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Abstract: The paper offers a sector based qualitative evidence on the climate and energy policy effects on eco innovations in the EU. It analyses through interviews to industry associations of ETS sectors the extent to which past innovation adoption dynamics were influenced by policy and regulatory levers, by looking at single and interaction effects of policies. As could be expected from the neo Schumpeterian theory on innovation (sectoral systems) sector differences emerge with specific contents. In the first place, policies appear to be of high relevance in some sectors, namely energy, coke and refinery, and paper and cardboard. Nevertheless, energy costs and energy taxation considerations dominate over potential effects of CO_2 targeted policies. Instead for Ceramics, environmental policy is a way to interact with policy managers in order to develop and design better policies. The bulk of significant CO_2 related innovations appeared well before 2000. Overall, Technological and organisational levels are both relevant: organisational innovations were relevant in most sectors, often operating as a leading force in technological development. We grant central importance to this 'complementarity' in the future path towards 2030 and 2050 aims, whose achievement is possible only by integrating technological, organisational, and behavioural innovations.

Dear editor,

we submit this paper which addresses the link between policy and carbon abatement innovations. It takes a qualitative view that complements econometric analysis, which is not able to provide sector based views in most cases due to data limits. It is an ex post assessment useful as hint to ex ante analysis aiming at investigating future technological trajectories.

Best Regards

Massimiliano Mazzanti

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http://scholar.google.com/citations?user=yFq2WBQAAAAJ&hl=it

Carbon abatement, sector heterogeneity and policy responses: evidence on induced eco innovations in the EU

Abstract. The paper offers a sector based qualitative evidence on the climate and energy policy effects on eco innovations in the EU. It analyses through interviews to industry associations of ETS sectors the extent to which past innovation adoption dynamics were influenced by policy and regulatory levers, by looking at single and interaction effects of policies. As could be expected from the neo Schumpeterian theory on innovation (sectoral systems) sector differences emerge with specific contents. In the first place, policies appear to be of high relevance in some sectors, namely energy, coke and refinery, and paper and cardboard. Nevertheless, energy costs and energy taxation considerations dominate over potential effects of CO_2 targeted policies. Instead for Ceramics, environmental policy is a way to interact with policy managers in order to develop and design better policies. The bulk of significant CO_2 related innovations appeared well before 2000. Overall, Technological and organisational levels are both relevant: organisational innovations were relevant in most sectors, often operating as a leading force in technological development. We grant central importance to this 'complementarity' in the future path towards 2030 and 2050 aims, whose achievement is possible only by integrating technological, organisational, and behavioural innovations.

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Introduction

Innovation is a crucial factor to achieve a sustainable and competitive economic development. Technological progress is the only exogenous driver of long run growth in income per capita in classic Solow-like models; Endogenous growth theory has emphasised the role of R&D and human capital as main forces behind countries (heterogeneous) performances; neo Schumpeterian evolutionary theory poses innovation in a broad techno-organisational meaning at the heart of economic systems development. In studies of environmental and economic performances, innovations – technological, organisational, behavioural - has gained increasing relevance as a key factor to obtain sustainable transitions (Costantini and Mazzanti, 2013; Mazzanti and Montini, 2010; van den Bergh, 2007).

Narrowing down the focus on environmental innovations (EI), it is worth noting that they are crucial to creating synergies between sustainability and competitiveness towards a greener economy (EEA, 2013; Gilli et al., 2013). Environmental innovations (Rennings, 2000, 1998) are a key factor, as it is well known that sustainable economic growth depends upon a constant investment in technological and new organisational/labour related ways of managing production. The Stern review itself acknowledges the role of technological change for climate change mitigation, as one of the three pillars (policy and behavioral change the others).

One of the most recent definitions of eco-innovation 'adoption' defines it as the production, application or use of a product, service, production process or management system new to the firm adopting or developing it, and which implies a reduction in environmental impact and resource use (including energy) throughout its life-cycle (Kemp, 2010).

We here link the analysis of EI adoption (not invention, namely patents) to policy and sectoral frameworks, thus with emphasis on idiosyncratic factors that characterize 'sector agents' (Maryse et al., 2009). Until twenty years ago, the economic discipline was dominated by the idea that any attempt conducted by environmental regulation in abating pollution would necessarily translate into an increase of internal costs for the compliant firm. Moreover, many theoretical studies during the 1970s support the idea that a country's comparative advantage could have been affected in a negative manner by stringent environmental regulation. For instance, the works of Pethig (1975), Siebert (1977) and McGuire (1982), stress that environmental policies increasing firms' internal costs affect countries' competitiveness, decreasing exports, increasing imports, and lowering the country's general capacity to compete on an international market. Nevertheless, in the last two decades, many scholars have challenged this dominant idea. In particular, Porter and Van der Linde, in different contributions (1991, 1995), strongly criticised this approach, underlining that the consolidated paradigm was not considering all aspects of the environmental regulation/competitiveness relationship. Moving from the static approach in which technology was held constant to a dynamic context, the authors showed how in practice some of the loss of competitiveness related to environmental regulation was compensated by an increase in innovation driven by the policy itself. In the view of Porter and Van der Linde, a properly designed policy framework may place pressure on firms, pushing them to develop new innovations and promoting technological change. Within this view, the additional policy-driven innovation may offset the loss of competitiveness due to the additional costs of regulation. Porter and Van der Linde show how regulation can specifically act through 5 different channels (1995). First, regulation signals resource inefficiencies and potential technological improvements to companies; second, regulation focused on information gathering can achieve major benefits by raising corporate awareness; third, regulation reduces uncertainty in pollution-causing activities; fourth, by putting pressure on firm cost function, regulation motivates cost saving innovations; fifth, regulation makes free riding behaviour in the transition phase through an innovation-based equilibrium more difficult. Based on this seminal work, Jaffe and Palmer (1997) discerned the three different implications of the Porter Hypothesis, proposing a taxonomy which is helpful in distinguishing the different lines of research that have further developed. The first idea, also called the Narrow Porter Hypothesis, shows that certain types of environmental regulations are able to stimulate innovation, following the idea that policy design matters, and command and control policies are generally (with exceptions) less efficient than economic tools in promoting innovation and technical change. A second version of the Porter Hypothesis, called Weak, in synthesis states that a well-designed environmental regulatory system may stimulate certain kinds of innovation. Finally, the strongest version of the Porter Hypothesis holds that not only regulation is able to spur innovation, but also that this gain in efficiency is able to completely offset any loss in competitiveness due to compliance costs. In other terms, this last approach suggests that more stringent and well-designed regulation promotes competitiveness.

Sectoral issues have gained considerable consideration since the Pavitt (1984) taxonomy was introduced into the economics of innovation. From a conceptual point of view, we mainly refer to the integrated concepts of sectoral and national systems of innovation, which have been consolidated into innovation-oriented evolutionary theory (Malerba, 2004) and have been exploited in environmental economics literature examining EI and policy (Crespi, 2013; Costantini and Mazzanti, 2012). Malerba promotes a sectoral system view of innovation. He stresses that sectors differ greatly with respect to their knowledge basis, technologies, production processes, policy and institutional environments, complementarity between innovations and market demand. Regarding policies, both within a strict innovation/industrial aspect and for what concerns an environmental aspect, these arguments matter. A ‘one size fits all’ approach may be not effective in supporting innovation diffusion and consequently economic and environmental performances. This is a hot-button issue in the EU, where ‘mainstream economics’ have probably influenced the implementation of policies that were constructed on the one-size-fits-all paradigm. The alternative is to shape policies according to sector and regional features following more bottom up and diversified approaches.

The Research hypothesis

This paper assesses *whether and to what extent energy and environmental policy instruments have been relevant forces behind the adoption of environmental innovations in the EU*. We focus on Technological and organisational innovations of product and process nature; incremental and radical features are additionally scrutinised.

The focus is thus on the ex post assessments of EI drivers, by looking at *single and interaction effects of policies*.

We take a sectoral perspective that is theoretically based on neo Schumpeterian evolutionary theory to qualitatively investigate the factors that characterise the adoption of techno-organisational innovations aimed at enhancing energy efficiency and abating CO_2 through interviews with industry representatives of key EU sectors: energy, chemical, paper and cardboard, ceramics and cement, metals/steel, coke and refinery. In terms of policy, though the EU ETS is an obvious keystone, the attention of the analysis is on 'drivers and obstacles' of innovation with some focus on the complementarities and trade off among policy tools as they emerge from interviews.

We claim that given the consolidated econometric evidence on the drivers of eco-innovations, qualitative investigations analyse the concrete developments of eco-innovation adoptions in sectors in an original way, by providing examples and evidence of specific technologies. This offers a unique contribution to the field of eco-innovation studies. Interviews, which are by definition not aimed at providing representative results but rather 'sector case studies', have the additional positive property that they may cover the EU as a whole under a dynamic perspective. The current availability of eco-innovation data in the EU (Community Innovation Survey data) limits the analysis to certain countries / years.

1. The impact of policy on environmental innovations: the survey and data

The analysis we present in this work aims at filling some gaps in the empirical literature on eco-innovations. The main research hypothesis we test is whether EI adopted over the 1998-2012 period had some policy support behind it. In doing so, we take a full sectoral perspective. Though some quantitative exercises partially look at sectoral specificity in the recognition that sectors possess idiosyncratic technological features and specific policy responses (Cainelli and Mazzanti, 2013; Marin and Mazzanti, 2013), it is only through more qualitative investigations that we can touch on the concrete innovations that have been introduced. One gap we wish to fill is thus to offer a sector-based view of the policy induced hypothesis, entering the realm of what technological and organisational innovations have taken place because of policy efforts (Questionnaire available in the annex[1]).

Specificity is thus sought with respect to (i) innovations adopted, (ii) policies that supported innovations. In addition, in cases where policies were not the main force behind adoption, we comment on the other factors that were possibily behind these innovations (market factors) as well as main hampering factors. Sector by sector features thus emerge through this exercise which

[1] The set of questions in the 2 pages questionnaire were used as a 'fil rouge' in the telephone and vis à vis interviews. The time span of reference is 1998-2012 (to set a boundary). The discussion went often beyond the list of questions

complements existing econometric-based evidence[2]. We also add one specific section to address the role of trade unions and industrial relations in the process of supporting the adoption of EI in firms as a key strategy in reconciling environmental, social and economic goals.

Interviews were carried out with specific industry representatives in June and July 2013 by a specialised Italian company (SWG Trieste[3]). We initially selected 48 'cases', or potential interviewees, in 6 sectors (ceramics and cement, chemical, steel, paper and cardboard, energy, coke and refinery) and 8 countries (CZ, PL, IT, DE; UK, ES, FR, NL). In total, 124 industry association representatives were contacted. Not all cases where fully relevant, as for example the ceramics sector, which is relevant to 3 countries in the EU (DE; IT, ES). 29 associations were successfully contacted (27 regarding the 4 sectors the analysis is based upon).

In addition to the initial set of interviewees, new experts and representatives were contacted depending upon availability[4]. Researchers themselves administered some questionnaires following personal contacts and contacts provided by industrial associations. This analysis is not aimed at providing any sort of full representative analysis, but rather at drawing out 'sector case studies' within a more general EU coverage (instead of focusing deeply on only one sector). As in all surveys, ex post results are affected by response rates. Average response rates for surveys range between 5% and 20%. The issue of subjective bias is common to most applied analyses based on surveys, for related discussion we refer to Collantes (2007). We here apply an approach based on semi-structured interviews, as in Mazzanti and Zoboli (2006), who analyse the effect of waste policies on techno-organisational trajectories, and Anadon et al. (2013) who rely on experts' opinions to analyse idiosyncratic technology sector features.

2. Empirical evidence: sector case studies

We here summarise the main evidence we derive from the series of qualitative interviews administered to various experts at the sector level and *industry representatives*[5].

We again stress that qualitative interviews provide evidence on techno-organisational innovation adoption in an original way that complements a more quantitative analysis, which by definition and data constraints is not able to produce detailed sector-based evidence on innovation adoption (EU data covers 2006-2008). Though results are not fully generalised, the views of industry (and

[2] The appendix shows figures related to economic and environmental performances in the EU by sector.

[3] Excel files and audio files of interviews are provided by SWG as output. SWG does not provide the names of interviewees, only codes, as per contractual agreement.

[4] A list of experts is provided. For privacy the information is for reviewers use only (to be verified for publication). We used discussions, comments and formal interviews as inputs to the analysis.

[5] Alternative research paths might be 'corporate case studies' or large surveys on firms. Studies based on samples of interviews appear in the innovation and management disciplines (we refer to Dubois and Gadde, 2002; Colyvas et al., 2002; Vohora et al., 2004 among others). A recent paper in the energy field is that of Anadon et al. (2013), based on 67 interviews. They aim is launching research questions and presenting a qualitative perspective on techno-organisational dynamics, which is not captured by large-scale quantitative studies. There are even cases where small samples are used to carry out quantitative analysis, as in the seminal paper by Ichniowski et al. (1997) on steel finishing lines.

not firm) representatives enlarge the innovation perspective scope. In each of the case studies, we provide information on the interviewees when it is possible. In the appendix, a general overview of the sector's innovation-economic-environmental performance is presented in a series of tables. We focus on 5 main ETS sectors. The chemical and steel sectors was deleted from the analysis due to insufficient data from interviews. Results are available, but not comparable in terms of number of interviews. Information on the two sectors are available upon request.

In the following 4 sections we present the insights for energy, ceramics, coke and refinery and paper & cardboard. Main insights regard the adoption of techno organisational innovations as induced by policies, their complementarity, and the role of policy interactions (trade off and positive integration). Throughout the text, when it is deemed relevant, we explicitly associate comments to the interviews (with a code; a list of coded interviews is presented at the end of each section).

2.1 Energy

2.1.1 innovation drivers

Interviews overall highlight the great importance of environmental and energy policies in shaping the rate and direction of innovation activities. This result appears to be in line with recent literature, which has shown that the policy inducement effect on technological change is relevant in this sector (Costantini and Crespi, 2007; Johnstone et al., 2010). Energy is the most studied sector in the empirical literature, because of its economic size and environmental impact. Compared to other sectors, references to scientific evidence for this sector are more frequently possible.

Regarding policy support, it is possible to distinguish between two main sets of policies: 1) legislation aimed at reducing CO2 emissions; 2) legislation aimed at promoting renewable energy.

According to the opinions expressed by the interviewed experts, within the first set, the major policy tool is represented by the Emission Trading Scheme (ETS), which represents a pillar in current EU policy framework (Borghesi, 2011). The discussion with experts also highlighted that legislation aiming at reducing CO_2 emissions has not contributed much to technological innovation per se in large combustion plants, but mainly promoted a fuel switch option. On the other hand, policies aimed at reducing CO2 emissions have spurred the generation and diffusion of *process innovations* related to carbon capture and storage.

With respect to legislation aimed at promoting the production and consumption of renewable energy, experts stressed that this has led to significant technological innovations in the field of renewable energy. In this context, feed-in tariffs and tradable green certificates emerged as the policies producing the most relevant impact in terms of technological innovation. Regulation and financial support for sustaining renewable energy has led to significant *product innovations*, concerning technologies for the production of photovoltaic and wind energy in particular.

Moreover, the policy framework has induced relevant innovation efforts in the field of technologies for the production of energy using biomasses. However, in this field, new generation technologies are yet to be fully developed and further research is needed in this sector in order to achieve a large-scale production of energy from biofuels obtained from new generation technologies (Costantini et al., 2013a,b).

Despite the importance of these technological innovations induced in the field of renewable energy, they are mainly *incremental innovations* to make renewable energy production more efficient.

Another important policy area leading to substantial innovative activities concerns regulations for energy saving in the residential sector (Noailly and Batrakova, 2010). In particular, experts highlighted how Ecolabelling schemes and incentives for energy efficiency in buildings favoured the generation and diffusion of innovations in new materials, fluorescent lighting, condensing boilers and cold generation.

Finally, it should be stressed that many innovations introduced in the energy sector have been patented, and there are increasing trends in energy patenting activities in recent years (OECD, 2013).

2.1.2 The role of policies in non-technological innovation

In the information we collected, public policies emerged as an important factor for the development of *organisational innovations* as well. This is an important finding as it confirms the importance of complementarity between technological and organisational innovation (Antonioli et al., 2013; Wagner, 2007; Ziegler and Nogareda, 2009). Renewable energy policies spurred organisational innovations in many companies. The same is true for ETS, which led to substantial organisational changes for implementing and managing emission monitoring activities. With regard to this, the importance of firms' functions devoted to environmental monitoring has substantially increased, with the creation of specific units for environmental monitoring and the coordination of all relations with environmental authorities for the implementation of ETS and environmental standards. This is to some extent an unintended and perhaps relatively overlooked impact of policies within the efficiency rationale. The whole set of organisational change measures are to be considered, not only EMS and ISO.

Interviewed experts have highlighted that a major system level innovation has been the market liberalization of the energy sector. The joint effect of this market reform with the implementation of renewable energy policies has favoured the introduction of major organisational innovations at the firm level as well.

The liberalised market gave the possibility to non-traditional parties to produce electricity themselves. Incentives in order to compensate for the excess cost of renewable energy compared to fossil-based energy have been given. Policy instruments, such as feed-in tariffs or green certificates have also been designed to this scope. Tradable guarantees of origin have been conceived in order to differentiate renewable power from fossil-based power. In some countries, similar guarantees of origin have been created to differentiate bio-methane from natural gas. Tradable green certificates and guarantees of origin clearly represent innovative concepts in the energy sector.

This policy framework has promoted renewable energy production at the consumer level, and photovoltaic energy in particular at the household level, but also spurred the development of renewable energy projects both in traditional and non-traditional energy companies. This phenomenon has led to substantial organisational innovations within firms due to the creation of new and differentiated energy production plants and the increasing need for coordination activities between them. New professional competences and dedicated personnel have been increasingly hired by firms to manage energy trading activities and energy production from different sources.

2.1.3 Policy Interactions

The contemporaneous presence of many different policy tools is perceived by the interviewed experts as a crucial issue in the design of policy framework and the effective achievement of environmental goals. This view is in line with the fast growing literature on this specific issue (Abrell and Weigt, 2008; Böhringer et al., 2008; Del Rio Gonzalez, 2007; Braathen, 2011). In particular the co-existence of different policy tools may represent an obstacle for innovation and for the achievement of environmental goals, even though the importance of preserving diversity in the portfolio of policy tools has also been highlighted in the interviews.

At the general level, policies that target renewable energy use are perceived as not helping achieve objectives in terms of increasing energy efficiency. More specifically, a common view among the interviewed experts is that tools other than ETS negatively interact with ETS since they are not aligned to it. According to this view, the use of policy tools different from ETS has increased the cost of climate change policies and left a very low carbon price (Borghesi, 2011). In particular, policies for renewable energies substantially contributed to the declining trend of emission permit prices and to reducing incentives for investments aimed at decreasing emissions per unit of produced energy from traditional plants.

Even though different policy tools are seen as negatively interfering, the interviews stressed the idea that the implementation of an articulated array of policy incentives and regulations has the potential of favouring the development of different technologies, which may lead to the emergence of relevant technological complementarities. A policy mix may help correct multiple reinforcing failures of private governance structures, such as pollution externalities and technological spillovers (Lehman, 2010). In this respect, it seems that the problem in the current policy framework is not represented by the presence of diversified tools but mainly by the lack of a proper policy coordination between these different tools which does not allow for exploitation of the potential positive interactions between them and, conversely, increases the cost of reaching fixed policy objectives (OECD, 2007).

2.1.4 Main insights

The interviewed experts all share the same opinion on the important role of environmental and energy policies in shaping the rate and direction of innovative activities in the energy sector. Interestingly, this effect emerged as being important in both technological (product and process) and non-technological (organisational) innovations. With respect to the former, innovative efforts in the energy sector have mainly led to incremental innovations rather than radical ones, with increasing trends in patenting activity in this sector.

Referring to Tables A.1-A.2, we note that the most significant period for the sector was between 2002-2008, when CO2 stopped increasing as it had in the past and 'economic efficiency' (CO2 on value added) started to substantially decrease. The qualitative analysis highlights the significant role played by environmental and energy policies, which is also found in the relevant literature. Nevertheless, it is always difficult to disentangle energy policies and market factors, such as oil price trends. We observe that over 2002-2008, the time span of EU-ETS and other EU policies, oil prices increased. We refer to Johnstone et al. (2010) for further discussions around this issue.

Though the sector like the EU economy does not present structural breaks over the past two decades (EEA, 2013), performance has improved consistently in efficiency terms. This is coherent with the emphasis on the incremental nature of most innovations. However, this is surely not sufficient enough to reach 2030-2050 targets.

While they highlighted the negative interfering effects of implementing different policy tools, the interviews also pointed out the potential of adopting a differentiated portfolio of policy tools if proper policy coordination is followed.

Finally, the analysis suggests that the joint effect of market liberalization in the energy sector and of the implementation of renewable policies induced firms to adopt relevant organizational innovations. In this respect, a crucial element to sustaining this process appears to be represented by research activities for the development of smart grids. The generation of innovation in electrical infrastructure, the implementation of new grid management processes and the development and diffusion of new technologies for stocking energy from renewable sources all emerged as crucial elements for the research agenda in the energy sector.

Interviews by SWG

5	IT_001	Italy
6	UK_001	United Kingdom
10	UK_005	United Kingdom
22	DE_001	Germany
23	DE_001	Germany

2.2 Ceramics

2.2.1 Drivers of innovation

All interviewees agree that in the considered interval inventions and innovations in the ceramics industry have not been carried out in reaction to environmental policies, but mostly in response to market demand and international market factors (the two features being perceived as the same, in an industry that exports 70-80% of its production). The channels to transforming environmental performance into higher market demand are product labels such as EU Ecolabel and LEED standard certification. Ecolabel is appreciated in Northern Europe, but - even though launched almost 20 years ago (10 years ago in ceramics) – it is not well-known by general public [ToE]; granted firms also consider it unsatisfactory, in part because of bureaucracy and the slowness of the national authority in answering requests [MaM].

In contrast, the more recent LEED certification has a gradually growing reputation, mostly in the richest markets throughout the world: Northern America and the Persian Gulf, Korea and Japan [MaM, BoG], and is now widening to the richest niches of the UK and Northern Europe [ToE]. In addition, Real Estate Funds in the US and Canada are interested in sustainability, so that the ecological rating of a building is quite important. The LEED standard assigns a higher rating to building materials with good environmental performance with respect to production, disposal, and recovery [SaW].

Another main driver for (process) innovation is cost saving, which involves energy efficiency [BoG]. Here innovation stems from more efficient machineries (kilns, furnaces and atomizers), heat and energy co-generation turbines, PV modules. Many of these imply forms of subsidies such as white/green certificates or feed in tariffs, but they are only a collateral advantage of the energy efficiency policy, and not at all the driving force [MaM]. The issue of energy saving is stressed even by non-Italian experts, both in ceramics and cement industries: according to these interviewees, most of the process innovation implemented in these sectors are due to the need to reduce the impact of fuel price increases, both recovering energy still present in heat and steam waste and, in a more modest way, addressing biomass and renewable sources [UK_009, PL_003, FR_005]. In some cases, the need to intervene in the energy process leaves companies without enough resources to invest in other kinds of process amelioration, in this way becoming a deterrent rather than a driver for technological change [UK_009].

As a sector dominated by SME, the ceramics industry relies on different kinds of services from outside the firm to support the development and adoption of CO2 abatement. With respect to energy saving, there is a continuous communication and information flow coming from the machinery industry (furnace and atomizer producers) [MaM]. Other communication services are provided directly by the entrepreneurial association, and independent R&D centres; this is, for instance, the case of the introduction of LCA in many companies' process, conveyed by Centro Ceramico [ToE].

2.2.2 Interaction between different policy instruments and the EU ETS

There's no complete agreement among interviewees with respect to the issue of policy interaction. Some of them remark that from a technical point of view there is a reciprocal positive influence between CO2 abatement policies and energy saving policies, so that the latter could be a driver for the former. At the same time, other interviewees remark that on the one hand there is an evident overlapping between EU and domestic regulations, and between different tools, generating confusion, complexion, and higher costs for EU companies [ES_003, FR_005, UK_009]. In this sense, the interaction between policies ends up overall as a deterrent for development, and detrimental for global competition.

As far as the EU ETS is concerned, the cap was set with reference to 2005-2008, while the efficiency process was implemented in the last years of the 1990s-early 2000s, when the standard furnaces were replaced with roll-furnaces that reduce burning time from 2 hours and half to 45 minutes. This means that at the moment it is very difficult for firms to abate under the cap, and they mainly have to buy quotas on the market [MaM]. As a sector subjected to Carbon Leakage, an amount of quotas were allocated free, but now the European Commission has proposed dropping ceramics from Carbon Leakage category, so that the problem of emissions will become even harder to face [CoA][6].

The most critical comments on the ETS by Italian Employers Association refer on one hand to the lack of transparency and of political commitments to future scenarios, affecting the capability to plan for investments; and, on the other hand, they regard additional costs in terms of the bureaucracy and human resources required by the ETS system. This last factor is a burden in an industry dominated by small-medium sized enterprises such as ceramics [Coa].

A somewhat different position is expressed by non Italian interviewees, all of which agree that ETS is the main EU environmental-energy policy, capable of redirecting the industry toward higher efficiency performances. This is true in particular with respect to energy consumption [UK_009, PL_003, ES_003, ES_004, FR_005].

2.2.3 R&D, cooperation and industry upgrading

As mentioned, the Italian ceramics industry is highly concentrated in the Sassuolo District, Emilia-Romagna Region. It is an area deeply studied in the past by both sociologists (Piore and Sabel, 1984; Helliwell and Putnam, 1995), and industrial economists (Brusco, 1989; Arrighetti and Seravalli, 1997; Russo, 1996), who at the time identified "social capital" (i.e. collective preferential

[6] Another question mark on the future of the industry is related to European Road Map 2050 targets (an emission abatement of 80%): it would mean a switch to electric or biogas fed furnaces, cogeneration, and other techniques that, according to simulations run by the Italian Entrepreneurial Association (Confindustria Ceramica), it would imply a 90 billion euro investment, equal to 2.5% of the total industry revenue.

treatment and cooperation between individuals and groups within a local community) as the main driver for local economic development.

In spite of this, nowadays the degree of cooperation in R&D and industry upgrading among firms in the district seems to be weaker with respect to the past. Every firm is quite jealous of its own ideas and production, while they are all located so close together and use the same providers, which means a high level of potential reciprocal copying [ToE].

Recently regional government has promoted two common R&D projects (CerPosa and InProCer), but the involvement of firms has been unsatisfactory: in both experiences, a deep mistrust still emerges among operators, perceiving each other as competitors [TiP].

According to local stakeholders, an undeniable role in promoting industry upgrading in an environmentally sound direction has been played by the Italian National Ceramics Employers' Association (Confindustria Ceramica). In the past 15 years they have made their members aware of the importance of an eco-friendly approach in the industry, promoted best practices and kept operators informed about novelties. Another institution operating as a 'scaffolding structure' for Italian industry is the Ceramics Centre (Centro Ceramico), which runs research projects for the benefit of the whole sector [SaW].

2.2.4 Main insights

Due to its three-decade long experience in enforcing thresholds on emissions and pollution, the ceramics industry has a long tradition in upgrading and innovation in an environmentally friendly direction.

From the mid-1990s, the main drivers for innovation in the industry were not predominantly environmental policies, but market competition and costs saving, even if with a non negligible positive impact on the environment: in an industry with a low emphasis on patenting, the most important innovations in past years have been the introduction of heat and energy co-generation with respect to processes (adaptive innovation), and the research of new functionalities in tile products (photo-catalytic, anti-bacteria, self-cleaning, slimness).

Certification policy, both for products and processes, is viewed as a market signalling tool, even if it supports higher efficiency in a sector where regulation is very demanding. Today, the entire Italian ceramics industry is committed to designing a unique sustainability label for its products: An ISO standard based on a rating system that is bound to be the first ISO standard for ceramic products. According to insiders, a beneficial approach which could be pursued by the European Commission would be to enforce directives and reward the most environmentally virtuous producers. This is not the mechanism followed by the ETS, perceived by operators as a system that penalizes without enforcing any amelioration. The criticism of the ETS does not seem to be shared by the majority of international interviewees, who in contrast depict the ETS as an important policy in fostering process innovation addressing energy efficiency, even considering the increase in costs imposed by green certificates or renewable energy.

In the 1998-2012 policies seem to have been a weak driver for innovation[7]. Nowadays, they are a tool for dialogue with the public sector; designing policies is a strategic activity carried out by the Italian National Ceramics Employers' Association (Confindustria Ceramica) in connection with law and policy makers at different levels (regional, national and European). One point of reflection for policy makers emerges: While it is true that the ceramics industry is not such a heavy emitter for energy, and its CO2/VA trends improved in the past (see appendix), overall performance in terms of CO2 emissions has somewhat worsened. The sector on the aggregate has not been as capable of reducing its impact as the steel sector has, for example. The weak reaction to more recent policies and/or the lack of a proper sector specific design of such policy packages might be the issues at hand.

Code	Name	Role	Organization
CoA	Contri Andrea	Environmental Expert, Contact for ETS	Confindustria Ceramica, www.confindustriaceramica.it
SaW	Sancassiani Walter	Head	Focus Lab Ltd,, www.fabbricaideedistretto.it/
TiP	Timellini Pier Giorgio	Head	Centro Ceramico Bologna, www.cencerbo.it
BoG	Borghi Gabriele	Head of product certification	Casalgrande Padana Inc. www.casalgrandepadana.it
MaM	Maffei Marco	Quality and Env. Manager	Florim Ceramiche Inc. www.florim.it
ToE	Tonelli Elisa	Quality and Env. Manager	COEM Ceramiche Inc. www.coem.it

Interviews by SWG

Code	Country
IT_003	Italy
UK_009	United Kingdom
FR_005	France
ES_003	Spain
ES_004	Spain
PL_003	Poland

2.3 Coke and refinery

2.3.1 Drivers of innovation

All respondents agree that implemented energy and environmental policies had an effect on both technological and organisational innovations, though they tend to disagree on the importance of such an effect. When asked about the two most relevant innovations, the UK respondent (UK_016) specifically mentioned energy management systems and combined heat and power generation (discussed in more detail below) as equally important innovations, while the Czech

[7] This evidence is coherent with the econometric analysis on CIS data (focus 2006-2008) presented by Borghesi et al., (2012), who discusses some strong potential weaknesses of ceramics in relation to the sector's innovative response to EU ETS stringency.

representative mentioned the creation of 'carbon footprint schemes' and of 'CO2 task forces' as the most relevant organisational innovations.

Among the relevant energy/environmental policies being implemented, three out of the five respondents (CZ_011, ES_011, NL_009) claimed that the EU climate change policy was a key factor for either technological or organisational innovations. Interestingly enough, however, the Dutch respondent (NL_009) claimed that the EU ETS (which currently covers 174 firms in the mineral oil refinery sector, see Table A.3) though being in principle a key policy has been insufficient in practice so far, since the carbon price is simply too low. This viewpoint seems consistent with this interviewee's statement that energy/environmental policies in general had little impact on innovation, which was mainly driven by economic rather than environmental motivations. Although the Dutch respondent showed the most critical position among the five interviewees, the Polish representative also pointed out that energy/environmental policies in general had had little or no impact on innovation in this sector.

One possible exception in this sense might have been the Ospar Convention for the protection of the marine environment in the North-East Atlantic, which, according to the Dutch respondent (NL_009), successfully reduced CO2 emissions from the coke and refinery sector without incurring in any conflict with other existing policy tools. This is case of unintended effects from another environmental policy arena, if we also consider that the Marine strategy deals with pollution more than climate change. This example, together with the critical viewpoint expressed on the EU-ETS, seems to implicitly suggest that in this sector recent market-based policies might have been less effective than the command and control policies adopted in the past. Through this perspective, we note some similarity with the ceramics case study, though the coke and refinery sector appears more dependent overall on policy levers.

2.3.2 Interaction between different policy tools

Practically all respondents – though to differing degrees - pointed out that the high overlapping of different policy tools may be detrimental for innovation, by generating confusion and adding to the overall complexity of the system. The British respondent (UK_016), for instance, claimed that the introduction of a carbon floor pricing has hindered the continuation of Combined Heat and Power (CHP) projects, some of which were cancelled due to the policy change and the withdrawal of government support for CHP. This is a particularly serious problem since the CHP is reasonably seen by UK_016 as a key innovation in the sector. In fact the CHP, namely, the simultaneous generation of usable heat and power in a single process that uses heat otherwise wasted when generating energy or mechanical power, can save about 20% of energy costs; a crucial feature in this sector since – as pointed out by the Spanish respondent - "in the refineries, 70% of the operative costs come from energy" (ES_011). Moreover, CO2 per unit of energy produced by the CHP is about one half that produced by a conventional coal-fired power station, according to estimations made by the Department of Energy and Climate Change of the UK Government (cf. http://chp.decc.gov.uk/cms/).

Other respondents (e.g. ES_011, PL_010) emphasised the existence of possible conflicting goals between renewable energy policy and energy efficiency policy. The Polish respondent, in particular, argued that taxing policies have made it very profitable for refineries to produce diesel fuel, which ends up increasing rather than decreasing their emissions. In this interviewee's opinion, moreover, fiscal policy has favoured small refineries over large refineries. It follows that, at the end of the day, the emissions of smaller refineries are much higher than those of the larger firms, with a negative effect on the emissions trend of the entire coke and refinery sector.

2.3.3 Main insights

Three main issues seem to emerge. First, recognition of the role played by EU policy as a driver for innovation, although such a role cannot always be ascribed to 'current' or recent policies. More distant waves of policy could be responsible for the innovation we observe today, and environmental policies taking affect in other areas could also provide unintended effects.

Figure A.1 and A.2 presents a somewhat different trend for the aggregated sector with respect to the others. The most significant (radical) change in efficiency is related to the late 90's (the Kyoto years), when the emissions generated by one unit of economic value sharply decreased. Since then, the sector has not progressed much. Its overall emissions and CO2/value have been more or less constant over 2000-2008.

The second issue involves perception of the harmonisation problem, both across countries and across sectors. This issue touches upon the general umbrella of national and sector systems of innovation: from a conceptual point of view, non harmonisation is mostly detrimental where significant differences exist. Environmental and other policy settings might take this view into account. While non harmonisation can generate cost in terms of unbalanced possibilities of supporting sustainability and competitiveness, it is also true that tailoring policies to specific needs could be efficient and effective in some cases. It is interesting that 'cross sector' harmonisation here also reflects key sector 'integration' issues: environmental performances by sectors are directly or indirectly assessed (the latter flows an integrated approach). The innovative and environmental performance of all sectors, and coke and refinery specifically, should be analysed along both lines. Input output extended to environmental accounts shed light on the matter. Section 6 will address the integration issue, namely integration as a lever of innovation.

The third main issue concerns the identification of interaction problems among different policy tools and mainly shows a consensus on the detrimental effect of policy overlapping on innovation, with potential conflicting goals between renewable and energy efficiency policies. In terms of policy design, a specific criticism of taxing policies emerges: policies favoured small refineries and made it very profitable to produce diesel fuel, so that the emissions of smaller refineries are considerably higher than those of larger firms. Besides the defined sector case study, this issue poses the question of the relative efficiency and effectiveness of general energy taxation (high as share of GDP, more consolidated, upstream imposed, as not related to CO2 emissions) and specific environmental taxation (low and declining as share of GDP, less consolidated, 'downstream' imposed, as related to CO2 emissions) around which proper ecological tax reforms should be based.

Interviews from SWG

Code	Country	Industry
UK_016	United Kingdom	Coke&refinery
CZ_011	Czech Republic	Coke&refinery
ES_011	Spain	Coke&refinery
NL_009	Netherlands	Coke&refinery
PL_010	Poland	Coke&refinery

2.4 Paper and cardboard

2.4.1 Innovation drivers

CO2 emissions from the paper industry are due to the production of electricity and heat power, which are needed for the production process to take place [IT_009].

The five available interviews cover five different countries (Italy, the UK, France, the Netherlands and Poland). In what follows we summarize the main conclusions that can be drawn from these interviews.

At the level of single countries, a significant role in energy efficiency improvements and innovation has been played by energy costs. This has been the case in Italy where high energy costs have boosted investments in energy efficiency and specific energy production systems, such as combined heat and power, to achieve a higher degree of competitiveness on EU and international markets [IT_009]. Competitiveness (in terms of energy cost reduction) is also identified in itself as a source of improvement in energy and environmental management, linked to but not exclusively based on climate targets [PL_011]. Focusing specifically on organisational innovation, a major example is the development of sustainable forest management practices, where the pulp and paper industry has been the largest investor among industrial sectors, though it is not the main resource user [IT_009]. Organisational innovation in the direction of increasing energy efficiency is predicted to take place due to both the costs of energy and environmental policies [UK_017]. The development of the Italian system of scrap paper collection, as well as “green” demand, can be identified as additional significant drivers of innovation in the pulp and paper industry [IT_009]. The Dutch expert further recognizes the importance of industry actors in driving improvements towards energy efficiency, although the high cost of energy is still seen as the main driver [NL_011].

2.4.2 Policies and interactions

The Italian expert [IT_009] suggests that regulations related to energy and environmental quality, in particular the EU ETS, do not seem to play a leading role in driving innovation; rather, such regulations contribute to incremental innovation processes which are already in place. Somehow paradoxically, the choices concerning regulations design might hamper CO2 abatement activities, when they imply the need for significant bureaucratic steps by State level or local authorities; this might be the case, for example, when a renewable energy plant needs an authorization to be released by a local bureaucracy; the related slowness can significantly increase the implementation time of regulatory provisions, harming the development of environmentally efficient technologies. The NIMBY syndrome might also play a negative role, by limiting the use of biomass as a source of energy. On the other hand, when dealing with organisational innovations, an important role is recognized for the waste policy realm (specifically focusing on the institution of the Italian Consortium for Packaging Paper Recovery) [IT_009]. The regulatory policies seem to have also contributed to increases in the use of biomass in energy production in France [FR_016], where biomass itself accounts for a significant part of thermal energy production in this sector.

The policy tools identified as the most relevant to the pulp and paper sector are linked to emissions from electricity and heat production, mostly EU ETS [IT_009] [FR_016] [NL_011], white certificates [IT_009], as well as the Renewable Energy Directive [FR_016] [NL_011] and (at least as concerns Italy) combined heat and power incentives [IT_009]. The UK environmental agreement is also suggested as a key tool [UK_017]. Further, the IPPC Directive [NL_011] as well as the expected evolution of standards related to other important air pollutants (e.g. NOx and water pollution) are recognised as important, suggesting that a more integrated approach to pollution is advisable [PL_011]. Eco-labeling also plays a role in driving reductions in the environmental impact of production [PL_011]. Interactions, albeit sometimes negative, between tools might arise: a significant example is found in subsidies for renewable energies in Italy, which are judged as disproportionate with respect to their environmental benefits and seen as taking financial resources away from other technologies, such as high efficiency combined heat and power [IT_009]. Policy-related uncertainty due to interactions might damage innovation and generate competitiveness issues [UK_017]. A typical example of a (potentially) negative interaction is identified by the French expert [FR_016] in the overlapping between the EU ETS and the (currently debated) Carbon Tax. The interaction between renewable energy and energy efficiency targets can be a deterrent to innovation as well, when measures are not efficiently weighed. Instruments that set targets for the long term (such as the Renewable Energy Directive) are crucial, while other local tools are more relevant for the sector at the moment [NL_011]. Finally, an example where interaction between policy tools is perceived as good concerns waste management and biomass related policies. A proper waste policy makes reuse and recycling easier and, at the same time, reduces the amount of waste that is not recovered [NL_011].

2.4.3 Technological and organisational innovations

No path breaking innovations are identified in this sector in the last ten years; only incremental improvements have taken place in the efficiency of the paper production process [IT_009].

French and Dutch experts mention the existence of process innovations. In France, the sector witnessed innovation in biomass use and cold generation [FR_016], while in the Netherlands innovative activities include energy efficiency measures related to the use of “new” presses instead of vacuuming, implying a reduction in the amount of energy needed for drying. The high percentage of re-used paper and cardboard in packaging also brings about savings in energy . These are not new techniques but, again, can be viewed as incremental improvements, which are made possible by a significant local networking [NL_011].

In Poland, the optimisation of existing vacuum systems and minimisation of the amount of water needed in production are among the most important innovations. Process innovation here also involves the substitution of other fossil fuels with a larger use of gas in order to reduce CO2 (for this reason new machinery and new boilers have had to be installed). Planting poplar trees (to produce paper and/or energy) is also part of an innovative pilot project [PL_011].

The development of sustainable forest management practices can be observed. Although this is relevant, as mentioned above, the pulp and paper industry is not the largest user of this resource [IT_009]. A continuous focus on organisational innovations devoted to energy efficiency improvements (and driven by costs of energy as well as by environmental policies) has been identified [UK_017].

The increase in networking that has taken place in the Netherlands is also relevant from an organisational point of view, since it implies a more integrated approach towards environmental problems along the entire paper value chain [NL_011].

In general, a significant change in management practices can be identified, based on a deeper involvement of staff and personnel through improvements in environment-related motivation. Environmental reporting is also expected to improve the image of paper industries [PL_011].

The Italian expert recognizes significant hurdles with respect to patenting , mostly due to a lack of integration between industrial and innovation policies, as well as to a lack of stability and the related uncertainty linked to regulatory design and implementation [IT_009]. In general, respondents provided little information concerning the patenting of innovations in this specific sector.

2.4.4 Main Insights

The main messages stemming from the interviews support the view of the pulp and paper sector as a “mature” industry where the bulk of innovation activity has taken place through incremental improvements.

Some parallels between empirical trends and qualitative analyses are illustrated by Figures A.1 and A.2, which show significant reductions in emissions and improvements in efficiency occurring in the 90’s. Since then, the trend in emissions has been positively correlated to the trend in oil prices, whose increase seems to have boosted efficiency in the past decade.

Respondents identify some key environmental policy tools, but recognize a crucial driver in the substantial energy costs and the need to improve competitiveness by reducing these costs. Important technologies in the sector are related to the use of biomass from scrap paper in producing energy. The specific role played by policies is identified in this respect, but some difficulties (for example related to the NIMBY syndrome) are reported as well. Examples of negative interactions across policy tools are also recognized.

Interviews from SWG

Code	Country	Industry
IT_009	Italy	Paper
UK_017	United Kingdom	Paper
FR_016	France	Paper
NL_011	Netherlands	Paper
PL_011	Poland	Paper

3 Conclusions

Overall, environmental policy packages appear to exert a role in the evolution of CO2/ energy technologies as expected. Nevertheless, as also expected from other results in the literature, an in depth investigation of the causes behind the adoption of eco-innovations makes for a more heterogeneous picture.

In the first place, policies appear to be of high relevance in some sectors, namely energy, coke and refinery, and paper and cardboard, all of which are heavy CO2 emitters under the EU ETS scheme. Energy costs and energy taxation considerations dominate over potential effects of CO2 targeted policies. It is interesting to note the varied nature of the evidence that the case of the ceramics and cement sector outlines. For this sector, environmental policy is a way to interact with policy managers in order to develop and design better policies. The bulk of significant CO2 related innovations appeared well before 2000, apparently driven by environmental considerations, but partially detached from policy making. At a more general level, it is worth noting that the hypothesis – posed by innovation economics studies and tested in the literature mainly through quantitative methods - that technological and organisational levels are both relevant and complement each other is not rejected: organisational innovations were relevant in most sectors, often operating as a leading force in technological development. This is a key outcome, and we grant central importance to this ‘complementarity’ in the future path towards 2030 and 2050 aims, whose achievement is possible only by integrating technological, organisational, and behavioural/educational innovations.

Specifically with reference to policy effects and features, two main considerations emerge. In some sectors – energy, chemical, ceramics, paper and cardboard --detrimental types of interactions were signaled, specifically between climate change and energy policies (coke and refinery is an exception, again flagging potential sector-specific issues). Linking to this point, innovative solutions are biased towards the ‘energy efficiency side’, following a policy bias that most countries reveal (this is coherent with the features of policy packages that the WP1 investigates). Notwithstanding the fact that reducing CO2 is largely an energy efficiency issue, the investigation confirms that specific and radical solutions to climate change have not been applied so far. Incremental innovations prevailed. The sector trends and figures (Annex A) support this statement in large part.

Some sectors state the need of financial support within a given policy package as an additional note for policy making. Policy certainty and financial support are two pre conditions to sustaining (initial) innovation adoption and diffusion. While on the one hand this is possibly part of a lobbying effort by industries or a preference for ‘non taxation policy tools’ (since environmental taxes and subsidies belong to the same ‘family’, latter being embedded in the first), sector representatives strongly recognize the role of policies in the field of climate change challenges. As we move forward towards the auction-based era of EU ETS and the opportunities posed by EU energy/carbon taxation, the design of ‘ecological tax reforms’ tailored to specific sector needs is worth considering. With the contribution of sector knowledge on idiosyncratic innovation features and options for short and long term goals, fiscal reforms might be structured -– on specific revenue recycling schemes that transfer part of green taxation revenue to best sector players. Policy efficiency, knowledge sharing and sector involvement could be brought together.

Within the realm of CO2 related innovation adoption, environmental and energy policies have had a role in sustaining incremental techno-organisational solutions. Policy pressures appear more effective in energy intensive sectors, where market and policy effects are equally relevant. A widespread positive integration can be found between technological and organisational innovations which may even lead to radical change. The complementarity of these two types of innovation is a key for future achievements and must be recognised in policy design. More negative signals are the lower 'policy effect' in some heavy sectors, such as ceramics, which does not present top figures for CO2 performances. In some sector situations the innovation wave seems to belong to the past. This poses question as to the current EU policy package, reinforced by strong expectations to support the adoption of EI.

Future research could attempt to provide complementary ex ante qualitative analysis on scenarios related to techno organisational dynamics capable of cutting CO2 by 50% and 80-90% as set by long run EU climate change targets. The knowledge that stem from ex post and ex ante studies is useful to (re)design policies in accordance to sector idiosyncratic techno organisational features and inter sector technological platforms.

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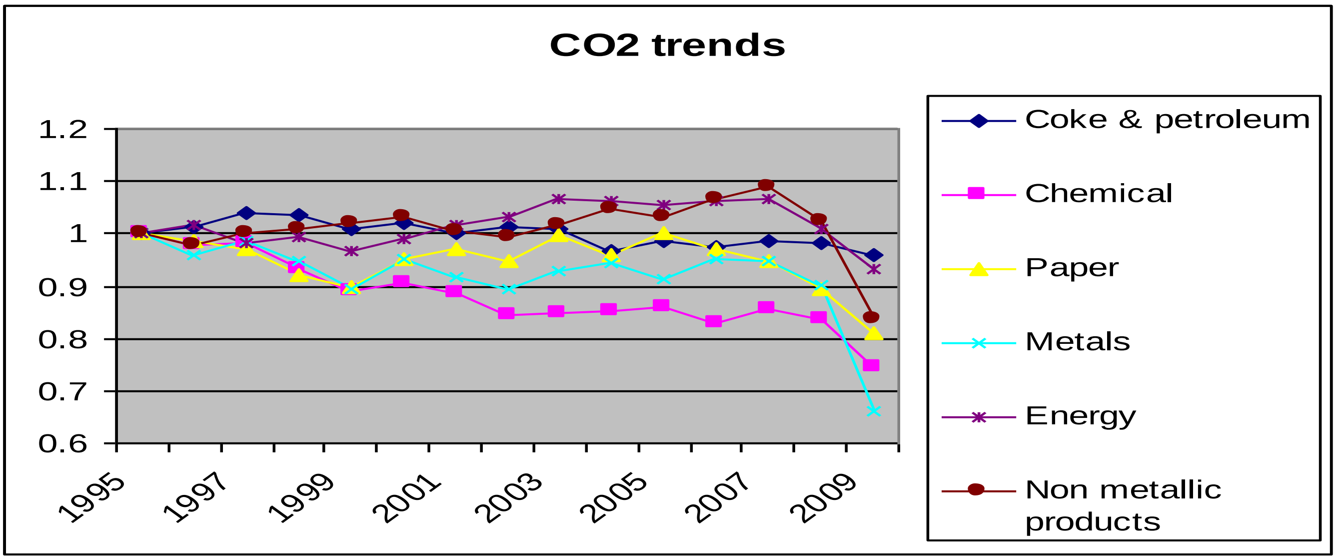
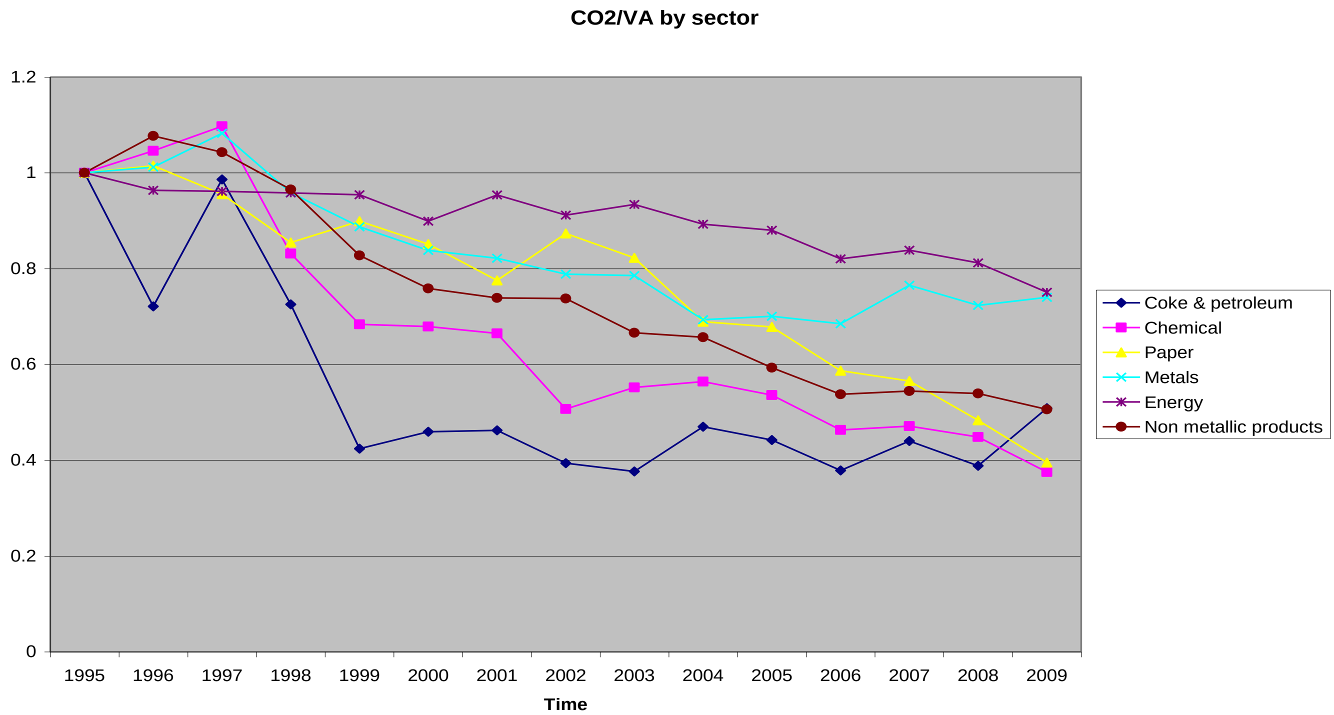
Annex A – Figures and trends on EU sectors[8]

A-1 CO2 trends in the EU (source: WIOD dataset[9], October 2013)

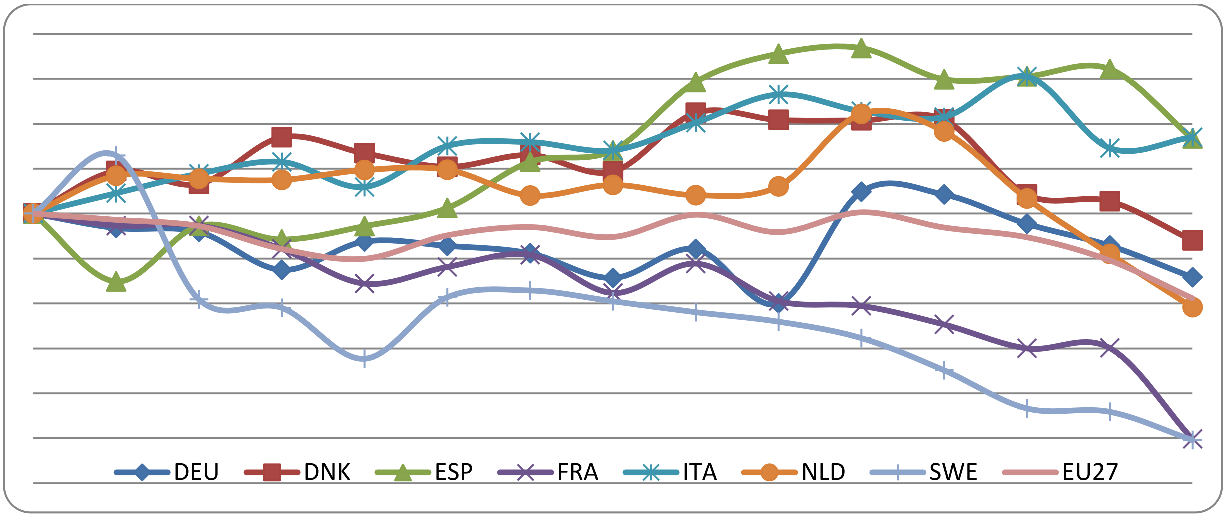




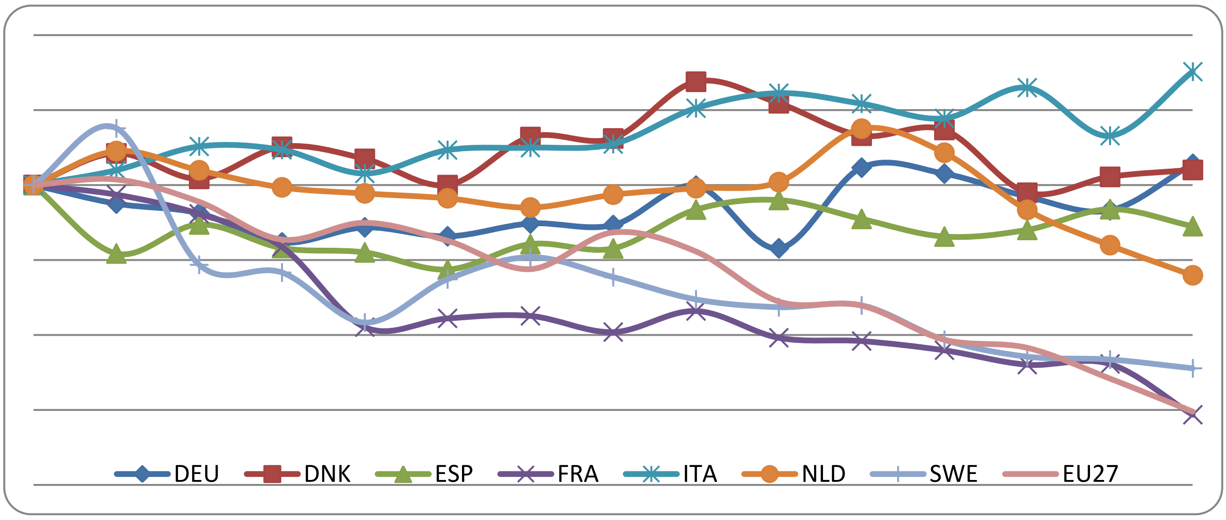
A-2 CO2/Value added trends in the EU (source: WIOD, October 2013)

[8] Figures of CO2 and CO2/VA are also available as tonnes of CO2 and tonnes/€ (excel files).
[9] WIOD is the world input output dataset developed within WIOD Fp7 project.

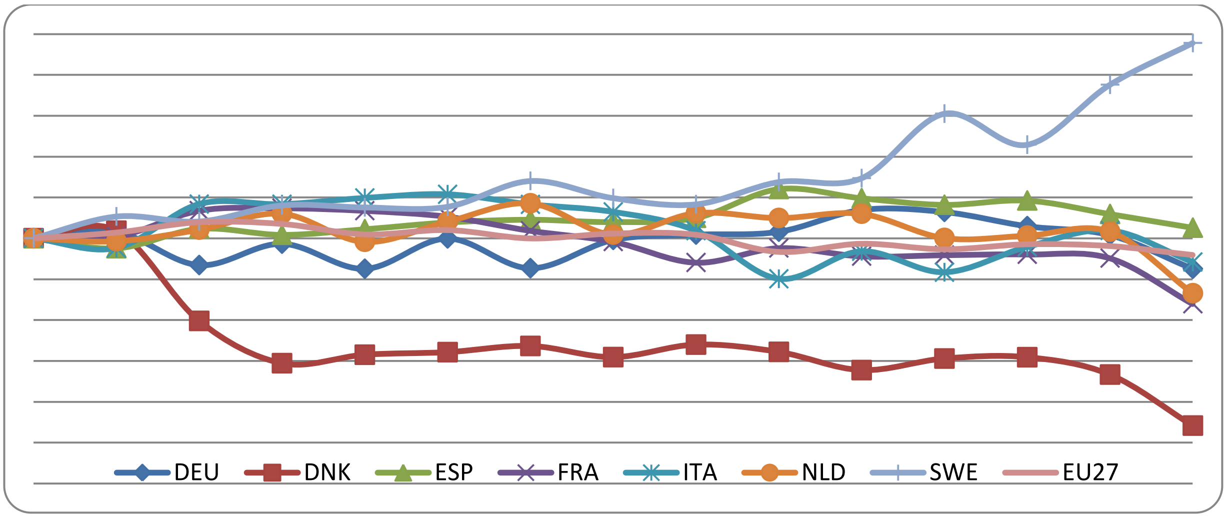
A-3 CO2 trends in the paper sector (source: Eurostat, August 2013)



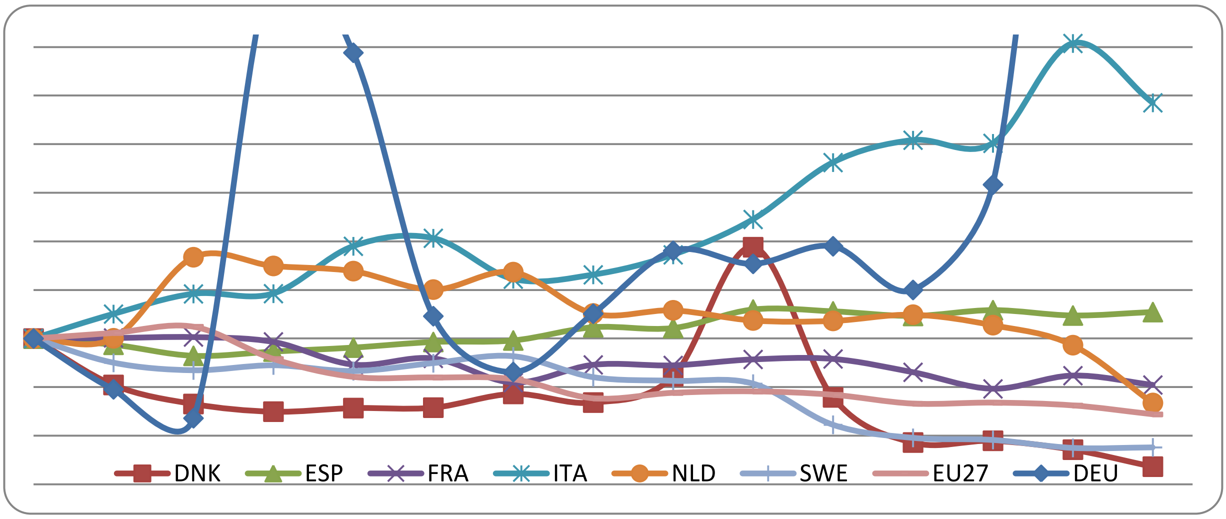
A-4 CO2/Value added trends in the paper sector (source: Eurostat, August 2013)



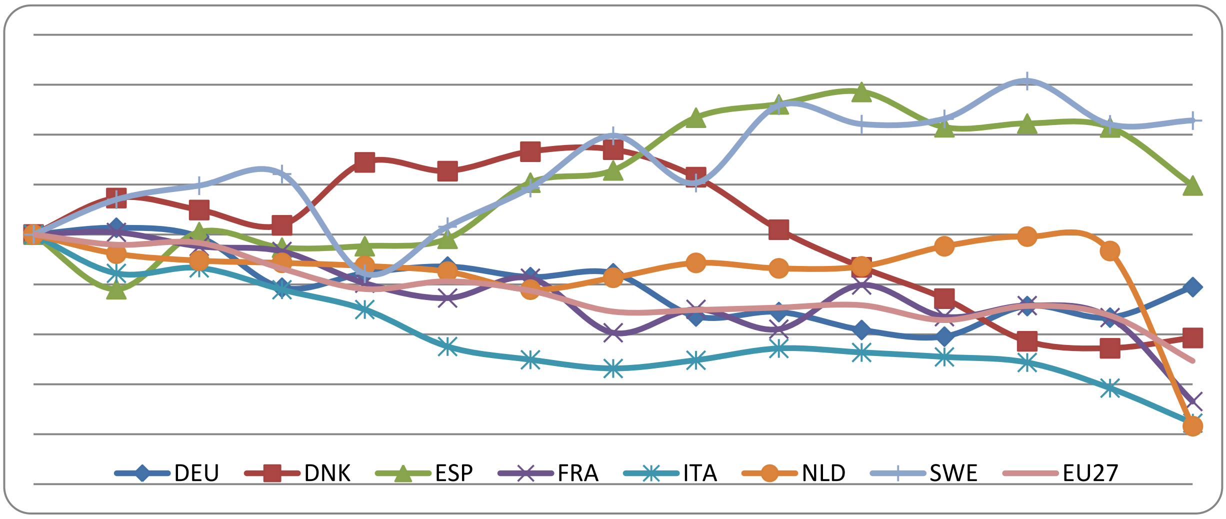
A-5 CO2 trends in the coke and refinery/petroleum sector (source: Eurostat, August 2013)



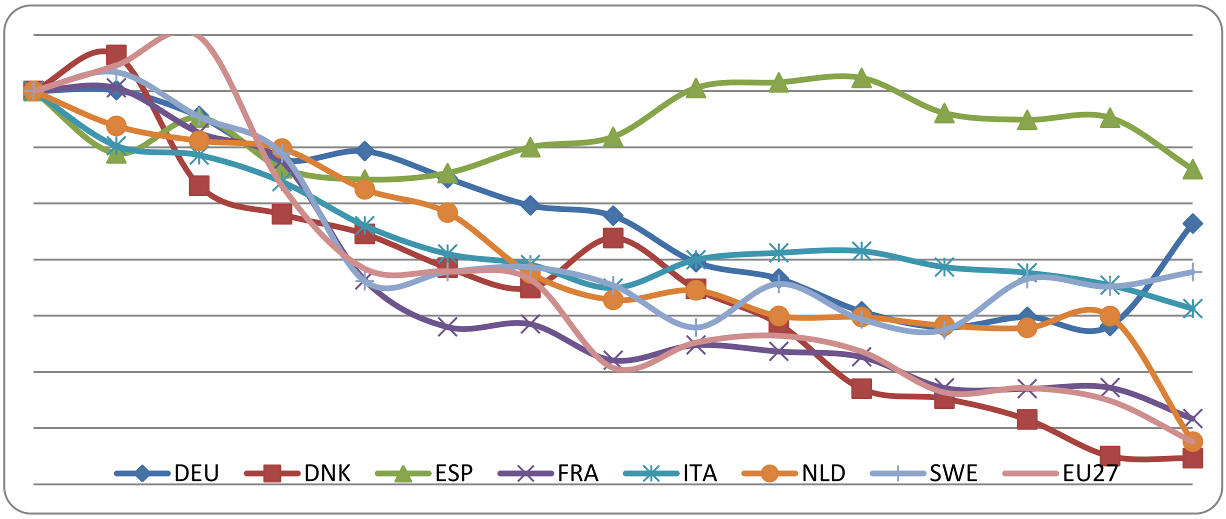
A-6 CO2/Value added trends in the refinery/petroleum sector (source: Eurostat, August 2013)



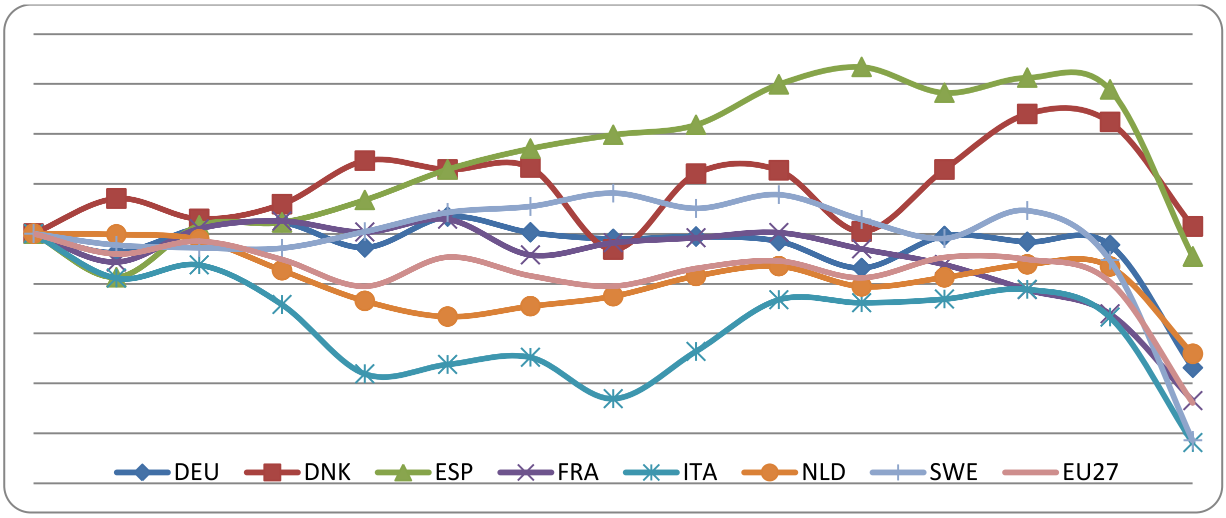
A-7 CO2 trends in the chemical sector (source: Eurostat, August 2013)



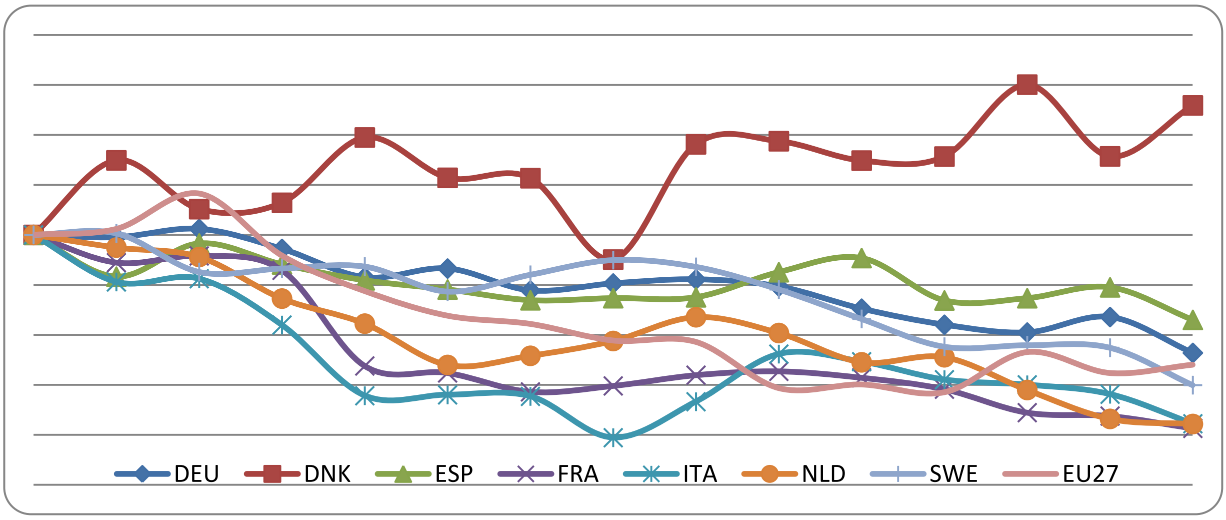
A-8 CO2/Value added trends in the chemical sector (source: Eurostat, August 2013)



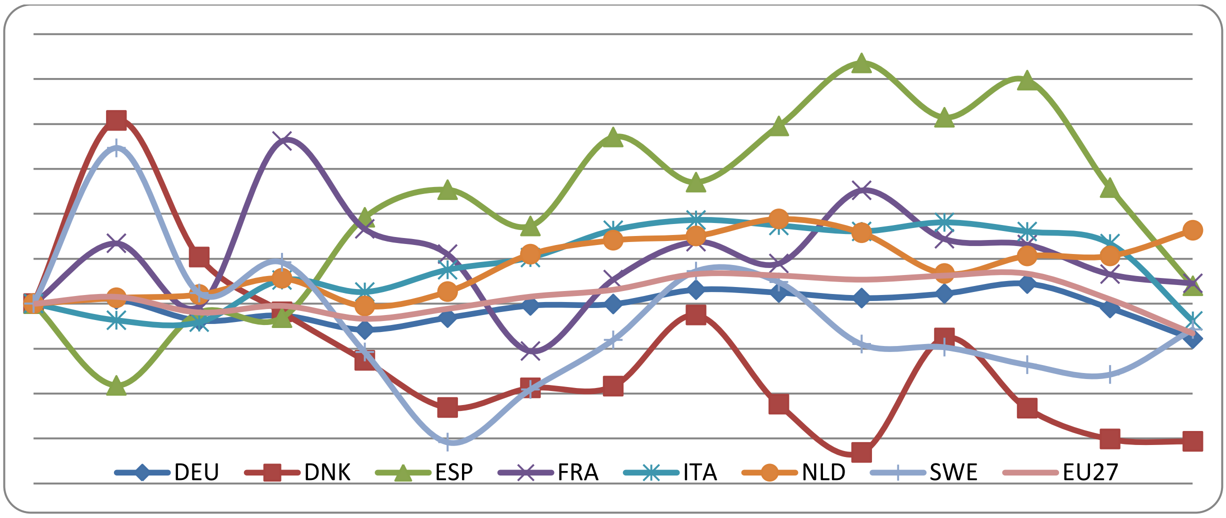
A-9 CO2 trends in the metal sector (source: Eurostat, August 2013)



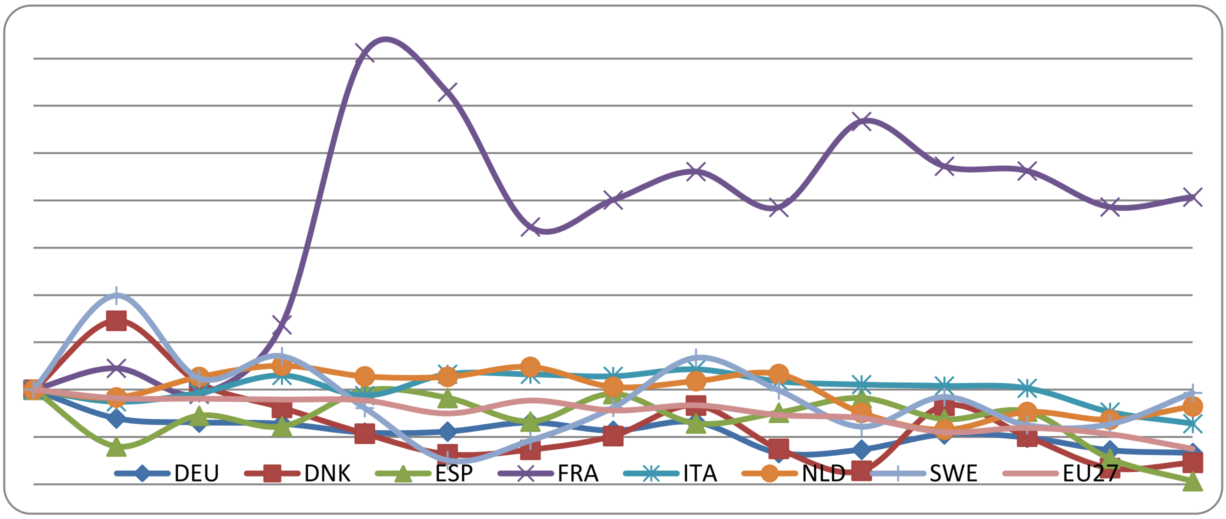
A-10 CO2/Value added trends in the metal sector (source: Eurostat, August 2013)



A-11 CO2 trends in the energy sector (source: Eurostat, August 2013)



A-12 CO2/Value added trends in the energy sector (source: Eurostat, August 2013)



List of experts (eventually included, for referees's use)

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