heteroskedastic, robust standard errors can be used to provide more accurate estimates. The null hypothesis (H0) of the Breusch-Pagan test states that the residuals are homoscedastic thereby making the alternative hypothesis (Ha) that the residuals are heteroskedastic.

The results show that Model 1A is homoscedastic with a p-value of 0.01 and is therefore homoscedastic while Model 1B has a p-value of 0.14 allowing for a rejection of the null hypothesis. The results from Model 2A and Model 2B show that the two models are homoscedastic with p-values 0.03 and 0.02. Finally, Model 3 shows signs of heteroscedasticity for both Model 3A and Model 3B with p-values 0.60 and 0.82 respectively. For more details see *Appendix 1*, *2* and *3*. Models 1B, Model 3A and Model 3B will therefore be subject to robust standard errors for the regressions.

4.2.3 Stationarity

As the data is time-series data, unit root tests will be performed on the variables to determine at what degree the different variables are integrated, in other words where they are stationary. Stationarity means that there is no time trend in the data, the data has a constant variance over time and no periodic fluctuations (NIST, n.d). Non-stationarity can result in an inflated R-squared value due to two unrelated variables having the same trend over time, making them highly correlated. As seen from Figure 2 the price of NZU has increased over time and it is reasonable to believe that GDP and GHG emissions have done so as well, hinting that the variables are non-stationary. However, the Augmented Dickey Fuller test will be used to determine the order of integration. Integrating variables is done through a process called differencing. First-order differencing is performed by taking the difference between the current observation and the previous observation (NIST, n.d). If the variable is integrated at the second order, differencing is performed twice to ensure stationarity, this can be repeated multiple times raising the order of integration (NIST, n.d). Results from the testing are presented in Table 2:

Table 2: Integration of the variables

Variable	Order of integration
NZU	3rd
GDP	2nd
GHG	1st
AR	2nd
CSC	3rd
Deforestation	3rd

As seen from Table 2, the variables are integrated at different orders. This is not optimal for the modeling in this research, as the thesis aims to study the relationship between the variables with lags. Since the dataset covers a short time period there are few observations, and even fewer with high levels of integration. Furthermore, the higher the levels of integration the more unstable the model (Enns et al., 2021). One way to increase the stability of the variables is to use the logarithm of the variable (NIST, n.d). This research will therefore use logarithms for the variables with positive values and present the modeled regressions with their correct order of integration after studying the initial models presented in Section 4.1 for comparison.

4.2.4 Endogeneity

Endogeneity exists when the dependent, explanatory and error terms are correlated. This correlation can result in feedback effects meaning the dependent variable influences the explanatory and vice versa, this phenomenon is also known as simultaneity. The endogeneity problem can be managed by using instrumental variables which refers to substituting the explanatory variable for another variable that is not correlated with the error term known as an Instrumental Variable (Greene, 2012). As deforestation, A/R and carbon sequestration can be considered correlated, there is a risk of simultaneity and finding suitable instrumental variables for these explanatory variables is difficult, therefore, they will be excluded from the regression and instead be considered as separate dependent variables, as seen in section 4.1.

4.2.5 Robustness

Applying additional tests to the model could further enhance the results and give a greater understanding for the relationships among the variables. Furthermore, additional control variables could be included in the study to advance the models. However, more advanced and complex econometric modeling lies beyond the scope of this research.

The tests show some violations of the Gauss-Markov assumptions which decreases the validity of the results. A potential reason behind the violations could include the short time span of the data and thereof lack of observations. Additional reasons behind the lack of robustness of the data includes that the forest variables *AR, Deforestation* and *CSC* could be determined by other variables not included in the research.

4.3 Limitations

One limitation with this research is the small study sample. As New Zealand is the only country that has fully integrated forestry into its ETS, the scope of potential countries to include in the study is limited. As a result, there is a risk that the observed trends might be country-specific effects, unique to New Zealand, and that the results are not transferable to other countries. Another limitation with the study is the short time span covered by the dataset, 2009-2020. As the data has a short time span it is difficult to draw conclusions related to long run effects arising from the implementation of the ETS, especially since the price of NZU might have lagging effects on forest activities. Despite these limitations, this thesis will seek to understand if there are any statistically significant or observable trends for forest management. Furthermore, as there is limited research on the topic there is no alternative dataset that could be used for a similar study.

4.4 Descriptive statistics

4.4.1 Sweden

Figure 3 shows forest sequestration in Sweden over the period 1990-2021. Negative emissions imply sequestration of carbon and a positive trend over time implies a decrease in carbon sequestration.

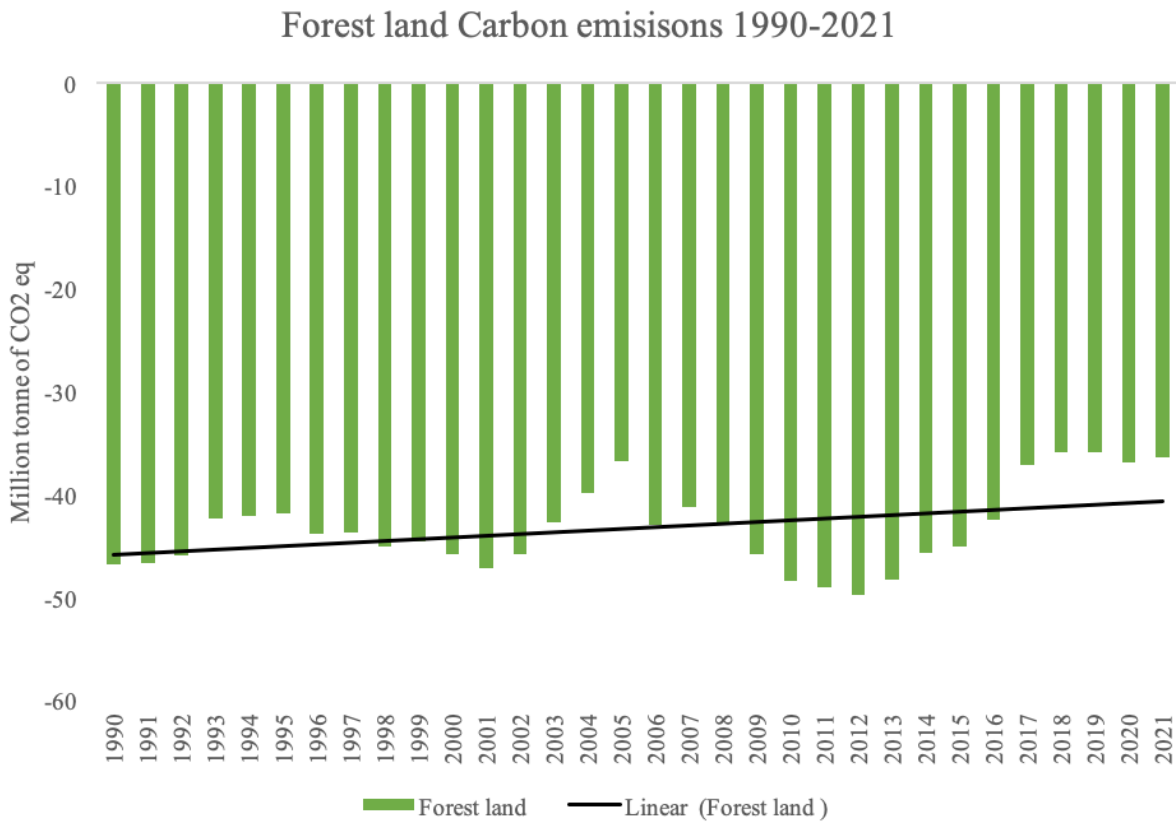

Figure 3 Carbon emissions from forest land
Source: Figure based on data from Naturvårdsverket (2023)

Figure 4 demonstrates the change of net forest growth over time in millions of cubic meters of forest, meaning planted minus harvested trees. The sample covers the time period 1956-2016 where the general trend over time has been slightly negative which can be observed by the linear trendline for the period. This means that more trees are harvested compared to replanted. The large spike in forest sink in 1971 is an outlier in the data which distorts the overall negative trend of -0.0014% decrease.

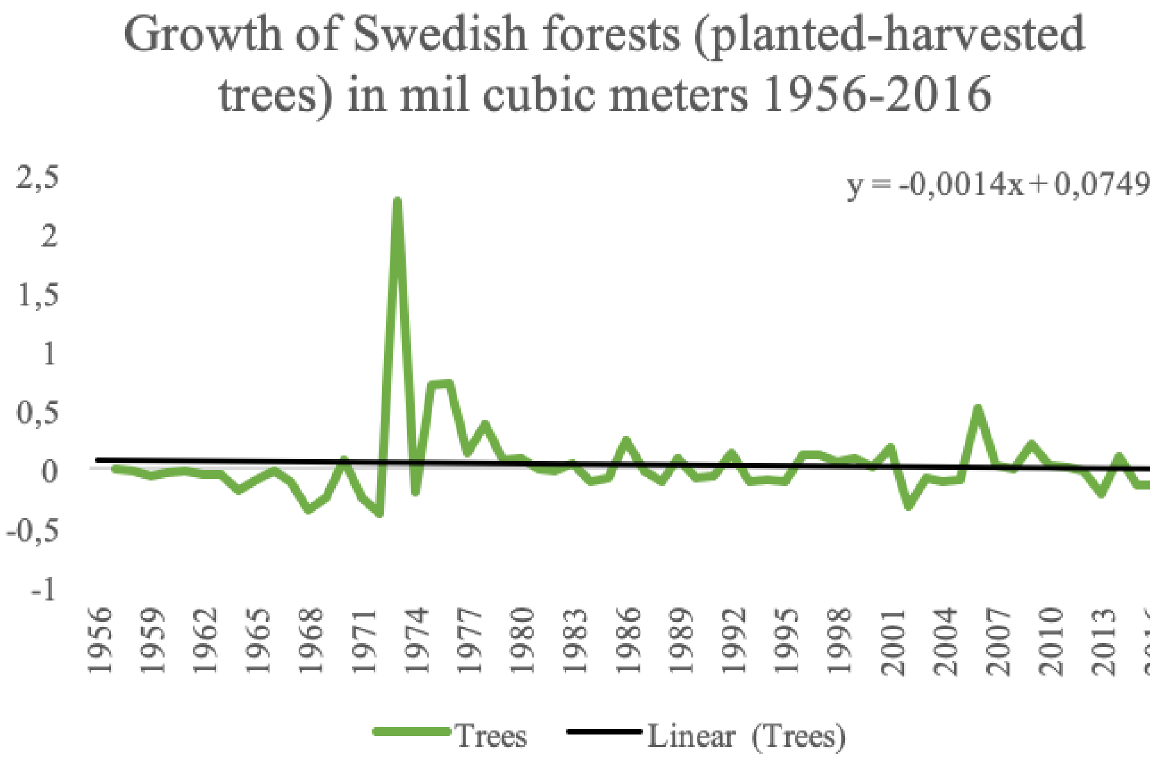

Figure 4 Percent change in trees (millions of cubic meters) planted-felled trees
Source: Graph based on data from Naturvårdsverket (2020)

4.4.2 New Zealand

Figure 5 portrays the development of the price of NZU and emissions from deforestation for the years 2008-2020. Observing the graph, there seems to be a negative relationship between the variables, meaning emissions from deforestation decrease once the price of NZU increases and vice versa.

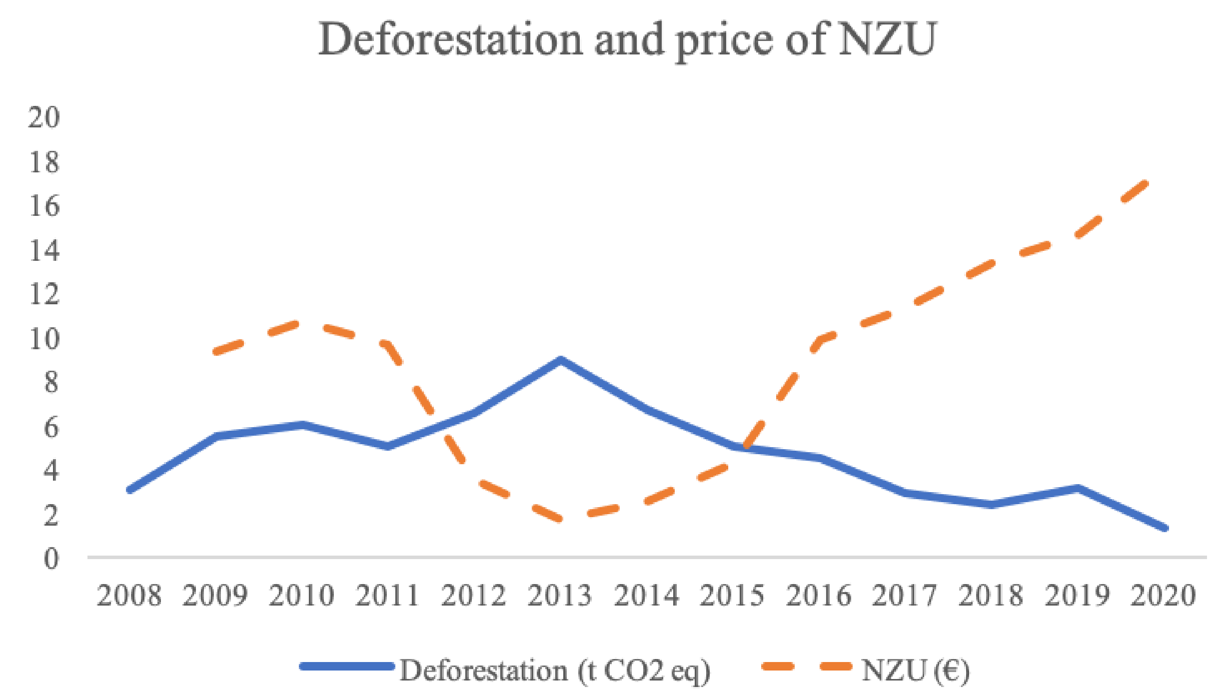

Figure 5**:** Emissions from deforestation in tonne of CO2 equivalent against the price of NZU in euro
Source: National greenhouse gas inventory New Zealand and ICAP

Figure 6 shows the price of NZU and sequestration from afforestation and reforestation for the period 2008-2020. The variables do not seem to have a substantial relationship. However, a slight positive trend can be observed from 2017 and onwards meaning less carbon is sequestered from A/R when the price of NZU increases.

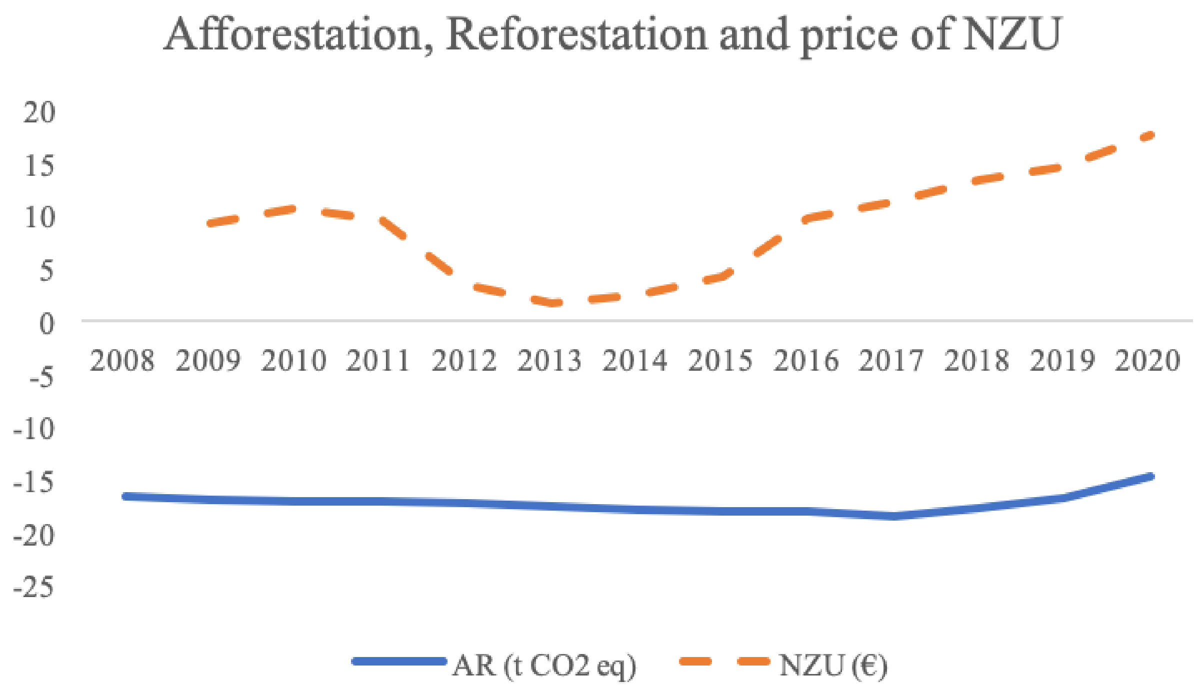

Figure 6**:** Sequestration from Afforestation and price of NZU in euro
Source: National greenhouse gas inventory New Zealand and ICAP

Figure 7 portrays the sequestration ability from changes in the remaining forest carbon sink and the price development of the NZU for the period 2008-2020. There seems to be a positive relationship, meaning sequestration increases (emissions decrease) once the price of NZU increases and vice-versa. However, this relationship does not appear to be stable over time which could be explained by lagged effects.

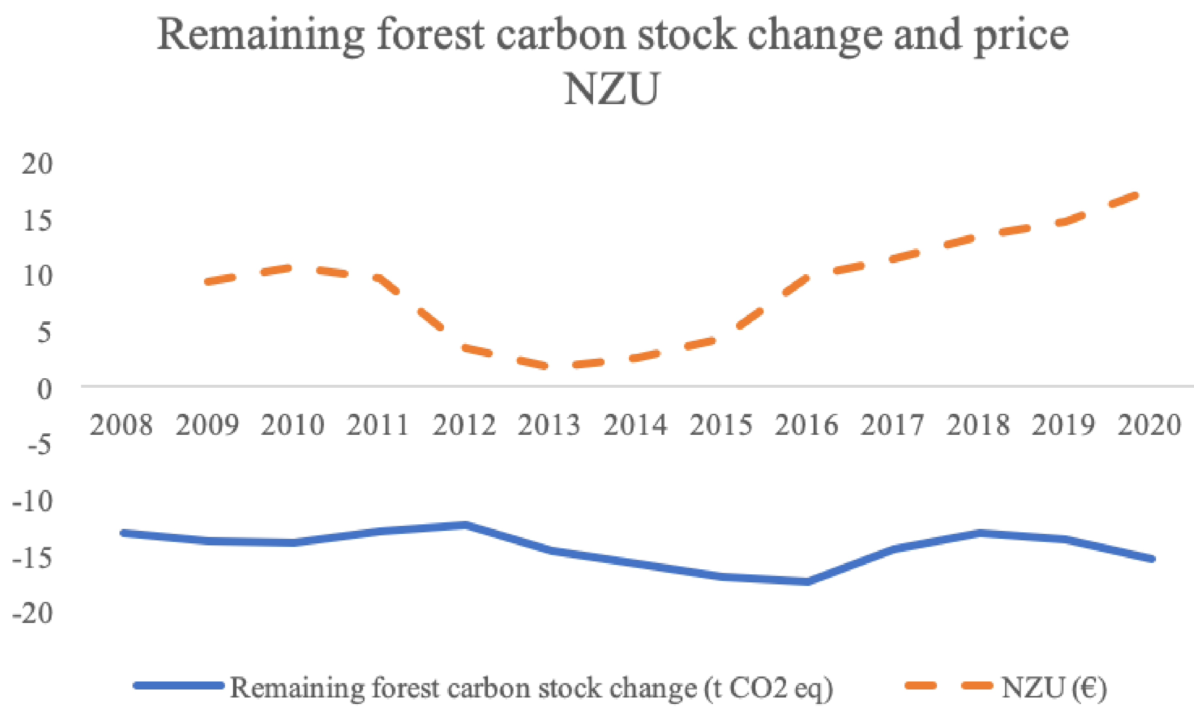

Figure 7**:** Sequestration from changes in the forest carbon sink and price of NZU in euro
Source: National greenhouse gas inventory New Zealand and ICAP

5. Results

Table 3 presents the results from the two-step linear regressions of Model 1A and Model 1B. The main findings from the regressions is the significant negative relationship between deforestation and time.

The price of NZU is negatively associated with emissions from deforestation, at the 1 and 5% level without any time lags for both Model 1A and Model 1B. This implies that a 1% increase in price of NZU, holding the other variables constant, results in a decrease of deforestation related emissions by 0.3% the same year.

As stated, regressing the price of NZU on emissions from deforestation without control variables, Model 1A, there is a negative relationship at the 1% level with no lags on the year and significance at the 5% level with one year lag. Upon adding the control variables, significance between the variables with one year lag disappeared, hinting that the relationship is not very strong. Moreover, a statistically significant relationship exists between GDP and deforestation at the 5% level with a two year lag. This implies that a 1% increase in GDP leads to an increase in deforestation-related emissions by 3.3% after two years. As the simple model, Model 1A, is homoscedastic, no robust standard errors were used for the initial regressions.

Table 3: Results from the estimation of Model 1 A&B, Dependent variable: Deforestation

	Model:1A			Model:1B		
Explanatory variable (ln)	No lags	One lag	Two lags	No lags	One lag	Two lags
NZU	-.396***	-.318**	-.146	-.299* (-.299)**	-.255 (-.255)	.120 (.120)
GDP				.350 (.350)	1.13 (1.13)	3.33** (3.33)
GHG				6.02 (6.02)	-2.29 (-2.29)	2.19 (2.19)
Year	-.083**	-.119***	-.156**	-.118* (-.118)**	-.167** (-.167)	-.332*** (-.332)

**** p<0.01, **p<0.05, *p<0.1*
Robust standard errors in parentheses.

Table 4 presents the results from regressions of Model 2A and Model 2B with the dependent variable *AR*. Overall the regressions show little significance both in the simple form and for the models with control variables.

There does not seem to be a trend over time as the variable *Year* has no significance at the 1, 5 or 10% level for any of the models. Significance at the 5% level is observed between the price of NZU and emissions from A/R with a two year lag. However, this relationship does not hold when adding the control variables. Instead, significance between the variables can be observed at the 5% significance level with one year time lag. For the cases where *AR* is significantly impacted by *NZU,* the relationship is positive. As this is a lin-log model, this implies that increasing the price of NZU by 1% increases emissions from *AR* by around one 0.9 tonnes of CO2 eq. From Figure 6 a similar result can be observed, with a lack of a relationship between the variables, although a slight positive trend can be observed from 2017. This means that rather than increasing sequestration, emissions from A/R appear to increase once the price of NZU increases.

Table 4: Results from the estimation of Model 2 A&B, Dependent variable: AR

	Model:2A			Model:2B		
Explanatory variable (ln)	No lags	One lag	Two lags	No lags	One lag	Two lags
NZU	.4928	.6559	.8805**	.0994	.1.280**	1.251
GDP				-2.328	-.8452	.8514
GHG				-18.08	71.62**	26.43
Year	.0127	.0492	.1089	.1761	-.1687	-.0070

**** p<0.01, **p<0.05, *p<0.1*
No robust standard errors needed as seen in section 4.2.2.

Table 5 presents the results from the regressions on Model 3A and Model 3B, change in remaining forest carbon sink. The regressions show a positive relationship between the price of NZU and emissions from *CSC*. This relationship stays significant at the 1% level with one year lag for both the simple and Model B with control variables. Overall, significance between the variables appears to be the strongest with a one year lag.

The trend over time appears to be negative, although not significant at all lag levels. Significance at the 5% level is observed between *Year* and *CSC* in Model 3B once the control variables are added. Furthermore, GDP is significant at the 1% level when using robust standard errors with a one year time lag. As the model is a lin-log model, this implies that if GDP increases by 1%, emissions from the forest carbon sink will increase by 11 tonnes of CO_2 eq in the following year. This shows, similar to Table 4, that an increase in price of NZU and GDP does not enhance the carbon sink, rather decreases it.

Table 5: Results from the estimation of Model 3 A&B, Dependent variable: CSC

	Model:3A			Model:3B		
Explanatory variable (ln)	No lags	One lag	Two lags	No lags	One lag	Two lags
NZU	.6698 (.6698)	1.749*** (1.749)***	1.930** (1.930)***	2.097** (2.097)**	2.310*** (2.310)***	1.026 (1.026)
GDP				8.293 (8.293)	11.47** (11.47)***	-7.779 (-7.779)
GHG				66.63 (66.63)	-30.63 (-30.63)	-27.36 (-27.37)
Year	-.1772 (-.1772)*	-.2240* (-.2240)*	-.1713 (-.1713)	-.7658* (-.7658)**	-.6810** (-.6810)***	.3039 (.3039)

**** p<0.01, **p<0.05, *p<0.1*
Robust standard errors in parentheses.

Table 6 presents the same models but with the variables without its logarithmic form and integrated at the correct order making them stationary. As differentiating the variables results in fewer observations the results are presented without any time lags. The main findings from the stationary regressions is the significant negative relationship between forest carbon sink and price of NZU. This association holds on the 1% level with robust standard errors and implies that a 1 Euro increase in NZU, decreases emissions from the carbon sink by around 0.3 tonnes of CO2 eq. This relationship stays significant when adding the control variables and is the opposite of what was found in table 5.

For the other variables, the regressions lacked significance. The stationary regressions showed no significance when regressing NZU on deforestation. This challenges the results seen in Table 3 where there is a negative relationship between NZU and deforestation, especially without time lags. Similar to the case of deforestation, no significant relationship is found between the price of NZU and emissions from A/R. However, this is more expected as the same relationship could be observed in Table 4.

Table 6: Results from regressions with integrated variables

	Model 1			Model B		
Explanatory variable	1. Deforestation	2. AR	3. CSC	1. Deforestation	2. AR	3. CSC
NZU	-.0315 (-.0314)	.0599	-.2784** (-.2784)***	.1134 (.1134)	.0376 (.0376)	-.3559** (-.2559)***
GDP				-2.05e-11 (-8.05e-11)	-1.36e-11 (-1.36e-11)	3.14e-11 (3.14e-11)*
GHG				.4166 (.4166)	-.1759 (-.1759)	-.2728 (-.2728)

**** p<0.01, **p<0.05, *p<0.1*
Robust standard errors in parentheses.

5.2 Discussion

The results from the empirical analysis confirm the relationships from the descriptive statistics to a varying degree. From the section on descriptive statistics, Figure 5 a negative relationship between deforestation and the price of NZU can be observed. This relationship holds true for Models 1A and Model 1B, however, once regressed in its stationary form, there is no evident relationship between price and NZU. This could be due to additional lagged effects not being controlled for in Table 6. Nevertheless, the general trend for deforestation over time appears to be decreasing as observed in both the descriptive and empirical analysis. The finding of a negative relationship between deforestation and price of NZU is in line with findings from Carver et al. (2022). However, the scholars also found a significant negative relationship between the price of NZU and deforestation.

Model 2A and Model 2B as well as Figure 6 present a more complicated relationship between A/R and price of NZU. This finding is also in line with those of Carver et al. (2022), whose main finding on the topic of A/R was that NZU decouples the historic negative correlation between afforestation and timber price, but could not necessarily determine a relationship between the price of NZU and increased sequestration from afforestation. This study did not include the perspective of timber prices and can therefore not explain the lack of significance between A/R and price. However, similarly to Carver et al. (2022), Rontard and Hernandez (2021) also discuss the lack of evident significance between afforestation and price of NZU. Therefore, the findings from this study regarding A/R and price of NZU seem to be in line with that of previous research. Findings from this research together with previous studies open up for further research on why A/R activities are not promoted by a price increase in NZUs.

Furthermore, Model 3A and Model 3B show a positive relationship between increased price of NZU and change in remaining forest carbon sink. This means that emissions from the carbon sink increased with the price of NZU. However, the trend over time appears to be negative. Interestingly, once the time trend was excluded and the variables were stationary a significant negative relationship could be observed between price and carbon sink, meaning the emissions from the carbon sink decrease once the price of NZU increases. This would imply that the NZ ETS functions in a way that enhances the carbon sink over time and contributes to reaching New Zealand's climate targets. An increasing carbon sink over time is what would be expected based on the theory of carbon pricing as carbon sequestration should become more cost-effective for landowners (Parry et al., 2022; Rontard & Hernandez, 2021; Shrestha et al., 2021). Furthermore, the increases in the price of NZU after 2020 seen in Figure 2 would, from this finding, entail a large increase in the New Zealand carbon sink.

Overall, the lack of stability and robustness of the models confirms the complicated relationship between forest management and emission trading brought up in the literature (Carver et al., 2022; Shrestha et al., 2021; Evison, 2017). The short time period available for studies on the topic further influences the robustness of the data and makes the models less trustworthy. A similar study would most likely benefit from a longer time frame where the emission trading system has had the ability to become more established. Furthermore, as seen in Figure 2, the prices of NZU have seen a sharp increase in recent years and it would be interesting to follow the development of forest management responses to such an increase in the following decade.

Figures 3 and 4 present the development of forest sequestration and forest growth in Sweden over the period 1990-2021 and 1956-2016 respectively. The trends in Sweden show decreasing carbon sequestration and total trees. Forest sequestration has been decreasing, especially since 2012, while the overall trend for total trees is relatively stable with a slight decrease over time.

This trend is slightly distorted by the sharp increase of trees in 1971. These findings are in line with the overall trend of decreasing sequestration capacity in the EU as stated by the European Environment Agency (2022). The findings from the descriptive statistics in this study as well as the literature confirm the overall discussion that increasing measures on carbon sink enhancement are necessary in order to reverse the current trend and reach international goals (UNEP, 2021; European Environment Agency, 2022).

The forest sector in Sweden is currently covered by one carbon pricing initiative, namely a national carbon tax. However, that tax corresponds to emissions related to forest management in the form of diesel vehicles, not to emissions arising from deforestation (Government Offices of Sweden, 2019). As this thesis did not study the statistical relationship between the Swedish carbon tax and forest carbon sequestration, it is difficult to determine the influence of the tax on the carbon sink. However, the carbon sink appears to be decreasing as observed in Figure 3 and is stated in the findings by Gong et al. (2022). It is therefore likely that the carbon tax is not sufficient for reducing the current trend of decreasing forests and carbon sink in Sweden.

This study sought to understand if emission trading systems are a good medium for carbon sink enhancement by looking at the case of New Zealand. Whether including forestry in the EU ETS framework would suffice as a measure to increase the carbon sink of Swedish forests is inconclusive from this study as the effects from New Zealand have a varying degree of unity. Furthermore, limitations due to studying the effects solely from one country make the conclusions difficult to transfer to a regional ETS like the EU's. Although New Zealand's and EU's land area is covered by a similar percentage of forest which could imply similar results for EU's carbon sinks, the composition of the EU with multiple member states makes conclusions from this study difficult. However, some of the results of the study are of statistical significance such as the relationship between forest carbon sequestration and decreased deforestation over time, which is a relationship also found in the literature. It can therefore not be excluded that an integration of forestry into the EU ETS would be beneficial for Swedish carbon sink enhancement.

Furthermore current projections of increasing prices on carbon units would together with the findings of this study entail that the carbon sink would increase for the case of New Zealand and support the need for further research on the case of the EU ETS (Keenor et al., 2021**;** World Bank, 2022). In addition, Gong et al.'s (2022) findings highlight forest units for emission trading as a potential policy measure to enhance carbon sinks in Sweden. However, the scholars highlight forest units in the form of offsets rather than fully merging forestry into emission trading, meaning compensation for carbon sequestration but not necessarily paying for emissions arising from deforestation as in the case of NZ ETS. How offsets influence the carbon sink lay beyond the scope of this thesis but could be interesting for future research. Moreover, as stated by the director at the European Commission's department for climate action, Artur Runge-Metzger, an integration of the forestry sector into the EU ETS cannot be dismissed (Simon, 2020). It is therefore of interest for future research to study the development of measures for carbon sink enhancement in the EU.

6. Conclusion

This thesis provides an insight to the need for further development on the topic of carbon sink enhancement in order to mitigate climate change and fulfill policy commitments. The aim of this thesis was therefore to examine New Zealand's ETS and how it has impacted forest management practices and to discuss these findings in relation to carbon sink enhancement policies in Sweden by looking at the European ETS.

To study the research question; *Has including forestry in the NZ ETS had a significant impact on forest management?* and Sub-research question; *To what extent are these findings relevant for the EU ETS and carbon sink enhancement in Sweden?,* previous research, descriptive statistics and pooled OLS time series regressions were used. The main findings from this research were that deforestation has decreased over time in New Zealand and that the carbon sink from remaining forests seems to increase positively with the price of NZU. However, the empirical research showed varying degrees of significance between the different forest activities: deforestation, A/R and carbon sink change, and price of NZU. Therefore, New Zealand's emission trading system can be said to influence forest management practices over time, although not with the same effect for all forest management practices presented in this study.

Moreover, this research has presented the complexity and volatility of emission trading systems which make it difficult to determine to what extent findings from New Zealand are applicable for the case of EU's ETS. Nonetheless, from this research it is clear that additional policy measures have to be taken to reverse the current trend of decreasing carbon sinks in Sweden and that current policy in the EU is inadequate to reach Sweden's national and EU's regional climate goals. The EU ETS is an interesting market mechanism that, building on the findings from New Zealand, could be further explored as a tool for carbon sink enhancement.

The subject of forestry and emission trading systems is scarcely researched. This holds true for the case of New Zealand as well as for the European ETS. Further research is therefore needed on the topic as a whole to understand potential difficulties and opportunities arising from a carbon market. Additional studies on forestry and carbon sink enhancement in relation to carbon pricing initiatives are needed to understand their impact on climate targets and commitments. Similar research to that performed in this study would be beneficial in the coming decade to understand how the ETS system in New Zealand has impacted forest management over time, especially as prices of carbon units are increasing. Moreover, studies on EU policy and member's carbon sinks are needed to comprehend what potential policy measures could reverse the trend of decreasing carbon sinks.

This paper contributes to the topic of carbon pricing by providing an area of research that could be further expanded: the consequences for forest management practices had forestry be included in the European Emission Trading System. As Sweden is densely forested, with decreasing carbon sinks, how the EU and Sweden manage policies on forestry are of utmost importance to achieve set climate targets. This research has shown that carbon pricing through emission trading could be a potential area of interest as positive results can be observed from the case of New Zealand. Carbon sink enhancement is necessary to reach global, regional and national climate targets in New Zealand, EU and Sweden. Findings from this thesis demonstrates that the direction both Sweden and the EU are heading towards regarding carbon sink enhancement is currently not sufficient and further measures need to be taken.

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Appendix

Appendix 1

	Model 1	
	A	B
Prob > chi2	0.0086	0.1423

Appendix 2

	Model 2	
	A	B
Prob > chi2	0.0293	0.0177

Appendix 3

	Model 3	
	A	B
Prob > chi2	0.6017	0.8287