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**Book**

# EU emissions trading : policy-induced innovation, or business as usual? : findings from company case studies in the Republic of Croatia

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# EU Emissions Trading: Policy-Induced Innovation, or Business as Usual? Findings from Company Case Studies in the Republic of Croatia

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**EU Emissions Trading: Policy-Induced Innovation, or Business as Usual?**
**Findings from Company Case Studies in the Republic of Croatia**


## Abstract

The European Union Emissions Trading Scheme (EU ETS), while primarily designed to reduce greenhouse gas emissions in an effective and efficient way, is supposed to serve as an instrument promoting investments in clean, low-carbon technologies by way of incentivizing associated innovation activity. Since empirical results concerning the instrument´s capacity of reaching this secondary policy goal are rare, this paper examines the innovation impact of the EU ETS among emissions-intensive companies in the Republic of Croatia. To this end the effects of the instrument on research, development and demonstration (RD&D), adoption, and organizational change are examined. The study accounts for the impacts of various context factors, including firm-external and firm-internal variables. The empirical analysis employs a multiple case study approach. While findings support the assertion that policy-induced innovation effects arise from the pricing of carbon, the innovation-fostering capacity of the instrument remains limited due to continued low levels of policy stringency and predictability. Long-term expectations of market actors appear to play a decisive role in decisions surrounding innovation activity, suggesting that signals of policy commitment are highly influential.



**Keywords:** European Union, emissions trading, Croatia, carbon, climate policy

**JEL classification:** O31, Q58

**Trgovina emisijama u Europskoj uniji: Potiču li klimatske politike inovacije?**
**Studija slučaja hrvatskih poduzeća**


**Sažetak**

Program trgovanja emisijskim jedinicama u Europskoj uniji (EU ETS), iako je razvijen prvenstveno s ciljem efektivnog i efikasnog smanjenja emisije stakleničkih plinova, koristi se kao alat kojim se potiču investicije u ekološki čiste tehnologije s niskim emisijama ugljičnog dioksida, promicanjem srodnih inovacijskih aktivnosti. Budući da postoje rijetki empirijski podaci o uspješnosti ovog alata u postizanju tog sekundarnog cilja, ovim se radom istražuje utjecaj programa EU ETS na inovacije u hrvatskim poduzećima s velikim emisijama stakleničkih plinova. Analiziraju se učinci ovog alata na aktivnosti istraživanja, razvoja i demonstracije (RD&D), usvajanja tehnologija i organizacijske promjene. Istraživanje uzima u obzir razne kontekstualne faktore koji utječu interno i eksterno na poduzeće, odnosno interne i vanjske varijable. Empirijska analiza provodi se metodom višestruke studije slučaja. Dok rezultati potvrđuju da na inovacijski učinak utječe cijena ugljika, učinak u smislu promicanja inovacija ostaje ograničen zbog nedovoljno strogih i predvidljivih politika. Dugoročna očekivanja sudionika na tržištu igraju veliku ulogu kod donošenja odluka o inovacijskim aktivnostima, što sugerira da je dosljednost u provođenju politika od velike važnosti.



**Ključne riječi:** Europska unija, trgovanje emisijama, Hrvatska, ugljik, klimatska politika

**JEL klasifikacija:** O31, Q58

## 1. Introduction[1]

In recent decades, the political appreciation for concerted efforts to reduce man-made pollution in order to curb climate change has grown significantly (UNFCCC, 1992). This tendency can be observed in the global efforts to determine climate action beyond the Kyoto Protocol (UNFCCC, 1997), in the realization of several policies aimed at increased environmental sustainability across a substantial number of countries (IEA, 2009), and not least in the recent Paris Agreement (UNFCCC, 2015), which as of now has been ratified by 145 parties, effectively surpassing the necessary threshold for its implementation.[2]

One major development in international climate action was the consideration of emissions trading as an effective vehicle in tackling excessive emissions levels (UNFCCC, 1997). Despite initial skepticism[3] towards emissions trading (Christiansen & Wettestad, 2003), the European Union (EU) has emerged as a frontrunner in terms of establishing a market for emissions (ibid.). In 2003 the EU established its Emissions Trading Scheme (ETS) via Directive 2003/87/EC (from here on *the Directive*). In 2005 the instrument launched. It holds the title for the world´s largest emissions trading program[4] spanning the 28 EU member states, Iceland, Liechtenstein and Norway, covering over 12,000 installations and 1,300 airline operators[5], responsible for approximately 45 percent of the Union´s total annual greenhouse gas (GHG) emissions[6]. Its hitherto 12-year period of operation has been divided into three phases, with its fourth phase commencing in 2021. Each successive phase has brought about more or less significant changes, with its current phase generally being regarded as the most stringent yet.

According to Article 1 of the Directive, the primary policy goal of the EU ETS is *"to promote reductions of greenhouse gas emissions in a cost-effective and economically efficient manner"*. However, the scheme also aims at promoting *"investments in clean, low-carbon technologies"*[7] and incentivizing associated innovation activity (EU, 2005). The crucial

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[1] This work is part of the master´s thesis "EU Emissions Trading: Policy-Induced Innovation, or Business as Usual? Findings from Company Case Studies in the Republic of Croatia" which was conducted within the study program of "European Governance". As a guest researcher, author Martin Larsson carried out this research at the Institute of Economics, Zagreb during the period between March 1, 2017 and June 30, 2017.

[2] UNFCCC (2017, May 8). *"Paris Agreement – Status of Ratification"*. Retrieved from http://unfccc.int/paris_agreement/items/9444.php (10.05.2017).

[3] Christiansen and Wettestad (2003) provide a comprehensive analysis of this topic.

[4] EU (2017, May 8). *"The EU Emissions Trading System (EU ETS)"*. Retrieved from https://ec.europa.eu/clima/policies/ets/pre2013_en (10.05.2017).

[5] EEA (2017, May 4). *"EU Emissions Trading System (ETS) data Viewer"*. Retrieved from https://www.eea.europa.eu/data-and-maps/data/data-viewers/emissions-trading-viewer-1 (15.05.2017).

[6] Supra, note 3.

[7] Supra, note 3.

importance of the development, demonstration and adoption of state-of-the-art low-carbon technologies has been acknowledged by several authors (IPCC, 2007; Kneese & Schultze, 1975; Orr, 1976; Stern, 2006) claiming that the provision of incentives for such measures should be considered a crucial component of environmental policy, if sharp decreases in emissions levels are to be achieved, with Kneese and Schultze (1975, p. 82) positing that:

*"Over the long haul, perhaps the single most important criterion to judge environmental policies is the extent to which they spur new technology towards the efficient conservation of environmental quality."*

Therefore, this research seeks to shed light on whether such innovation-inducing effects are in fact observable, what role the design features of the EU ETS play in achieving such effects, how the respective mechanisms associated with the EU ETS influence innovation activity, and what type of innovations are most likely to emerge. The research seeks to contribute to the empirical literature by offering insights into the innovation impacts of the EU ETS during its current trading phase, and focuses on the Republic of Croatia, which did not join the EU ETS until its third phase was in effect.

In order to answer the research questions this work takes the following approach: section 2 will highlight the analytical fundamentals of environmental policy´s nexus with technological change, and provide detailed insights into the specific policy instrument under investigation, including its most significant reformations over time. It also entails an extensive review of the available literature on links between environmental regulation and innovation, and briefly revisits the relevance of this research by identifying the current limits of that literature and potential gaps therein. Section 3 introduces the theoretical focus of this study by delineating and explaining the fundamentals of environmental economics and the economics of technological change, which constitute the very foundation of this thesis. Based on the review of the theoretical underpinnings, a reliable research framework guiding the empirical component of this work will be constructed. Section 4 addresses the methodological approach chosen for the empirical investigation of the issue at hand by explaining choices relating to the research design, including the justification of a multiple case study design, the underlying reasoning for the specific selection of cases, as well as the choice of data collection and data analysis methods and techniques. This section concludes by addressing concerns related to the validity and reliability of this study, and by presenting some of the difficulties experienced during the conduct of this work. The study´s findings are presented in section 5, including the discussion of relative influences of explanatory variables. Section 6 concludes the work, and includes implications for society and academia, policy recommendations and recommendations for potential future research.

## 2. Background

### 2.1. Analytical Fundamentals

Environmental economics, and by extension the evaluation of environmental policy, is mainly concerned with the idea of externalities. The concept refers to environmentally harmful consequences of economic activity, negative externalities, imposing costs, which at least partially are being borne by another party than the one responsible for the creation thereof (Jaffe et al., 2005). Due to the circumstance that the polluter does not bear the cost associated with pollution, there are no economic incentives to minimize it, causing underinvestment in abatement technology (Popp, 2010), and thus an oversupply of pollution. Environmental policy attempts to increase these incentives, either via the internalization of the environmental cost by way of market-based policy instruments, such as emissions trading or emissions taxes, or via so-called command and control instruments, such as emissions standards or prescribed technologies or processes (ibid.).

A substantial body of theoretical literature has attempted to rank these different policy instruments with respect to their capacities of providing such incentives[8]. Downing and White (1986) and Milliman and Prince (1989) provided the basis for further attempts in this direction by the likes of Jung et al. (1996) amongst others (Gagelmann & Frondel, 2005). These early studies can be credited with the emergence of a long-held belief that market-based policy instruments are generally superior to direct regulation regarding their abilities to induce technological change, with auctioned permits seemingly providing the largest incentives (Milliman & Prince, 1989; Jung et al. 1996). However, later studies not only challenged the notion that market-based instruments provide superior innovation incentives to conventional command and control policies (Montero, 2002; Fischer et al., 2003), but also the superiority of permit trading within the category of market-based instruments (Keohane, 1999; Schwarze, 2001; Requate & Unold, 2003). It is, however, to be kept in mind that the underlying assumptions of the models used to arrive at these conclusions are as diverse as their results.

[8] For a comprehensive review see Requate (2005).

Although environmental externalities are prominently featured throughout environmental economics, and pose an intuitive starting point for the examination of lacking pollution control incentives, technological change with a view to eco-innovation is characterized by what has been referred to as the *double externality problem* (Rennings, 2000; Jaffe et al., 2005).

The economics of technology suggest that technological change suffers from so-called knowledge externalities (Griliches, 1992; Jaffe et al., 2003; Jaffe et al., 2005). While pollution is considered a negative externality, causing the market to overproduce it, technology on the other hand poses a positive externality, causing the market to underproduce it. Investments in new technology tend to be a costly exercise, a fact overlooked by the static models referred to above. These costs are typically borne by the respective firm, while the benefits created can be reaped by others. This is due to the public-good qualities of novel knowledge. Although patents and some other institutions can serve a protecting function in terms of the dispersion of the benefits derived from investments in innovation, such protection is characterized as *inherently imperfect* by Jaffe et al. (2005, p. 167).

The double-externality remains at the core of deliberations concerning technology policies in the environmental domain. However, Jaffe et al. (2005) note that further market failures, concerning the adoption of new technologies and information inefficiencies, have entered the debate as of late. Despite its brevity, this introduction shows that markets tend to undersupply eco-innovation, and supports claims that environmental policies need to be geared towards fostering innovation. Furthermore, the intersection of market failures located at the nexus of environmental and technology economics solidifies the case for an integrated approach to the analysis of environmental policy, as furthered by Rennings (2000) and Jaffe et al. (2005).

The following sub-sections will provide some background information on emissions trading in general, the EU ETS specifically, and a review of the literature investigating the policy instruments performance with a view to innovation, before the succeeding sections will return to the theoretical focus of this study in greater detail.

## 2.2. Emissions Trading and the EU ETS

The concept of emissions trading emerged via Ronald Coase´s (1960) seminal work on social costs, which advocated the introduction of property rights to the debate surrounding environmental regulation, and laid the groundwork for escaping a lasting impasse caused by a fundamental disagreement between policy makers and economists (Tietenberg, 2006) regarding the approach to the overexploitation of common goods (Olstrom et al., 2002), such as our atmosphere. By letting markets play a more central role in the valuation of common goods, disadvantages associated with both command-and-control as well as taxation approaches to environmental regulation could be overcome in a cost-effective manner (Tietenberg, 2006). Dales (1968) later refined Coase´s (1960) approach, and is commonly credited with the development of emissions trading as we know it today.

Generally, emissions trading schemes involve limiting the collective emissions of a predefined population of emitters by setting a reduction target as compared to a chosen baseline. Covered emitters are then allocated a fraction of the collective total of emissions rights, also called allowances, which provide the right to emit one ton of carbon dioxide[9] (CO2). The allocation process generally takes the form of either freely allocated allowances, based on historic emission levels, or the acquisition of allowances takes place via auctioning. The collective emissions limit, or cap, is gradually reduced over time in order to achieve an overall reduction in emissions. The regulated entities then choose from a set of coping strategies. If individual emissions do not exceed the held allowances, excess allowances can be sold on the market. Conversely, if individual emissions exceed held allowances, additional ones can be bought. Companies with relatively low abatement costs will, based on a cost-savings rationale, reduce their emissions, while others, that face higher abatement costs, will choose to acquire additional allowances. Over the long run, the incentives to reduce emissions will increase due to increased allowance prices stemming from the continuous reduction of the cap.

The EU ETS, which lies at the core of this research, represents the world´s largest emissions trading scheme, and constitutes the most important example of tackling climate change issues via market-based policy instruments to date (Ellerman, Marcantonini & Zaklan, 2016). The scheme can be categorized as a classic cap-and-trade system (ibid.), as outlined above. However, its large dimensions regarding its geographic scope, the amount of covered installations and emissions sources, as well as its multinational nature contribute to its uniqueness. While its emergence can be considered somewhat of a surprise considering initial reservations of the EU towards emissions trading[10], the system has now been operational since 2005, covering almost half of the EU´s total GHG emissions. Its operation has been

[9] In case of other greenhouse gases, allowances cover one ton of CO2-equivalent. That is the amount of any given GHG, with the same global warming potential (GWP) as one ton of CO2 over 100 years.
[10] Supra, note 2.

divided into three phases, each of which has introduced more or less radical changes in the instrument´s design features, which as will be illuminated later, have significant implications for its impact on technological change.

During the EU ETS´s first phase, spanning three years between 2005 and 2007, only CO2 emissions from a very limited number of sectors were covered. Grandfathering, the distribution of emissions allowances free of charge, was by far the dominant allocation mechanism[11]. During this phase the national governments of participating states played the central role in determining the overall cap, as each member issued a National Allocation Plan (NAP). These plans in turn were mostly based on loose estimates, accounted for by the scarcity of reliable emissions data[12]. Initially, the European Commission had aimed at a total number of allowances short of so-called business-as-usual projections by requiring members to present NAPs, which signaled a credible commitment to reduction targets derived from the Kyoto Protocol (Wråke, Burtraw, Löfgren & Zetterberg, 2012). However, many members grossly overstated their needs for emissions allowances, contributing to widespread critique against the NAP procedure, as it was considered the driving force behind windfall profits in the electricity sector and distortionary effects on competition (Ellerman et al., 2016). Furthermore, the overallocation of allowances provoked allowance prices to hit zero in 2007[13], adding to the legitimacy of claims that the system was far too lax, consequently providing weak incentives for emissions reduction. However, this first phase was branded a pilot phase of "learning-by-doing" as a form of preparation for successive phases, and succeeded in establishing a carbon price as well as a marketplace for allowances within the EU, and allowed for the development of the necessary infrastructure in relation to monitoring, reporting and verification tasks.[14]

Although the second phase of the EU ETS, covering five years between 2008 and 2012, retained the NAP approach and reduced the share of freely allocated allowances by only 5 percentage points, from 95 percent to 90 percent (Ellerman et al., 2016), a number of important changes took place. Apart from the inclusion of nitrous oxide emissions, and the accession of Iceland, Liechtenstein and Norway to the program[15], concerns about the credibility of the EU ETS, based primarily on a potential reinforcement of extremely low allowance prices due to continued overallocation (Wråke et al., 2012), were met with a

[11] EU (12 May 2017). *"Phase 1 and 2 (2005-2012)"*. Retrieved from https://ec.europa.eu/clima/policies/ets/pre2013_en (16.05.2017).
[12] Supra, Note 10.
[13] Supra, Note 10.
[14] Supra, Note 10.
[15] Supra, Note 10.

comparatively drastic cap reduction by 6.5 percent compared to 2005[16] as well as tightened criteria for the approval of NAPs by the Commission (Wråke et al., 2012). Despite these efforts, the economic crisis of 2008 caused emissions levels to decrease beyond predictions, yet again causing an oversupply of allowances, which according to the EU[17] suppressed carbon prices throughout the phase. Nevertheless, Wråke et al. (2012) note that improvements in the availability and reliability of information surrounding emissions and allocation contributed to increased allowance price stability throughout that period, as compared to the rather high levels of volatility in the preceding phase.

The third phase of the scheme, which commenced in 2013 and will last until 2020, is the focus of attention of this work. This phase coincides with the accession of the Republic of Croatia to the EU, which took place in July 2013, and automatically made the country part of the EU ETS. Simultaneously this phase entails the most drastic and significant changes to the scheme thus far (Ellerman et al., 2016). For one, the phase covers eight years, constituting the hitherto longest phase, which in turn can be expected to have implications for regulatory uncertainty (Engau & Hoffmann, 2009). Secondly, the list of included GHGs was extended, while several new sectors were included in the system[18]. The most significant changes stem from harmonization efforts, which were informed by the lessons drawn from the preceding phases[19]. These efforts include the choice of auctioning as the default mode of allowance allocation[20], with approximately 50 percent of allowances now being auctioned (Ellerman et al., 2016), as compared to 5 percent and 10 percent in earlier phases (ibid.), while rules for the free allocation of allowances have been harmonized across the participating states (Wråke et al., 2012). The most fundamental reform, however, is the determination of the cap at the central EU level, doing away with the NAP approach (ibid.). This can be considered a decisive step in avoiding what Wråke et al. (2012) refer to as a "race to the bottom" in the form of substantial overallocation, characteristic of the first two EU ETS phases. Additionally, the cap is set to be linearly reduced by 1.74 percent annually (Ellerman et al., 2016).

[16] As the pilot phase had provided data on actual emissions levels, the cap reduction during phase two corresponded to more precise numbers as compared to the initial estimates; Supra, Note 10.
[17] Supra, Note 10.
[18] EU (12 May 2017). *"The EU Emissions Trading System (EU ETS)"*. Retrieved from https://ec.europa.eu/clima/policies/ets_en (16.05.2017).
[19] EU (12 May 2017). *"The EU ETS Handbook"*. Retrieved from https://ec.europa.eu/clima/sites/clima/files/docs/ets_handbook_en.pdf (16.05.2017).
[20] Supra, Note 17.

This recap of the development of the EU ETS goes to show that its rules and design features, which have been identified as important influences on innovation (Kemp & Pontoglia, 2008; Vollebergh, 2007), have changed quite drastically since the EU ETS´s inception. The circumstance that the Republic of Croatia did not join the scheme until increased harmonization had bolstered its stringency, as compared to earlier phases, makes it a unique case in the sense that regulated entities did not experience phases of vast overallocation of allowances and the associated windfall profits. On the other hand, the frequent changes in legislation contribute to perceived low levels of predictability associated with the instrument; a feature previously identified as decisive in shaping corporate strategy (Engau & Hoffmann, 2009; Hoffmann, Trautmann & Schneider, 2008). The following sub-section will review the available literature on the EU ETS´s impact on technological change, and identify the need for further research, especially during this third phase of the EU ETS.

### 2.3. Literature Review

The empirical literature on the innovation-inducing effects of the EU ETS can be distinguished into two sub-categories. Firstly, a few ex-ante studies have attempted to predict the EU ETS´s impact on technological change based on its initial design. Secondly, numerous ex-post studies have been conducted, evaluating this impact both qualitatively and quantitatively. This sub-section will offer a review of these studies, address potential shortcomings, and return to the relevance of this study by identifying gaps and omissions.

Seminal work in the former category includes a study conducted by Gagelmann and Frondel (2005), who review the theoretical literature on environmental policies, specifically permit trading, and evaluate the available empirical evidence on innovation effects of three US trading schemes. They arrive at the conclusion that the EU ETS is likely to have limited innovation-inducing effects in its initial phase, mostly due to the generous allocation of allowances, as pointed out above. Similarly, Schleich and Betz (2005) predict only modest innovation incentives, mainly due to generous allocation approaches and the associated low cost of compliance. Additionally, they point out that regulatory uncertainty, stemming from unspecified future rules, further hampers technology investments. Both studies predict low-risk and low-cost strategies, such as fuel substitution, to be the dominant coping strategies, rather than change in the form of more drastic product or process innovations. Furthermore, in an analysis of NAPs paired with a simulation game, Ehrhart, Hoppe, Schleich and Seifert (2005) find that the scheme will likely fail to live up to its theoretically ascribed cost-efficiency. In line with the previous studies, they identify the generosity in allocation as a main reason for this, and point out that these flaws in the scheme´s initial design inhibit well-founded investment decisions with a view to emissions abatement. As will be shown throughout the following paragraphs, these predictions turned out accurate; however, it is to be kept in mind that these studies base their predictions on the design of the first phase, which as was shown in the preceding sub-section, has changed to a large extent. Both acknowledge that tightened stringency and the expected changes in legislation would have the potential to increase the innovation-inducing capacities of the instrument.

Turning to the empirical ex-post examination of the EU ETS´s innovation effects, the bulk of the available literature is located during the first trading phase. In line with predictions from Gagelman and Frondel (2005) and Schleich and Betz (2005), Hoffmann (2007), conducting case studies in the German electricity sector, finds that although the EU ETS can be considered a driver of small-scale, low-risk investments, its impact on large projects and research and development efforts is in fact limited. Hoffmann (2007) attributes this to a lack of cap-stringency and regulatory uncertainty, further confirming ex-ante predictions. Contrastingly, in a qualitative study of sectoral innovation systems in the power generation sector, Hoffmann and Rogge (2010) find that the EU ETS has primarily impacted large-scale power generation technology. Although the authors confine these results to coal-based power generation, the contrast to earlier findings remains interesting. Pontoglio (2008, p. 18) reaches very similar conclusions to Hoffmann (2007) in the course of a case study of the Italian paper industry, characterizing the EU ETS as *"a system scarcely favorable to innovations"*. These findings are largely mirrored in a mixed methods study of the German pulp and paper industry conducted by Rogge et al. (2011a). Löfgren, Wråke, Hagberg and Roth (2013) choose a quantitative approach, and examine firm-level data from Swedish enterprises covering the years 2002 to 2008. Examining the data, Löfgren et al. (2013) add to earlier findings pointing to significant limitations in influence on investment and innovation. Despite their discouraging conclusions, all authors acknowledge the potential to improve the efficacy of the EU ETS in incentivizing technological change based on the announced efforts to alter allocation processes and to tackle the overallocation of allowances, thereby increasing instrument stringency.

Conversely, Calel and Dechelzepretre (2012), who take a quantitative approach in examining the patenting activity of several thousand companies, find a distinct increase in low-carbon innovation among companies covered by the EU ETS within its first five years of operation. The authors, however, acknowledge that patents are not necessarily capturing all aspects of innovation, such as operational, organizational and strategic changes, and that difficulties in isolating the EU ETS´s effect were present. Nevertheless, it is worth noting that the findings represent a sharp contrast to earlier studies, maybe best captured by the statement that the EU ETS´s impact on regulated firms *"may in fact be quite large, even ... where permits in the initial trading phases were very likely overallocated"* (Calel & Dechelzepretre, 2012, p. 189).

Schmidt et al. (2012) examine survey data from about 200 power generators and technology providers across seven countries. This study is similar to Calel and Dechelzepretre (2012) in that the compared timeframes are identical, and a quantitative approach was chosen. Schmidt et al. (2012), however, arrive at contrasting results, identifying limited or even controversial effects of the policy instrument on technological change. Yet again these shortcomings are attributed to a lack of stringency.

Lastly, both Cames (2010) and Rogge et al. (2011) find evidence of a limited impact of the EU ETS on innovation, attributed to a lack of stringency and predictability. While Rogge et al. (2011) suggest that the EU ETS appears to be an insufficient instrument for incentivizing innovation and should be complemented by additional policies specifically aimed at innovation incentives, they do also acknowledge that the expected revisions would enhance the regulatory pull effect of the instrument. This is a notion supported also by Cames (2010).

Not only does this review show that empirical investigation of the EU ETS´s capacity to induce low-carbon technological change is scarce, and inconclusive at best, but that the clear majority of the conducted studies rely on data from the first trading phase, which, as was identified earlier, constituted a low-stringency pilot phase. Considering the revisions undertaken within the past ten years, and bearing in mind that these revisions correspond to the recommendations furthered by several authors, it appears reasonable to expect an altered impact on technological change. Furthermore, a substantial share of early studies fail to take into consideration an array of related variables, including firm-internal characteristics and firm-external influences (Del Rio Gonzalez, 2009), the relevance of which will be discussed in the following section.

## 3. Theoretical Focus

The theoretical literature surrounding technological progress is vast, and a plethora of approaches have been employed to analyze the underlying processes. This study, however, will focus on only a few theories, which have specific relevance for the task of orienting technological advances. The employed theories and analytical approaches are, as stated by Del Rio Gonzalez (2009, p. 863), *"not mutually incompatible and should be combined"* in efforts to capture the complexities of environmental technological change.

The examined theories can be said to sharply contrast a large fraction of traditional economic theory in that technological change is treated endogenously. Viewing technological change as an exogenous variable, as mainstream economics tend to, makes it immune to the influences of economic activities and policy. Such approaches focus on depicting the effects of technological change but, by design, ignore the processes which contribute to its occurrence, and thereby can be deemed unfit for the exercise of determining the extent to which public policy induces such change.

The emergence of what Jaffe et al. (2003) refer to as the *modern theory of technological change* is associated with the process of *creative destruction*, a term coined by Josef Schumpeter (1942), who viewed innovation as the fundamental component of the modern capitalist system. The process, which describes the introduction of superior products or processes, motivated by the desire to increase market power and gain excess profits, is characterized by the three distinct stages of invention, innovation and diffusion. Invention involves a scientific or technological advance novel to the world, while innovation describes the establishment of an invention as a commercially feasible and marketable product or process. However, an innovator does not necessarily have to invent, as the identification of previously non-commercialized ideas and their consecutive introduction to the market suffice to be an innovator. These two initial stages are, according to Jaffe et al. (2003), mostly carried out in private firms, and often summarized under the term research and development (R&D). The final stage – diffusion – describes the adoption and application of a successful innovation by a wider audience. Collectively these stages are commonly referred to as technological change.

Building on Schumpeter, a large body of literature, both theoretical and empirical, emerged, treating innovation *"as a purposive economic activity"*, attempting to *"discern its determinants and effects"* (Jaffe et al., 2003, p. 469). Within the literature on the determinants of technological change, two major sub-categories can be identified, one of them being the induced innovation approach.

### 3.1. Induced Innovation

Induced innovation, first furthered as a hypothesis by Sir John Hicks (1932, p. 124), is centered around the premise that the rate and direction of innovation are responsive to variations in relative prices of factors of production[21]. With a view to environmental policy, Jaffe et al. (2003, p. 469-470) posit that *"since environmental policy implicitly or explicitly makes environmental inputs more expensive, the induced innovation hypothesis suggests an important pathway for the interaction of environmental policy and technology, and for the introduction of impacts on technological change as a criterion for evaluation of different policy instruments"*.

Hicks himself did not formalize the link between his hypothesis and the process of technological change, a task which was accomplished in the 1960s (Ahmad, 1966; Kamien & Schwartz, 1968) and later refined by Binswanger (1974)[22]. The induced innovation approach views R&D as an investment aimed at the creation of novel and profitable products and/or processes. Consequently, decisions concerning such investments are subject to firms´ desires to maximize their value, making the cost of R&D as well as expected rates of return decisive factors. Notwithstanding the inherent difficulties and challenges of testing the hypothesis (Cames, 2010; Jaffe et al., 2003), evidence of the inducement of innovation is relatively ample[23], suggesting that changes in relative prices indeed exert influence on the investment decisions of firms and thereby lending support to the assertion that policies which induce price adjustments can foster innovation.

In the course of induced innovation research, theory and evidence have suggested that several factors are important in determining the optimal levels of R&D (Jaffe et al., 2003). These studies include the works of Schmookler (1966) and Rosenberg (1974), who are most commonly referred to when speaking of the concepts of supply-push (or technology-push) and demand-pull (or market-pull), which have dominated the debate in innovation economics (Rennings, 2000). In relation to eco-innovation, technology-push emphasizes the influence of

[21] As Hicks´s hypothesis materialized before Schumpeter´s creative destruction, his use of the term "invention" should be interpreted in a more general way, including the notions of both invention and innovation.
[22] For an exhaustive account of this literature see Binswanger & Ruttan (1978).
[23] For a detailed summary of empirical studies concerning pollution abatement and energy conservation innovation see Jaffe et al. (2003, p. 474-476).

scientific advances on the rate and direction of innovation, while the demand-pull argument focuses on market factors such as consumers´ preferences for environmentally friendly products or increased competitiveness of firms with an environmentally friendly image (ibid.). Empirical evidence has shown that both arguments are relevant (Pavitt, 1984). However, several externalities are at play when it comes to eco-innovation, causing a situation to arise in which the factors of technology-push and market-pull are insufficient to trigger technological change.

As acknowledged in section 2.1, eco-innovation is characterized by the double externality problem[24]. On the one hand, environmental externalities, such as pollution, are being oversupplied by the market as the costs of pollution are being borne by other parties than the polluters, causing a situation in which the polluters face no incentive to reduce their environmentally harmful impact. Simultaneously, investments in eco-friendly products or processes are being hampered by knowledge externalities, which create a reversed situation in which the benefits of technological progress are being enjoyed by other parties than the ones incurring the costs thereof, effectively reducing incentives to invest even further. Economists (Jaffe, 1986; Jones & Williams, 1998; Mansfield, 1977) have found that these spillover effects cause a discrepancy between private and social rates of return, with social rates of return outweighing the private rates of return previously identified as decisive in the investment decisions of firms, ultimately leading to socially desirable investments in R&D being ignored. R&D efforts are, however, not the only component of technological change suffering from externalities. Jaffe et al. (2005) argue that the adoption and diffusion of novel technology can be hampered via dynamic increasing returns, a term which describes the phenomenon that users of technology will benefit from a larger population using the same technology (Berndt & Pindyck, 2000). Dynamic increasing returns arise in different ways. “Learning-by-using” describes a situation in which the adopter of a new technology creates a positive externality for other potential users by generating additional knowledge about that technology´s existence, characteristics and potential superiority (Jaffe et al., 2005). “Learning-by-doing” describes an additional adoption externality related to the circumstance that a user of novel technology can, over time, become experienced enough in the use of said technology to decrease production costs. If this additional experience spills over, other manufacturers may benefit (ibid.). Lastly, both the innovation and consecutive diffusion of new technologies suffer from information-related market failures, which go beyond the ones

[24] For an exhaustive account of the market failures permeating eco-innovation see Jaffe, Newell & Stavins (2005).

just examined (ibid.). Investments in innovation and technology are generally characterized by particularly pronounced uncertainty relating not only to the expected returns on such investments, which make the acquisition of capital for such endeavors problematic, but also to large uncertainties associated with the future challenges of climate change and the extent and development of policy intervention (ibid.). The latter is particularly true for eco-innovation.

These particularities of environmental technological change support the notion that a strong regulatory framework is necessary in order to attain the socially desirable levels of innovation and technology adoption. Rennings (2000) therefore coined the term "regulatory push/pull effect", which summarizes policy efforts aimed at the provision of increased incentives to research and adopt new technology aimed at the reduction of environmentally harmful impacts of productive activity.

### 3.2. Evolutionary Perspectives

The arguments examined so far all portray technological change as an investment activity guided by profit considerations of private actors. However, while the neoclassical approach exhibits considerable advantages when analyzing incremental or marginal technological change (Rennings, 2000) induced by, for instance, price incentives, its reliance on equilibrium models and the related, heroic assumptions about the behavior of economic subjects provoked the emergence of new approaches to the concept of technological change, with Nelson and Winter (1982) constituting the most prominent and influential proponents thereof.

During the 1970s Nelson and Winter released a series of articles (Nelson & Winter, 1973, 1974, 1975) leading up to their influential 1982 book *An Evolutionary Theory of Technical Change*. The theory draws on biological research in that it employs evolutionary concepts such as variation, selection and stabilization for the explanation of the process of technological change. Building on the behavioral theory of the firm, it aims for a more realistic description of the underlying mechanisms of R&D (Ruttan, 1997), which are said to remain in a "black box" in neoclassical approaches (Rennings, 2000; Ruttan, 1997). This is a circumstance which, according to Rennings (2000), also limits the capacity of neoclassical approaches to appreciate radical change, especially in organizational and societal terms. The central argument of the theory is that due to the large uncertainties associated with the outcomes of technological change, firms are incapable of making optimal investment decisions. In this regard Nelson and Winter (1982) rely on Simon´s (1947) notion of bounded rationality, causing economic actors to engage in "satisficing" as opposed to optimizing behavior. According to this notion, arriving at an optimal decision requires investment that, by far, outweighs the additional benefit as compared to a sub-optimal decision. Nelson and Winter (1982) therefore argue that firms determine innovation-related investment decisions by the way of "rules of thumb" and "routines".

Based on these premises, Porter and van der Linde (1995) developed what has become known as the Porter hypothesis. As firms are no longer assumed to behave in an optimizing fashion, it is no longer possible to be sure that new constraints, as imposed by policy intervention, lead to higher costs. At least theoretically, the possibility exists that a satisficing firm, forced to reevaluate its strategy in response to such a constraint, discovers inefficiencies in its operations and ultimately finds ways of increasing its profit. Porter and van der Linde (1995, p. 98), as well as other so-called "win-win" theorists, argue that regulation can lead to "innovation offsets", which *"can not only lower the net cost of meeting environmental regulations, but can even lead to absolute advantages over firms in foreign countries, not subject to similar regulations"*. Several reasons have been presented for such offsets to occur. Firstly, policy intervention can potentially direct the attention of firms towards resource inefficiencies. If pollution is assumed to be an indicator for the wasteful use of resources, regulation can provide signals which guide efforts towards cost-saving efficiency improvements (Porter & van der Linde, 1995). Secondly, regulation is able to decrease the uncertainties surrounding eco-innovation investments by making the social benefits of reduced environmental impacts valuable at a private level – a situation that, due to the externality problems elaborated on earlier, is unlikely to arise in the absence of regulation. Another argument linked to the externalities discussed is that regulation drives the acquisition or dissemination of valuable information, which based on its properties of a public good, tends to be underprovided. Ultimately, Porter and van der Linde (1995, p. 100) point out the pressures created by regulation as an important factor *"to overcome inertia, foster creative thinking and mitigate agency problems"*. In their influential article, Porter and van der Linde (1995) present numerous case studies indicating that firms have been able to profit via the exploitation of previously undiscovered potentials for efficiency improvements in response to the imposition of new regulation.

The win-win hypothesis has been met with skepticism[25] by economists (e.g. Palmer, Oates & Portney, 1995), and its empirical plausibility seems to be limited (Cames, 2010).

[25] For a detailed overview of concrete criticism see Jaffe et al. (2003, p. 487-488).

Nevertheless, evolutionary approaches have found their way into the research debate surrounding environmental technological change as of late (e.g. Arentsen, Kemp & Luiten, 2002; Cames, 2010; Fri, 2003; Jaffe et al., 2003; Kemp, 1997; Rennings, 2000; Rogge et al., 2011; Rogge et al., 2011), and are recognized as important in providing complementary insights to the process of technological change, as they allow for a broader appreciation of diverse factors outside the reach of neoclassical approaches. Rennings (2000) considers it beneficial to link neoclassical and evolutionary approaches, and refers to Kemp´s (1997) approach of introducing uncertainty, technology characteristics and consumer preference via evolutionary models while retaining elements of rational choice and optimization found in neoclassical models. In a similar vein, Del Rio Gonzalez (2009), in reference to works by Rip and Kemp (1998) and Unruh (2000), argues that evolutionary economics can provide the framework for integrating a multitude of perspectives on technological change in order to appreciate the inherent complexities of the process.

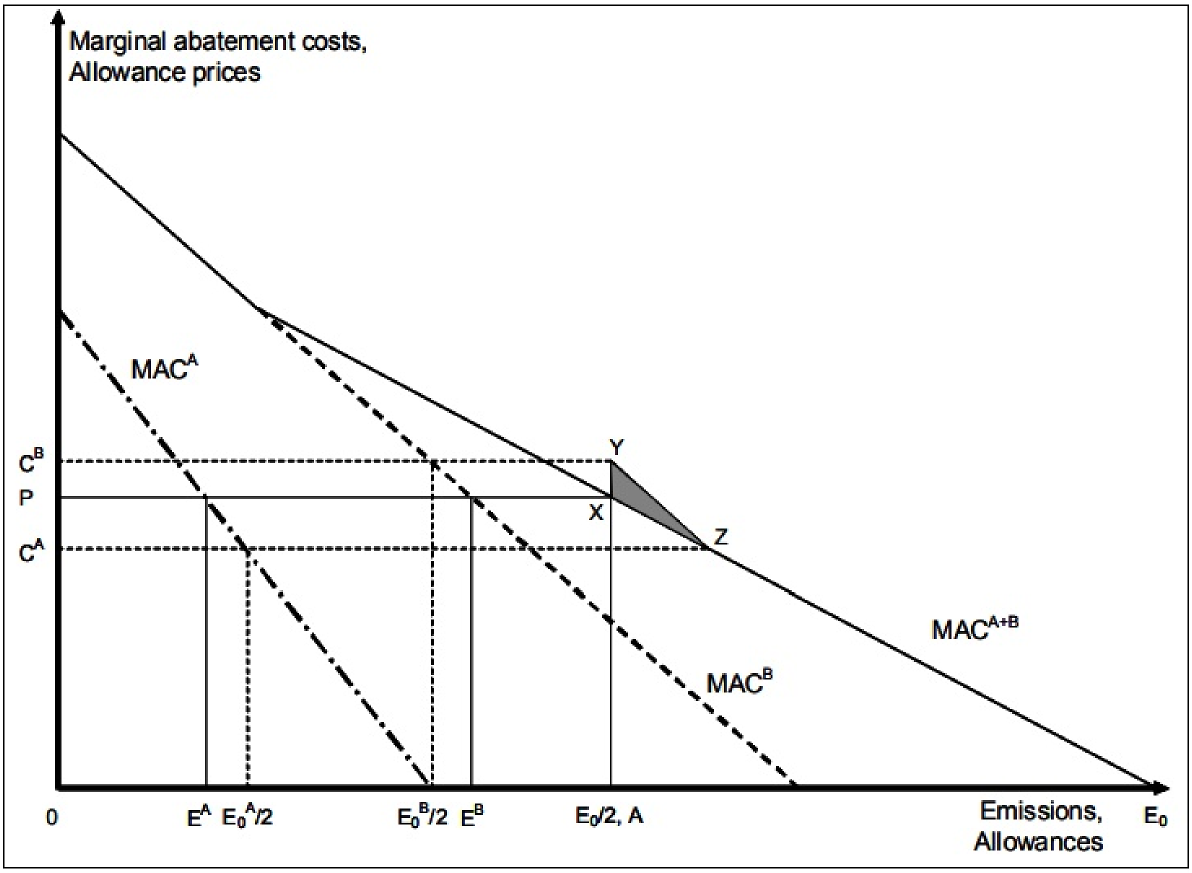
### 3.3. Emissions Trading, Efficiency, and Technological Change

As touched upon in section 2.1, there are two broad categories of environmental policies. In comparison to so-called command and control policies, market-based instruments are generally preferable from an economic point of view (Requate & Unold, 2003). This preference is based on their superiority with respect to several economic criteria, most clearly outlined by Fritsch, Wein, and Ewers (2003) and Endres (2007).

One assessment criterion concerns the efficacy of an instrument in attaining a predetermined environmental objective, referred to as environmental accuracy. As briefly outlined in section 2.2, emissions trading involves the setting of a total permit amount, which, as long as the enforcement regime is intact, ensures that a certain amount of emissions is not exceeded. The biggest advantage of emissions trading in this regard is that it does not require continued intervention, regardless of the growth rates of the economy or inflation, two factors which emissions standards and emissions taxes are susceptible to (Bader, 2000).

Secondly, the economic theory of environmental policy has long focused on the static efficiency of policy instruments. That is the capacity of a given instrument to achieve its environmental objective at the lowest cost. The cost-efficiency of permit trading has frequently been pointed out as a crucial advantage over command and control approaches (e.g. Tietenberg, 1985; Tietenberg, 2006). Figure 1 visualizes the advantages of permit trading vis-à-vis command and control instruments in a two-firm setting with differing abatement costs, under the assumption that total emissions are to be decreased by 50 percent, irrespective of the applied policy instrument, to $\frac{E_0}{2}$. $MAC^{A+B}$ represents the aggregate social abatement cost, which consists of the marginal, individual abatement cost curves of the respective firms. In the case of a command and control instrument, firm A is expected to decrease its emissions to $\frac{E_0^A}{2}$ at the marginal abatement cost of $C^A$. While facing equal constraints, firm B, however, operates at a higher marginal abatement cost of $C^B$. This circumstance indicates that the situation under a command and control policy is inefficient (Weimann, 1991). This notion finds support in several empirical analyses (e.g. Atkinson & Lewis, 1974; Atkinson & Tietenberg, 1982; McGartland & Oates, 1985; Tietenberg, 1974). Under permit trading a different situation arises. As the environmental objective remains unchanged, the regulator issues *A* amount of allowances equal to the target of $\frac{E_0}{2}$. However, in this case, firm B, facing a higher marginal abatement cost, will choose to reduce its emissions no further than to $E_B$ at a cost of *P*, while acquiring additional emissions permits to cover its remaining emissions. Simultaneously, firm A, facing a lower marginal abatement cost, will decrease its emissions by a factor larger than under command and control, reaching $E_A$, also at cost *P*. Exceeding emissions will again be covered via the acquisition of additional allowances. This example shows that the flexibility of emissions trading enables the equalization of marginal abatement costs, resulting in a cost-efficient approach (Weiman, 1991). Companies facing low marginal abatement costs will prefer avoiding emissions, freeing up allowances, which consequently can be acquired by firms facing higher marginal abatement costs. The efficiency improvement under emissions trading is visualized by the area *XYZ*. In conclusion, static efficiency of emissions trading is superior to command and control instruments. It should be noted that environmental economists are not in agreement whether emissions trading or emissions taxes are superior in this regard; however, this debate has no influence on this work and will therefore be omitted.

*Figure 1 – Efficiency of Emissions Trading vs. Command and Control*

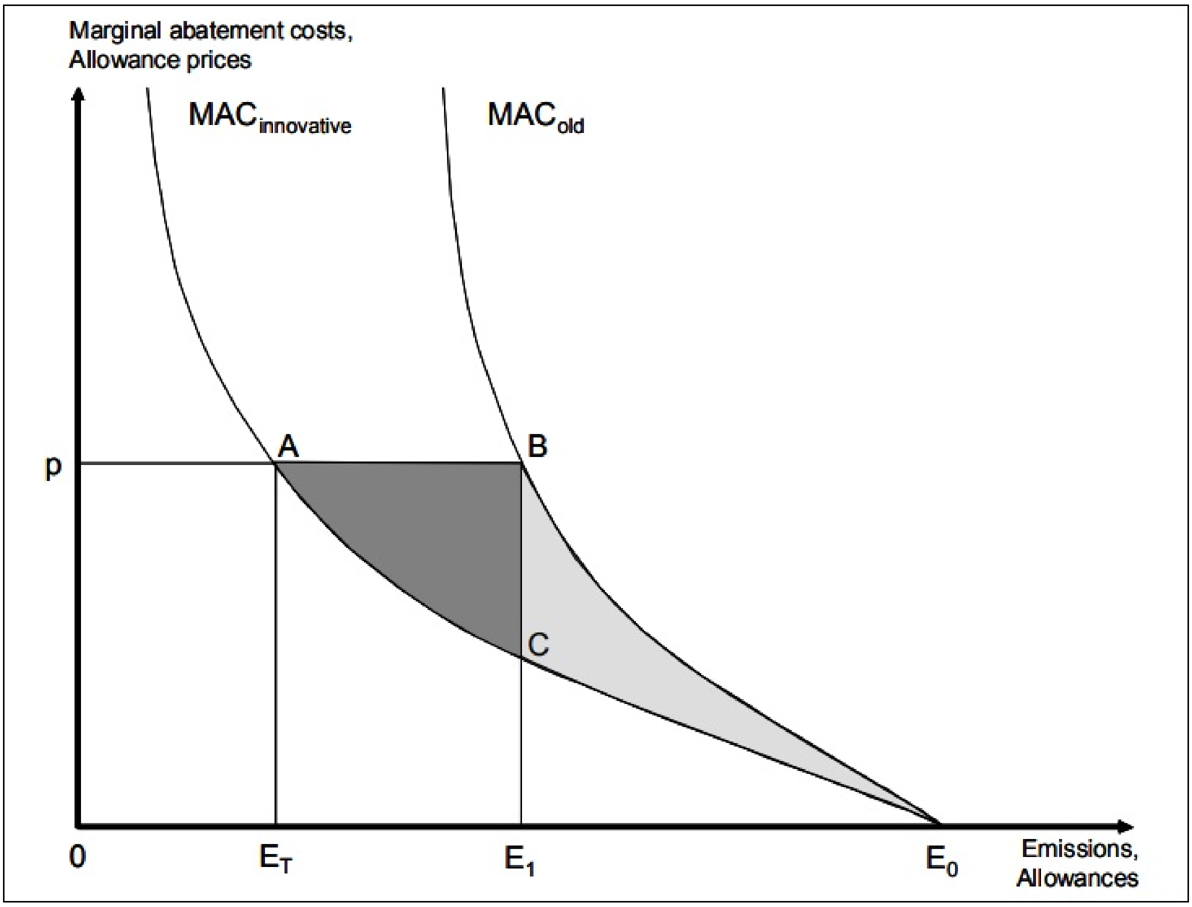



*Source: Cames (2010).*

While static efficiency properties are important for the efficient use of resources under given technological circumstances, the dynamic efficiency of policy instruments, that is their capacity to stimulate the search for and application of novel abatement approaches, has enjoyed increasingly more attention as of late (Endres, Bertram & Rundshagen, 2007). There has been a considerable amount of theoretical analyses comparing different policy instruments´ abilities in this regard, and the results are mixed[26]. However, this study neither attempts to justify the choice of emissions trading as an environmental instrument, nor tries to establish a ranking amongst different instruments. Therefore, the following paragraphs will merely present the theoretical arguments building the very foundation of the premise that emissions trading spurs technological change, and illuminate how such change is being incentivized, what the potential shortcomings of emissions trading are in that context, and which design features factor into its innovation-inducing capacity.

[26] Supra, note 8.

*Figure 2 – Innovation Incentives of Emissions Trading vs. Command and Control*




*Source: Cames (2010).*

Based on the seminal works of Downing and White (1986) and Milliman and Prince (1989), Figure 2 illustrates the difference in cost savings associated with technological change under command and control vis-à-vis emissions trading, for a single firm. Prior to policy intervention, emissions levels are at $E_0$. Under a command and control policy, this company is required to cut its emissions to $E_1$. With its current technology, marginal abatement costs are at *p*, while total abatement costs equal area $E_0E_1B$. With the introduction of a new technology, the marginal abatement cost curve *MAC* shifts left, reducing the company´s total abatement costs by the area $E_0CB$. This area describes the individual price incentive to decrease emissions. Contrastingly, in the case of emissions trading, allowances amounting to $E_1$ are issued, leading to a permit price of *p*. Total abatement costs with the initial technology amount to the area $E_0 0 pB$. The shift of the marginal abatement cost curve, caused by the introduction of new technology, leads to savings the size of the area $E_0AB$. The achieved cost savings via technological change under a policy of permit trading thereby exceed those under the alternative instrument by the area of *CAB*, showing that incentives for technological change are more pronounced under emissions trading.

It is important to note that, *ceteris paribus*, the company´s demand for emissions allowances drops to $E_T$ after innovating. Based on the assumption that the single firm examined in Figure 2 is small enough, compared to the entire population of regulated entities, this development has a negligible effect on the price of allowances. However, the widespread introduction of innovative technology across larger parts of the regulated population will cause allowance prices to decrease (Milliman & Prince, 1989), as a result of a significant reduction in the demand of allowances. As the allowance price is of crucial relevance for the trading schemes innovation-inducing capacity (Schleich & Betz, 2005), with higher prices creating larger incentives, this effect needs to be offset via the gradual reduction of the cap at rates corresponding to the rate of progress (Cames, 2010). As mentioned in section 2.2, the EU ETS now incorporates a centralized and gradual cap reduction paired with ambitious environmental objectives, indicating that policy makers are aware of this effect. Nevertheless, Keohane (1999) is skeptical of regulators´ capabilities to identify the appropriate rate of such reduction, a view supported by notions of public choice theory (Rennings, 2000). In relation to this criticism, Fischer et al. (2003) posit that emissions taxes would be superior.

While the conclusion that emissions trading provides larger incentives than command and control policies may seem odd at first glance, the underlying argument is widely recognized (e.g. Downing & White, 1986; Jung et al., 1996; Kerr & Newell, 2003; Milliman & Prince, 1986; Sorrell & Skea, 1999). At its core, this advantage of market-based instruments, and emissions trading in particular, lies in the premise that command and control instruments provide no incentives for abatement efforts going beyond the prescribed objective. Emissions trading on the other hand provides continuous remuneration for such efforts. In economic terms, such remuneration comes in the form of additional revenue, either via the sale of excess allowances that have been freed up through the implementation of new technology, or via the cost savings associated with a decreased total amount of acquired allowances (Rennings, 2000; Schleich & Betz, 2005). This circumstance leads to what Tietenberg (1985, p. 33) calls *direct innovation effects*, i.e., the accelerated diffusion of efficient technology and/or increased R&D of such (Kerr & Newell, 2003). These theoretical arguments for the superiority of emissions trading have also been called into question, most notably by Malueg (1989), who argues that the strength of innovation incentives under emissions trading highly depends on whether a firm is a buyer or a seller of emissions allowances. The central claim of Malueg (1989) is that the acquisition of additional allowances can constitute a relatively inexpensive compliance strategy. Therefore, according to Malueg (1989), companies that are buyers of allowances before the potential acquisition of new abatement technology, and would remain buyers after its acquisition, face lower incentives to adopt new technology than under command and control approaches, where such a firm would be forced to invest in abatement to some predefined degree. Companies that already are, and consequently remain, sellers of permits after the acquisition of new technology do however face larger incentives under emissions trading. In cases in which the market role changes from buyer to seller, Malueg´s (1989) findings are ambiguous.

The arguments and advantages outlined hitherto mostly originate from neoclassical economics. However, one potential advantage of emissions trading becomes especially apparent when viewing the instrument via the rather systems-oriented evolutionary perspective. As touched upon in the previous section, this approach emphasizes the importance of concepts such as selection and variety in the process of technological change (e.g. Metcalfe, 1994; Nelson, 1995). Emissions trading, compared to command and control approaches, provides regulated entities with substantially more freedom of choice concerning their compliance options (Swift, 2001). Prescribed abatement solutions are said to suspend the development of new technology, as such would not match legislation (Jaffe et al., 2002). Furthermore, the possibilities of partial abatement (Bader, 2000), and even so-called business-as-usual scenarios, are not excluded (Rennings, 2000). This has the advantage that firms can defer large investments in order to obtain more effective or advanced solutions down the road (ibid.). These considerations find support in Newell and Stavins (2003), who emphasize that *“abatement cost heterogeneity is a fundamental determinant of the potential cost-savings associated with market-based instruments”*.

Another consideration that has implications for the innovation effects of emissions trading is the associated policy uncertainty (Engau & Hoffmann, 2009; Hoffmann, Trautmann & Schneider, 2008; Marcus, 1981), which has enjoyed more attention in some of the recent literature identifying particular design features as more relevant to technological change than the instrument type itself (Kemp & Pontoglio, 2008; Vollebergh, 2007). Rogge et al. (2011a, p. 515) stress the importance of the predictability of policy instruments, especially if *long-lived capital-intensive investments* are concerned, as can be considered the case in sectors covered by the EU ETS. From a neoclassical perspective, it is rather apparent that a trading scheme cannot provide the same type of planning security as could command and control approaches. The EU ETS´s permit price, identified as a crucial component of the instrument´s innovation incentives earlier, is subject to demand and supply, making it inherently responsive to market developments (Rennings, 2000). From an evolutionary point of view, which allows for the appreciation of uncertainties originating from the complex interactions between institutional, social, political and managerial dimensions of technological change (Schleich & Betz, 2005), the issue is ever so present. As, for instance, Fri (2003) and Arentsen, Kemp, and Luiten (2002) acknowledge, the multiplicity of actors and their respective decisions are an important factor of influence in sectors in which technological change is a tedious process. The EU ETS has been characterized by significant changes, and although the primary reason for authors such as Hoffmann et al. (2008) and Hoffmann et al. (2009) to ascribe substantial regulatory uncertainty to the scheme, namely the NAP approach, has been remedied, trading phases remain relatively short, and the regulatory details of, for instance, future allocation rules often remain nebulous due to the largely unpredictable nature of political negotiation.

Directly related to the concept of regulatory uncertainty is the problem of credible policy commitment (Brunner, Flachsland & Marschinski, 2012). Credibility has been recognized as an issue in a multitude of regulatory contexts (Helm, Hepburn & Mash, 2003), and its introduction to the academic debate is mostly traced back to macroeconomic policy analysis by the likes of Kydland and Prescott (1977), and Barro and Gordon (1983). The general argument underlying credible policy commitment issues is the fact that regulatory environments are subject to political influences, which, due to regular elections can change frequently, thereby increasing regulatory uncertainty, undermining political commitment, and consequently harming the investment environment. In regard to carbon-related policy, Brunner et al. (2012, p. 255) describe the relation between policy commitment and investments in neoclassical terms as follows:

*"Rational actors will discount the expected carbon price and will do so even more when it is felt that the government might not stick to its commitment. Firms will either postpone investing until uncertainty regarding future carbon policy is resolved or require higher rates of return. In both cases, this will reduce the total level of emissions abatement."*

While the neoclassical argument is of paramount importance to the analysis of the impact of regulatory uncertainty on investment decisions, the evolutionary appreciation of the multiplicity of involved actors and institutions is equally important. Although it can be argued that EU legislation is not subject to the same political cycles as domestic policy, and that the fundamental design of the instrument (including a harmonized and centrally administered cap and allocation approach) remains intact, the shaping of the rules of the EU ETS is influenced by many stakeholders, including national politicians, and organized interests.

### 3.4. Research Framework

In defining environmental innovations scholars commonly rely on guidelines provided by the OECD and Eurostat (2005) in the so-called Oslo Manual (e.g. Rogge et al., 2011a; Rogge et al., 2011b; Rennings, 2000; Rennings & Rammer, 2011). According to the manual, environmental innovations encompass product or process innovations, as well as organizational innovations, which contribute to a reduced environmental impact. A process innovation enables the production of a certain output with reduced input factors. Product innovations describe the improvement of current products (goods or services) or the introduction of new ones. Organizational innovations occur when new organizational methods are introduced or new business practices are implemented. The application of the Oslo Manual also allows for a focus on innovation and technological change that is new to the firm, as opposed to new to the world. Explicitly accounting for the different forms of innovation furthermore appears necessary in assessing the impact of environmental regulation (Bernauer, Engels, Kammerer & Seijas, 2006), given that differential impacts based on such a distinction have previously been discovered (e.g. Cleff & Rennings, 1999; Hemmelskamp, 1999).

In line with the guidelines, Kemp and Pearson (2007, p. 7) provide the following definition of eco-innovation: *"Eco-innovation is the production, application or exploitation of a good, service, production process, organizational structure, or management or business method that is novel to the firm or user and which results, throughout its life cycle, in a reduction of environmental risk, pollution and the negative impacts of resource use (including energy use) compared to relevant alternatives"*.

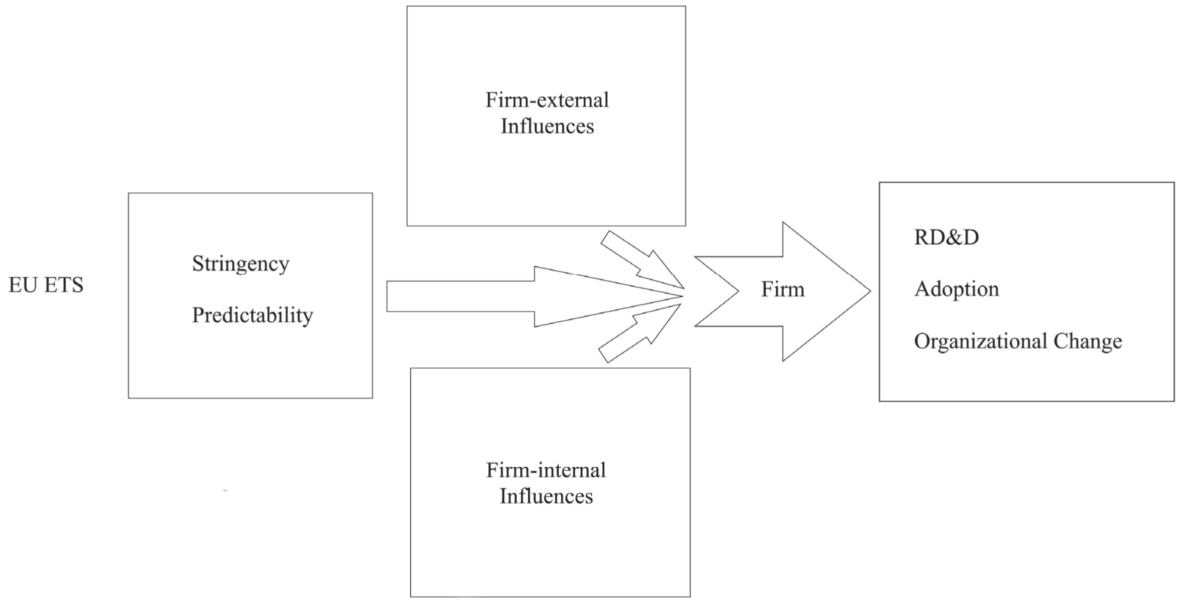
However, in keeping with the neoclassical and evolutionary conceptualizations of technological change, the process is differentiated into research, development and demonstration (RD&D), adoption, and organizational change. The first dimension describes the execution of *basic laboratory research*, *testing of new technology on a small scale* and the *first larger scale implementation* thereof (Rogge et. al, 2011). Adoption refers to the acquisition of advanced technology, which can entail both the ex-post modification of operational facilities or the construction of entirely new ones. Organizational change describes the modification of existing or introduction of new business procedures, operational approaches, organizational structures, and altered perspectives or conceptions contributing to a changed vision. While investigating these dimensions, the above distinction derived from the Oslo Manual and the provided definition of eco-innovation remain important for several reasons. Both the development and adoption of new technology remain subject to the differentiation of product and process innovation, while simultaneously the focus on innovations new to the firm remains. Lastly, the prerequisite of such innovations enhancing the environmental performance of an operation precludes the acknowledgement of innovations unrelated to environmental performance.

The creation of the research framework moreover draws considerably on the recommendations and suggestions furthered by Bernauer, Engels, Kammerer and Seijas (2006), and del Rio Gonzalez (2009). The authors provide guidelines for the empirical assessment of regulation-induced eco-innovation, incorporating the neoclassical and evolutionary theories and approaches discussed in the preceding section, ultimately allowing for the construction of a multidimensional framework. Such a framework acknowledges not only the influences of regulation, but also context factors, such as firm-external factors like market conditions, including consumer demands, and competitiveness, as well as firm-internal circumstances, such as commitment to environmental sustainability and firm size. Figure 3 depicts the applied framework.

Following the recommendations by Bernauer et al. (2006) and del Rio Gonzalez (2009), and based on the discoveries of Ashford, Ayers & Stone (1985), the influence of the policy instrument is being assessed via its stringency on the one hand, and, based on findings of Ashford et al. (1985), Engau and Hoffmann (2009) and Jaenicke (1997), via its predictability on the other. Both criteria have been found to be positively related to the rate and direction of technological change (e.g. Ashford et al., 11985; Engau & Hoffmann, 2009).

Stringency is commonly used to describe the amount of change the compliance with a given policy instrument induces in a firm (Bernauer et al., 2006). Data concerning stringency is rare (Del Rio Gonzalez, 2009), which has lead this variable to be expressed via compliance costs in earlier research (e.g. Rogge et el., 2011a; Kerr & Newell, 2003). The stringency of the EU ETS is determined by several factors (Schleich & Betz, 2005). Firstly, the allowance price and thereby the emissions cap are a crucial component of price and cost incentives, as explained in the previous sub-section. The lower the quantity of allowances in circulation, the more pronounced their scarcity and consequently the higher their price. Additionally, stringency depends on the rules governing the allocation of allowances (Schleich & Betz, 2005). To appreciate the peculiarities of the allocation process and the associated rules, a brief excurse building on the introduction in section 2.2 will be necessary.

*Figure 3 – Research Framework*




*Source: Author´s drawing; adaptation of Bernauer et al. (2003).*

The abolishment of the NAP approach to allocation with the beginning of the third phase of the EU ETS went hand in hand with new rules and procedures regarding the allocation of the allowances. Although the free allocation of allowances was abolished in favor of auctioning as the default mode of allocation (Ellerman et al., 2014), auctioning remains in the process of phase-in until 2027 (ibid.). While the electric utility sector already faces full auctioning, with minor exceptions, other sectors, depending on their exposure to competitive pressures from outside the Union, and their associated risk of carbon leakage[27], still enjoy the free allocation of allowances[28,29].Clearly, the imposed compliance cost depends on whether allowances are allocated free of charge or need to be acquired at market price. Large differences with respect

[27] *"Carbon leakage refers to the situation that may occur if, for reasons of costs related to climate policies, businesses were to transfer production to other countries with laxer emission constraints. This could lead to an increase in their total emissions."* - EU (2017, June 19). *"Carbon Leakage".* Retrieved from https://ec.europa.eu/clima/policies/ets/allowances/leakage_en (19.06.2017).
[28] For the current carbon leakage list see http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014D0746&from=EN (19.06.2017).
[29] The precise rules governing free allocation are not relevant to this study and will therefore be omitted. For a recent detailed account see Stenqvist & Åhman (2016).

to this circumstance were to be observed in the chosen sample of firms, with freely allocated allowances ranging from approximately 12 percent to approximately 131 percent of verified annual emissions in 2015[30]. While it could be argued that this indicates continued overallocation to some extent, it is to be kept in mind that the market situation for some manufacturing industries at risk of carbon leakage has not yet recovered entirely and low demand consequently contributes to lower-than-expected emissions levels. In addition, the geographical location of the Republic of Croatia, with direct borders to extra-EU countries, increases the risk of carbon leakage and competitive pressure from extra-EU manufacturers considerably.

The second policy feature included in the framework, predictability, is directly related to questions of uncertainty discussed in the preceding sub-section. Predictability describes the level of certainty associated with the given policy instrument in light of potential future changes (Hoffmann et al., 2008). Engau & Hoffmann (2009) show that firms which perceive high regulatory uncertainty are more likely to postpone strategic decisions such as investments in abatement technology. Higher levels of certainty reduce the risk associated with such investments, and therefore have a positive impact on innovation (Bernauer et al., 2006). So far, research suggests that the EU ETS is characterized by high levels of uncertainty (e.g. Engau & Hoffmann, 2009; Hoffmann et al., 2008, Cames, 2004). However, these studies are focused on the first two trading phases, which in terms of certainty differ considerably from the current phase. Not only has the length of trading phases increased from initially 3 to 5 and then to 8 years, but the NAP approach, which was identified as a source of significant regulatory uncertainty (Hoffmann et al. 2008), was replaced by a centrally determined allowance budget and allocation rules. The evaluation criterion of predictability also needs to take into account the previously acknowledged issues surrounding credible policy commitment (Brunner et al., 2012; Helm et al., 2003). Even if the perceived predictability of the instrument´s future development is found to remain low, perceptions of credible commitment to climate change policies could still foster an environment in which regulated entities invest in abatement technology in anticipation of continuously tightened controls.

Furthermore, this study incorporates firm-external context factors (del Rio Gonzalez, 2009) in its research framework, capturing relevant influences from social, institutional and market actors. Besides the EU ETS, it is advisable to pay attention to the influence of the policy mix, since domestic legislation, such as for example support for renewable sources of energy

[30] Author´s calculations based on data from the European Union Transaction Log, retrieved from http://ec.europa.eu/environment/ets/oha.do (19.06.2017).

(Croatian Environment Agency, 2015), or other international legislation, such as for example the Industrial Emissions Directive[31], could prove more influential than, or at least complementary to, the EU ETS. Firm-external influences furthermore cover market influences, such as market structure, and demand factors. Findings and predictions concerning the influence of market structure are ambiguous (Bernauer et al., 2006). While the industrial organization literature predicts decreased innovation activity in highly competitive markets, this notion finds no support in empirical evidence (Aghion, Bloom, Blundell, Griffith & Howitt, 2005). Based on work by Scherer (1967), a strand of literature emerged which asserts an inverted-U relationship between competition and innovation. Indeed, there is empirical support for the existence of non-linearities in the innovation process (Aghion et al., 2005). It also appears that high levels of competition are conducive especially of product innovation activity, since competitive pressures require firms to differentiate themselves via superior product quality, whereas firms operating in concentrated markets are more prone to investments in process innovation (Link, 1982). Related to improved product quality, the strategic management and green marketing literature asserts that market demand for green products exerts considerable influence on innovation activity in that direction, since firms come to realize that improved environmental performance constitutes an important differentiation tool (e.g. Belz, 2001; Meffert & Kirchgeorg, 1998).

Moreover, innovation activity can be influenced by firm-internal determinants. Acknowledging these enables the study to appreciate firm heterogeneity, which has been found to impact corporate strategy (Barney, 1991). They are especially emphasized (Bernauer et al., 2006) in the evolutionary, resource-based approach to innovation (e.g. Nelson & Winter, 1982). Small firms usually do not command similarly ample resources as large firms, either in terms of finance, technical know-how or human capital (Bernauer et al., 2006; del Rio Gonzalez, 2009), ultimately constituting a restraint to innovation activity. Firm size has also been found to influence the type of innovation most likely to occur in a given firm (Scherer, 1983; Cohen & Klepper, 1996). Lastly, the framework takes account of the proactivity of environmental strategies of firms, which, resulting from the commitment of higher management levels to environmental performance (Kagan et al., 2003), exerts positive influence on environmental innovation activities (Bernauer et al., 2006; del Rio Gonzalez, 2009).

[31] EU (2010, December 17). *"Directive 2010/75/EU"*. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0075&from=EN (20.06.2017).

Having established a research framework building on relevant theory and recommendations from the more recent literature, the following paragraph briefly returns to the main and ancillary research questions this work seeks to answer, after which the applied methodology is discussed.

First and foremost, it is this research´s aim to answer whether the EU ETS has contributed to an increased focus on the development and adoption of products, processes, and business practices aimed at the reduction of GHG emissions. Therefore, the central research question of this study is: Has the introduction of the EU ETS induced innovation activity among emissions-intensive business operators in the Republic of Croatia? In answering this question, it needs to be established whether such innovation activity in fact takes place, to what extent it takes place, and how it is distributed across the various innovation dimensions. Then it needs to be determined to what extent these activities have been influenced by the EU ETS, whether a regulatory push/pull effect is detectable, and how the instrument with its various design features and mechanisms has impacted regulated companies´ decisions concerning such efforts. In doing so, it also needs to be examined what role context factors play relative to the policy instrument.

## 4. Methodology

In order to empirically assess whether the EU ETS does in fact promote firm-level innovation, a multiple case study approach was selected. The approach was chosen based on its suitability for the examination of complex contemporary phenomena (Eisenhardt, 1989; Yin, 2009). Furthermore, the choice enables the comprehensive collection of relevant aspects of real-life events, including *managerial and organizational processes* (Yin, 2009), such as investment decisions in new technology. Case study designs are commonly employed in social sciences research, including case studies of public administration (e.g. Agranoff & Radin, 1991), which can be considered to encompass decisions on the design of environmental policies, such as the EU ETS.

Although there is no universally accepted rule for when to employ a case study design, Yin (2009) provides some conditions which should be met to avoid a grave misfit, including a focus on contemporary events, incapacity of the researcher to manipulate the relevant behavior pertaining to such events, and research questions dealing with *“operational links needing to be traced over time, rather than mere frequencies or incidence”* (Yin, 2009, p. 9).

Considering that the EU ETS is currently operational, undergoes periodical revision and, as a market-based instrument, is subject to market forces, it is safe to say that its effects on regulated entities constitute a complex contemporary phenomenon. This holds equally true for considerations about technological change and innovation. Moreover, as corporate decisions concerning innovation, be it via specific investments or organizational changes, are guided by factors far beyond the control of the researcher, the behavior of the units of observation can be considered immune to manipulations by the researcher. This circumstance then satisfies the second condition for relying on case study designs. Lastly, as this work is examining how the relatively abrupt introduction of the hitherto most stringent emissions trading policy is exerting influence on certain decisions, while taking into consideration its former absence, current form and potential future developments, operational links with a view to changes over time are center stage. Thereby all prerequisites for the use of a case study are met.

It is also worth pointing out that the method has been employed in a number of previous works relating to the innovation-inducing effects of environmental policy, and specifically the EU ETS (Hoffmann, 2007; Rogge, Schleich, Haussmann, Roser & Reitze, 2011; Rogge, Schneider & Hoffmann, 2010), as discussed in the literature review section of this work.

The following paragraphs will illuminate several methodologically relevant aspects, including the choice of cases, and the employed data collection and data analysis methods. Moreover, some of the methodological difficulties will be discussed in relation to the individual steps during which they emerged. Finally, the section will address the credibility and validity of the conducted work.

### 4.1. Case Selection

In line with the characteristics of qualitative research (Miles & Huberman, 1994), the central aim in selecting relevant cases was to allow for the analytical generalization of findings (Yin, 2009), rather than creating a statistically representative sample allowing for statistical generalization, a strategy prevalent in quantitative research (Miles & Huberman, 1994). Analogous to multiple experiments (Yin, 2009), multiple case study designs rely on a replication logic in order to enable such analytical generalization (ibid.), as opposed to a sampling logic usually employed in surveys. By replicating the findings from one experiment, the results of the initial experiment are being solidified (ibid.). Applied to case study research, this means that cases need to be selected on the basis of either achieving literal replication, that is discovering similar results due to similar conditions, or theoretical replication, that is predictably dissimilar results due to deviations in certain conditions (ibid.).

This goes to show that the selection of cases is not based on representative grounds but on conceptual ones (Miles & Huberman, 1994), which in turn are grounded in the theoretical framework of this thesis. Yin (2009) stresses the importance of a rich theoretical framework, as developed in the preceding section, for the exercise of replication procedures, as it provides the conditions under which one can expect certain results to emerge, or not to emerge.

According to Miles and Huberman (1994), there are two central actions to be taken in selecting cases. First certain boundaries need to be established. On the one hand, such boundaries are influenced by the present limitations in resources, such as time. On the other, however, cases need to be selected, which *"directly connect to your research questions, and that probably will include examples of what you want to study"* (Miles & Huberman, 1994, p. 27). Secondly, it is necessary to establish *"a frame to help you uncover, confirm, or qualify the basic processes or constructs that undergird your study"* (ibid., p. 27). This second action relates to the importance of a well-developed theoretical framework, stressed by Yin (2009), which enables the identification of certain conditions and circumstances whose variation potentially contribute to the robustness of findings (Miles & Huberman, 1994; Yin, 2009).

Considering that innovation in the private realm usually takes place at the firm level, it is apparent that the unit of analysis are firms. Keeping in mind the necessity of a direct connection to the research questions and this work´s concern with the EU ETS, it is also apparent that the chosen companies need to operate at least one installation covered by the EU ETS. This boundary already minimized the potentially relevant cases for this research to 40 companies, operating all 59 installations covered by the EU ETS in the Republic of Croatia, as identified via the respective company accounts within the European Union Transaction Log. Another 7 of those relevant companies have failed to report emissions during the relevant period, have reported zero emissions, or have since the introduction of the EU ETS been excluded from the scheme, leaving 33 companies. Another 15 of the remaining 33 companies exhibit emissions levels below 25,000 tons of CO2 annually, thereby being categorized as *mini* in size by the European Environment Agency (EEA). Those companies were excluded for several reasons. Firstly, combined, these companies represented a mere

1.07 percent[32] of total annual emissions covered by the EU ETS in the Republic of Croatia, as of 2016. Secondly, in the year 2016, these companies, on average, received approximately 135 percent of their annual emissions allowances via free allocation. Furthermore, 111.7 percent of the total emissions of *mini* operators were covered by free allowances in 2016. It is reasonable to assume that these circumstances weaken any motivation to undertake eco-innovations aimed at emissions reductions, and mostly disable the exploitation of economies of scale for these operators, as the additional cost imposed by the EU ETS is negligible compared to the investment cost of both state-of-the-art emissions abatement technology and research and development. It is therefore also reasonable to assume that those cases are unlikely to include examples of the phenomena under investigation in this study or to aid in uncovering or confirming any of its underlying processes or constructs, thereby not matching the selection criteria as posited by Miles and Huberman (1994).

The remaining 18 companies were then categorized along the employed theoretical frame, with firm-internal and firm-external characteristics determining their respective suitability for examination. In order to appreciate the inherent diversity and heterogeneity of the emissions-intensive corporate landscape and the associated diversity in reactions to regulatory impetuses, such as the EU ETS, differences in firm characteristics represent an important feature of the chosen sample. As such, companies from diverse sectors, of different size, different emissions intensity, and different corporate vision were chosen.

A total of 14 companies were identified as suitable cases and consecutively contacted via e-mail. E-mail addresses were acquired via the respective company websites, and in some cases provided by fellow researchers who had been in prior contact with the respective companies in the course of other projects. Initial contact e-mails included a brief explanation for getting in touch and several attachments, including an introduction letter explaining the research´s motivation, relevance, method, and use, as well as a non-disclosure declaration and a document confirming the author´s affiliation with a well-renowned Croatian research institute, so as to bolster credibility and trustworthiness. For several reasons, which will be outlined in sub-section 4.4, the final number of cases amounts to five. The five companies examined during this study, however, match the desired variation criteria, and thereby allow for the desired replication processes. The final sample includes large and medium emitters, as defined by the EEA, companies of different size, with differing vision, operating in different

[32] The percentages presented throughout this paragraph are based on the author´s own calculations, which in turn are based on data from the European Union Transaction Log, retrieved from http://ec.europa.eu/environment/ets/oha.do (04.05.2017).

sectors. Furthermore, it is worth noting that the examined companies represent 67 percent of total annual emissions of the Republic of Croatia.

### 4.2. Data Collection

The case studies were conducted through April and May of 2017, which marks the fifth year of EU ETS participation of regulated companies in the Republic of Croatia. A total of five company case studies were conducted, each entailing the careful examination of background information retrieved from archival data, such as company websites and annual reports, and consequent semi-structured interviews with company officials. This approach of interviewing, as opposed to fully structured interviews, allowed for a deeper understanding of complex issues (Brenner, 2006), the appreciation of contextual conditions (Yin, 2010), and the avoidance of suggestive questions (ibid.). Based on the background analyses, the respective interview guides were customized to a certain extent in order to avoid questions irrelevant to certain sectors. To the largest extent, however, the degree of uniformity among the interview guides was kept high so as to ensure comparability.

Interviews were conducted face-to-face in the majority of cases, with the exception of two telephone interviews. Depending on the organizational configuration of the participating companies, the number of interviewees varied between one and four, totaling at ten interviewees. As far as possible, given constraints in time and availability, the interviewed officials covered the functions relevant to eco-innovation, including strategy, environmental sustainability, technology, and sales. Interviews lasted between 50 and 180 minutes, totaling at approximately 390 minutes.

Interview questions were related to the relevant factors and determinants identified and operationalized in the preceding section, including eco-innovation strategies, sustainability strategies, corporate social responsibility, R&D activity, technology adoption, corporate vision, the perceived role of the EU ETS in relation to these concepts and several context factors.

During interviews the interviewer took detailed notes, which were subsequently used to compile detailed research protocols, which in turn were used for data analysis, the particularities of which will be discussed in the succeeding sub-section.

### 4.3. Data Analysis

In designing a case study, it is advisable to select some analytic strategy in order to facilitate data analysis by ensuring the collection of relevant and analyzable data (Yin, 2009). This study combines two analytical strategies by first and foremost relying on theoretical propositions (Yin, 2009) developed in the preceding section. These propositions guide the data collection plan by determining the research questions and the reviewed literature (ibid.). Moreover, the underlying theoretical propositions also unveil potential rival explanations (ibid.), the examination of which serves as the second analytical strategy included in this work.

Once an analytical strategy has been chosen, a desirable analytical technique needs to be picked. As mentioned elsewhere, qualitative case studies rely on analytical generalization, which in turn involves the reconciliation of previously developed theory with empirical results (Yin, 2009). The most desirable technique (ibid.) to perform such a task is the employment of pattern matching. When it comes to analyzing data from multiple cases, cross-case analysis furthermore plays a significant role (Miles & Huberman, 1994). Once an initial case has been examined in detail and a pattern has been discovered, which corresponds with the theoretical propositions, successive cases are examined in order to determine whether the observed pattern holds true for a larger population. Moreover, cases are analyzed which due to theoretical propositions can be assumed to yield different results.

In performing these analytical tasks, a four-step approach mirroring the delineated methodology was followed. Initially, a code list, founded on the theoretical framework, was developed, which was then refined in the process of coding the first interview. Secondly, interview protocols were triangulated with archival data in order to investigate any discrepancies and to increase construct validity. Then, the remaining interviews were coded, and based on these codes several impact-categories of the EU ETS on the dependent variables were identified. Once all cases were examined, the cross-case analysis including pattern-matching techniques was applied in order to illuminate common outcomes, while paying attention to rival explanations, thereby increasing the internal validity of the presented results. As concerns about validity and reliability are omnipresent in qualitative research, the next sub-section will address these in greater detail.

## 4.4. Validity and Reliability

Considering the necessity of research to exhibit logically comprehensive and coherent explanations and descriptions, its quality is judged via logical tests. The most commonly used tests to assess the quality of empirical social research relate to construct validity, internal validity, external validity and reliability (Yin, 2009). This section will address the implications of these tests and provide insights as to how this research remedies the issues concerning its quality.

Concerning construct validity, which describes the appropriateness of operational measures of the concepts under investigation (Kidder & Judd, 1986), especially case studies are prone to criticism regarding the subjective nature of data collection and insufficiently operationalized measures (Yin, 2009). Although the measures, as identified and operationalized throughout the theoretical section of this work, are well-founded in theory, the precision with which they can be documented is not perfect. Yin (2009), however, identifies remedies to this issue, including the use of multiple sources of evidence, achieved via the inclusion of archival data as well as interviews in the data collection process, and the maintenance of a chain of evidence.

A further test, which has important implications for explanatory case studies (Yin, 2009), is concerned with a study´s internal validity. That is whether the aim of establishing causal relationships can be met without fallaciously identifying spurious relationships as causal ones (Kidder & Judd, 1986). The most relevant threat to internal validity is the omission of potential rival explanations and thereby relates to the general difficulty of making correct inferences (Yin, 2009). Even in the event that resources, such as time, were unlimited, to incorporate every potential, rival explanation in any study would exceed the cognitive capacities of any researcher. However, the anticipation and incorporation of questions addressing rival explanations, the robustness of findings, and the convergence of evidence mark an important step in dealing with the difficulties of making correct inferences, and thereby remedying concerns about internal validity (ibid.). The pattern-matching strategy employed in the data analysis of this research and explained in the preceding sub-section, as well as the explicit account for rival explanations via the incorporation of context factors, both serve as tactics improving its internal validity, following recommendations made by Yin (2009) in this regard.

The last validity test stems from concerns regarding the generalizability of a given study´s findings (Kidder & Judd, 1986). External validity in case study research is, unlike survey research, a product of analytical generalization, which seeks to transfer certain results to a broader theory (Yin, 2009). By following the replication strategy, addressed at an earlier point, and testing whether the propositions of the employed theory hold in multiple cases for which that theory predicts such outcomes, this research employs the best available strategy for improving external validity (ibid.).

In conclusion, the question of reliability remains. The reliability test refers to the possibility of repeating the steps of a given study, such as data collection and analysis, and to arrive at the same results (Kidder & Judd, 1986). According to Yin (2009), the desired goal of reliability is to curtail biases and mistakes. This research, in accordance with Yin´s (2009) recommendations, closely documents the steps carried out in order to allow for repetition. It furthermore utilizes case study protocols and relies on a database, thereby increasing reliability via the operationalization of as many processes as possible (ibid.).

### 4.5. Difficulties

Several difficulties arose throughout this research. This section will address the most severe and important ones while referring to the stages at which they arose.

One of the issues this research faced was the very limited population of relevant cases from the outset. As pointed out in sub-section 4.1, several reasons contributed to an initially small number of suitable cases. This circumstance was further aggravated by significant difficulties in gaining access to knowledgeable and cooperative interviewees. Although relevant companies were contacted via e-mail up to 5 times, and in cases in which telephone numbers were available also via phone, responses were only received from 9 of the 14 companies. This circumstance can possibly be attributed to the present language barrier, as the author does not speak the native language of the population under investigation. However, two companies explicitly declined to partake in this study, with one referring to internal rules on the participation in research, and the other not specifying any reasons for declining. Other respondents who ultimately did not partake in the study were either unable to identify the organizational unit responsible for handling the request, ceased contact after initial introduction of the project, or considered themselves unsuitable for participation based on the official´s perceptions of company irrelevance to studies linked to innovation activity. Although this remains speculation, it appears reasonable to assume that a number of non-respondents may have had similar reasons for ignoring all efforts to establish contact.

Another important issue arose concerning sensitive and particularly confidential information about companies´ strategies. Despite efforts such as non-disclosure agreements, this circumstance contributed to certain questions yielding unreliable answers, or none at all. For example, when asked which role emissions trading assumed in the respective organization, one official replied that company management had advised her not to speak about the topic. In connection to this problem, interviews were not recorded and the author agreed to anonymize gathered data and results in order to disable any ex-post identification of specific companies or interviewees. To this end it was also necessary to omit explicit mentions of certain products, technologies, product-categories, or examined sectors. The reconciliation of information provided in section 4.1 with the European Union Transaction Log and the presented findings could enable the identification of specific firms, and thereby put the author at risk of a breach of contract.

Despite the mentioned efforts of increasing trustworthiness and conceding anonymity to interviewees, several instances arose in which questions were answered in what could be characterized as an evasive manner. This circumstance can possibly be attributed to interviewees´ efforts to protect or even embellish the public image of their employer in relation to environmental consciousness and responsibility.

Lastly, in some instances, the language barrier between the author and the respondents remained problematic to the extent that some questions as well as answers needed additional clarification. Moreover, in very few instances, respondents identified themselves as incapable or unqualified to answer certain questions, which in turn remained unanswered as limitations in time and capacity did not allow for follow-up interviews with responsible or knowledgeable units. This final issue was especially pronounced in relation to questions concerning the role of emissions trading and/or research and development activity, which especially in the case of multinational companies tends to be centralized in global headquarters or innovation centers.

## 5. Findings

### 5.1. Research, Development and Demonstration

The majority of investigated firms engage in some form of RD&D activities. As was expected, the extent and direction of these efforts differ across firms and sectors. All firms active in RD&D appear to engage in all three RD&D components primarily in the quest for innovations. Process innovations, on the other hand, only involve all three RD&D components in manufacturing industries, while the remaining firms were not found to engage in basic laboratory research. A pattern emerged that product innovations were more commonly researched, developed, and demonstrated in firms from manufacturing industries, which also belong to the smaller-size operations represented in the sample. Process innovations were developed and/or demonstrated in all firms active in RD&D, but more pronounced in utilities firms, which belong to the larger-size operations represented in the sample.

While it is true that some component of RD&D could be found in most investigated firms, its extent should not be overstated, especially in relation to process innovations. This is exemplified by companies that, since the introduction of the EU ETS, have started employing technologies new to their operations, which, although they require some extent of development to match company-specific circumstances, and certainly constitute demonstration on the company level, are to be located closer to the adoption dimension, which will be examined in the succeeding sub-section.

Nevertheless, one specific area of increased RD&D efforts was to be found in carbon capture and storage (CCS). Albeit not relevant for all investigated firms, and even incompatible with the operations of some, RD&D efforts in CCS were found in some firms. CCS, which describes the technique of capturing CO2 with its subsequent storage underground, is of particular interest with a view to the EU ETS, and has been described as *"one of the key technological mitigation options"* (Rogge et al., 2011).

Relying on the applied definition of eco-innovation, all RD&D efforts mentioned in the previous paragraphs are directly related to the environmental performance of the examined firms. However, as established throughout section 3, such findings say nothing about the underlying drivers of these efforts, and do not address the reasons for firms´ diverse approaches.

Generally, RD&D efforts were found to be impacted by the EU ETS to varying degrees in all investigated firms. Surprisingly, even firms that due to freely allocated allowances exceeding annual emissions did not experience any direct cost associated with the system, appeared to have carried out, or at least considered, RD&D efforts in product and/or process innovations resulting in decreased CO2 emissions. While many company officials remained careful attributing these efforts directly to the EU ETS or identifying the instrument as their sole driver, all identified a regulatory push/pull effect. Most pronounced RD&D effects were found in relation to CCS, mirroring findings by Cames (2010) and Rogge et al. (2011), with one company official (Case #5) stating that *"CCS will be the next hot topic in the industry"*.

Although a regulatory push/pull effect on RD&D activity was found, context factors appear to play equally decisive roles in these considerations. All investigated companies identified at least one factor aside from the EU ETS as equally or more decisive in shaping decisions regarding RD&D. Such include savings via reduced fuel consumption, pressures from local communities and the public salience of climate change, environmental consciousness of top-management, and other environmental policies. Concerning the policy mix, the Industrial Emissions Directive[33] (IED), the Energy Efficiency Directive[34] (EED), and the Renewable Energy Directive[35] (RED) were found to be less influential than the EU ETS, if having any impact at all. None of the investigated firms attributed any pronounced influence to domestic legislation.

In relation to the observed pattern of some firms being more likely to invest in RD&D directed at product innovation, while other firms appear to put a stronger emphasis on process innovations, it appears reasonable to conclude that factors other than the policy mix are decisive. Since all observed companies are subject to the same environmental legislation, inter-firm differences are likely to stem either from firm heterogeneity or varying market conditions, such as firm size and market structure. This notion finds support in the findings of *inter alia* Link (1982) and Scherer (1983). In agreement with the findings of Link (1982), this study finds that the share of R&D directed at process innovations appears to be positively related to market concentration. Additionally, the observed firms operating in more concentrated markets are larger in size than their counterparts. Scherer (1983) and Cohen and Klepper (1996) find that resources devoted to R&D in process innovations tend to increase with firm size, providing further support for the conclusion that inter-firm differences related to innovation types are mainly related to context factors.

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[33] EU (2010, December 17). *"Directive 2010/75/EU"*. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0075&from=EN (28.06.2017).
[34] EU (2012, November 14). *"Directive 2012/27/EU"*. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0027&from=EN (28.06.2017).
[35] EU (2009, June 5). *"Directive 2009/28/EC"*. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=EN (28.06.2017).

### 5.2. Adoption of Eco-Innovations

While findings on the policy instrument´s impact on RD&D are few, and rather mixed, the adoption dimension of innovation was found to be more fruitful in terms of evidence, which in turn generated more straightforward results.

Four of five investigated firms have invested in new facilities or the retrofitting of existing facilities since the introduction of the EU ETS. Retrofits, as well as the construction of new facilities, were found to be directly related to the environmental performance of the respective firms throughout. While the nature of the adopted technology varied to a certain degree, depending on the respective operations of the examined firms, some patterns emerged.

All firms found to invest in new facilities exhibited a focus on renewable sources of energy. Several projects were identified which committed sizeable investments to, *inter alia*, solar energy plants, bio-mass plants, and alternative fuels facilities. Besides CCS, these measures exhibit the most obvious connection to the EU ETS, and contribute considerably to the decrease of CO2 emissions. Retrofits to existing facilities were found to be more diverse, ranging from modernization efforts due to age or wear to conscious abatement efforts. Nevertheless, all retrofits appeared to contribute to reduced emission levels.

In comparison to RD&D efforts, adoption measures were more conclusively found to be related to the EU ETS. This finding appears especially true for investments in new facilities. As one company official stated (Case #5), *"These* [facilities] *were both triggered by EU legislation. These projects only make sense when taking into account the CO2 price"*, also assuring that: *"We* [the company] *had no interest in alternative fuels before we became part of the EU ETS"*. Another (Case #3) identified the EU ETS´s influences as *"not marginal"* in relation to adoption measures. Other company officials (Case #2) posited that adoption measures´ *"main targets are CO2 emissions"*, further underlining the EU ETS´s impact on these. Although the EU ETS was found to be the main driver of investments in this direction, the influence of the RED with respect to facilities for the sourcing of renewable energy cannot be ignored.

Turning to retrofits to existing facilities, motivations are more diverse, but remain supportive of the assertion that the EU ETS has exerted additional pressures in the direction of their adoption. While retrofits were often labeled as efficiency-enhancing measures, one company official´s (Case #2) statement that *"energy efficiency and CO2 emissions are directly connected"* is an important assertion. When asked whether such efficiency-enhancing retrofits would have taken place regardless of the consideration of CO2, another official from the same firm replied: *"I think yes, but it would take a bit longer"*. Nevertheless, it appears that the EU ETS serves more of a complementary role to the IED and EED with a view to retrofits and modernizations, as compared to the construction of new facilities. One company official notes that although (Case #3) *"there is a lot of overlap, the IED was probably most decisive"*.

Generally, the findings on adoption suggest that the broader EU-level policy mix has had a significant impact on the investment strategies of regulated firms, with the EU ETS playing a considerable role with a view to long-term returns. As one official (Case #2) puts it: *"If it weren´t for the EU regulatory framework, we would not have implemented these changes at the same pace"*.

Adoption decisions appear to have been influenced to a far lesser extent by context factors other than the EU policy mix, as compared to RD&D efforts. While differences in chosen technologies certainly mirror the heterogeneity of investigated firms, adoption strategies appear to be a rather uniform response to regulation. Decision patterns to diversify technology portfolios away from fossil fuels were found to be largely informed by long-term considerations of the impacts of environmental regulation, including the EU ETS. However, the public acceptance of renewable energy sources, customer demand for environmentally friendly services and products, as well as long-term competitiveness considerations and a general proactivity of firms were identified as facilitating factors to varying degrees.

### 5.3. Organizational Change

The final innovation dimension, organizational change, encompasses operational change, procedural change, structural change, and changes in corporate vision. The impacts of the EU ETS differ across these categories, and are often complemented or triggered by context factors rather than the policy instrument under examination.

In terms of operational changes, all investigated firms were found to have altered operational processes in favor of environmental performance. All firms applied at least one such change, including fuel substitution, the substitution or reduction of certain input factors in the respective production process and operational fuel saving techniques. However, the EU ETS was not found to be the main driver of such process innovations. The instrument did serve a complementary function due to additional cost savings in most cases, especially with a view to long-term costs. *"Yes, but they are becoming more and more important now that CO2 is an* *additional cost factor"* one official (Case #2) stated, when asked whether fuel and raw material substitution had been important strategies before the introduction of the EU ETS.

Currently operational changes appear to be more decisively influenced by various context factors. No clear pattern emerged, making it unfeasible to generalize. The following quotes will exemplify the diverse findings in this respect. One official (Case #1) responded: *"Again, the price of emissions is not that high … the deciding factor is, however, fuel prices"*, when asked about the main motivation behind fuel saving techniques. Another (Case #3), while speaking about the substitution of liquid fuels with gas, attributed more importance to the IED, saying: *"*[We substitute fuel] *because of SO2 and NOx and particle matters, other pollutants* [than CO2] *… The IED was more decisive in the fuel substitution than the EU ETS"*. It appears reasonable to conclude that a mix of various factors contribute to the widespread application of operational innovations.

Turning to procedural changes, a different picture emerged. While yet again all investigated firms were found to have undergone procedural innovations to some degree, these were found to have been determined by the EU ETS to a considerably larger extent than was the case with operational changes. For one, since the introduction of the EU ETS, CO2 was found to play a far more significant role in the risk management of all investigated companies. One company official (Case #4) states: *"Emissions are included in risk management, which was not the case before"*. Another interviewee (Case #5) goes into further detail when asked whether CO2 is included in the firm´s risk management, responding: *"Yes. Even in day-to-day business. We are practically calculating per contract …* [whether we are] *able to cover opportunity costs of not selling CO2* [allowances] *that is* [are] *required to cover production"*. Secondly, the investment strategies of most investigated companies were found to be impacted by the EU ETS considerably. As one company official (Case #1) states, *"It has definitely changed our way of thinking and our strategy. It changed our priorities in terms of investment … It forced us to include additional variables in our calculations"*. When asked about the influence of the EU ETS on investment strategies, another interviewee (Case #2) posits: *"*[The carbon price] *has influenced our decisions regarding all new projects. We prepare these calculations and our plan is to include this into the decision-making procedure"*. Generally, the EU ETS and the associated price for carbon appear to be reflected in the strategic decisions of investigated firms. Conversely, sustainability strategies were found to be impacted by the EU ETS to a much lesser extent. While some interviewees identified an increase in emphasis on climate change since the introduction of the EU ETS, context factors were found to be more relevant in this respect. The public salience of climate change, pressures from local communities, and customer demands proved most important in this regard, with top-management commitment and environmental proactivity further benefiting the increased attention paid to climate change and related sustainability questions.

Concerning structural change, the effects of the EU ETS were found to be limited. With few exceptions, the investigated companies had not introduced any new organizational units or task forces in response to the EU ETS. Presumably in order to keep compliance costs at an acceptable level, previously existing units´ responsibilities were simply extended in most cases. *"We did not make big organizational changes, we just added additional tasks"* one respondent (Case #3) stated, with another (Case #4) saying: *"Not so much fundamental changes, but a bolstering of existing structures"*, when asked whether the EU ETS had provoked structural changes in their respective organizations.

Turning to changes in corporate vision, findings are diverse. While all investigated firms exhibit varying degrees of commitment to sustainability and environmental responsibility, the influence of the policy instrument covers a wide range. Since all investigated firms have environmental and/or energy management systems in place, and devote large sections of their annual and/or sustainability reports, and/or websites to questions of sustainability and environmental protection, including climate change, it can be concluded that a certain level of environmental awareness and sense of responsibility is present across the sample. However, whether the EU ETS has provoked an increased focus on these issues cannot be answered uniformly for the chosen sample. While some firms appear to have picked up on questions of environmental protection only after the introduction of the EU ETS, with one representative (Case #1) stating: *"It made us realize that we are impacting the environment. I´m sure, if there was no ETS, there would be no ISO 14001*[36] [environmental management standard]*, which is our voluntary choice"*, others acknowledged that the instrument increased the perceived importance of these issues in their respective firms, but insisted that other factors, such as the public salience of climate change, the proactivity of top-level management, or local community pressures, had directed attention towards environmental issues long before the introduction of the EU ETS. Such claims seem credible, since the firms in question were found to have implemented, for instance, environmental management systems or voluntary emission reduction targets before the announcement was made that the EU ETS would become operational in the Republic of Croatia. It can then be said that context factors appear

[36] See https://www.iso.org/iso-14001-environmental-management.html (26.06.2017).

to play a decisive role in shaping corporate vision on environmental responsibility, with the EU ETS mostly playing a marginal or complementary role.

### 5.4. Discussion

Having presented the main findings, the following sub-section will recap the results, go into more detail concerning the relative influence of various explanatory variables, and present some additional findings. While the qualitative nature of this study does not enable a quantitative interpretation, it appears that the EU ETS has exerted additional pressures in the direction of eco-innovation, thereby confirming that a regulatory push/pull effect is present. However, the findings also suggest that the EU ETS´s influence remains weak in some aspects, and that context factors have played an important role.

#### 5.4.1. Innovation Impact

The findings presented in the preceding section show that eco-innovation can be detected in all firms represented in the sample. However, they also show that impact of the EU ETS exhibits considerable variation across innovation dimensions and between firms.

The level of observed RD&D was low. While manufacturing firms appear to engage in RD&D to a larger extent, the EU ETS does not appear to have triggered such efforts. For one, manufacturers are striving to differentiate their product portfolios in order to gain competitive advantages, and although it is true that certain RD&D efforts are aimed at the reduction of CO2 emissions in order to reduce compliance costs and offer competitive product pricing, the identified importance of context factors suggests that these efforts are merely being reinforced by the EU ETS, rather than triggered or even made worthwhile. With a view to service providers and utilities firms, RD&D efforts were found to be minimal. While the company-level demonstration of new technology was found to be widespread, such efforts should not be overstated in the strict sense of RD&D, since the applied technologies have been researched, developed and demonstrated before, rendering their application more of an adoption phenomenon. It is to be kept in mind that RD&D is costly, and that uncertainties surrounding its outcome are very likely to hamper any such efforts. It therefore appears that the market failures surrounding this dimension are not easily cured by the EU ETS, especially considering the still low carbon price and the not unsubstantial share of free allocation to be found in the Republic of Croatia. Nevertheless, CCS was found to be an important area of

RD&D. Although not widespread yet, it is reasonable to assume that it will gain attractiveness if compliance costs increase.

The adoption of new, eco-friendly technologies showed more widespread than RD&D. Simultaneously, the EU ETS´s influence was found to be more pronounced in this dimension, especially with a view to the construction of new facilities aimed at the sourcing of renewable energy. The EU ETS was found to have complemented a number of context factors here. Although the carbon price remains low, the expectations surrounding climate policy, including the EU ETS, play an important role in decisions surrounding this adoption category. However, the influence of especially the public acceptance of renewable energy sources and the RED cannot be neglected. When looking at retrofits, the EU ETS´s impact was found to be slightly more limited. While additional savings from efficiency increases might have exerted positive influence on retrofit decisions, the IED and EED were identified as most decisive in this category of the adoption dimension.

Finally, organizational change was found to be the most widespread. The findings suggest that operational changes were caused by context factors to a large extent, with the IED and fuel prices being the most decisive. Nevertheless, it can be asserted that the EU ETS provided additional impetus for some of these changes. Procedural changes, with the exception of modified sustainability strategies, exhibited the most pronounced impact of the EU ETS. The instrument appears to introduce the issue of climate change to higher management levels via the inclusion of carbon-related variables in investment decisions. Structural change was scarce, most likely resulting from desires to keep compliance at low levels. Lastly, observed vision changes seem to be largely influenced by context factors, such as local community pressures and public salience of climate change. However, it is reasonable to conclude that long-term international climate targets play a significant role in shaping corporate vision. As such, the EU ETS can be considered to bolster the credibility of such commitments, thereby contributing indirectly to vision changes.

### 5.4.2. EU ETS Features

In determining the influence, or lack thereof, of the EU ETS, it is worth revisiting some of the findings which emerged throughout the qualitative interviews regarding the two main design features of the policy instrument.

In terms of stringency, which was operationalized as compliance cost, the findings suggest that the EU ETS does not impose any sizeable cost on regulated entities. All interviewees′ accounts match in this aspect. Clearly the low carbon price, the free allocation of allowances to varying extents, and in some instances an interplay with still recovering target markets and consequently reduced output levels, are factors which contribute to this circumstance. Quotes such as: *"As a change motivator? Allowances have been hovering between 5 and 8 Euros, now being around 5-ish. To tell you the truth, this is not enough to motivate any company to undertake drastic changes. The expense per customer or per year is not a big deal. Heavy modifications cost more"* (Case #2) or *"We spend more money on plastic cups* [than on EU ETS compliance]*"* (Case #1) are fairly clear indicators.

Turning to the predictability of the instrument, a similarly negative picture emerged. Short trading phases, frequent changes in legislation, the cumbersome process of determining the rules for subsequent phases, and the associated late arrival of definitive information on those rules were all cited as reasons for the low levels of predictability all respondents ascribed to the policy instrument. As one company official (Case #3) stated, *"It is unpredictable, as can be seen now with the process of defining the rules for Phase 4"*. Another (Case #5) notes that *"We have never been able to even closely predict the CO2 price. Also, there is big uncertainty about what will happen post 2020. We do not know how the allocation of allowances will be calculated, what the benchmarking rules will look like, and so on"*. In connection to these issues another interviewee, when asked whether these uncertainties defer investments in new technology aimed at abatement, responded with a firm *"Yes"*.

These findings beg the question, if the EU ETS is neither stringent, nor predictable, how can it have induced innovation activity? Simply put, the findings suggest that the expectations related to the future of the policy instrument have had a decisive effect. While some firms already experience added cost via the carbon price, which explains the observed price-induced innovation activity to some degree, recent climate policy, and thereby the EU ETS, appear to have signaled strong political commitment to long-term carbon reduction goals. In combination with various context factors, this has caused the inclusion of carbon prices in corporate strategy, which in turn has spurred first forays into the development or application of novel abatement technology, such as CCS, the demonstration of renewable energy sources, and the adoption of a number of low-cost abatement strategies such as fuel substitution. *"Analysts say that until the year 2020 the price of allowances will be around 24 Euros, and then it is a completely different ballgame"* one company official (Case #1) stated in relation to the expected future impact of the instrument, a sentiment closely mirrored by other firms represented in the chosen sample.

In conclusion, it can be said that most interviewees were sure that increased carbon prices, and a decrease in freely allocated allowances, would force their respective organizations to tackle GHG emissions more aggressively. Additionally, the extension of the length of trading phases, and even more so the earlier announcement of definitive rules, would enable an investment environment more conducive of eco-innovation. This finding lends support to theoretical implications and earlier conclusions, that a further tightening of stringency and especially enhanced predictability would improve the capacity of the instrument to foster low-carbon innovation.

### 5.4.3. Firm-External Factors

Turning to firm-external context factors, several categories were determined to influence the investment and innovation activities of the examined firms. Depending on the innovation dimension and firm-characteristics, these factors were found to be varyingly decisive, ranging from no detected impact to more influential than the policy intervention.

Firstly, the policy mix was found to be highly influential. While RD&D efforts remained largely unaffected by the EU-level policy mix, both adoption and organizational change, especially operational change, were subject to considerable influence from the IED and EED, and to a lesser extent from the RED. This finding appears reasonable, since the IED prescribes the mitigation of certain pollutants under threat of facility closure. Similarly, the EED has a rather prescriptive character as compared to the EU ETS. *"It is definitely the entire EU policy mix that contributes"* one official (Case #3) stated in relation to this. The RED was found to have played a significant role in the adoption of renewable energy sources only. It is, however, to be kept in mind that there is significant overlap with the EU ETS when it comes to the employment of renewable sources of energy and efficiency-enhancing measures. Domestic policies were found to play no significant role in the innovation activity of the observed firms. When asked, for instance, about the scheme for the support of renewables, one company official (Case #5) stated: *"The government does not have enough funds to cover the contracts they sign"*. Similarly, another respondent (Case #2) stated: *"It is not very clear what the vision of the national authorities is. It is more stable to look at the EU policies. More reliable than Croatian legislation"*, when asked about the influence of national legislation.

Secondly, market factors were determined to have been influential with regard to adoption and organizational change, especially in the operational and vision categories. For one, fuel prices appear to have influenced a number of decisions in both innovation dimensions, although to a larger extent in the operational category of organizational change. It is also to be kept in mind that certain market circumstances may have oppressed the implementation of changes in some firms. Regarding such instances, one company official (Case #5) stated: *"Market factors are very important. Using bio-mass, for example, is simply not feasible"*, referring to the high transportation costs. Next, concerns about competitive pricing of goods and services posed an influential factor in businesses where the added cost of emissions had the potential to cut a supplier out from a highly competitive market. Moreover, customer demand for eco-friendly services was identified to have a considerable impact on some firms. Two of the examined companies, however, were found to experience absolutely no demand-pull in the direction of eco-innovation. As one company (Case #4) representative put it: *"I am afraid our customers do not care about that. We are having a hard time marketing products with lower CO2 footprints"*.

Lastly, public salience and local community pressures were found to influence both adoption and organizational change. In terms of adoption, it appears that the public salience of climate change and the public acceptance of renewables contributed to investment decisions concerning especially the construction of new facilities aimed at the sourcing of renewable energy. In terms of retrofits, these social influences were found to be weaker, although in some instances, pressures from local communities had urged the application of new technologies or the discontinuation of certain others. With regard to organizational change, the public salience of climate change and environmental protection was found to have had impacts mostly on the vision of examined companies, contributing to increased awareness of and regard for environmental issues, including climate change.

### 5.4.4. Firm-Internal Factors

Similar to firm-external context factors, firm-internal context factors were found to show differential impacts across innovation dimensions, and were determined to exhibit varying degrees of importance in relation to the facilitation or impediment of innovation.

With respect to firm characteristics, it is important to note that the sector a company belongs to determines its predisposition for certain technologies, processes, and products. With firm heterogeneity, the feasibility and applicability of certain technologies and practices varies across the chosen sample, restraining the available scope of action for each individual case. For instance, CCS was not a feasible option for all investigated firms. Moreover, differences in respective markets, for instance market concentration, international competition, or demand for eco-friendly goods or services were identified, and deemed to decrease or increase the radius of operation in terms of innovation, depending on the individual firm´s characteristics. For example, firms which operated in highly competitive markets, subject to international competitive pressures, showed a greater concern for the added cost of the EU ETS than firms in concentrated markets. Although these influences strictly fall into the firm-external category of context factors, this goes to show that their impact varies depending on which sector the firm belongs to.

Turning to the firm-internal determinants of innovation featured in the research framework, firm size was determined to play a role mostly in relation to the differentiation between product and process innovation, with larger firms exhibiting less tendencies of product innovation than smaller firms. Another finding related to size is that smaller firms appeared to have less resources at their disposal for innovation activity. Quotes such as: *"In the end, if you don´t have the money for it, you cannot do it* [acquire low-carbon technology]*"* (Case #1) and *"The initiative* [a CCS project] *did not get approval, we didn´t get funds"* (Case #5) exemplify this circumstance.

Concerning corporate vision and environmental proactivity, it was found that all investigated firms had made credible commitments to sustainability and environmental protection. These commitments certainly facilitate an increased rate of the development and application of low-carbon technologies and practices. While the special emphasis some interviewees put on the impact of the environmental awareness and proactivity of their respective firms relative to policy intervention, and some of the more influential context factors, should be viewed with caution, it is clear, that companies have internalized environmental issues, and are aware that business-as-usual scenarios will not be feasible in the future. This corporate appreciation of the realities of environmental responsibility exerts positive influence on the decision-making process regarding eco-innovation.

Lastly, the firms´ geographical locations made them more or less susceptible to pressures from local communities. Firms located in densely populated areas exhibited a more proactive stance in abatement, and appeared more understanding of the necessity of an aggressive approach to environmental issues.

## 6. Conclusion

The analysis of emissions-intensive business operators in the Republic of Croatia has shown that innovation activities are being carried out across multiple innovation dimensions, influenced by a multitude of innovation determinants. Although context factors were found to still play significant roles in this respect, the EU ETS appears to have evolved into a powerful part of the integrated climate and innovation policy mix aimed at the decarbonization of European economies. The following paragraphs will sum up the findings and outline some of their implications.

In essence, the fundamental economic proposition for the EU ETS works. It has established a price for GHG emissions, which has come to be reflected in multiple areas of the corporate decision making of regulated entities, and thereby influences investment and innovation activity. In this sense, the EU ETS should be considered an important advance in international climate policy. The findings have confirmed that the instrument exerts a regulatory push/pull effect in the direction of eco-innovation, which is especially pronounced with a view to procedural organizational change and the re-orientation of technology portfolios towards renewable energy sources. While induced product innovations are rare, process innovations have been fostered to a considerable extent by the instrument. Nevertheless, the generous application of free allocation in the Republic of Croatia, paired with the remaining low allowance price, hinders the instrument to unfold its full innovation-inducing potential. Although the design features of the EU ETS were found to be sub-par, with low levels of predictability and moderate stringency, expectations surrounding the instrument´s future, coupled with the perceived strong political commitment to increasingly strict climate policy, complement the hitherto modest price-induced effects.

The findings of this study largely mirror earlier results by the likes of Cames (2010) and Rogge et al. (2011), amongst others. Low-cost and low-risk compliance solutions still enjoy preference to extensive RD&D efforts associated with high risks and cost. Furthermore, low carbon prices remain an obstacle. However, in contrast to these earlier studies, corporate focus on renewables and the associated mobilization of sizeable investments were found to be more pronounced. Also, and somewhat surprisingly, this study does not detect any significant influence of domestic policies on the innovation activities of the examined firms, but concludes that the EU policy mix is of paramount importance in this regard.

Although findings support the theoretical propositions that emissions trading and the associated change in factor prices, or at least the expectation thereof, induce innovation, it seems clear that environmental policy needs to be supported by policies aimed specifically at innovation, if the ambitious climate targets are to be met. On the EU level this necessity appears to have been acknowledged, since the EU Commission has put forward a proposal for the revision of the EU ETS including an innovation fund[37]. On the domestic level, the policies in place do not seem to achieve the desired effects and should be revised accordingly. The reasons for the inefficacy of domestic policies and concrete suggestions for their improvements would, however, require new research.

Concerning potential improvements of the design features of the EU ETS, it is reasonable to assume that the gradual decrease of the allowance budget and the increase of auctioning as an allocation mechanism will cure the issues associated with the low allowance price, and consequently the instrument´s stringency. It should be kept in mind that the pace of this process cannot be accelerated arbitrarily, since, in order to avoid large economic disruptions, regulated entities require ample adjustment time. The predictability of the instrument, however, could be enhanced considerably by expanding the duration of trading phases on the one hand, and on the other by ensuring the early announcement of new rules. Such improvements would contribute significantly to a more stable investment environment, provide regulated entities with the necessary adjustment time, and enable the reconciliation of planning and investment horizons with the arrival of new rules.

This thesis is not without limitations, warranting further research. The study was focused on one country, and while companies from different sectors were included, the small sample size did not allow for an in-depth comparative analysis of cross-sectoral impacts. Future research should include multiple countries and expand the sample size in order to enable a comparative analysis between countries as well as sectors. Furthermore, continued research should pay attention to a multitude of actors, rather than focusing only on the regulated entities, as such an inclusion of technology providers and consumers could prove beneficial.

[37] EU (16 January 2017). *"Finance for innovation: Towards the ETS Innovation Fund"*. Retrieved from https://ec.europa.eu/clima/news/finance-innovation-towards-ets-innovation-fund_en (29.06.2017).

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