MASTER THESIS

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How much will it cost to pollute in the future? Corporate Carbon Price Expectations in the EU Emissions Trading System

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Abstract

EN

Expectations about future carbon prices play a considerable role in investment decisions and decarbonisation efforts. This thesis explores how companies in the EU Emissions Trading System form carbon price expectations. By conducting a survey among executives and professionals of EU ETS companies, empirical evidence is collected as a basis for analysis. The findings suggest that energy prices represent the most important factor for the formation of expectations before institutional changes and macroeconomic developments. The greatest uncertainties concerning price determinants are attributed to political and regulatory developments. Moreover, the results extend previous literature by showing that companies strongly rely on in-house expertise, apply a variety of models and that most companies update their long-term expectations infrequently. Collectively, the results yield valuable insights for market participants and policymakers.

DE

Erwartungen zur zukünftigen Entwicklung von CO_2-Preisen spielen eine wichtige Rolle für Investitionsentscheidungen und damit für die Dekarbonisierung der Wirtschaft. In dieser Arbeit wird untersucht, wie Unternehmen im EU-Emissionshandelssystem Preiserwartungen bilden. Mittels einer Umfrage unter Führungskräften und Fachleuten von EU-EHS Unternehmen werden empirische Daten als Grundlage für die Analyse gesammelt. Die Ergebnisse deuten darauf hin, dass Energiepreise den wichtigsten Faktor für die Bildung von CO_2 Preiserwartungen darstellen, noch vor institutionellen Veränderungen und makroökonomischen Entwicklungen. Die größten Unsicherheiten bezüglich Preisdeterminanten werden politischen und regulatorischen Entwicklungen zugeschrieben. Darüber hinaus ergänzen die Ergebnisse die bisherige Literatur, indem sie zeigen, dass sich die Unternehmen in hohem Maße auf internes Fachwissen verlassen, eine Vielzahl von Modellen anwenden und dass die meisten Unternehmen ihre langfristigen Erwartungen nur selten aktualisieren. Insgesamt liefern die Ergebnisse wertvolle Erkenntnisse für Marktteilnehmer und politische Entscheidungsträger.

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List of Abbreviations

C-MIDAS	Combination-Mixed Data Sampling
CBAM	Carbon Border Adjustment Mechanism
CO_2	Carbon dioxide
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
EMD	Empirical Mode Decomposition
ETS	Emissions Trading System
EU	European Union
EU ETS	European Union Emissions Trading System
EUA	European Union Allowance
FGLS	Feasible Quasi Generalized Least Squares
G20	Group of Twenty
GARCH	Generalized Auto Regressive Conditional Heteroskedasticity
GDP	Gross Domestic Product
IPCC	Intergovernmental Panel on Climate Change
LRF	Linear Reduction Factor
NAP	National Allocation Plan
MSR	Market Stability Reserve
OECD	Organisation for Economic Co-operation and Development
SO_2	Sulfur dioxide
TGARCH	Threshold Generalized Auto Regressive Conditional Heteroskedasticity
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
WTO	World Trade Organization

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On my honour as a student of the Diplomatische Akademie Wien, I submit this work in good faith and pledge that I have neither given nor received unauthorized assistance on it.

Alexander Panhofer

1 Introduction

Keeping global warming close to 1.5°C above pre-industrial levels represents an existential challenge for humanity. A failure to do so would result in catastrophic consequences for biological and human-managed systems (IPCC 2014). Whereas recent years have seen a shift in public opinion and politicians have announced more ambitious climate targets, implementation measures often fall short. One essential instrument in the fight against climate change is carbon pricing. By pricing emissions, carbon-intensive sources and products become more expensive compared to low-carbon alternatives. As a result, fossil fuels lose in attractiveness and clean technologies become more competitive. From an economic viewpoint, this policy corrects a market failure as externalities arising from climate damages are incorporated into the price. The main benefit of this market-based instrument, which is usually implemented through a tax or an emissions trading system (ETS), is that it is flexible and cost-efficient.

Importantly, one needs to consider that when households and companies take long-term investment decisions, not only are current carbon prices relevant but future carbon prices also need to be estimated. The question of whether one should opt for a green investment or a fossil fuel substitute depends on the costs and revenues over the whole investment horizon. This holds true for homeowners who contemplate changing their heating systems as well as for energy companies investing in power plants (Flues and van Dender 2020). Therefore, expected prices play a significant role in decarbonisation efforts. Unfortunately, carbon prices are difficult to predict in the medium and long-term. The Paris Agreement obliges countries to step up their contributions to emissions reductions at regular intervals which means that carbon prices can be expected to rise. The exact price trajectory however remains uncertain as even policy recommendations differ widely. The High-Level Commission on Carbon Prices set up by the United Nations Framework Convention on Climate Change (UNFCCC) for example concluded in 2017 that prices should climb to USD 50-100 tonne/CO_2 to reach net-zero carbon emissions by mid-century provided that supportive policies are in place (Stern and Stiglitz 2017). More recent estimations by the Organisation for Economic Co-operation and Development (OECD) recommend a benchmark of EUR 120 tonne/CO_2 to meet the climate goals (OECD 2021b).

The prediction of future carbon prices is essential as uncertainty or underestimation of future emission costs lead to lower investment in environmentally friendly energy sources and technology (Stern 2006). This can have twofold implications. First, environmental objectives will not be achieved as less effort is put into decarbonisation. Second, prices will rise because there will not be enough clean energy supply and pollution costs will be passed on to consumers. Scientific research in the area of carbon price expectations has mainly focused on the prediction of prices in emissions trading systems via historical data (Alberola et al. 2008; Chevallier 2009; Byun and Cho 2013; Segnon et al. 2017; Zhao et al. 2018; Adekoya 2021). This focus can be explained by the fact that carbon taxes give a stable price signal in the short and medium-term whereas prices in carbon markets fluctuate constantly due to the trading of pollution permits (Borenstein et al. 2019, p. 2). Scholars identified energy prices, macroeconomic developments and regulatory changes as key price determinants in carbon markets (Christiansen et al. 2005; Aatola et al. 2013; Zhu et al. 2019; Xu et al. 2019). However, there is little knowledge about how companies form their expectations, and what variables and methods they use. As Kahneman and Tversky (1972), Gennaioli and Shleifer (2018) and Bordalo et al. (2019) have shown, the formation of expectations is not perfectly rational but influenced by psychological factors and other constraints. For this reason, the exploration of how companies in emissions trading systems estimate future prices could yield valuable insights for market participants and policymakers who aim to drive decarbonisation.

Against this background, the thesis seeks to answer the question of how companies in the European Union Emissions Trading System (EU ETS), the first international ETS, form carbon price expectations. To provide an empirical foundation for analysis, data was gathered via a cross-sectional online survey among professionals of companies operating in the EU ETS. The survey consisted of quantitative and qualitative questions that intended to reveal the influence of different price signals, sources and methods in the expectation formation process. As such, the explorative study aims to contribute to the understanding of the carbon market and to give policymakers, companies, and other stakeholders insights into how corporate carbon price expectations are formed.

The findings suggest that energy prices represent the most important factor for the formation of expectations before institutional changes to the EU ETS and macroeconomic developments. Complementary climate policies that do not alter the EU ETS but influence business as usual emissions also play a substantial role. The greatest uncertainty regarding price determinants is attributed to political and regulatory developments. The free allowance allocation was rated as the most important in this respect. Also highlighted by the results is the reliance on in-house expertise to form expectations, though four-fifth of the surveyed companies updates long-term expectations only quarterly or annually. Moreover, the results obtained show that practitioners apply various models including econometric forecasting models, scenario analyses, sensitivity analyses and probability assessments of policy changes to come up with price estimates. The latter two methods, which are strongly based on beliefs and prone to bias, occupy a more prominent role for long-term expectations, while historical price developments are less meaningful for this due to structural price breaks. Lastly, on average, respondents expect a significant carbon price increase by 2030, however, the expectations exhibit a great variance.

The thesis is organised in the following way. The first chapter is dedicated to carbon pricing, whereby the theoretical concept is introduced and evidence of carbon pricing in practice is presented. To provide an interdisciplinary perspective on the subject, the political aspects of carbon pricing are also addressed. Further, this chapter scrutinises the EU Emissions Trading System from a technical, political, and environmental viewpoint before it concludes with an analysis of carbon price drivers. The second chapter discusses the role of price expectations in economics, methods to form expectations and the role of the rational expectations hypothesis. This is followed by a portrayal of the research methodology and survey design. Further, the findings of the survey are presented and analysed. The final section draws upon the entire thesis, tying up the theory with the empirical results to reach a conclusion.

2 Carbon Pricing

This section on carbon pricing builds the first of two theoretical parts that act as a basic framework for the empirical research of the thesis. First, a brief review of the economics of climate change introduces the notion of why carbon pricing is necessary to combat rising temperatures. This is followed by an elaboration of the theory behind the market-based instrument. How the theory is applied in practice in various countries worldwide and how successful it has proven environmentally is analysed in a further section. The political perspective on carbon pricing including issues such as distributional concerns, intergenerational conflict and effects on jobs in the industrial sector is also presented. Further, as a central element of the thesis, the European Union Emissions Trading System is introduced and discussed with a focus on regulatory design questions. Finally, the section on carbon pricing concludes with a theoretical analysis of the price determinants in the EU ETS and other cap and trade systems.

2.1 An Introduction to the Economics of Climate Change

The climate crisis presents one of the most serious challenges in human history. Since the industrial age, fossil fuels have been extracted and burnt on an increasing scale. Neglecting the environmental effects of greenhouse gas emissions, the world has been steering towards a warmer planet with catastrophic consequences for all living species. Extreme weather events, sea-level rise, the loss of species and existential risks for people worldwide were linked to global warming (IPCC 2014). Tasked with assessing scientific literature related to climate change, the UN's Intergovernmental Panel on Climate Change (IPCC) regularly produces reports which show an alarming development. The scientific consensus states that the earth is heating up and anthropogenic greenhouse gas emissions are a major contributor (IPCC 2014). For this reason, the international community adopted the Kyoto Protocol in 1997 which committed its parties to reducing emissions to prevent "interference with the climate system" (United Nations Framework Convention on Climate Change 1997). Originally signed by 84 parties, it entered into force in 2005. Nevertheless, the emissions' upward trajectory did not change much while scientific evidence on the severity of climate change was mounting (IPCC 2014).

The "Stern Review - The Economics of Climate Change", a landmark study published in 2006, highlighted the economic implications of climate change (Stern 2006). It compared the economic costs and risks of the business-as-usual scenario with the scenario of climate action. According to economic modelling at the time, the costs of inaction would be equivalent to a worldwide loss of 5-20% GDP annually forever, whereby further risks could even exceed the projections (Stern 2006, VI). On the other hand, swift climate action that would impede the adverse effects of climate change would only cost about 1% of global GDP. Therefore, the report concluded that "strong and early action" would clearly be beneficial compared to the economic costs of inaction (Stern 2006, VI). What needs to be mentioned is that estimations of climate damages differ substantially and that they are constantly updated in light of new scientific evidence about climate risks. The issue of climate damage estimation is discussed further in the next section.

Importantly, the "Stern Review" described climate change as "the greatest and widest-ranging market failure ever seen" (Stern 2006, I), a finding that is shared by numerous scholars (Carlin 1995; Andrew 2008; Greene et al. 2009; Kaur 2009; Ostrom 2012; Nordhaus 2019). The economic concept of market failure refers to the state that an economically inefficient amount of goods and services is produced which leads to a poor outcome for society. With regards to climate change, the amount of (carbon) emission-intensive goods and services that are distributed is higher than would be optimal for society. This phenomenon occurs because the costs of climate change that are caused by emissions are not included in the price and often carbon-intensive goods are even subsidised. To counter this pervasive market failure, a carbon price can be implemented, or low-carbon technologies subsidised. The High-Level Commission on Carbon Prices set up by the United Nations Framework Convention on Climate Change (UNFCCC) in 2016 concluded that carbon prices of USD 40-80 tonne/CO_2 by 2020 increasing to USD 50-100 tonne/CO_2 by 2030 are required to reach net-zero carbon emissions by mid-century provided that other climate policies are in place (Stern and Stiglitz 2017). More recent estimations by the Organisation for Economic Co-operation and Development (OECD) recommend EUR 120 tonne/CO_2 to meet the climate goals (OECD 2021b).

Recent years have seen a shift in public opinion, politics and economics. Global movements like "Fridays for Future" have made climate change salient and reframed the issue as a crisis that needs to be addressed. The turnaround has been set in motion and governments are increasingly setting more ambitious targets to mitigate their emissions to achieve the 1.5°C warming goal declared in the Paris Agreement, the most significant legally binding international treaty on climate change (United Nations Framework Convention on Climate Change 2016). However, the transition to a low-carbon economy requires more than setting targets. Concrete policies and instruments need to be implemented and all available tools need to be utilised to decouple economies from CO_2 emissions. Carbon pricing can play a central role in this respect. The theory behind the concept is introduced in the following section.

2.2 The Theory of Carbon Pricing

Putting a price on carbon has become an indispensable instrument for achieving effective and cost-efficient decarbonisation (Stern and Stiglitz 2017, p. 9). The theory behind carbon pricing sounds simple and intriguing. By pricing emissions, carbon-intensive sources and products become more expensive compared to low-carbon solutions. Carbon-intensive sources lose attractiveness and low-carbon sources become more competitive (Arlinghaus 2015, p. 7). This should lead to a decrease in emissions and a boost in green investments. The main benefit of this market-based instrument is that it allows flexibility in how emissions are reduced. Emitters are incentivised to find innovative solutions that lower emissions in the cheapest way. The overall abatement costs, the costs for mitigating negative environmental effects, can be minimised according to the theory.

Historically the concept of carbon pricing can be traced back as far as 1920 to English Economist Arthur Cecil Pigou. In Pigou's time, industrial air pollution caused problems for the public as smoke led to health problems and extra costs for cleaning and electricity (Edenhofer et al. 2021). In his influential book "The Economics of Welfare" Pigou defined positive and negative externalities and presented a way of how market failures can be corrected with taxes and subsidies (Pigou 1920). According to Pigou, externalities are costs or benefits that are not priced into a product but that indirectly impact a third party. He viewed the existence of such externalities as a justification for government intervention in the market.

> "… for every industry in which the value of the marginal social net product is less than that of the marginal private net product, there will be certain rates of tax, the imposition of which by the State would increase the size of the national dividend and increase economic welfare; and one rate of tax, which would have the optimum effect in this respect." (Pigou 1920, pp. 224–225)

Pigou's concern was the maximisation of economic welfare. Comparing the marginal social net product with the marginal private net product means simplified comparing the public benefits with the private benefits of an economic activity. If the overall welfare decreases through production, then the state should intervene. In theory, the optimal Pigouvian tax should be set equal to the marginal damage (cost of pollution caused by one more unit of production) at the point where social welfare is maximised (Kallbekken 2013).

However, defining a tax rate that leads to the best outcome for society remains a challenge as uncertainties about environmental damage are considerable. Calculating the marginal environmental damage at the social optimum presents a fundamental issue in environmental economics. This is why numerous scholars have dedicated themselves to the quantification of the true cost of carbon and the ideal tax rate (Parry 1995; Cremer et al. 2003; (Cremer et al. 2003; Parry 1995; Jacobs and de Mooij 2015; Edenhofer et al. 2021; Gillingham et al. 2018; Nordhaus 2017). Especially the estimation of costs of climate damages, the pollution of ecological systems, technologies and the definition of normative parameters like discount rates remain significant challenges (Nordhaus 2017; Gillingham et al. 2018).

Roughly 50 years after Pigou, the economists Thomas Crocker and John Dales introduced a different approach to carbon pricing, the concept of emissions trading. In their works “The Structuring of Atmospheric Pollution Control Systems” and “Pollution, Property, and Prices: An Essay in Policy-Making and Economics” they coined the idea of curbing emissions by limiting the overall amount of emissions and issuing tradable emission permits (Crocker 1966; Dales 1968). The system, also known as cap-and-trade, caps the total emissions and requires companies to hold as many allowances as they emit tons of carbon dioxide. Depending on the system, permits can be issued for free or through an auction mechanism which generates income for the government. Companies can then sell surplus allowances if they have too many or buy allowances if the emissions are higher than expected. By creating supply and demand for emission permits, a market price for carbon is formed. This carbon price gives a signal to companies to invest in cleaner technologies or to shift to clean energy sources (Ball 2018, p. 136). In theory, the cap ensures that the emissions are limited at a predetermined target while at the same time companies enjoy flexibility in how they reduce emissions.

Overall, a price on carbon should ensure that emitters bear the responsibility for the reduction of emissions. A well-designed carbon price system can lead to the accomplishment of environmental goals at the lowest costs for society. The theoretical optimality of the market-based instrument is relatively undisputed among scholars (Edenhofer et al. 2021, p. 1095). However, the practical effectiveness of carbon pricing remains a hot topic as the subsequent sections show. Low carbon taxes that fail to cover the marginal damage of emissions, overly generous caps, unstable prices or distributional issues are just some of the challenges that the practical implementation faces.

2.3 Carbon Pricing in Practice

The popularity of carbon pricing has expanded considerably in recent years. Proponents of the market-based instrument reach across the political spectrum, from environmental NGOs to businesses. (Ball 2018, p. 134). International organisations like the World Bank or the Organisation for Economic Co-operation and Development (OECD) advocate the implementation of carbon taxes or trading systems as they describe carbon pricing as a “very effective decarbonisation policy” (OECD 2021b; World Bank 2021). In face of the climate challenge, a growing number of national and subnational governments have recognised the need for the internalisation of emission costs and have introduced both carbon taxes and trading systems. One of the latest additions is China’s national emissions trading program which launched in 2021. According to World Bank estimates, 21.5% of global greenhouse gas emissions were covered by an explicit carbon price instrument in 2021 and further instruments are scheduled for implementation as figure 3 illustrates (World Bank 2021, p. 25).

Carbon pricing map 2021

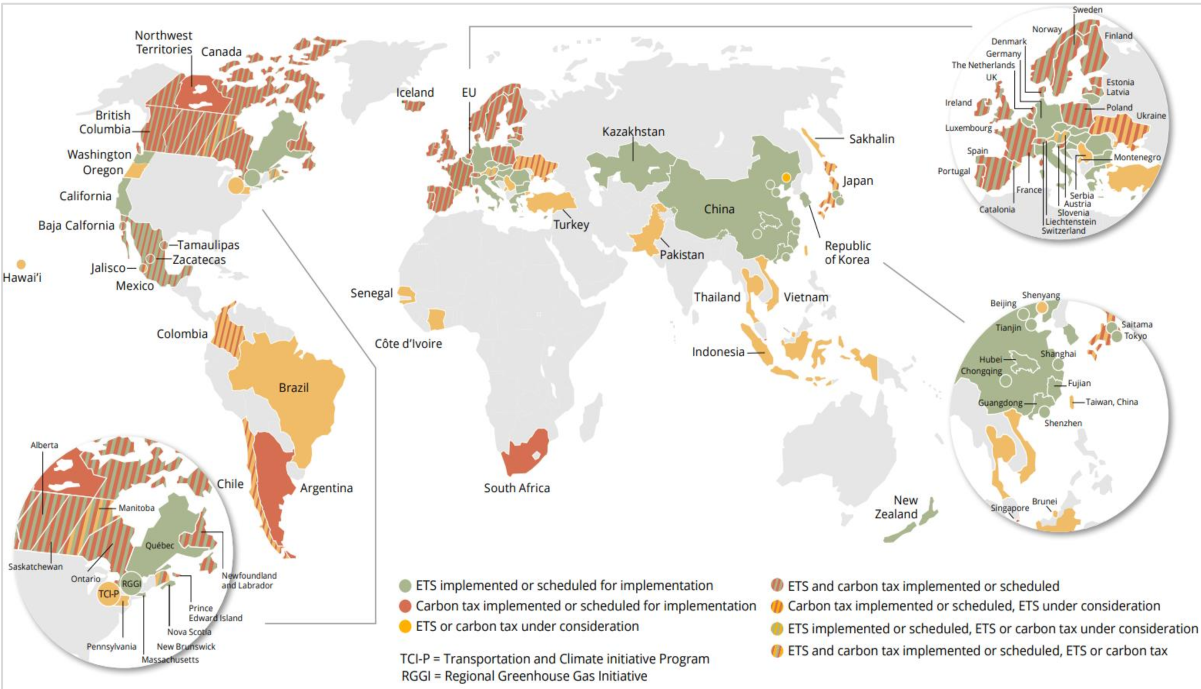

Figure 1: Carbon pricing map 2021 (World Bank 2021, p. 10)

However, only 3.76% of those instruments had a carbon price above USD 40/tonne CO_2 in 2021, which means that only a tiny share of carbon emissions was priced above the lower threshold of prices that the High-Level Commission on Carbon Prices recommended for the beginning of the decade (World Bank 2021, p. 25). For this reason, questions about the effectiveness of carbon pricing for tackling climate change have been raised (Ball 2018). Slightly more promising figures come from the OECD which calculates “effective carbon rates” that do not only include explicit carbon price instruments but also implicit carbon prices like fuel taxes. Strong progress can be observed in Group of Twenty (G20) countries, which account for 80% of global carbon emissions. In 2021, 49% of carbon emissions were priced in G20 countries, up from 37% in 2018, albeit at the low average rate of EUR 19/tonne CO_2 (OECD 2021a, p. 5).

Although low prices still hamper the ability of carbon prices to reduce emissions, historical cases prove that carbon pricing works in practice. The world's first modern large-scale emissions trading system was introduced in 1995 in the United States (US) to reduce sulphur dioxide (SO2) emissions. It achieved extensive emission reductions and was positively evaluated by numerous scholars (Ellerman 2003; Chestnut and Mills 2005; Napolitano et al. 2007). Chestnut and Mills (2005, p. 254) estimated for example that emissions were 50% lower in 2010 than they would have been without the instrument (Chestnut and Mills 2005, p. 254). Andersson (2019) analysed Sweden, the country with the highest carbon tax globally. He found a "significant causal effect of carbon taxes on emissions", specifically that carbon emissions in the transport sector decreased by 11% due to the implementation of a carbon tax. Moreover, he observed that the tax elasticity of fuel demand is three times larger than the corresponding price elasticity which suggests that the effects of carbon taxes might be underestimated. Bang et al. (2017) assessed California's cap-and-trade program, a subnational multi-sectoral ETS. They concluded that design and policy diffusion are central to the success of a carbon price policy. The world's largest emissions trading system operates in the European Union. It covers about 40% of all emitted greenhouse gases in the EU and has managed to reduce them by around 35% from 2005 to 2019 (European Commission 2022d). Although the early stages of the EU ETS were flawed with low allowance prices, Ellerman et al. concluded in 2016 that the system presented a success. One of the most compelling arguments for the environmental effectiveness of carbon pricing comes from an analysis of cross-sectional OECD data. Analysing OECD countries Sen and Vollebergh (2018) showed that an increase of EUR 10 in carbon prices leads to a 7.3% reduction in emissions in the long run.

Evidence shows that carbon pricing works in practice. However, according to the United Nations (UN) Emissions Gap Report 2019, global emissions have to be cut by 7.6% each year from 2020 to 2030 to reach the 1.5°C target of the Paris Agreement (UN Environment Programme 2019, p. 26). To achieve this goal carbon prices would have to rise substantially.

2.4 The Political Economy of Carbon Pricing

If low prices represent the main obstacle to the functioning of carbon pricing, why are prices not adjusted accordingly? This is first and foremost a political question. Although carbon pricing is on the front foot, a significant gap between the economic theory of carbon pricing and the political implementation remains (Edenhofer et al. 2021, p. 1094). The introduction of a carbon price represents a political intervention in the market. Governments need to take initiative to change the status quo which might leave some people worse off. As a Special Eurobarometer survey from 2019 showed, despite climate change being a very important topic for EU citizens, pricing mechanisms are receiving little public support (European Commission 2019). This is why currently prices are not based on the marginal damage of emissions but on political considerations of what prices are feasible and supported by the electorate.

Political barriers are numerous. One major challenge is that whereas the benefits of climate change policies are uncertain and lie in the future, the private costs of higher energy prices are felt immediately in people's household budgets (Edenhofer et al. 2021, p. 1095). Not only does this represent an intergenerational problem. It also creates a public choice issue whereby it might be rational for individuals to oppose measures but that combined are against the interest of the general public (Jenkins and Karplus 2017, p. 40). Moreover, some interest groups like the fossil fuel sector or energy-intensive industries are affected particularly strongly and therefore they voice strong opposition against carbon pricing. Unfortunately those vested interests are influencing the policy formation process above average (Stigler 1971).

Distributional issues are at the heart of the problem. Carbon taxes for example lead to a price increase in fossil fuels which impacts poor people the most as they spend a higher proportion of their budget on energy (Mattioli et al. 2018). Thus, carbon taxes can have a regressive effect when policymakers do not take countermeasures (Edenhofer et al. 2021, p. 1096). The "mouvement des gilets jaunes" (yellow vests protest) constitute a vivid example of a backlash against carbon pricing. When France increased energy taxes from EUR 30.5 tonne/CO_2 to EUR 44.6 tonne/CO_2 in 2018 with further hikes scheduled until 2022, people took to the streets and riots raged across the country (Mehleb et al. 2021). The OECD recommends a range of policies to address distributional issues (Flues and van Dender 2020). For countries in which low support for carbon taxes exists, tax revenues can be returned to citizens via lump-sum transfers. A further possibility is to cut other taxes to display revenue-neutrality. Further suggestions include revenue spending on other climate policies with social support only for particularly affected groups.

Another barrier to carbon pricing, especially emissions trading, is the competitiveness of carbon-intensive industries. Linked to this issue is carbon leakage, the situation in which companies relocate their production to countries with less stringent environmental regulations. Industry representatives often present carbon leakage as the main argument against carbon prices as they would lead to the loss of competitiveness and hence to deindustrialisation, the loss of jobs and greater emissions elsewhere in the world (Branger et al. 2016). The European Commission addressed this issue in the EU Emissions Trading System with the allocation of free allowances and cost support measures for companies in industries where the danger of carbon leakage is the highest, like steel and cement companies. Partly due to those policies Branger et al. (2016) and Naegele and Zaklan (2019) do not find a significant effect of carbon pricing on carbon leakage in the EU ETS. However, as exemptions from the carbon pricing are no long-term solution, the idea of strengthening climate measures unilaterally via a carbon border tax has emerged. Countries that implement higher carbon prices can levy taxes on imports of carbon-intensive goods which are not subject to the same carbon pricing standards to avert carbon leakage. The EU currently plans the implementation of a "Carbon Border Adjustment Mechanism", a carbon border tax, for selected goods. Whereas the idea sounds plausible in theory, practical obstacles including compliance with World Trade Organization (WTO) law need to be overcome (European Commission 2022a).

2.5 EU Emissions Trading System

The European Union's Emissions Trading System, launched in 2005, can be considered one of the most influential carbon price mechanisms globally. As one of the first major emissions trading systems, covering over 10,000 power plants and industrial installations, it had to face many teething troubles but significant reductions in pollution in recent years support the claim of the EU that the ETS represents a central instrument of climate policy (European Commission 2022d). This section first explains how the ETS works and provides a summary of its historical development before it evaluates the system's environmental and economic outcomes and gives an outlook on the pressing regulatory policy questions that will shape its future.

In terms of basic functionality, the EU ETS operates like a textbook example of a cap and trade system (European Commission 2022d). The European Commission determines a maximum amount of greenhouse gas emissions that can be emitted by all installations and a linear reduction factor (LRF) that ensures that the cap is tightened annually so emissions fall gradually. Participants of the system must hold EU Allowances (EUAs) for each tonne of CO_2 equivalent emissions that they produce. At the end of each year, installations submit an emissions report which has to be accredited. Installations, not companies are therefore the basic entity in the system. After verification, the appropriate number of emission allowances must be surrendered, otherwise heavy fines are charged. Allowances are distributed by auction or by free allocation to installations. They can also be traded on a secondary market whereby installations that have surplus allowances can sell theirs and installations in need of allowances can acquire more. The limited availability of permits should ensure that supply and demand create a carbon market price. Due to the complicated task of emissions verification, only a selected number of emission-intensive economic sectors are part of the system. Companies in those sectors are obliged to participate in the ETS although some small installations are exempted. The first key sector is electricity and heat generation. The second key sector is energy-intensive industries including "oil refineries, steel works, and production of iron, aluminium, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids and bulk organic chemicals" (European Commission 2022d). Installations that produce greenhouse gases other than carbon as in acid and aluminium production are included too. Moreover, since 2012 aviation in the European Economic Area also falls under the EU ETS. Combined, those sectors represent around 10,000 installations and cover about 40% of the EU's emitted greenhouse gases (European Commission 2022d).

The history of the EU Emissions Trading System is a history of evolution and constant change. Lawmakers have made numerous institutional reforms and adaptions to transform the carbon price instrument from a much criticised, costly system into an effective instrument for climate action. Originally, the system was introduced to equip member states with a policy instrument to achieve the legally-binding emission reduction goals agreed in the Kyoto Protocol (Ellerman et al. 2016, p. 90). In 2003, the European Council adopted the EU ETS Directive which established the EU ETS starting with a trial period from 2005 to 2007 and full implementation scheduled from 2008 to 2012 (European Parliament and Council of the European Union 2003). The three-year trial period was intended to build the system infrastructure and test it so companies could understand the system. During this period, allowances were allocated for free based on historical emissions and the cap was determined through a decentralised system in which national governments submitted NAPs (National Allocation Plans) that were added up in the end (LIFE ETX 2021, p. 11). Due to the original absence of reliable data, too many allowances were allocated, and the total amount of allowances exceeded the actually verified emissions. As could be expected, the oversupply resulted in the emission price dropping to zero.

Phase 2, from 2008 to 2012, launched with several reforms. Based on the verified emissions from the trial phase, the cap was strengthened (-6.5%) and penalties for non-compliance increased (European Commission 2022c). Moreover, the free allocation of allowances decreased to around 90% and the first auctions were held. Unfortunately, the second phase coincided with the financial crisis which led to falling outputs, lower demand for allowances and therefore a low carbon (allowance) price (LIFE ETX 2021, p. 11). Another issue that hindered the formation of higher prices was the availability of international offset credits that was extensively used. Both of those developments did not only lead to massive oversupply, some polluters, especially in the industrial sector, even generated profits from the EU ETS as they sold generously allocated allowances or bought cheaper international offset credits to cover their emissions (LIFE ETX 2021, p. 20). At the end of phase two, intra-EU aviation was added to the EU ETS. In phase 3, running from 2013 to 2020, major changes were introduced. The NAPs were scrapped for an EU-wide cap and rules for the free allocation of allowances were harmonised (European Commission 2022c). Further sectors were added to the system and international offsets were limited. Importantly, electricity companies, which accounted for half of the EU ETS emissions, did not receive free allowances anymore (Ellerman et al. 2016, p. 92). This development ensured the “polluter pays principle” in which emission costs are shouldered by the emitter. The manufacturing sector started with free allocations of 80% of allowances which decreased annually to 30% in 2020. Industries in high danger of carbon leakage received 100% allowances for free. What needs to be noted is that practically all industrial sectors could be found on the “carbon leakage list”, thereby leading to no economic incentive for decarbonisation in the industrial sectors (LIFE ETX 2021, p. 25). Overall, the measures did not result in higher carbon prices as figure 2 below illustrates.

EU carbon prices since the start of Phase 2

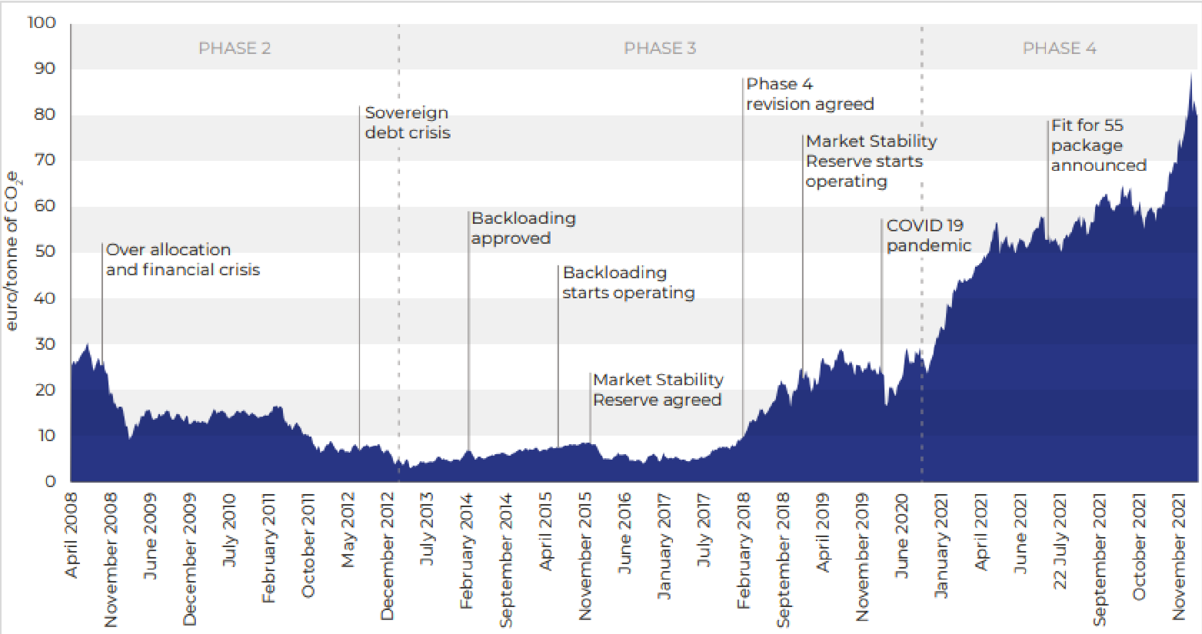

Figure 2: EU carbon prices since the start of Phase 2 (LIFE ETX 2021, p. 19)

The allowance surplus persisted due to the continuous inflow of offset credits and lower emissions than projected because of other emission reduction policies in several member states (Flachsland et al. 2020, p. 134). Policymakers reacted with the postponement of EUA auctions, described as backloading, to restrict the supply of allowances. As a permanent solution, the Market Stability Reserve (MSR) was legislated in 2015 to tackle the structural oversupply and to create more stable prices. At pre-defined thresholds, the MSR takes allowances from the market in times of oversupply, or it releases allowances in times of extreme scarcity. Recent years have shown that the MSR managed to reach its goal of reducing surplus allowances and it has therefore been positively evaluated (European Commission 2021b). Phase 4 of the EU ETS started in 2021 and ends in 2030. Revisions included a faster tightening of the cap through an increase of the LRF from 1.74% to 2.2% (European Commission 2022d). Offsets are no longer possible and the MSR has been strengthened by a gradual increase of its intake rate from 12% in 2019 to 24% in 2023 (Flachsland et al. 2020, p. 135). The strengthening of the MSR supports price stability, which in the past was threatened by external demand shocks. The free allocation system will be kept in place until the end of phase 4, however, free allocation will be phased out from 30% to 0 after 2026 for sectors that are less exposed to the risk of carbon leakage (European Commission 2022d). A broad range of industries will still receive 100% free allowances although the allocation also decreases in line with the LRF. In addition, two funds of about EUR 86 billion were established to support investment in decarbonisation and clean energy projects from 2021 to 2030 (European Commission 2022d).

To assess the success of the EU Emissions Trading System both environmental and economic factors need to be taken into account. At first sight, the environmental delivery of the EU ETS seems clear-cut as emission reduction goals were achieved and even exceeded. A reduction of 43% emissions of the combined emissions of all covered installations from 2005 to 2030 was the declared target when the EU ETS launched (ERCST et al. 2021, p. 28). This target was already reached in 2021 which indicates that the EU ETS was either overly successful or the target unambitious. On second glance, the environmental success proves to be contentious. Disaggregating the sectors as in figure 3 reveals that the central source of emissions reduction was the power sector whose emissions fell on average 5.6% annually since 2013 (ERCST et al. 2021, p. 11). However, the power sector's development contrasts strongly with the industrial sector which did not see any significant abatement except for 2020, a year marked by the Covid crisis.

Index of verified emissions 2013-2020

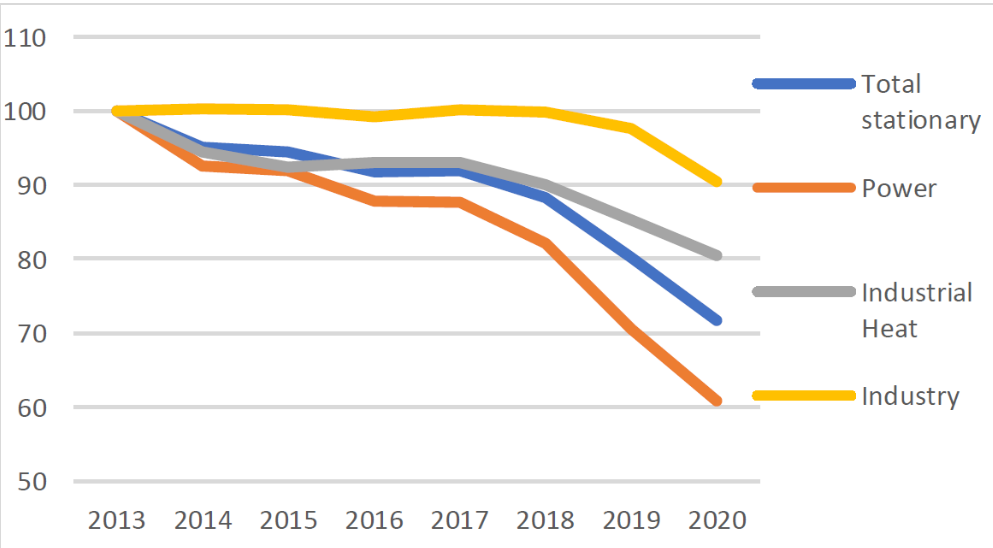

Figure 3: Index of verified emissions 2013-2020 (ERCST et al. 2021)

One explanation is that industry received most allowances for free and therefore had no incentive to change whereas the power sector had to pay for all of their allowances since 2013. Another factor for the fall in emissions in the power sector are complementary climate policies and renewable energy targets in several member states. Whereas it is difficult to distinguish between the effect of the EU ETS and other policies, the "2021 State of the EU ETS Report" concluded that the EU ETS prices were not the main driver that caused emissions reductions in the power sector (ERCST et al. 2021, p. 1). However, the price surge in recent years has begun to turn this picture and now prices are high enough to incentivise the switch from coal to gas in the power sector. The relevance of prices represents a link to the economic goals of the EU ETS. Ideally, an emissions trading system leads to the most cost-effective and economically efficient decarbonisation. To achieve this, prices have to be the driver of decarbonisation. Whereas the EU ETS was flawed with low prices until recently, researchers have found that even the low prices positively affected the reduction of greenhouse gas emissions (Ellerman et al. 2016; Bayer and Aklin 2020; ERCST et al. 2021). In addition, the market functions well with high liquidity and transparency for participants (ERCST et al. 2021, p. 24). On the downside, price volatility is high as figure 2 indicates. Compliance entities who need to base their long-term investments on the prices would benefit from more stable prices. Concerns about carbon leakage were addressed by Branger et al. (2016) and Naegele and Zaklan (2019). Their research found no evidence of carbon leakage caused by the EU ETS which they partly link to allowance subsidies to sectors that are particularly affected by energy prices.

Demonstrated by experience, further institutional changes to the EU Emissions Trading System are necessary to make it fit for the future. Recent years have seen a surge in confidence in the EU ETS but high carbon and energy prices will pose a challenge in the coming decade. The EU's climate ambitions have increased, an emissions reduction target of 55% by 2030 compared to 1990 was negotiated in 2020 and has to be translated into concrete climate policies. Although the European Commission has put forward a range of proposals, including an amendment of the EU ETS Directive, uncertainties regarding the implementation of reforms are significant. One of the most decisive open questions concerns the strengthening of the cap. The Commission proposed to lift the EU ETS target considerably from -43% to -61% by 2030 (European Commission 2021a, p. 17). To reach this target, the proposal foresees a change of the LRF from 2.2% to 4.2% and a one-off reduction of the cap so the new LRF would be equally effective as if it had already been applied since 2021. Moreover, the Market Stability Reserve is to be amended. Thereby the intake rate, intake thresholds and the calculation of the total allowances in circulation will be changed (European Commission 2021a, p. 21). Importantly, the Commission also seeks to introduce an invalidation clause which cancels all allowances kept in the MSR above the auction volume of the previous year. This MSR revision would not only have effects on price stability, but it could also influence the overall ambition of the EU ETS. For manufacturing and industry, changes to free allocation rules play a crucial role. Whereas the basic system of free allowance allocation will be prolonged until 2030, the Commission proposed to strengthen it by making it conditional on energy efficiency and decarbonisation measures (European Commission 2021a, p. 17). Sectors with a low risk of carbon leakage will see their free allocations phased out after 2026 from 30% to zero. A great unknown variable is the EU's Carbon Border Adjustment Mechanism (CBAM), especially for industries that are on the carbon leakage list and therefore receive 100% of their allowances for free. The CBAM, which is currently under deliberation, should address the problem of carbon leakage by taxing carbon-intensive goods that are imported into the EU (Council of the European Union 2022). As such it is proposed as a parallel instrument to the EU ETS that deals with carbon leakage, to be phased in from 2023 to 2026 (European Commission 2022b). However, as it represents an alternative measure to free allocation, the plan foresees ending free allocation for sectors that are included in the CBAM. For the cement, fertiliser, aluminium, electricity generation, iron and steel sectors, which are scheduled to be the first in the CBAM, this will herald a new age in carbon pricing (Council of the European Union 2022). Further institutional changes concern the general scope of the EU ETS. It is likely that the maritime sector will be included gradually from 2023 on, whereby emissions from intra-EU transport and 50% of international transport bound for the EU will be covered (European Commission 2021a, p. 16). Uncertainties also remain regarding aviation as the international CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) system conflicts with the EU ETS (Mai 2021). Moreover, a separate ETS for the buildings and road transport is envisaged. Overall, open regulatory policy questions will significantly shape the future of the EU ETS and it remains to be seen how they are answered.

2.6 Carbon Price Determinants

This section examines the drivers of carbon prices. What moves carbon prices in emissions trading systems is a crucial question for all system stakeholders. Policymakers intend to create carbon prices that drive decarbonisation, compliance entities look at prices to determine production costs and non-compliance traders aim to profit from fluctuations. Thereby, the complexity of carbon markets exacerbates the disentangling of carbon price drivers. For academia, the somewhat new carbon markets present a novel research field. Whereas there is an abundance of knowledge on pricing in financial markets, studies on carbon prices are scarce. Scholars mainly focused on identifying the driving factors for price movements in the short or medium term. In general, however, three key factors were identified: policy and regulation, macroeconomic development and energy prices (Christiansen et al. 2005; Alberola et al. 2008; Aatola et al. 2013; Xu et al. 2019).

Policy and regulation represent one of the key price drivers which should not come as a surprise since carbon markets themselves are created by regulatory intervention to adjust a market failure. This theoretical point was already made by Christiansen et al. (2005) before the start of the EU ETS. The institutional design of an emissions trading system primarily influences the supply side of the price mechanism. Setting the total number of allowances that are circulated and deciding at which rate the cap should shrink sets the stage for price discovery. What happens when the cap is too loose, and the supply is too high, could be seen in the first phase of the EU ETS when the carbon price dropped close to zero (Ellerman et al. 2016, p. 98). More ambitious climate goals accelerate the need for decarbonisation which is why policymakers should aim to increase carbon prices gradually (Stern and Stiglitz 2017). A gradual rise in carbon prices would be beneficial but regulatory events can have a stabilising and volatile effect (Xu et al. 2019, p. 2). Changes to the cap reduction factor, the possibility to use offsets, intertemporal banking or allowance allocation can lead to price jumps in the system (Alberola et al. 2008; Chevallier 2009). The introduction of a price floor or a system that deals with shocks through the withdrawal or injection of allowances such as the MSR can reduce volatility (Fell 2016; Kollenberg and Taschini 2016). Notably, not only the institutional design of an emissions trading system affects its prices but also complementary climate policies like renewable energy goals or energy efficiency targets. Regarding the EU ETS, ERCST et al. (2021) concluded that the deployment of renewable energy sources in the power sector led to a decrease in demand for pollution permits and hence to lower prices.

Macroeconomic development is a key carbon price driver as it influences economic activity and thereby carbon prices. The assumption behind this account is that greater economic output leads to an increase in carbon emissions, consequently producers have a higher demand for allowances and thus prices rise. Chevallier was one of the first to examine macroeconomic factors as carbon price drivers. In 2009 he examined the correlation between stock market variables and carbon prices whereby he found a weak connection and in 2011 he applied Markov-switching models to show that macroeconomic activity affects carbon prices with a lag (Chevallier 2009, 2011). The general notion that carbon prices respond to economic growth is also supported by Creti et al. (2012) and Koch et al. (2014). Alberola et al. (2009) looked specifically at the influence of industrial production. They identified that variations in production in the combustion, paper and iron industries had a significant effect on EUA prices.

Energy prices are frequently described as the most important price driver (Mansanet-Bataller et al. 2007; Alberola et al. 2008; Aatola et al. 2013; Zhao et al. 2018; Adekoya 2021). This is because carbon emissions are created by the combustion of fossil fuels and therefore a link between the carbon market and energy markets exists. The consumption of fossil energy depends on the prices of energy sources such as coal, natural gas or crude oil which in turn affects the demand for carbon allowances (Zhu et al. 2019, p. 203). Volatilities in the energy market can therefore directly translate into the carbon market (Alberola et al. 2008). Two different effects can be observed. First, the income effect where energy prices are negatively correlated with carbon prices (Zhu et al. 2019, p. 203). The effect presumes that a rise in energy prices leads to a fall in fossil fuel demand, a decrease in energy consumption and hence a fall in allowance prices. Second, the substitution effect, where the market structure of energy influences the carbon price as producers can switch between different fossil fuels (Alberola et al. 2008, p. 789). Thereby the relative prices of coal, gas and oil are decisive. Switching from coal, the most carbon-intensive fossil fuel, to more eco-friendly natural gas due to high coal prices represents an opportunity to abate emissions. When coal prices are low on the other hand, power generators might decide to switch to coal which leads to an increase in emissions and higher demand for carbon allowances. Zhao et al. (2018) concluded that coal prices are the best indicator for carbon prices followed by crude oil. The importance of the price difference between coal and gas was affirmed by Aatola et al. (2013) and Alberola et al. (2008). Aatola et al. (2013) also highlighted that electricity prices can have a significant effect short-term effect on carbon prices as higher electricity prices lead to an expansion of electricity production.

3 Price Expectations

Our economy relies on beliefs and expectations to function (Beckert 2016). Labour is rewarded with money which itself has no intrinsic value, but we are content to receive it nonetheless as we expect to be able to exchange it for goods or services. Investments are taken with the conviction that profits are going to exceed investment costs over the future life cycle of an investment. Expectations also play a crucial role in carbon pricing and decarbonisation efforts. The following sections address the special characteristics of carbon price expectations. First, the role of carbon prices for corporate investments is analysed before the question of how companies form expectations is examined. Various information sources and forecasting methods are presented in this respect. Finally, the question of how rational (carbon) price expectations are is discussed and the consequences of biased expectations are highlighted.

3.1 The Role of Expectations for Investments

In the short run, carbon prices provide an incentive for emission abatement as some companies can switch between energy sources to produce cost-efficiently. In the long run, carbon prices should drive investment decisions that lead to permanent decarbonisation. Carbon prices aim to accelerate the shift to low-carbon energy sources and facilitate innovation in technology such as energy efficiency. A distinct feature of power and industrial companies, the entities in most emissions trading systems, is that their investments have long time horizons. Coal or gas plants typically run for about 40 years whereas modern wind turbines are designed to last for some 20 years (Flues and van Dender 2020, p. 17). The question of whether one should opt for clean technology solutions, or fossil fuel investments depends on the costs and revenues over the whole investment horizon. Carbon prices represent one variable in the equation. In investment appraisals in which cost or profitability comparisons are made, the future expenditure for carbon allowances must be estimated. As prices change over time, this is no easy task. Depending on the expectation about future price developments, the decision to adopt a project can be positive or negative. Thus, carbon price expectations have a direct influence on decisions about decarbonisation.

Unfortunately, carbon prices are difficult to predict in the medium and long-term. However, “robust” carbon price expectations are required according to Stern (2006, p. 352) to facilitate investment in low-carbon technology innovation. Research has shown that volatile carbon prices harm decarbonisation efforts (Hoel 2010; Xu et al. 2019; Flues and van Dender 2020; European Commission 2021b). This is because risk-averse investors prefer stable returns relative to volatile ones. Even when the expected returns of a low and high carbon project are the same, uncertainty about future carbon prices can lower the expected utility due to risk aversion and hence lead to an abandonment of the low emission project (Flues and van Dender 2020, p. 15). Studies support the assumption that companies are risk-averse as companies seek to manage risks to avoid costs of financial distress or bankruptcy (Froot et al. 1993; Rampini et al. 2014).

Carbon taxes seem to evade the issue of price fluctuations as they are set to a fixed rate. However, as the debate on climate change evolves and governments change so do carbon tax rates. Hoel (2010), Lemoine (2017) and Mignone et al. (2017) examined the environmental effects of anticipated tax changes. Lemoine (2017) reported that anticipated carbon price rises can result in increased emissions. This is because fossil fuel extraction is brought forward to escape tax increases. Emissions trading systems tend to be volatile in general as figure 4 shows. The EU ETS, for example, has seen its carbon price halved from nearly EUR 30 to EUR 15 in 2008. During the sovereign debt crisis in 2012, prices even fell below EUR 5. With the implementation of the MSR, prices picked up in 2018 and soared to over EUR 90 at the end of 2021. As described in the previous section, various price drivers impact the price development which makes it difficult to form expectations about the future. Borenstein et al. (2019, p. 3) argue that inelastic allowance supply paired with a broad probability distribution of business as usual emissions are the causes of extreme price fluctuations. To sum up, carbon price expectations play a significant role in clean investments. Policymakers should aim to give credible signals for substantial and predictable carbon prices to ensure a low-carbon transition.

ICAP allowance price explorer 28/03/2008 - 31/03/2022

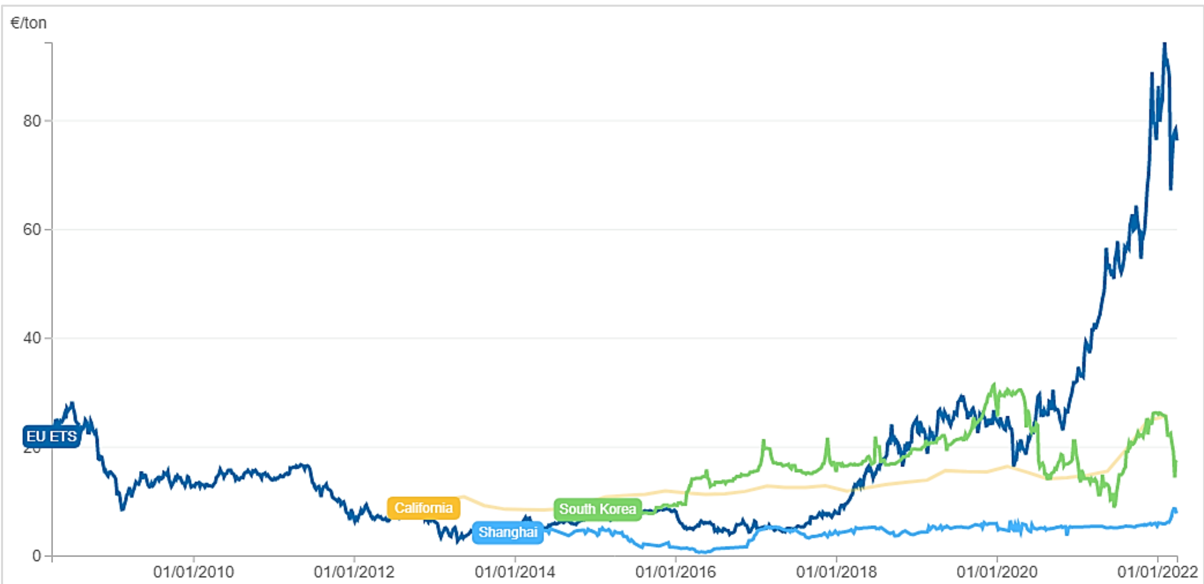

Figure 4: ICAP allowance price explorer 28/03/2008 - 31/03/2022 (International Carbon Action Partnership 2022)

3.2 Methods of Expectation Formation

The previous section illustrated that carbon price expectations are relevant for corporate planning but how do companies form those expectations? This section touches upon the role of various information sources, forecasting methods and models that are employed to shape expectations. Generally, expectations are formed by combining new information about the future with the extrapolation of historical data, the statistical forecasting based on past trends (Kahneman and Tversky 1972; Gennaioli et al. 2016). The first component, new information, influences the beliefs about the likelihood of future outcomes. Thereby, the arrival of new information can have an affirmative effect on already held beliefs or lead to a drastic change in expectations (Flues and van Dender 2020, p. 17). In the realm of carbon pricing, regulatory policy changes can significantly alter the course of price development. This is why beliefs about the modality and likelihood of future policy interventions play a central role. Policy announcements about institutional design changes or complementary climate policies such as renewable energy goals or decarbonisation targets are meaningful information sources in this respect (Borenstein et al. 2019).

The second component, statistical forecasting, predicts future outcomes based on historical data. Such econometric modelling has drawn a great deal of academic interest in the area of emissions pricing. At the centre of the discourse are the search for the best predictive variables and models. While the carbon market developed, so did the forecasting models ranging from simple Generalized Auto Regressive Conditional Heteroskedasticity (GARCH) type models to recently introduced sophisticated multifractal models (Segnon et al. 2017). Chevallier (2009), for instance, employed an asymmetric Threshold GARCH model (TGARCH) to find a weak connection between stock and bond market variables and carbon prices. Various GARCH-type models were compared with an implied volatility model and the k-nearest neighbor model by Byun and Cho (2013). They suggested brent oil, coal and electricity prices to forecast carbon futures. The importance of electricity and coal prices, especially coal gas price differences, was also highlighted by Aatola et al. (2013) who used several econometric models with multiple stationary time series. Combination-Mixed Data Sampling (C-MIDAS) models, as adopted by Zhao et al. (2018), provide even better forecasting results than traditional models as they allow the inclusion of multiple factors sampled at different frequencies. The Empirical Mode Decomposition (EMD) method, another possibility to forecast carbon prices, decomposes time series into several intrinsic mode functions and can thereby disentangle the influence of various price drivers (Xu et al. 2019). More recent works from Zhu et al. (2019) who use multivariate EMD methods or Adekoya (2021) who applies a novel Feasible Quasi Generalized Least Squares (FGLS) estimator also achieve enhanced forecasting performance.

In addition to the two components discussed above, aggregated external expectations data can yield valuable information for forming own expectations. Collectively held expectations, even if they seem irrational, play a vital role as predictions often turn into self-fulfilling prophecies (Beckert 2016). If no one invested in low-carbon technologies because the consensus expects investments to be unprofitable then low-carbon technology would remain expensive in the future. Expectations are surveyed for a range of variables that are relevant to carbon prices. Energy demand, energy prices, macroeconomic outlooks and even carbon price expectations themselves are gathered by various institutions including national banks, industry associations or consultancies. The "GHG Market Sentiment Survey" commissioned by the International Emissions Trading Association, for example, surveys global expectations about carbon markets and the "Refinitiv Carbon Market Survey" specifically looks at expectations in the EU ETS though the majority of respondents are carbon or commodity traders (International Emissions Trading Association 2021; Refinitiv 2021).

What the wealth of data from different sources offers, is the possibility to go beyond conventional forecasting that seeks to identify the most likely future scenario. Scenario analyses, for example, have advantages in the implementation of new information as they are not focused on the most likely future but produce a multitude of possible outcomes which can be compared (Huss 1988). A scenario is defined as "a narrative description of a consistent set of factors which define in a probabilistic sense alternative sets of future business conditions" (Huss 1988, p. 378). The method is particularly suitable for uncertain, long-term projections, as turning points such as regulatory changes can be better mapped. This makes it useful for the long-term investments of energy and industrial companies. Uncertainties for key parameters are best captured by sensitivity analyses, another advanced analysis method (Borenstein et al. 2019). Sensitivity describes how much the change of one input variable affects the output variable. Notably, the choice of what parameters/variables one should include and what probabilities one should assign poses a challenge. On the whole, companies can combine various methods to form sophisticated planning tools, either by putting in their own efforts and resources or by employing specialised external consultants (Borenstein et al. 2019).

3.3 Rationality, Bias and the Consequences of Misjudgement

According to the rational expectations hypothesis, participants in a market use all available information to predict the future in a statistically optimal way (Muth 1961). In a hypothetical world of full-information rational expectations, this would mean that one would not have to worry about irrational carbon price expectations, and one could trust that prices are correctly predicted. However, there is overwhelming evidence that price expectations are not perfectly rational but influenced by psychological factors and other constraints (Kahneman and Tversky 1972; Akerlof and Shiller 2009; Coibion and Gorodnichenko 2015; Gennaioli et al. 2016; Gennaioli and Shleifer 2018; Bordalo et al. 2019, 2020a; Bordalo et al. 2020b). This section describes the limits of rational expectation formation and highlights the possible consequences of biased carbon price expectations.

The theme of rational expectations has experienced rising interest in recent decades and has produced a wealth of literature that challenges the neo-classical assumption that economics is exclusively driven by rationality and equilibrium. Akerlof and Shiller (2009), for example, take up the term "animal spirits", coined by John Maynard Keynes, to illustrate how human psychology influences the economy. Writing from a social science perspective they conclude that while businesspeople are constrained by financial metrics, in the end, investment decisions depend on their psychology and intuition. The factors confidence, fairness, money illusion, corruption and bad faith are central to how the economy works according to them. Gennaioli and Shleifer (2018) argue that expectations are extrapolative rather than rational and therefore expectations are too positive in good times and too negative in bad times. They claim that investors are forward-looking but they react to news in a distorted way. Bordalo et al. (2019) link this phenomenon with the kernel-of-truth hypothesis which states that individuals react to news in the correct direction but too extremely. The argument is substantiated by an analysis of macroeconomic forecasts and ex-post forecast errors. Under rational expectations, the forecast error should be unpredictable and no correlation should be found, yet data shows that this is not the case (Bordalo et al. 2020b).

Another example of the violation of full-information rational expectations is heuristics, studied extensively by Kahneman and Tversky (1972). Heuristics are mental shortcuts to estimate probabilities quickly and efficiently without considering all relevant information, thereby often producing suboptimal results. Bordalo et al. (2021) base their belief formation mechanism, named diagnostic expectations, on the representativeness heuristic and present a behavioural market model that shows how diagnostic expectations lead to initial underreaction, then overshooting and finally to a crash. The aspect of not considering all available information presents a general problem in expectation formation. Information rigidity, for instance, refers to the lag and infrequency in incorporating new information in expectations as updating and acquiring information sets is costly (Coibion and Gorodnichenko 2015). Heuristics also play a role in non-rational deliberations about climate change. Zaval and Cornwell (2016) summarise a range of literature on decision biases on climate change matters reaching from bounded rationality over the interaction between emotions and experience to peoples' risk perception. Kahn (2016) highlights the fact that expectations about climate risks are often based solely on historical trends and that information on how risks evolve in the future is neglected.

The consequences of biased expectations can be profound. Errant price expectations were part of the toxic mix that led to the financial crisis in 2008 (Gennaioli and Shleifer 2018). Participants in the financial market formed price expectations based on upward price trends but failed to take into account the increasingly frequent payment defaults in the subprime market (Akerlof and Shiller 2009). If investors had considered all information, then they would not have made impossible assumptions about the future. With regards to carbon pricing, biased expectations that underestimate future carbon prices because of an overreliance on historical data or wrong perceptions about climate risks, lead to lower investments in low-carbon technology (Stern 2006, p. 352). Firms are less likely to invest in energy transition if they underestimate future emission costs. This can have twofold implications. First, environmental objectives will not be achieved as less effort is put into decarbonisation. Worsening climate conditions including natural disasters like flooding, droughts or forest fires will cause immense human and economic damage as a result (Stern 2006). Second, prices will rise stronger. This is because there will not be enough clean energy supply to match demand and the production and combustion of fossil fuels will become more costly. Importantly, evidence shows that allowance prices are passed through almost completely (Borenstein et al. 2019, p. 18). Power plants and industrial companies will see their costs exceed expectations and will pass them on to consumers in the end. As energy represents a central input factor for production in many sectors, an underestimation of future carbon prices could affect the general price level.

Considering the rejection of rational expectations and the relevance of carbon price expectations for investment decisions, the analysis of surveyed expectations can be extremely helpful for gaining an understanding of market prospects and decarbonisation efforts. However, although some institutions survey expected prices, there is little research on how companies form those expectations. A wide gap remains in the understanding of how carbon market participants come up with price expectations in the rapidly changing market environment. Exploring this research gap could improve the understanding of the market and yield valuable insights for market participants and policymakers who aim to drive effective decarbonisation.

4 Methodology and Survey Design

The central question that this thesis aims to address is how participants of the EU Emissions Trading System form carbon price expectations. Thereby the study aims to contribute to the growing literature on carbon pricing and to provide EU ETS stakeholders with a better understanding of the role that various price signals, information sources, forecasting methods and beliefs play in the expectation formation process. To answer the research question, an online survey among companies that participate in the EU Emissions Trading System was conducted. As data on expectation formation processes is scarce, the collection of new data through a survey was deemed to be an important step for providing an empirical foundation for further analyses. Expectations data can be very useful for predicting behaviour and analysing methods and models as Gennaioli et al. (2016) emphasise. As such, the survey can make an important contribution to understanding the market.

Using SociSci Survey, an academic online survey application, a cross-sectional survey was administered from 21.3.2022 to 21.04.2022 whereby respondents had the opportunity to answer 17 questions. With regards to the EU ETS schedule, the survey was conducted in the early stage of the fourth EU ETS phase which lasts from 2021 to 2030. It also came at a time of increasing uncertainty about energy security due to the Russian invasion of Ukraine which began on 24.2.2022 and which entailed strong sanctions by the international community. In the survey period of one month, the survey garnered 50 valid responses from company representatives in Europe, with the majority being from Austria. The response rate was roughly 11% as 451 personalised invitations to participate were dispatched. Participants were contacted via email and invited to fill out the survey, whereby they were offered the sending of the survey results to raise the response rate.

The target group for the survey were senior executives, managers and professionals of sustainability or energy-related departments of companies that fall under the EU Emissions Trading System. Focusing solely on reactions from practitioners provides added value as unfiltered data can be gathered for analyses. Contact data was obtained by first consulting the European Union Transaction Log about the installations and companies that take part in the EU ETS (European Commission 2022e). These are companies that deal in power and heat generation or in energy-intensive industry sectors like steel, iron, cement, pulp or chemicals production. Airlines that operate intra-EU flights are also part of the EU ETS but were not included in the study as it is unclear whether they will shift to the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), an international emissions trading system, in due course. Further, contact details of people that belong to the target group were collected via company websites and LinkedIn.

Overall, more than 10,000 power plants and industrial installations are subject to the EU ETS. As many companies operate several installations and some of them exhibit complex ownership structures, the total number of EU ETS compliance companies proves difficult to estimate. Additionally, limited time resources for this thesis meant that the survey had to be conducted with a smaller sample. To maximise the response rate, companies in Austria and Germany were chosen as primary objects of investigation due to their geographic proximity and familiarity with the Diplomatic Academy of Vienna. Moreover, this opened the possibility to offer the survey both in English and German. First, representatives from all the 86 Austrian companies that operate around 200 installations in the EU ETS were contacted before the largest energy and industrial companies in Germany by turnover were approached (Österreichische Emissionshandelsregisterstelle 2022). Therefore, the survey does not claim to be representative of the whole European Union but it provides a good indication of how carbon price expectations are formed. Besides, the survey received responses from over a third of all Austrian EU ETS companies.

The design of the online survey was based on academic knowledge of carbon pricing and expectation formation. It included 17 quantitative and qualitative questions, separated into four thematic sections. The majority were single- and multiple-choice questions, some questions were open for comments. As such, the cross-sectional survey aimed to quantify the process of expectation formation but at the same time, it offered the possibility to dive deeper into the subject matter through open questions. It was decided that such an explorative approach could yield the best results. The four thematic sections focused on the relevance of carbon prices for companies, the price determinants in the EU ETS including relevant policies, information management including sources and methods and finally information about respondents. Collectively, the questions present a broad picture of the expectation formation process. Before finalising the survey, a pre-test was conducted with a small number of participants to evaluate the survey and to make relevant adaptions.

Finally, some observations regarding the interpretation and analysis of the survey results need to be made. First, the sample size differs between results as some respondents did not answer every question. In addition, for several questions, respondents could select multiple answers which is why not all displayed percentages add up to 100%. Third, self-selection might have led to a bias in the results as representatives from companies who place a higher focus on climate action could have been more likely to respond to the survey invitation. Fourth, the geographical focus on Austria and Germany complicates generalisations for the whole EU ETS.

5 Findings and Analysis

This section presents the results of the carbon price expectations survey conducted in the spring of 2022. Overall, the answers provide insights into the expectation formation process of companies who operate in the EU Emissions Trading System. The analysis of results seeks to objectively illustrate the opinions and attitudes of respondents. Moreover, the data is put in conjunction with literature to review existing theories and to check whether the views from practitioners align with academic insights. Split into four sets of questions, the section first introduces information about the survey respondents and their respective companies. This is followed by the categories “Relevance of Carbon Prices” and “Carbon Price Determinants”. Finally, the last question set outlines the results of how companies acquire and process information. At the end of the last section, the company’s carbon price expectations for 2025 and 2030 are presented before a conclusion is drawn in the final section.

5.1 Information about Respondents

This question group captured information about the professional background of respondents in addition to basic data about the companies that respondents work for. As such, the data supports the classification and interpretation of other questions as it sheds light on what entities are represented in the sample. In total, 50 valid responses were collected.

Survey respondents by country

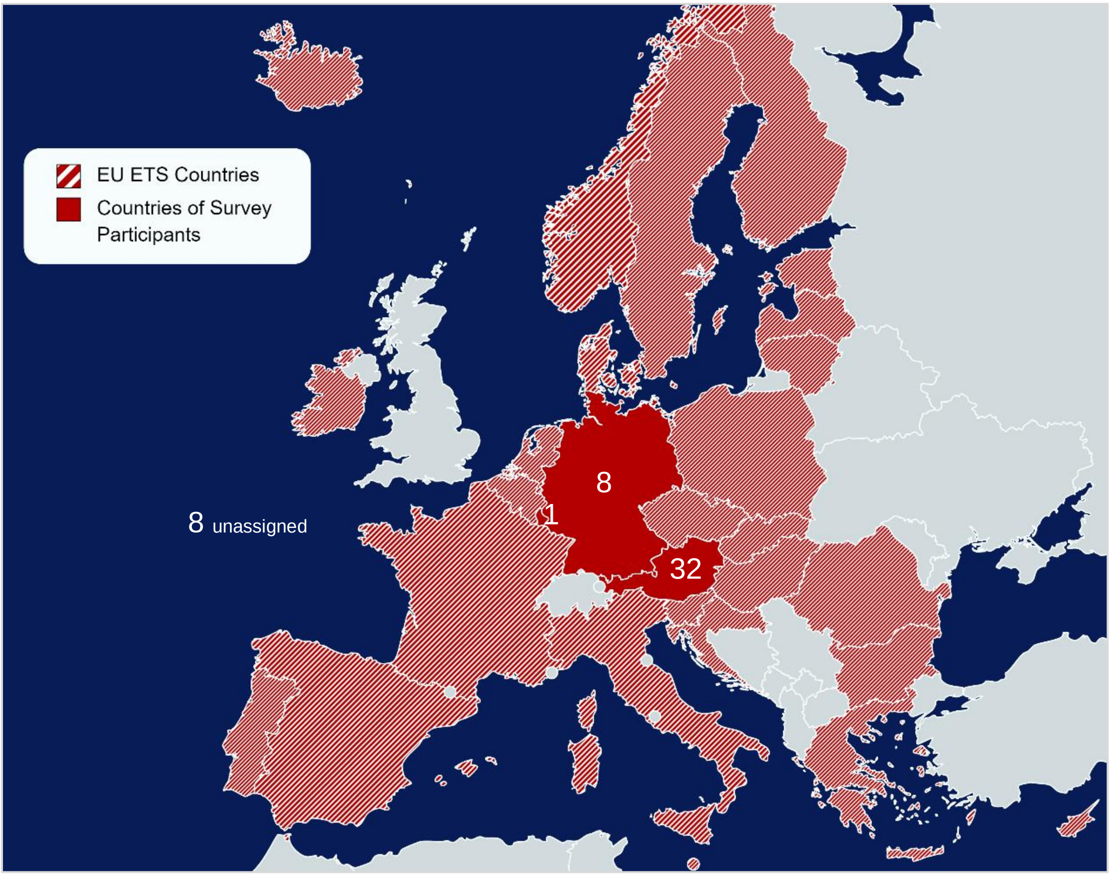

Figure 5: EU ETS countries and survey respondents by country

Looking at the geographic location of respondents in figure 5 it can be seen that respondents were primarily based in Austria and Germany. Asked in what country respondents are working, 32 said Austria, 8 Germany, 1 Luxembourg and 8 did not provide an answer. As survey invitations were exclusively sent to Austrian and German companies it can be assumed that the unassigned respondents originate from Austria or Germany. Figure 5 also shows the full coverage of the EU Emissions Trading system which extends over all EU countries plus Norway, Liechtenstein and Iceland. The survey sample only covers a small segment of EU ETS countries which is why the results are not intended to be statistically representative for all countries. However, the survey received responses from over a third of all Austrian EU ETS companies.

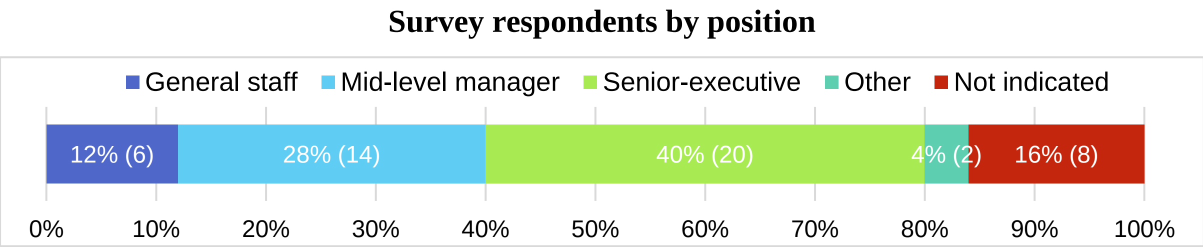

Figure 6: What position do you hold in your company? (n=50)

Figure 6 illustrates what positions respondents held in their companies. Generally, survey invitations were posted to senior executives, managers and professionals of sustainability or energy-related departments of EU ETS companies. The survey attracted a high number of responses from senior executives and managers. It can therefore be assumed that the survey results are based on a high level of expertise from practitioners with decision-making authority. What has to be emphasised is that in contrast to other carbon expectation surveys which typically include interest organisations, government officials or commodity and carbon traders, this survey focused solely on people that work in EU ETS companies. This unique feature offers the benefit of providing unfiltered insights into the role of carbon price expectations and the formation process. Overall, 20 respondents stated that they held a senior executive position in an EU ETS company, 14 respondents identified themselves as mid-level managers, 6 described themselves as general staff, 2 as other and 8 did not indicate in which position they worked.

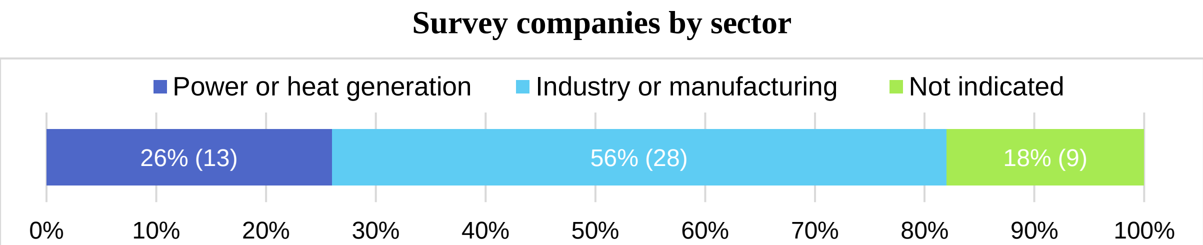

Figure 7: In what sector does your company operate? (n=50)

The majority of responses to the survey came from the industry or manufacturing sector as figure 7 shows. Responses from representatives of power or heat generation companies amounted to about half as many. Not every business sector is treated equally or affected equally by the EU ETS which is why the sector affiliation can play an important role in the carbon price expectation formation process. One distinction for example is that power and heat generation companies have to pay for all of their pollution permits (European Union

Allowances) whereas companies from the industry and manufacturing sector receive free allowances depending on the risk of carbon leakage.

Survey companies by environmental impact - required EU Allowances

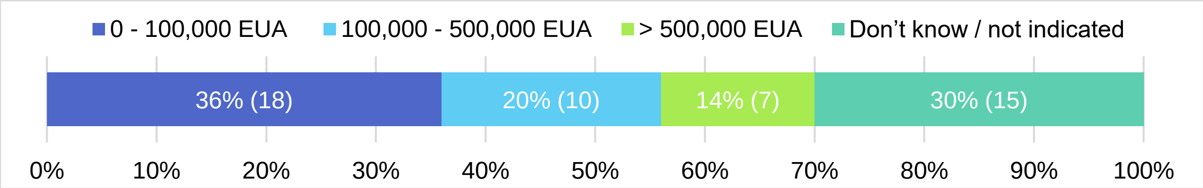

Figure 8: How many EU Allowances did your company require last year to cover its emissions? (n=50)

A further variable that was gathered to assess the environmental impact of the surveyed companies was the amount of European Union Allowances that the companies required to cover their emissions. For the emission of one tonne of carbon or carbon equivalent, a company needs to surrender one permit. About one-third of respondents did not know or did not want to indicate the number of EUA as figure 8 illustrates. Most responses came from companies that required up to 100,000 pollution permits (18). 20% fell into the category 100,000 - 500,000 EUA and the smallest group of respondents can be described as very significant emitters with carbon emissions of over 500,000 tonnes of CO_2 equivalent per year. To put this in perspective, the average Austrian citizen produces 7 tonnes of CO_2 equivalent per year and Austria's combined greenhouse gas emissions amounted to 73.6 million tonnes of CO_2 equivalent in 2020 (Umweltbundesamt GmbH 2022).

5.2 The Relevance of Carbon Prices

The following survey questions aimed to shed light on the relevance of carbon prices for companies. With the implementation of a carbon pricing instrument, policymakers intend to accomplish a shift from carbon-intensive production to climate friendly-energy sources and technology. In theory, the carbon price should lead to decarbonisation through a change in company behaviour. The responses from practitioners in EU ETS compliance companies provide an insight into whether the theory also applies in reality.

Strong support for carbon pricing as an instrument against climate change

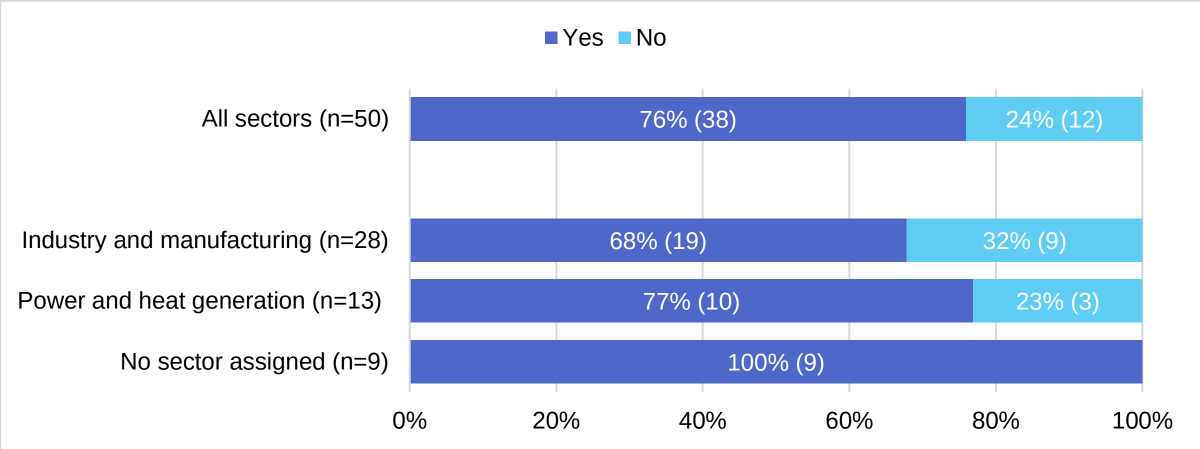

Figure 9: Do you think carbon pricing is an effective instrument to tackle climate change?

The survey results show that representatives from EU ETS companies see carbon pricing as an effective instrument in the fight against climate change. Three-quarters of respondents shared the notion that carbon pricing represents an effective instrument for decarbonisation. Splitting the results into sectors as in figure 9 reveals slight differences in opinions. Respondents from the power and heat generation sector reacted more positively to carbon pricing than respondents from the industry and manufacturing sector. The most obvious explanation for this divergence is that the power and heat generation sector managed to reduce its emissions markedly, on average -5.6% annually since 2013 (ERCST et al. 2021, p. 11). Industry and manufacturing on the other hand did not register any significant abatement until 2020, a circumstance which can be traced back to the free allocation of permits.

Relevance of future carbon prices for investment decisions

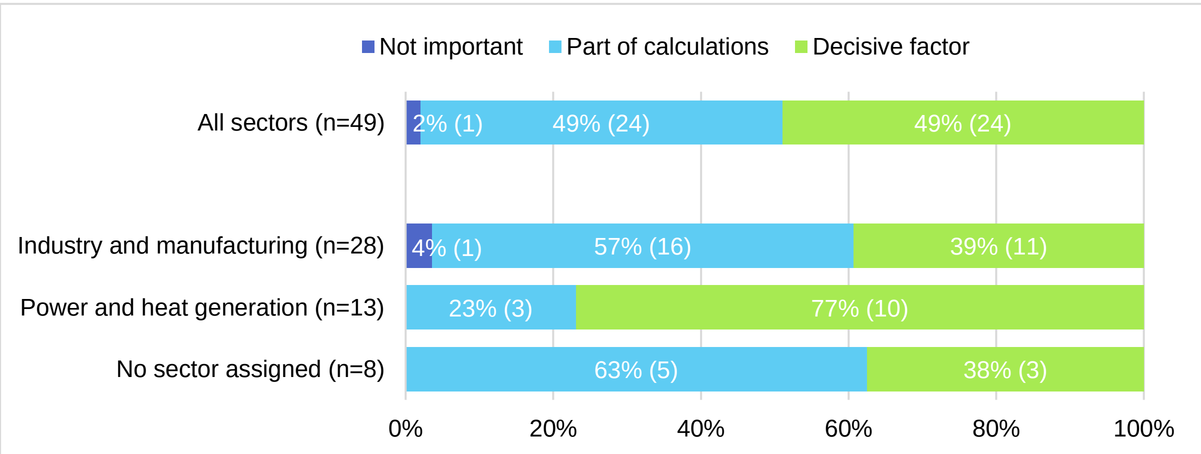

Figure 10:How important are future carbon prices for your company's investment decisions today?

Asked directly about the importance of future carbon prices for their current investment decisions, respondents could select one of three options: not important, part of calculations or decisive factor. Viewed from a company perspective, carbon prices represent operation costs. For long-term planning, companies have to estimate future carbon prices in their calculations as prices evolve over time. In principle, investments in the energy and industrial sectors have long time horizons which is why future prices can affect the profitability of a project. Depending on the expected price of carbon, the inclusion of the carbon variable can be negligible or decisive for the outcome of an investment decision.

Half of all survey respondents indicated that they viewed future carbon prices as a decisive factor in investment decisions. This implies that for the respective companies, carbon prices have a strong steering effect. 49% of respondents said that future carbon prices are a part of calculations for current investment decisions as figure 10 shows. Only 2% of respondents reported that future carbon prices were not important. Once again, a split between sectors can be observed, with permit costs having a higher relevance for the energy sector than for the industrial sector. Overall, responses show that expected carbon prices play a prominent role in investment calculations, especially in the energy sector.

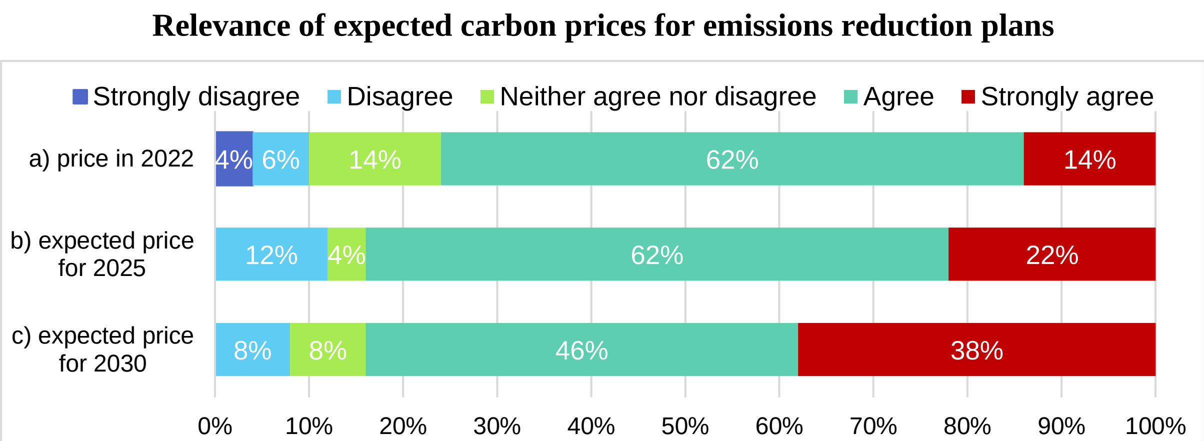

Figure 11: Please indicate to what extent you agree with the following statements: The a) carbon price in 2022, b) expected carbon price for 2025, c) expected carbon price for 2030 affects my company's emissions reduction plans. (n=50)

In the final question on the relevance of carbon prices, illustrated in figure 11, respondents were asked to indicate how much they agreed with statements that described the effect of carbon prices on their company's emissions reduction plans. Although the question can be considered similar to the previous one, the environmental viewpoint of the question provides an alternative angle on the topic. Moreover, it distinguishes the influence of prices from different time horizons. A first look at the results reveals that an overwhelming majority of respondents agree or strongly agree with the statement that carbon prices affect emissions reduction plans regardless of the time horizon. About three-quarters of respondents reacted affirmatively to the statement that the current price (price of 2022) affects emissions reductions. One-tenth disagreed or strongly disagreed with the statement whereas 14% neither disagreed nor agreed. Looking at sub-questions b) and c) the results show that the expected prices for 2025 and 2030 are more important for emissions reductions than the current price. For instance, the share of respondents that strongly agreed with the relevance of carbon prices for decarbonisation plans was almost three times higher for prices expected for 2030 (38%) than for current prices (14%). This observation is noteworthy as it highlights the importance of carbon price expectations for decarbonisation efforts.

5.3 Carbon Price Determinants

How do companies estimate how much they have to pay for their emissions in five or ten years? A crucial question for understanding how carbon price expectations are formed is what factors or variables are included in the expectation formation process. The survey results presented in this section explain which price determinants companies deem to be the most relevant and what variables are associated with the greatest uncertainty.

Importance of carbon price determinants in the EU ETS (low 0-10 high)

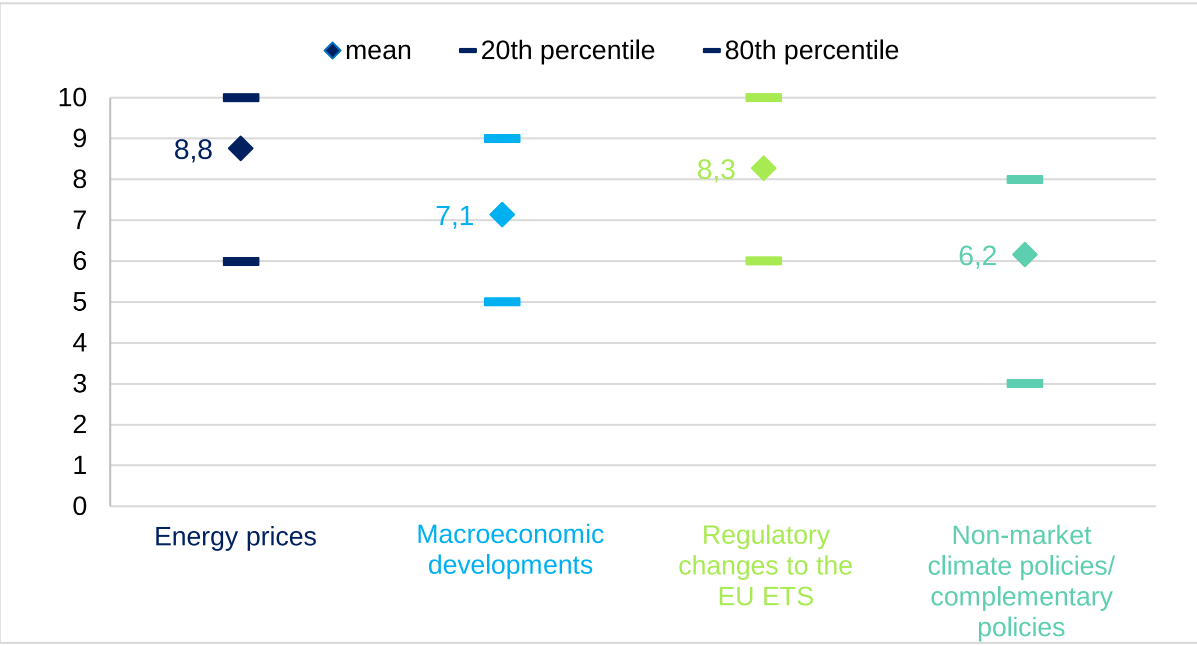

Figure 12: In your opinion, how important are the following carbon price determinants in the EU ETS? (low 0-10 high; n=45)

To gain an insight into the importance of different carbon price determinants in the EU ETS, survey participants were asked to rate four factors on a scale of zero to ten (figure 12). With a mean score of 8.8 out of 10, respondents rated energy prices as the most important carbon price driver in the EU ETS. Regulatory changes to the EU ETS were considered only slightly less relevant. Macroeconomic developments ranked third behind energy prices and ETS changes, however with a still high mean score of 7.1 out of 10. Non-market climate policies/complementary policies were regarded as the least important out of all options. In general, the importance of all price determinants was rated relatively highly by survey respondents. This does not come as a surprise because the survey question included only factors that were selected based on academic knowledge about influential price drivers. With this in mind, it can be asserted that academic researchers and practitioners have a very similar assessment of market conditions. Besides this finding, the survey results provide a ranking of the most important factors. Scholars disagree on which factor influences carbon prices in emissions trading systems the most. The results indicate that energy prices trump all other factors in relevance although institutional design issues come close in second place. Interestingly, climate policies that do not lead to any design changes in the EU ETS received noteworthy scores in the survey. This can be explained by the fact that complementary climate policies can change business-as-usual emissions and thereby they lower the demand for emission allowances.

Regulatory proposals for the EU ETS that influence carbon price expectations

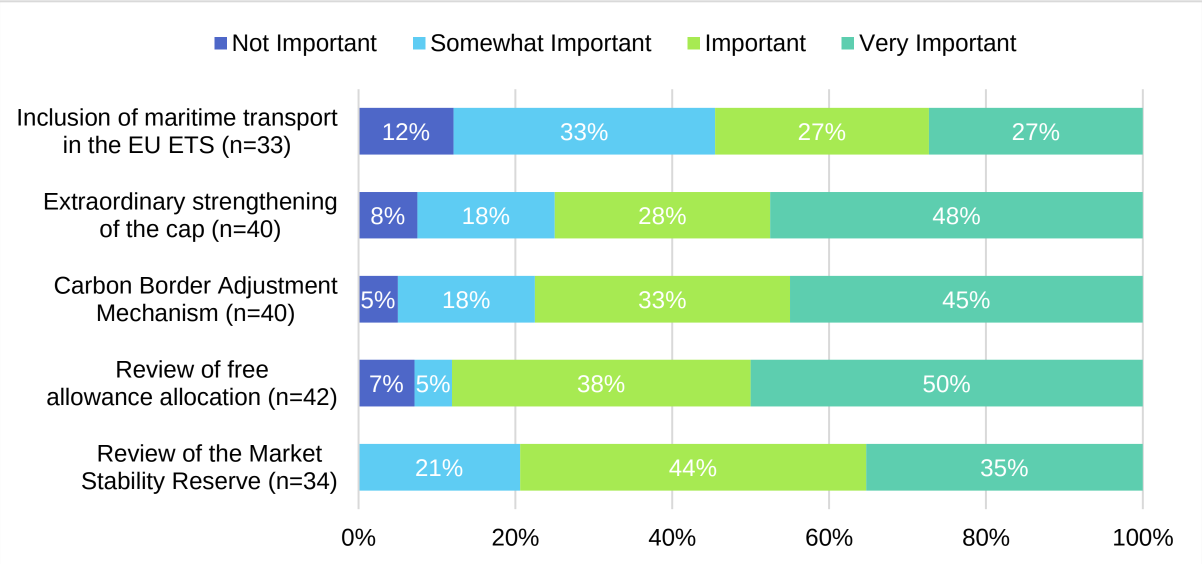

Figure 13: In your opinion, how important are the following proposed policies for the formation of carbon price expectations in the EU ETS?

Regulatory changes to the EU ETS represent an essential factor for the formation of carbon price expectations as the previous question has proved. Considering the European Union has continuously adapted its emissions trading system to make it more robust and functional, further changes can be expected in the future. Moreover, increased climate targets further advanced the need for reform which is why the EU Commission has proposed a range of policies as described in section 2.5 and summarised in figure 13. When, and to what extent those policies will be implemented remains to be seen. Respondents were asked to share their views on the importance of various policy proposals for their expectations of carbon prices.

Generally, one can observe that most respondents agreed that all proposed policies are at least somewhat important to their expectations. The least relevant regulatory proposal according to respondents is the inclusion of maritime transport into the system. More than one in ten rated the proposal as not important and a third of the participants said that it was only somewhat important. The review of free allowance allocation to industrial and manufacturing companies was considered to be the most influential policy for the formation of carbon price expectations. Half of all respondents stated that a change to the free allocation rules plays a very important role to expectations and 38% described it as important. The high rating is interesting as a change of allocation rules does not alter the total number of emission certificates in the market. However, a decline in free allowances would increase the number of allowances available for auctions and more importantly it would mean that industrial companies must pay for more (or all) allowances which would drastically increase their costs. The Carbon Border Adjustment Mechanism, effectively a carbon border tax, was also rated very influential for price expectations. Although strictly speaking it depicts a separate instrument created against carbon leakage, its implementation could lead to a cancellation of free allowances or cost support measures which were granted to counteract international competitive disadvantages. Somewhat surprising is that respondents did not rate the extraordinary strengthening of the cap or the review of the MSR as most important policies. Both proposed measures would directly influence the supply of allowances and would therefore have an immediate effect on the price. One explanation for the rating might be that respondents already have clear expectations of how the policies will be implemented and therefore their relevance for the formation of price expectations decreases.

Greatest uncertainty factors for carbon price expectations

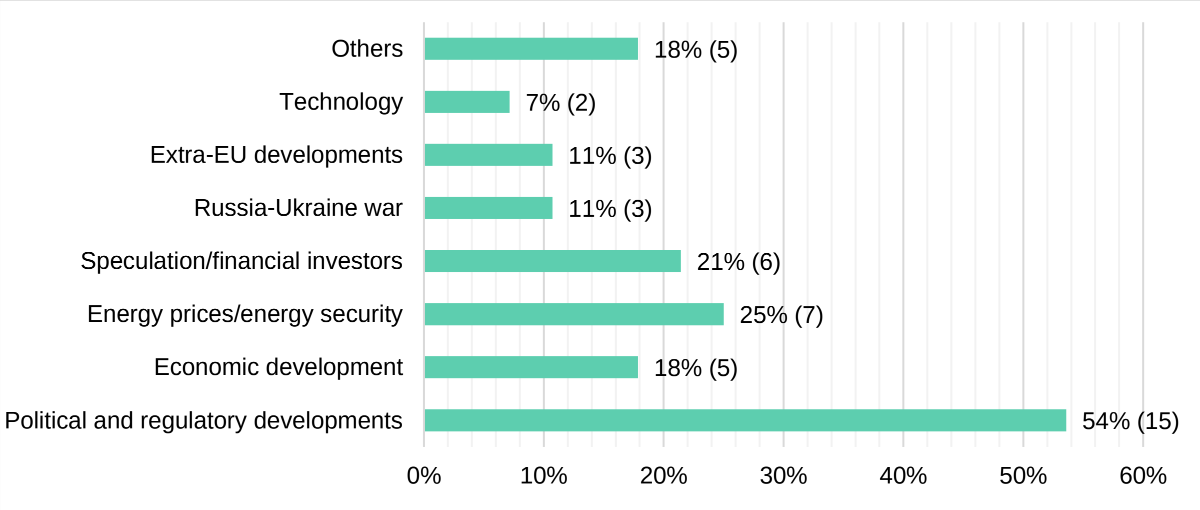

Figure 14: What do you think are the greatest uncertainties for forming carbon price expectations? (n=28)

Previous questions already focused on the relevance of various price drivers. To assess what factors are associated with the greatest uncertainty for the formation of carbon price expectations, participants of the survey were asked to answer an open-ended question. On the basis of clarity and meaningful evaluation, the responses were grouped into eight categories as illustrated in figure 14. Some answers included multiple factors which is why the percentages do not add up to one hundred. Out of all factors, political and regulatory developments were by far the most frequently mentioned. More than half of all respondents indicated that political interventions and regulatory developments are a factor of great uncertainty. This puts the category far ahead of other fundamental price drivers like energy prices and economic development. According to the UN-facilitated High-level Commission on Carbon Prices, carbon prices need to increase to achieve decarbonisation but policies should be “predictably flexible” to be most effective (Stern and Stiglitz 2017, p. 4). The market sentiment gathered by this survey does not match the ideal conditions of “predictably flexible”, respondents rather described political and regulatory developments as great uncertainties. A broad understanding of the urgency of climate action among EU states and political parties and a clear roadmap for decarbonisation would certainly facilitate the accurate estimation of future carbon prices.

About a quarter of respondents mentioned energy prices and energy security as great uncertainties for the formation of carbon price expectations. Thereby the “energy price development”, the “relationship of energy prices of different energy sources”, the “security of fossil fuel supply within the EU” and the “dependence on gas supplies from Russia” were raised among other issues. Energy security was also linked with the Russia-Ukraine war, another source of uncertainty brought up by respondents. Surprisingly, 6 out of 28 answers cited speculation and financial investors as a source of great uncertainty. This puts the category even ahead of economic development in the frequency of mentions. However, data from the European Securities and Markets Authority refutes the argument of speculation as an influential price driver (European Securities and Markets Authority 2021). Financial investors that are purely active in the market for financial gains only hold a tiny share of emission certificates and derivatives thereof whereas compliance companies own the vast majority. The remaining amount of allowances is held by banks, funds and investment firms which also take part in the market but unlike “speculators” they provide valuable services like hedging against price fluctuations or the provision of market liquidity. Therefore, speculation has at best a short-term price impact but cannot be considered a long-term price driver (Flues and van Dender 2020, p. 19). Public clarification of the influence of financial actors on allowance prices could reduce uncertainty in this area. Further areas of great uncertainty mentioned by respondents were developments outside the EU, for example, carbon prices in other countries or the “verification of offset measures”, and technology, for example the “maturity of decarbonisation technologies”.

5.4 Information Management and Methods

Having analysed the central determinants for the formation of expectations, this last survey section outlines the results of how companies acquire, and process information about the factors. Thereby, the role of various information sources, methods, external consulting and the frequency of expectation updates were surveyed. At the end of this question set, the company’s carbon price expectations for 2025 and 2030 are presented before a conclusion is drawn in the final section.

Information Sources

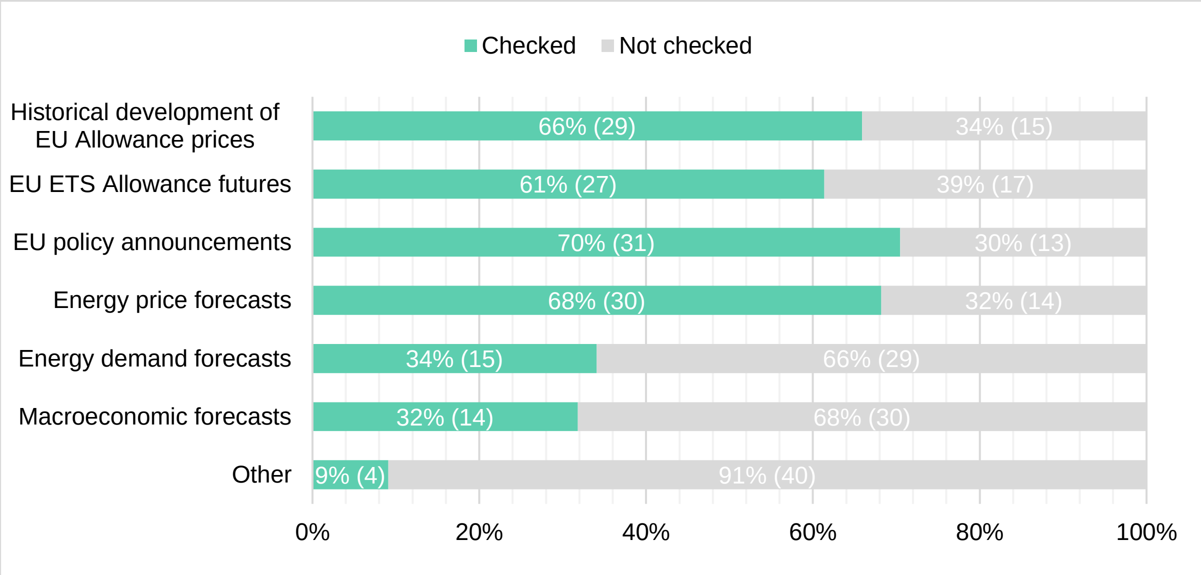

Figure 15: Which of the following information sources does your company use to form medium to long-term carbon price expectations? (n=44)

Respondents rated the historical development of allowance prices, allowance futures, EU policy announcements and energy price forecasts as the most important sources of information for medium to long-term carbon price expectations (figure 15). As described in section 3.2 "Methods in Expectation Formation", expectations are formed by combining new information about the future with the extrapolation of historical data (Kahneman and Tversky 1972; Gennaioli et al. 2016). Insofar it is surprising that while two-thirds of respondents draw on historical EUA prices, one-third said that they do not resort to the information source. One explanation for this result is that the EU ETS market is fast-moving and marked by structural breaks which arise from policy interventions. For this reason, historical price developments are less meaningful for the formation of medium to long-term expectations than in other markets.

Besides historical prices, the price of carbon futures offers a useful information source. 61% of respondents indicated that they look at EUA futures. This is because futures, which are used for hedging or speculation, reflect market expectations about future prices. With 70%, EU policy announcements were the most often selected information source by respondents. The result corresponds with the survey finding of uncertainty factors which described political and regulatory developments as the greatest uncertainties. Accordingly, it can be stated that political announcements have a decisive influence on the formation of expectations. Respondents almost equally often selected energy price forecasts as an information source which does not come as a surprise as energy prices are a fundamental carbon price driver. On the contrary, the relatively minor importance of macroeconomic forecasts, indicated by only a third of respondents as an information source, was unexpected.

Methods of expectation formation

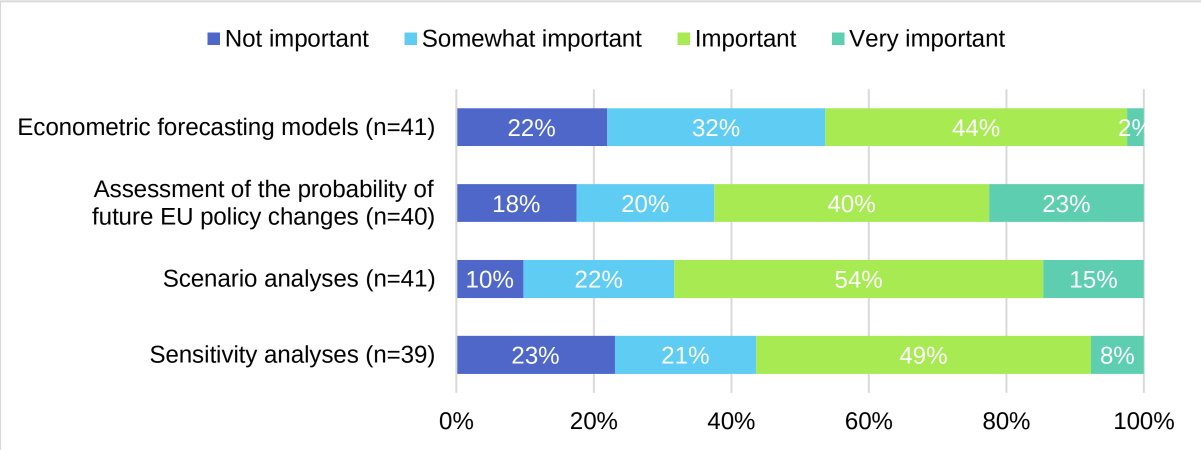

Figure 16: How important are the following methods for your company to predict medium to long-term carbon prices?

The results of the question about methods used to estimate medium to long-term carbon prices show a relatively similar rating of econometric forecasting models, the probability assessment of policy changes, scenario analyses and sensitivity analyses (figure 16). This indicates that practitioners apply various models and that there is no clear preference in the industry for a certain method. Overall, the vast majority of respondents said that all models are at least somewhat important. On average only about one-fifth described the methods as not important. However, differences can be observed regarding the classification as very important. 23% said that the probability assessment of future EU policy changes is very important while only 2% described econometric forecasting models as such. This comparably low rating of econometric forecasting models can be explained by the phrasing of the question which explicitly refers to medium to long-term expectations. For this time horizon, historical price developments are less meaningful whereas policy interventions have a greater weight. Importantly, the likelihood assessment of policy changes is strongly based on beliefs which, as described earlier, are not perfectly rational but are prone to bias.

Furthermore, survey participants were asked to indicate what specific model their company employs. Unfortunately, this question drew only a few responses. One respondent reported that they use a model from an external consulting firm. Two others said that they developed their own model to predict carbon prices.

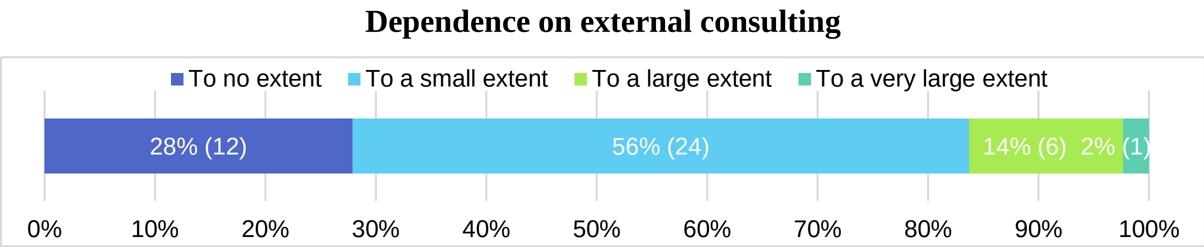

Figure 17: To what extent does your company rely on external consulting to form carbon price expectations? (n=43)

Asked to what extent their companies rely on external consulting to form carbon price expectations, the large majority of respondents reported that external consulting does not play an important role in its processes (figure 17). 56% said that their companies use external consulting to a small extent while 28% indicated that the whole expectation formation process is performed in-house. Combined, only 16% of companies adopt external consulting to a large or very large extent according to the survey. Overall, the results imply that there is a high level of expertise in the companies, which reduces the importance of external consultants.

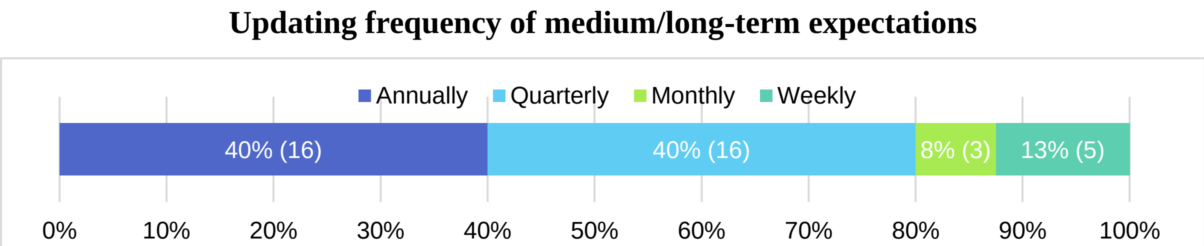

Figure 18: How often does your company update medium to long-term carbon price expectations? (n=40)

Contrary to what the rational expectation hypothesis would suggest, expectations are not constantly updated by companies. While one-fifth of respondents said that their companies revise medium to long-term expectations weekly or monthly, 80% indicated that their companies review expectations less often (figure 18). Of that 80%, half reported an updating frequency of one quarter and the other half of one year. As described earlier, the reason for this information rigidity is that the acquisition and incorporation of new information into expectations are costly (Coibion and Gorodnichenko 2015).

Historical and expected carbon prices in the EU ETS

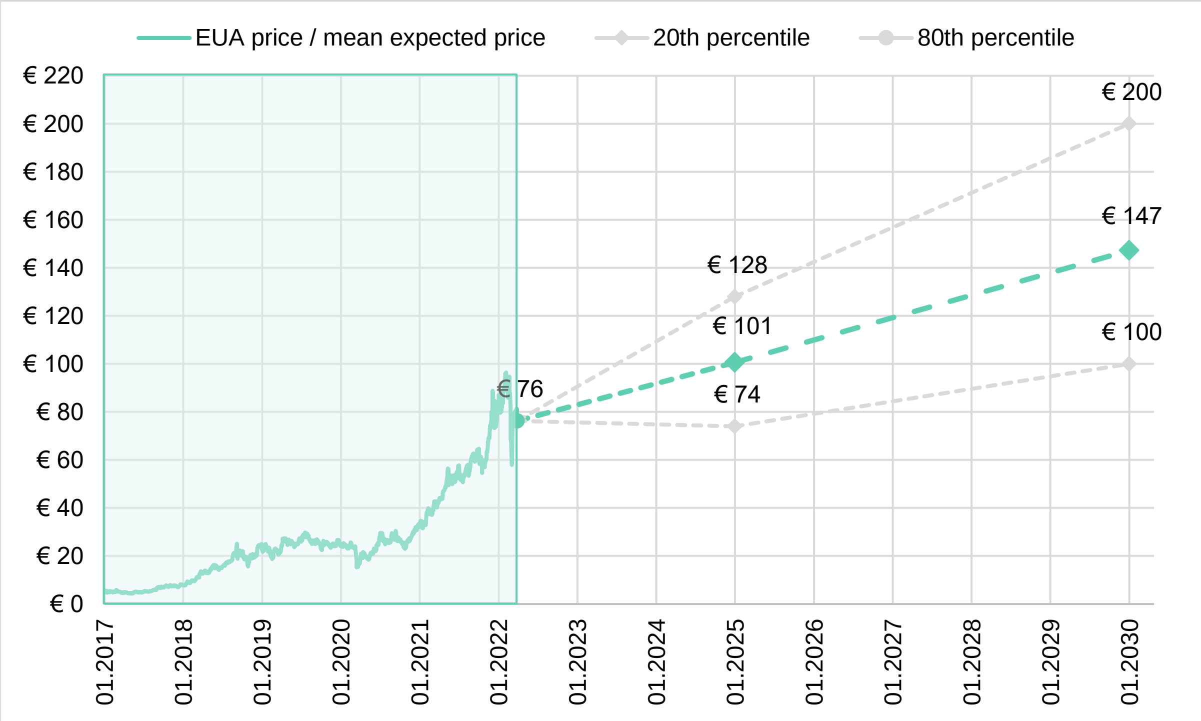

Figure 19: What do you think will be the price of EU Allowances in 2025 and in 2030? (n=38; source of historical carbon prices: International Carbon Action Partnership 2022)

After questioning survey participants about the formation of price expectations, they were asked to disclose their expectations for the carbon price in 2025 and 2030. Two critical developments can be observed from the results, illustrated in figure 19. First, on average, the carbon price is expected to significantly increase over the decade. The current price (31.3.2022) of EUR 76 tonne/CO_2 is on average expected to rise to EUR 101 tonne/CO_2 in 2015 (+33%) and to EUR 147 tonne/CO_2 in 2030 (+93%). Thus, on average, respondents expect the allowance price to almost double by 2030. Second, the expectations show a great variance that increases over time. For 2025 the 20^{th} and 80^{th} percentiles are EUR 54 apart and for 2030 even EUR 100. The standard deviations of expectations for 2025 and 2030 are EUR 30 and EUR 54 respectively. Overall, this implies that the price level remains highly uncertain.

The average expected prices are roughly in line with analysts' predictions. A Reuters survey of seven analysts showed that carbon price forecasts averaged EUR 94 for 2024 (Reuters 2022). BloombergNEF, Bloomberg's research outlet, predicted a price of EUR 108 for 2030 (Bloomberg 2021). Compared with price recommendations required for decarbonisation in line with the Paris Agreement, the average surveyed price expectations are promising from an environmental viewpoint. The price of EUR 147 tonne/CO_2 even exceeds the estimated prices of the High-Level Commission on Carbon Prices (USD 50-100 tonne/CO_2 by 2030) and the OECD (EUR 120 tonne/CO_2 by 2030) (Stern and Stiglitz 2017; OECD 2021b). What dampens confidence in rapid decarbonisation is the great uncertainty surrounding the future price. As mentioned before, research has shown that price uncertainty harms decarbonisation efforts (Hoel 2010; Xu et al. 2019; Flues and van Dender 2020; European Commission 2021b)

6 Conclusion

It is clear that climate change represents a serious threat to humanity and bold action is required to limit the world‘s temperature increase. From an economic viewpoint, a central issue that fuelled the exploitation of fossil energy sources is that the true cost of fossil fuels, which includes the damage brought about by emissions, is not reflected in prices. To correct this pervasive market failure, policymakers have sought to internalise emission costs by putting a price on carbon. This thesis highlighted the significance of expectations with respect to carbon prices in the EU Emissions Trading System. Besides a strong price signal in the present, a predictable carbon-price trajectory in the future is required to drive decarbonisation as investments in the energy and industrial sectors have long time horizons. Both uncertainty about future emission costs and an underestimation of carbon prices reduce the incentive to switch to clean energy and technology. Therefore, it is imperative to understand the carbon market forces, as a failure to do so could have negative environmental and economic effects.

This thesis set out to investigate how companies in the EU ETS form carbon price expectations. An online survey among senior executives, managers and professionals of sustainability or energy-related departments of EU ETS companies was conducted to receive unfiltered insights from practitioners. The survey, consisting of quantitative and qualitative questions, garnered 50 responses, primarily from Austria and Germany. The results demonstrated the great magnitude of estimated future carbon prices for investments and decarbonisation plans. Half of the respondents indicated that expected carbon prices play a decisive factor in investment decisions whereas for the other half they are at least part of calculations. Differences could be observed between the energy and the industrial sector, whereby the latter reacted slightly more sceptically to carbon pricing. Moreover, the survey showed that expected prices are more important for corporate emissions reduction plans than current ones.

A crucial question for understanding how carbon price expectations are formed is what variables are included in the expectation formation process. The findings suggest that energy prices represent the most influential price determinant, with regulatory changes to the EU ETS being almost equally significant and macroeconomic developments occupying the third place in relevance. Complementary climate policies that do not alter the EU ETS but influence business as usual emissions also play a substantial role. The results are largely consistent with those of other studies that tried to disentangle carbon price drivers. Looking specifically at the relevance of proposed EU ETS policies for price expectations, one unanticipated finding was that the review of free allowance allocation was rated the most important. However, the introduction of the Carbon Border Adjustment Mechanism, the proposed review of the Market Stability Reserve and the extraordinary strengthening of the cap were also described as influential on expectations. In general, respondents cited political and regulatory developments as the greatest uncertainties regarding future prices, way ahead of other fundamental price drivers. Thus, the market sentiment identified in this survey does not correspond to the ideal conditions of "predictably flexible" prices (Stern and Stiglitz 2017, p. 4).

Regarding the processing of information, the findings imply that various methods are employed to form expectations. This includes econometric forecasting models, sensitivity analyses, scenario analyses and probability assessments of future EU policy changes. The latter two methods, which are strongly based on beliefs and prone to bias, occupy a more prominent role for long-term expectations, while historical price developments are less meaningful for this due to structural price breaks. Another interesting finding is that most companies largely rely on in-house expertise to form expectations, though four-fifth of the surveyed companies updates long-term expectations only quarterly or annually. Lastly, respondents on average estimate a significant carbon price rise to EUR 101 tonne/CO_2 in 2015 and to EUR 147 tonne/CO_2 in 2030. Importantly, the expected prices show a large variance that increases over time. Compared with price recommendations required for decarbonisation in line with the Paris Agreement, the average surveyed price expectations are promising from an environmental viewpoint but the great uncertainty surrounding the future price harms decarbonisation efforts.

What needs to be acknowledged is the possible bias in survey responses and the relatively small sample. Further research should expand the sample to gain more insights into carbon expectations. Nevertheless, this thesis contributes to the understanding of the carbon market in Europe, and it gives EU ETS stakeholders an indication of how companies estimate future carbon prices. Taken together the results suggest that more political and regulatory certainty on carbon prices, through a broad understanding of the urgency of climate action, would be beneficial for the decarbonisation process.

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