Firm Surveys relating Environmental Policies, Environmental Performance and Innovation: Design Challenges and insights from Empirical Application

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ABSTRACT

This report provides a review of recent firm-level and plant-level surveys containing questions on environmental policies, innovation practices or performance which are relevant for environmental policy analysis and assessment. We specifically focus on the core element that relates environmental policies to environmental and economic performance, namely the adoption of innovative practices and environmental innovations by firms. The study gives an overview of the main literature exploiting surveys, with the aim of discussing main themes and their core limitations to propose advancements for future research. The report provides technical details on surveyed questionnaire implementation, by focusing on to the intrinsic trade-off in the design of alternative questions. It also discusses how environmental policy and its stringency have been measured in previous literature. Finally, it provides suggestions on how to implement a multi-country survey and on other ways to better harness firm-level data in the analysis of effects of environmental policies on business behaviour.

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EXECUTIVE SUMMARY

Firm survey data are useful tools for assessing the effects of environmental policies on firm behaviour, economic and environmental outcomes and, in particular, on decisions to innovate. Existing firm surveys have been widely used in empirical analysis and this report focuses on reviewing such surveys and their applications to draw conclusions on the future use of firm-level information. These insights are cast in the context of three potential ways of exploiting firm data: a) designing a dedicated firm survey, b) appending or extending existing firm surveys with additional questions or improving the existing question set and c) harnessing existing firm data collection mechanisms.

Reactions to environmental policies can depend by firm, national circumstances and policies, the state of the economy and the time horizon. For example, they can be relatively defensive or proactive, short or longer term. Firms may decide to cut other costs (labour, investment, innovation) in order to cope with the increasing compliance costs of new environmental regulations. They may also decide to relocate or outsource part of their activity. On the other hand, and especially in the medium to longer term, firms may move into new products and markets, as well as, invest into (environmental) innovation in order to improve the efficiency of their processes and facilitate future compliance. Their future environmental and economic performance will depend on the combination of strategies adopted. Therefore, a thorough investigation of reactions to policies would ideally provide data on firms' behaviour over time and other firm characteristics to control for.

Reviewing empirical applications of survey data, and a number of specific, innovation-related surveys in detail, we argue that gathering this type of data through a survey poses significant challenges. Still, while firm surveys will necessitate compromises across these challenges, they are crucial in understanding the micro-level consequences of environmental policies and the channels through which they feed into overall macroeconomic and environmental performance.

A primary challenge for accurate survey design is related to **taxonomy and definitional issues**. Depending on the research objectives and on budget constraints two options can be envisaged: a semi-structured questionnaire with general questions or a structured questionnaire with specific and in-depth questions. The first option is less costly and should limit the burden on the respondents, their competencies and ability to answer. We argue that in the first case both a Computer Assisted Telephone Interview (CATI) or a web survey are suitable, while in the second case a web survey would provide the respondents the adequate time to gather accurate information. However, there is a trade-off; the web surveys usually provide lower response rates than the CATI surveys.

The second issue concerns the **sampling** strategy, which is linked to budget constraints. On the one hand, a wide sector and country coverage can allow appropriate and varied analyses of policy effects, even considering sector issues and spatial or economic spillovers triggered by environmental policies. First, it allows an analysis of the policies' effects on under-researched sectors, such as services. Second, cross-country approaches may provide rich information and heterogeneous data to control for effects of other policies and characteristics and better identify the actual effect of environmental policies. Third, surveys of many sectors and many countries can be helpful in providing counterfactuals for empirical analysis.

On the other hand, narrowing the attention on a few countries and few sectors is less costly, and probably permits the extension of the questionnaire and ability to gather more specific and in-depth information, thereby focusing the analysis on specific questions. Moreover, it may also be easier to merge such a survey with external data such as accounting data.

A crucial issue concerns the collection of follow-up information and sensitive data and, in particular, the possibility of merging the survey with external sources of data. Direct collection of sensitive information (i.e. financial and accounting data, location details) may induce a significant drop in the response rate, but it offers the possibility to extend the scope of the analysis and carry out sensitivity tests (e.g. comparing results that use either internal or external data). A particularly strong point would be to retrieve an identifier for each firm that can be used to match the survey sample with external data sources. The idea of collecting information over time through targeted follow-up questionnaires on selected issues or through repeated surveys, structured like the original one, is a question of research objectives.

Different typologies of policy and performance data can increase the robustness of the analysis or offer more variegated insights. For example, policy questions and indicators can be binary, qualitative, quantitative etc. However, the collection of diverse indicators can increase respondent burden and lower response rates.

One of the main issues is **endogeneity** – basically the problem of attributing effects of an alternative driver to that of environmental policies, or in some cases problems of distinguishing causes from effects. The ability of the analysis to circumvent these problems will depend on the data collected – whether it will suffice to control for or instrument for such effects both across firms and over time. Richer information collected through cross-country surveys can help identify policy effects and distinguish them from other effects, e.g. due to policies or firm characteristics mitigating simultaneity problems. Some strategies directly related to the questionnaire design may avoid the presence of selection bias from the beginning. For example, we would advise avoiding some filter questions that make sub-samples of respondents difficult to compare. Extending questions on firm or plant specific characteristics, but also to some key respondent characteristics, can reduce the problem due to unobserved heterogeneity. Following firms over time to construct a panel, as a long term objective, may help reduce endogeneity in the phase of analysis, though the dataset will be more and more unbalanced as years increase.

Finally, it might be wise and effective to set ex ante a **response rate** target. The questionnaire and the methodology of data collection can be tailored on the basis of such target. The trade-off is trivial: a shorter questionnaire, while likely benefiting from a higher response rate, will have a weaker capacity to mitigate the endogeneity problem in the phase of analysis, due to a more limited information base.

We argue that the selection of a survey strategy must be made according to the budget constraints and research objectives, both in the short and long run. Increasing the budget is not enough if the wide and interrelated framework composed of the main methodological issues is unknown. The *ex-ante* setting of a survey should be fully aware of all critical aspects, with their pros and cons, in order to decide on a specific design which is coherent with the budget and the set of research aims.

Above listed alternatives to a stand-alone survey, such as b) appending or extending existing firm surveys, and c) harnessing existing firm data collection mechanisms, constitute attractive ways of dealing with some of the above problems. A number of existing firm-level surveys and other data sources provide the advantages of: tracking firms over time (potentially reducing endogeneity issues), collecting economic performance data and high levels of representativeness (high response rates or coverage rates). However, such data may often be confidential and requires the collaboration with national or supra-national institutions – who own such tools. Depending on the exact research questions, a number of the issues described in this report, such as definitions and taxonomy, should guide the selection of relevant existing surveys to use or append and the design of questions to be included.

SYNTHÈSE

Les données d'enquêtes auprès des entreprises sont utiles pour évaluer l'incidence des politiques de l'environnement sur le comportement des entreprises, leurs résultats économiques, leur performance environnementale et, surtout, leur décision d'innover. Dans une large mesure, les enquêtes actuelles servent aux analyses empiriques. L'objet du présent rapport est de les passer en revue et d'étudier leurs applications afin de dégager des conclusions sur l'utilisation future qui pourrait être faite des informations obtenues au niveau micro-économique, et ce compte tenu des trois manières possibles d'exploiter les données relatives aux entreprises : a) concevoir une nouvelle enquête auprès des entreprises, b) modifier ou compléter les enquêtes existantes en améliorant le questionnaire ou en y ajoutant de nouvelles questions et c) tirer parti des dispositifs de collecte de données d'entreprises déjà en place.

Les réactions aux politiques de l'environnement varient selon les entreprises, le contexte national, l'action des pouvoirs publics, l'état de l'économie et l'horizon temporel. Ces réactions peuvent être relativement défensives ou anticipées, intervenir à court terme ou à plus long terme. Dans certains cas, les entreprises décident de réduire une partie de leurs dépenses (main-d'œuvre, investissement, innovation) pour faire face à la hausse des coûts de mise en conformité aux nouvelles règles environnementales. Elles peuvent aussi choisir de délocaliser ou d'externaliser une partie de leurs activités. Dans d'autres cas, surtout à moyen et à plus long termes, elles s'intéresseront à de nouveaux produits et marchés et investiront dans l'innovation (environnementale) de manière à rendre leurs procédés plus efficaces et à faciliter ultérieurement leur mise aux normes. À terme, leur performance économique et environnementale dépendra de la combinaison de stratégies adoptée. En étudiant de manière approfondie les réactions des entreprises aux mesures prises par les pouvoirs publics, on devrait donc théoriquement obtenir des données sur le comportement des entreprises dans la durée ainsi que sur d'autres caractéristiques à neutraliser.

Ayant passé en revue les applications empiriques qui sont faites des données d'enquête et examiné en détail un certain nombre d'enquêtes concrètes, en lien avec l'innovation, nous soutenons qu'il est particulièrement difficile de recueillir ce type de données par voie d'enquête. Bien que les problèmes soulevés supposent d'opérer certains compromis dans les enquêtes auprès des entreprises, celles-ci n'en sont pas moins indispensables pour comprendre les conséquences des politiques de l'environnement au niveau micro-économique ainsi que leurs répercussions sur les résultats macro-économiques et sur la performance environnementale.

L'une des premières difficultés à surmonter pour bien concevoir les enquêtes concerne la **taxonomie et les définitions**. Selon les objectifs de recherche et les contraintes budgétaires, deux solutions sont envisageables : un questionnaire semi-structuré comportant des questions générales ou un questionnaire composé de questions précises et approfondies. La première option est moins coûteuse et normalement moins contraignante pour les répondants, en termes de compétences et d'aptitude à répondre. Nous soutenons que, dans le premier cas, l'entretien téléphonique assisté par ordinateur (CATI) ou l'enquête web sont tout aussi adaptés, alors que, dans le second, l'enquête web convient mieux dans la mesure où les répondants ont le temps de retrouver les informations voulues. La contrepartie est que le taux de retour des enquêtes web est habituellement plus faible que celui des enquêtes CATI.

La deuxième difficulté concerne la stratégie d'**échantillonnage**, qui est liée aux contraintes budgétaires. D'un côté, la couverture d'un grand nombre de secteurs et de pays permet de procéder à diverses analyses des incidences des politiques, même en tenant compte des problématiques sectorielles et des externalités spatiales ou économiques des politiques de l'environnement. Premièrement, cela permet d'analyser les conséquences des politiques sur des secteurs peu étudiés, comme celui des services. Deuxièmement, l'analyse de plusieurs pays peut être une source d'informations riches et de données

hétérogènes atténuant une partie des problèmes d'endogénéité liés au recensement des effets des politiques. Troisièmement, les enquêtes concernant un grand nombre de secteurs et de pays présentent l'intérêt de fournir des données sur un groupe témoin pour les besoins d'analyses empiriques.

Cela dit, limiter le champ d'une enquête à un petit nombre de pays et de secteurs se révèle moins coûteux et, en principe, permet d'allonger le questionnaire, de faciliter la collecte de renseignements plus précis et détaillés et, partant, de cibler l'analyse sur des questions concrètes. Par ailleurs, il est certainement plus facile de fusionner les résultats avec d'autres données, comme les données comptables.

Un point essentiel touche à la collecte de renseignements de suivi et de données sensibles et, en particulier, à la possibilité de fusionner les résultats d'une enquête avec des données émanant d'autres sources. La collecte directe d'informations sensibles (données financières et comptables, coordonnées) risque de faire chuter le taux de retour, mais donne aussi la possibilité d'élargir le périmètre de l'analyse et d'effectuer des tests de sensibilité (par exemple, comparer les résultats uniquement fondés sur des données internes ou externes). Il serait particulièrement avantageux de pouvoir, pour chaque entreprise, récupérer un identifiant qui permettrait d'associer l'échantillon d'une enquête à des sources de données extérieures. L'idée de recueillir des informations dans la durée, à l'aide de questionnaires de suivi thématiques ou moyennant la réalisation de nouvelles enquêtes, structurées sur le modèle de la première, relève des objectifs de recherche.

L'existence de **différentes typologies des données relatives aux politiques et à la performance** peut renforcer la robustesse de l'analyse ou favoriser la variété des indications fournies. Par exemple, les questions et les indicateurs qui concernent les politiques peuvent être binaires, qualitatifs, quantitatifs, etc. En revanche, la collecte de divers indicateurs peut rendre l'exercice plus contraignant pour les répondants et faire baisser les taux de retour.

L'un des principaux problèmes rencontrés est celui de l'**endogénéité**. L'information plus riche apportée par les enquêtes internationales peut aider à mettre en évidence les effets des politiques et atténuer les problèmes de simultanéité. Certaines stratégies, en lien direct avec la configuration du questionnaire peuvent éviter la présence initiale de biais de sélection. Par exemple, nous conseillons d'éviter les questions filtres qui entraînent la constitution de sous-échantillons de répondants difficiles à comparer. Développer les questions relatives aux caractéristiques de l'entreprise ou de l'usine considérée, mais aussi à certains traits fondamentaux des répondants, peut atténuer le problème dû à l'hétérogénéité non observée. En suivant des entreprises dans la durée pour, à terme, disposer d'un groupe d'observation, on pourrait réduire l'endogénéité dans la phase d'analyse, même si le jeu de données est appelé à devenir de plus en plus déséquilibré au fil des années.

Enfin, il pourrait être avisé et utile d'arrêter au préalable le **taux de retour** visé, sur la base duquel le questionnaire et la méthode de collecte des données seraient ensuite ajustés. Il y a tout à y gagner : un questionnaire plus court bénéficiera certes d'un taux de retour plus élevé, mais sera aussi moins à même d'atténuer le problème d'endogénéité dans la phase d'analyse puisque la base informative sera plus étroite.

Nous affirmons que la stratégie d'enquête doit être arrêtée en fonction des contraintes budgétaires et des objectifs de recherche, à court comme à long termes. Dès lors que l'étendue du cadre et les relations d'interdépendance entre les principales questions d'ordre méthodologiques sont inconnues, on ne peut se contenter d'augmenter le budget. Pour concevoir une enquête adaptée au budget et à l'ensemble des objectifs de recherche, il y a lieu de définir au préalable le contexte dans lequel l'enquête s'inscrit, en gardant à l'esprit l'ensemble de ses éléments clés, de même que les avantages et inconvénients qu'ils présentent.

Les solutions de remplacement à l'enquête isolée, précédemment énumérées - comme b) modifier ou compléter les enquêtes déjà menées auprès des entreprises et c) tirer parti des dispositifs existants de collecte de données d'entreprises - offrent des moyens séduisants de traiter une partie des problèmes susmentionnés. Il existe déjà un certain nombre d'enquêtes auprès des entreprises et d'autres sources de données qui permettent de suivre l'évolution d'entreprises dans la durée (et, potentiellement, d'atténuer les problèmes d'endogénéité), de recueillir des données sur les résultats économiques et d'obtenir des niveaux élevés de représentativité (taux de retour ou de couverture élevés). Il n'est pas rare toutefois que ces données revêtent un caractère confidentiel et doivent faire l'objet d'une collaboration avec les institutions nationales ou supranationales dotées des outils adéquats. Selon la nature exacte des questions de recherche, un certain nombre des questions décrites dans le présent rapport, comme celles des définitions et de la taxonomie, devraient fournir des indications utiles sur la manière de procéder pour sélectionner, parmi les enquêtes existantes, celles à utiliser et à compléter, ainsi que pour concevoir les questions à y faire figurer.

1. INTRODUCTION

1.1 Environmental policy and firm's performances in a comprehensive framework

Environmental policies are primarily aimed at correcting the market failure related to negative externalities (e.g. pollution). On the one hand, policies such as market-based instruments and other tools (e.g. uncertainty) can achieve Pigouvian static optimality under certain conditions. On the other hand, single policies or policy portfolios can support dynamic efficiency properties, largely through inducing innovations that reduce the use of natural resources and pollution. Regarding dynamic efficiency, both pricing tools (i.e. taxes, subsidies, trading schemes) and standards are potentially able to deliver new innovation trajectories (Kemp, 1997; van den Bergh, 2008; Del Rio, 2009 and 2013) (Figure A1). Whether those strategies are incremental or radical largely depends upon the feature of the single tool in a contingent situation and on the complementarity or substitutability among the different tools that are applied.

Two issues are highlighted. First, environmental policies change the relative prices of green/brown inputs or set new green-oriented standards. The expected effects are increases in resource and environmental productivity through investments in broadly defined 'innovation' and in new capital stocks (Mohnen and Hall, 2013).[1] We observe that though often focusing on eco-innovations, we always refer to a broad innovation realm here, wherein the synergies and complementarities among innovations (marketing-technological-organisational) are conceptually and empirically emphasised.

Second, policy portfolios are deployed to tackle different objectives, economic and environmental aims, or more specifically different externalities. Combinations of taxes, standards and subsidies for R&D are an example (Baumol and Oates, 1987; Christiansen and Smith, 2015). In this context, complementarity of policy instruments is a key issue to understand the complex set of consequential relationships that are activated by a given environmental policy (Figure 1) (Antonioli et al., 2013; Gilli et al., 2014; Mohnen and Roller, 2005; Mohnen and Hall, 2013, among others).

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1 . Mohnen and Hall (2013) discuss the channels through which innovation impacts TFP, with attention to which innovations affect TFP and the complementarity among innovations. They survey studies that analyse innovation and output, with details and comments on the nature (continuous, binary, etc...) of innovation measures. They conclude that 'all four types of innovation considered – product, process, organisational and marketing innovations – contribute to a better productivity performance. Given the imperfect measurement of innovation and the simultaneity of different types of innovation, it is difficult to isolate the individual effect of each. Some complementarity between them seems to exist, even though it is hard to get a good grasp of the exact nexus of complementarities' (p. 61).

Figure 1. Policy, firm strategies (innovation) and short/long term performances: a sketch
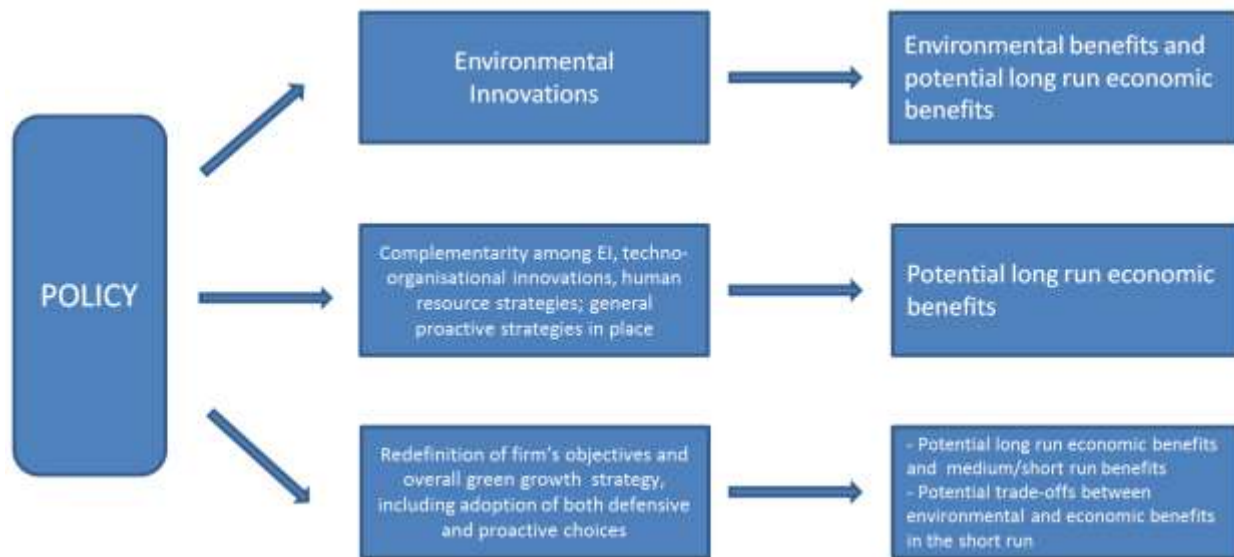
Within policy portfolios, complementarities (and substitutability) are thus relevant to the analysis of existing interrelations between policies and innovations. In a nutshell, complementarity points to increasing returns to scale: joint factors (policies, innovations) deliver returns that are higher than the sum of the single parts. Substitutability signals trade-offs among policies and innovations.[2] It addresses a concrete point since the real world situation analysed is always characterised by the presence of multiple policies and strategies, which are often introduced and adopted at different periods of time. Thus, stringency, predictability and flexibility should be assessed both at the level of single instruments and regarding the mix of relevant policy levers.

The main empirical question regarding economic performance is how "traditional" economic (labour, multi-factor) productivity and resource productivity jointly change, both in the short and the long run (Marin and Mazzanti, 2013; Mazzanti and Zoboli, 2009). Assuming that environmental and resource productivity will eventually increase as a consequence of EP; the open integrated question for research is threefold:

- What are the consequences for economic (productivity) performance in the medium/long run, and even in the short run in some cases?[3]

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2. For a conceptual analysis and a survey of seminal works see Gilli et al. (2014). See also Mairesse and Mohnen (2010).

3. See below more hints on the Porter hypothesis, that links mainstream and evolutionary thinking (for a discussion Costantini and Mazzanti, 2012; Albrizio et al., 2014; Ambec et al. (2013). Since the Porter Hypothesis has been formulated (Porter, 1991; Porter and van der Linde, 1995) emphasis has been given to the potential competitive and productive gains (rather than losses) that might be deriving from the adoption of stricter environmental regulation. This Hypothesis has been argued to consist of three versions, the weak, narrow and strong one according to Jaffe and Palmer (1997) and understanding how environmental policies can avoid harming growth, is a crucial issue in designing policies. Theory would prescribe that eventual positive economic effects of EP are in the medium/long run. This is nevertheless linked to the well-known 'innovation offsets' which Porter sets as main compensating element of EP burden. We also recall that even in a static framework environmental policy, if well designed (e.g. market tools), delivers net social benefits, if we assume that the tax revenues is recycled to society. This is a crucial point in itself: the likelihood of positive economic benefits may depend upon this feature: namely the 'double dividend' hypothesis.

- Which mix of policies and eventually mix of firms' strategies is more likely to enhance economic performances (short/long run)?

- What type of economic performance (productivity, profits, exports, wages, etc…) is more likely to be supported by EP (short/long run)?

Environmental policies are also complements to other policies, and have both environmental and economic effects. Hence, the induced innovation effects are a complex set of interrelated 'eco' and pure economic strategies. The key challenge for policy and management is precisely to create the pre-conditions – by effective and efficient design – to stimulate productivity and profits for the economy as a whole. And firm reactions will be crucial. Examples include investment in tangible and intangible assets, new strategies; searching new links with market partners, etc.

The main intended or unintended reactions of a firm to environmental policy (EP) highlighted include: (i) the use of non-innovation and non-environmentally featured compensating strategies such as delocalisation, job cuts, R&D cuts, employment cuts, etc. (ii) the adoption of radical environmental innovations, which can be generated within the firm or from spillovers or cooperation and (iii) the investment in environmental R&D to generate inventions and patents enhancing a firm's capacity to absorb innovation and skills through higher knowledge stock.

Table 1 sketches what a possible categorisation of firm reactions may be, including, but not limited to, innovations.[4] Defensive and proactive strategies are classified in short, medium, long term scenarios.

Strategies activated by EP and eventually delivering enhanced economic or environmental performance are testable with either cross-section or panel data. Medium and long run effects are mainly testable with panel data, while existing dedicated surveys often resort to cross-section analysis, whose main 'cost' is the very limited ability to identify the effects of environmental policies. This caries the risk that effects of other, unobserved characteristics, constant or changing over time, may be erroneously attributed to environmental policies. These issues can be addressed by resorting to repeated surveys or dataset mergers with external sources that allow lags between dependent and independent variables in cross-section environments as a way to introduce dynamic elements.

In what follows, we provide a short overview of the empirical literature using survey data to look for links among environmental policies, environmental innovation and economic performance (Section 2). We then take a closer look at the some of the surveys that allow for such an analysis in Section 3. Section 4 provides an overview of the main ideas that might be developed through a proper survey and ways of addressing them. Annex A1 gives methodological recommendations on how to build a new survey and alternative avenues to better harness on-going data collection efforts. Annex A2 discusses the surveys' approaches to measuring environmental policy stringency.

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4. Bresson, Etienne and Mohnen (2014) recently use country panel data and estimate an augmented productivity equation to analyse how important innovation is: they show that Total Factor Productivity – which confirms to outpace capital accumulation as creator of wealth - is correlated with, and eventually driven by, infrastructures, technology and institutions. Among those factors, technology ranks second.

2. INNOVATIONS IN FIRMS AND SECTORS: SELECTED INSIGHTS FROM EMPIRICAL RESEARCH

The link between environmental policy and economic performance is a specific piece of the above framework. The focus of this report is the assessment of firm reactions to environmental policy. 'Reactions' can be categorised as (Table 1):

- Proactive / defensive
- Short run / long run oriented

Table 1.   Firm's reactions to EP in the short and long run dynamics

	Short/medium run oriented (possibly profit enhancing)	Medium/Long run oriented (potentially enhancing both profits and productivity)
Relatively Defensive (biased towards economic outcomes)	- Cutting labour costs - Cutting labour force (with emphasis on flexible labour force) - Cutting investment or production - Cutting general R&D, other innovations and training - Tax abatement oriented delocalisation (to compensate EP burden)	- Structurally cutting overall energy costs - Offshoring / outsourcing - Delocalisation of production (e.g. division of firm's units: R&D and production) - Enlarging/downscaling activity size, becoming unit of a business group / owned by a MNEs (to reduce exposure to competition, reduce entry barriers, etc..) - Increasing compliance with policies / interaction with policy makers to 'influence' policy / reduce policy uncertainty
Relatively Proactive (trying to purposefully link economic and environmental outcomes)	- Reallocate firm's divisions and units (e.g. as part of ISO/EMS strategy) - Moving into new products/markets - New training (e.g. energy efficiency training for blue collars) and recruitment of 'green jobs' - Adoption of incremental environmental innovations (taken from the market: competitors, suppliers etc.) - Finding new sources of finance to address the challenge of EP (e.g. bonds, venture capital, banks funding)	- Environmental innovations (green technologies, environmental management systems, green training) aimed at addressing specific environmental productivity policy objectives (e.g. cut CO_2) - Redesigning strategies in a complementary fashion (linking human resource management, technological and organisational practices; product and process innovations) - Developing connections and networking with research centres; develop stable networking with other firms within and outside the sector (e.g. district Ems adoption) - Developing internal environmental R&D units to patent EI - Developing innovation and performance oriented workers involvement and participative industrial relations

We note that some firms may adopt all such short and long term options in a diversified strategy, while others may focus only on sub-areas. Short and medium term reactions may be oriented to cost compensation (thus trade-offs appear). This is the typical short term conflict: some or all costs of EP can be compensated. On the other hand, different compensations may come about by adopting incremental innovations even in the short run: greening the labour force, adopting incremental innovations (even coming from the marketplace), etc.

Figure A1 shows the basic theory behind the potential net benefit coming out of environmental policy. When EP imposes costs to firms, there might be a net benefit in increasing abatement through innovations. Consequently, the related decrease in marginal abatement costs lowers overall costs. If this decrease is large enough to compensate the compliance costs, a net benefit arises. But EP can also take the form of direct support, such as subsidies rewarding improved performance or investment in innovation. In this case, while environmental and possibly economic performance of the benefactor are likely to improve, the key issue of interest is to what extent, and whether this is an efficient outcome from the point of view of the economy.[5] A key related issue is the problem of establishing the counterfactual scenario, i.e. what would have happened if the support measure was not in place and hence its deadweight loss.

More medium-long term strategies are on the one hand aimed at targeting synergies between economic and environmental realms with a tendency towards the economic side (e.g. enhancing links to international markets to increase knowledge, policy compliance, and barriers; focusing on energy efficiency, the relatively more 'private' side of environmental strategy (Grubb, 2014; Corradini et al., 2014). On the other hand, well-designed and more stringent EP can stimulate (for some firms and sectors) radical strategies, that include radical technology development, 360° cooperation with other firms, institutions, stakeholders and a full redesign of internal strategies along competitiveness and sustainability views.

Finance deserves special attention. While it offers some ways to cut short term costs by reallocating risk, it also supports innovation and investments in the long run, the latter role being more relevant (Ghisetti et al., 2015; Mazzucato and Penna, 2015; the FP7 CECILIA2050 Project; and EEA 2014, chapter 8). Finance is relevant because the possibility of reacting proactively depends on the discounting of future investment benefits. Discounting is affected by structural features and financial conditions.

Structural features matter for firm reactions, for survey design and data analysis of EP effects. For example, some firms (e.g. SMEs) may focus more on short-run strategies due to lack of access to external resources or knowledge and 'financial' size, while the most productive firms may adopt both short run and long run strategies (Albrizio et al., 2014). Energy intensive sectors may be structurally more ready to cope with EP challenges and bring together economic and environmental performances[6] (Cainelli et al., 2013).

Considering environmental innovations (EI) in a broad sense[7] and including complementarity issues as a structural factor of analysis, we might explore firm reactions to EP taking EI as a pivot element, to

5. These general equilibrium effects may not be possible to capture in a survey, but the magnitude of the effect of subsidies etc. is crucial for their understanding.

6. EP is incremental in the sense that when it is applied to energy intensive sectors (e.g. EU ETS case), it stimulates reactions on top of inertial and structural ones that may depend on the overall target of reducing energy costs. In some cases, reactions to energy intensity may be exacerbated by the monopolistic structure of energy markets. This means that EP historically follows an evolution of reactions. It mainly focuses on externality abatement and sustains investments that present private positive costs, against low hanging fruits related to energy efficiency (see Grubb, 2014, chapter 2, analysis of the McKinsey figure of carbon abatement costs). Empirical analysis should take this into account. Structural and policy effects should be disentangled as much as possible. Possible ways are analysing sector sub samples, interacting sector and policy indicators, using extensive controls of different nature (e.g. NACE, Pavitt, skill based taxonomies, see Consoli and Rentocchini, 2013).

7. In this report we refer to one of the broadest and comprehensive definitions of EI which comes from the One of the broadest and more comprehensive one came from the "Measuring Eco Innovation" (MEI) project, according to which EI can be defined as "the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organisation (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives" (Kemp and Pearson, 2007:7). See Wagner (2013) on the relationships between green HRM and EMS as a driver of increasing performance in firms, which passes through upgraded skills and competences in the firm's labour force.

which other elements may be linked (Table 1). The integration of EI and other strategies is a channel through which short/medium/long run economic and environmental benefit may jointly turn up (Figure 1).[8]

EI is a potential force that may both reduce emissions and increase economic value (Value Added, labour productivity): process and product innovation adoption in fact potentially reduce energy and material use/costs (process) and increase mark-ups (product). The reduced costs may then further boost demand through lower product prices, or enlarging profit margins.

The effects of EP on EI may also depend upon many factors, such as geography, sector of activity or type of externality. Policy stringency and implementation may vary across geographical areas (e.g. regions) due to decentralised implementation and subsidiarity, innovation diffusion and idiosyncratic regional factors (Cainelli et al., 2015). Second, sectoral characteristics, static and dynamic, as well as sectoral policies and innovation systems will play a role (Pavitt, 1984; Malerba, 2004; Crespi, 2013; Costantini and Mazzanti, 2012). Moreover, firms' incentives to abate environmental pressures highly depend upon the type of environmental issue (Corradini et al., 2014). They are generally higher for energy and material efficiency (more appropriable), lower for CO_2 cuts (whose benefits are less appropriable due to the strong public good flavour). Environmental policy influences this 'disparity' by internalising negative externalities concerning public goods.

A strong research effort has been devoted to the analysis of the effects of environmental policies both on innovative activities and on competitiveness. It recognises that regulation strongly induces technological change and results are supported either using survey data (e.g. Horbach et al., 2012, Rennings and Rexhäuser, 2010) or patents (e.g. Brunnermeier and Cohen, 2003; Costantini and Mazzanti, 2012, 2013; Jaffe and Palmer, 1997; Johnstone et al., 2010, 2012; Lanjouw and Mody, 1996).

This evidence supports the hypothesis that properly designed policies may foster firms' EI and hence improvements in the environmental performance of their products or production processes. However, a key question is whether EI crowds out other strategies - a situation that could be detrimental to overall productivity growth (Marin, 2014).[9] The most solid findings concern increases in EI, but not necessarily total innovation efforts – referred to as the "weak" Porter Hypothesis (Jaffe and Palmer, 1997). Evidence of effects on competitiveness and general economic performances are rarer, and often constrained by data quality and availability (Koźluk and Zipperer, 2014). When panel data are available, economic effects induced by EP and innovation seem to be more likely to be observed (Costantini and Mazzanti, 2012 on exports, Ghisetti and Rennings, 2014 on profits), but cannot be taken for granted.

To sum up, the effects of environmental policies on economic performance (productivity, namely value added on employment as key factor, Pessoa and Van Reenen, 2014) might be even more complex

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8. OECD (2011, executive summary) states: "Opportunities for innovation, spurred by policies and framework conditions that allow for new ways of addressing environmental problems".

9. Among others, Berman and Bui (2001) found that air pollution regulation in the oil refining industry determined a significant productivity increase while Gray and Shadbegian (1998) in analyising the pulp and paper industry found that pollution abatement investments "crowded out" more productive investment and Greenstone (1998) found a negative productivity impact engendered by air pollution regulation. More recently, for EU countries, Ghisetti and Rennings use CIS German data to address the 'does it pay to be green?' question. They find heterogeneous effects across eco innovation types: while innovations leading to a reduction in the use of energy or materials per unit of output positively affect firms' profitability, externality reducing innovations hamper it. Marin (2014), who exploits a CDM model to address both eco innovation drivers and eco innovation effects, finds that innovation efforts of polluting firms is significantly biased towards environmental innovations and that environmental innovations tend to crowd out other more profitable (at least in the short run) innovations. Old and new studies thus confirm the very specific and idiosyncratic nature of results. Meta-analysis and meta-surveys can help summarising what the various results in the literature are.

than those on innovation, as regulations overall and final impact strongly depends on the innovation 'reaction'. This means that

1. Short run and long run effects usually differ (temporal dimension), in addition

2. Reactions differ across sectors and firm's type (e.g. SME vs corporations) which defines the 'structural change' dimension of the issue (composition effects, entry/exit of firms), and finally

3. Reactions differ across economic outcomes: labour productivity, turnover, profits,[10] jobs (as part of productivity) present specific time-related features regarding the policy-innovation effect.

Studying this temporal and structural performance heterogeneity requires defining the lags between key variables ex ante. Different imposed lags refer to somewhat different research hypotheses and relate to points 1-3 above through different combinations (e.g. short run profit effects by SMEs, long run productivity by corporations, etc.).

A survey is a contingent snapshot of a larger dynamic evolution.[11] It is thus of major importance to precisely define the scope of any specific analysis of the economic effects of EP in terms of the time dimension, the type of firms and sectors, the environmental policies and economic performance of interest. Examples of empirical literature of relevance to this report are summarised in Table 2 with a focus on studies that touch upon environmental policy, innovation and economic performance.

Many contributions have conceived environmental innovations (EI) as means to restore competitiveness while reducing environmental pressure and have consequently focused on the analysis of their drivers (e.g. Horbach, 2008; Inoue et al., 2013). Special attention has been devoted at analysing the role that policy plays in inducing the adoption of such innovations (e.g. Crespi, 2008; Veugelers, 2012) and, in particular, on the role played by the European Emission Trading Scheme (EU ETS) (Borghesi et al., 2014; Calel and Dechezlepretre, 2012; Martin et al., 2013). Survey data have been also been crucial for the analysis of the economic effects of environmental policies (e.g. Lanoie et al., 2011) and for the adoption of EI (Cainelli et al., 2011; Ghisetti and Rennings, 2014; Kalamova and Johnstone, 2011) as well as for their environmental effects (Arimura et al., 2008; Bloom et al., 2010).

Each of the aforementioned topics, has also been analysed using either a single region or province focus (Antonioli et al., 2013; Cainelli et al., 2012; Mazzanti and Zoboli, 2005, 2008; Veugelers, 2012), a single country focus, mainly Germany (Cleff and Rennings, 1999; Frondel et al., 2008; Horbach, 2008; Horbach et al., 2012; Rehfeld et al., 2007), Ireland (Ryan and Doran, 2012), Italy (Cainelli and Mazzanti, 2013), Japan (Arimura et al., 2008; Inoue et al., 2013) Spain (De Marchi, 2012), UK (Bloom et al., 2010; Demirel and Kesidou, 2011) or even multiple countries and states such as all European countries (Triguero et al., 2013), US states (Brunnermeier and Cohen, 2003; Jaffe and Palmer, 1997) selected EU countries (Schmidt et al., 2012; Wagner, 2008) or OECD countries (Frondel et al., 2004; 2007; Kalamova and Johnstone, 2011; Lanoie et al., 2011). Differences in the designs of these surveys are outlined in the next section.

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10. Schmalensee (2012) notes green strategies (CSR firms' strategies) may reduce on the one hand the accounting profits generated by firm's assets, but on the other hand increase the stock market value. Though some studies focus on stock market performances (Oberndorfer et al., 2013, in this report we mainly put emphasis on (labour) productivity and profits as key performance indicators for firms. The necessary reference to SMEs when implementing surveys which represent the economy as a whole is among the main motivation.

11. The possibility to structure panel based surveys will be discussed below. The option is nevertheless expensive and complicated. Most analyses on innovation are for this reason of cross section nature.

Table 2. Background literature on firm's performances, innovation and environmental policy

TOPIC covered	Short reference	Focus & Data	Objective
Drivers of EI	Antonioli, Mancinelli and Mazzanti (2013)	Emilia Romagna Region manufacturing firms, Own survey	Complementarities between strategies of High Performance Work Practices (HPWP) and Human Resource Management (HRM) in green strategies
	Cainelli, Mazzanti (2013)	Italian service firms, CIS data	Determinants of EI in the service sector and role of manufacturing-service integration
	Cainelli, Mazzanti and Montresor (2012)	Emilia Romagna Region manufacturing firms, own survey	Internationalisation strategies and EI
	Cainelli, Mazzanti and Zoboli (2012)	Emilia Romagna Region manufacturing firm > 20 employees. Own survey	Role of inter-firm network relations in local production system to stimulate EI adoption
	Cleff and Rennings (1999)	German firms, MIP 1996	Determinants of EI distinguishing between product and process EI
	De Marchi (2012)	Spanish manufacturing firms, PITEC	Analysis of R&D cooperation in spurring EI adoption
	Demirel and Kesidou (2011)	UK firms, Government Survey of Environmental Protection Expenditure by Industry 2006	Analysis on the drivers of EI in UK
	Frondel, Horbach and Rennings (2004)	Manufacturing German firms, OECD survey data	Relationship between environmental auditing schemes and pollution abatement innovations
	Frondel and Horbach Rennings (2007)	OECD survey on Canada, France, Germany, Hungary, Japan, Norway and the USA.	Differential effect of regulation on cleaner production and end-of-pipe technologies.
	Frondel, Horbach and Rennings (2008)	German facility and firm level survey, from OECD survey 2004	Test of the simultaneity between EMS and EI adoption
	Horbach (2008)	German firms, IAB and MIP	Determinants of EI
	Horbach, Rammer and Rennings (2012)	German firms, MIP 2009	Determinants of different typologies of EI
	Inoue, Arimura and Nakano (2013)	Japanese facility data, OECD survey	Role of EMS on environmental innovation
	Mazzanti and Zoboli (2005)	Emilia Romagna Region manufacturing firms	Determinants of EI in a local production system, with focus on networking activities' effects on EI
	Mazzanti and Zoboli (2008)	Reggio Emilia manufacturing firms with more than 50 employees. Own survey	Drivers of EI and complementarities between different EI adoption and between innovation inputs
	Rehfeld, Rennings and Ziegler (2007)	German manufacturing firms, own ZEW telephone survey in 2003	Relation between EMS - IPP-measures and environmental product innovations.
	Triguero, Moreno-Mondéjar and Davia (2013)	European SMEs, Flash Eurobarometer survey #315 (Attitudes of European Entrepreneurs Towards Eco-innovation)	Determinants of EI for SMEs
	Wagner (2007)	German firms, own survey	Link among EMS, EI and patenting
	Wagner (2008)	Manufacturing Firms of 0 EU	EMS effects on EI

		countries, European Business Environment Barometer 2001/2002 (Belgium, France, Germany, Hungary, Netherlands, Norway, Sweden, Switzerland, United Kingdom).	
	Ziegler and Nogareda (2009)	Germany, manufacturing with >50 employees questionnaire-based telephone survey 2003	Bidirectional link between EMS and EI
	Ziegler and Rennings (2004)	German firms, manufacturing with >50 employees questionnaire-based telephone survey 2003	EMS and EI
Environ- mental performance	Arimura, Hiniki and Katayama (2008)	Japanese facility level; OECD survey 2004	Effects of implementation of ISO14001 on environmental performance
	Bloom, Genakos, Martin, Sadun (2010)	Manufacturing firms in UK, CEP survey 2006	Link between management practices and energy use
	Gilli, Mancinelli Mazzanti (2014)	Sector analysis of EU, CIS data	Effects of innovation on environmental productivity
	Meilhac and Recoules (2014)	French manufacturing, Antipol and various surveys (energy consumption, hazardous waste, pollutant emissions, etc.)	Effects of ISO 14001 certification and EMAS on CO_2 and waste.
	Testa, Rizzi, Daddi, Gusmerotti, Frey and Iraldo (2014)	Energy intensive plants in Italy. EPRTR data on plant emissions; ACCREDIA data on EMS and EMAS register	Effects of EMAS and ISO14001 on the reduction of CO_2
Policy and EI	Borghesi et al. (2012)	Italian manufacturing firms, CIS	Effects of the first phase of EU ETS on innovative activities
	Brunnermeier and Cohen (2003)	US manufacturing industry, Pollution Abatement Costs and Expenditures Census Bureau's Survey, PACE, 1983-1992	Effects of regulation (pollution abatement expenditures) on environmental innovation (patents in green technologies) by US manufacturing industries
	Calel and Dechezlepretre (2012)	European companies in 18 countries	Effects of EU ETS on the development of low-carbon technologies
	Crespi (2008)	Sectoral data on 8 countries (DE, FR; IT, NO, Netherlands, Portugal, ES, UK), 22 manufacturing sectors, Urbino Sectoral Database	Effects of environmental policy on induced technological change in energy and resource efficiency technologies
	Hemmelskamp (1999)	German firms, MIP 1993	Determinants pf EI with particular emphasis on policy effects on EI. Only energy and material efficient innovations
	Jaffe and Palmer, 1997	US manufacturing industry, Pollution Abatement Costs and Expenditures Census Bureau's Survey, PACE, 1976-1991	Effects of the stringency of regulation (environmental compliance expenditures-capital cost) on innovation (R&D expenditures & patents) at the industry level
	Lanoie, Lucchetti, Johnstone and Ambec (2011)	7 OECD countries (Canada, FR, DE, HU, Japan, NO, US), facility level, OECD 2003 survey	Test on the competitiveness effect of the adoption of regulation (Porter HP) and on its environmental performance effects

|	Martin, Muulus and Wagner (2013)	Manufacturing sector; 6 countries	Effects of EU ETS on competitiveness
	Rennings and Rexhauser (2010)	German firms MIP 2009	Effects of long term regulation on EI differentiating by type of EI
	Schmidt et al. (2012)	Own survey on the electricity sector in seven EU countries (FR, DE, IT; Poland; UK, Slovakia, Spain)	Impact of EU ETS on technological change
	Testa, Iraldo and Frey (2011)	Construction sector; IT-FR-Netherland; own survey	Significant Role of stringency of policy on innovation in construction sectors
	Veugelers (2012)	Flemish firms, CIS data	Determinants of EI focusing on demand and regulatory factors
Economic performance of EI	Cainelli, Mazzant and Zoboli (2011)	Italian firms in services, CIS data	Effects of environmentally oriented innovative strategies on productivity in services
	Delmas and Pekovic (2013)	French manufacturing firms & employees; merge of three surveys: Organizational Changes and Computerization (COI), the Annual Enterprise Survey (EAE) and the Annual Statement of Social Data (DADS).	Relationship between ISO 14001 certification and labour productivity
	Ghisetti and Rennings (2014)	Manufacturing firms, Germany, Mannheim innovation Panel	Profitability effect of different typologies of EI
	Horbach and Rennings (2013)	German manufacturing firms, MIP	Employment effects of EI
	Hottenrott, Rexhauser and Veugelers (2012)	German firms, MIP 2009	Complementarity effect of EI and organisational innovations on productivity (TFP)
	Kalamova and Johnstone (2011)	OECD 27 countries	Environmental policy stringency on MNC FDI
	Peukert et al. (2014)	43 countries, 2000-2004	Competitiveness effect of different regulatory designs.
	Rennings and Rammer (2010)	German firms, MIP 2003	Economic effects of regulation driven EI (different typologies) in terms of sales with new products and cost savings
	Rexhauser and Rammer (2014)	German firms, MIP 2009	Test on the Porter Hypothesis, effects of regulation induced innovation on firms' profitability
	Ryan and Doran (2012)	Irish CIS 2006-2008	CDM model to identify Factors that drive EI and test if EI perform better that non-EI firms in terms of turnover
	Vachon and Klassen (2008)	Own conducted plant-level survey of the North American package printing industry plus the Packaging Sourcebook (United States) and Scott's Industrial Directory (Canada).	Environmental collaborations' effects on plants' manufacturing performance

3. EXISTING SURVEYS: A CRITICAL ASSESSMENT

Surveys mixing questions on environmental policies and economic effects, which also eventually include innovation or EI are extremely rare, but they would contribute to the understanding of the circular and cumulative relationship between economic performance, R&D activities and innovation (Box 1). Surveys feature some flexibility and eventually cover all firms (not only corporations or SMEs as from some official source). They may also cover the full spectrum of innovation in a broad sense (not only patents). As for policies, in practice it is likely that an optimal survey does not yet exist, given the many advantages and drawbacks, but a well-designed survey is feasible if one knows the key critical points and inherent trade-offs.

Box 1. Circular relationship: Economic Performance → R&D and policy → Innovation and Invention → Performance

The relationship between performance, policy, measures of innovation-input such as R&D expenditure and innovation output (e.g. technological innovation) is a rather overlooked part of the literature that deserves future attention from academia and policy makers. The aim is to understand the full chain of events that can be represented as follows in Figure 2.

Figure 2. Cumulative and circular relations: Innovation, policy and economic performance
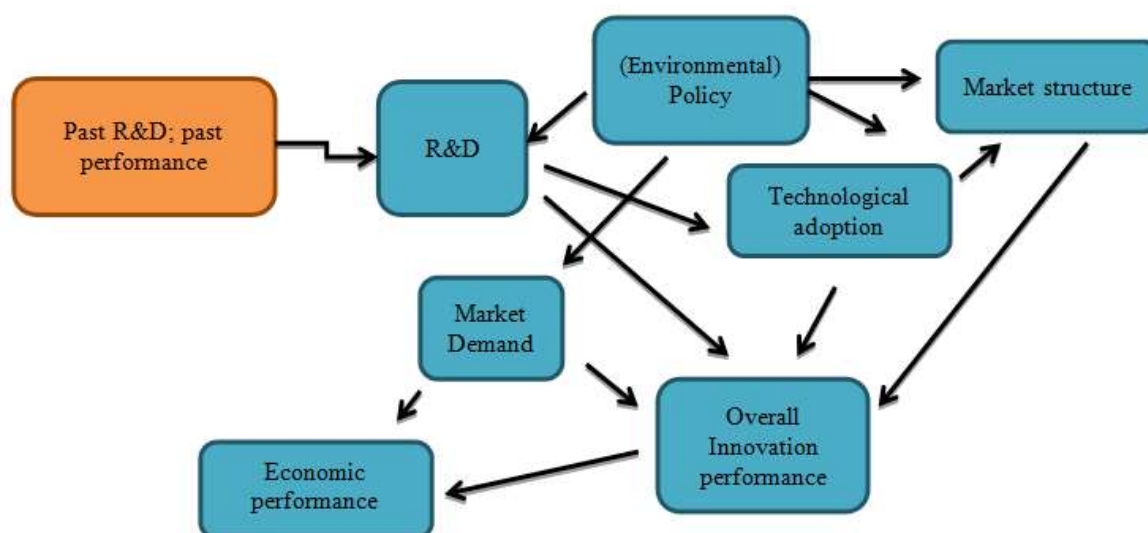
In the feedback-loop that involves performance, R&D activities and innovation output a relevant role may be played by policies, especially for EI, as well as by market demand (demand pull effects) and by technology (technology push) effects (Antonucci and Pianta 2002; Bogliacino and Pianta 2012). Empirical investigations on the issue of the circular relations in Figure 2 are not straightforward, also because of lack of data, which should have a time dimension in order to account for cumulative effects over time and the persistence of innovation (e.g. the effect of lagged profits on R&D or the cumulative effect of past R&D on the present one). Indeed, R&D and policy are two key drivers of innovation, either substitutes or complements. The more radical an innovation is, the more likely that complementarity among drivers is needed to support and diffuse innovation. It is also worth noting that the set of links depicted above might be assessed within or outside a strict 'production function' approach.

Source: Own elaboration from Bogliacino and Pianta (2012), "Profits, R&D and innovation. A model and a test" Industrial and Corporate Change (2012): 1-30.

It would be useful to have a comprehensive survey that would help in disentangling and measuring the nexus reported in Box 1. However, each existing survey has shortcomings. A main list of issues is

reported in Table 3 and each point, when relevant in a specific survey, is discussed below. A synthesis is provided in Table 4.

Table 3.   Main issues in survey development and analysis of survey data

Issue	Description	Associated Risk	Example solutions
Setting the survey			
Definitional and taxonomy issues	Difficulties in precisely defining concepts of relevance for the objective of the study and making them clear to respondents	Information not adequate for the analysis	Specifying a precise definition of EI (e.g. based on Kemp, 1997).
Sampling	Defining the appropriate sampling strategy	Problems in applying inferential statistics	A precise sampling procedure to stratify the sample by firm size, geographical region and sector.
Follow-up information	Envisaging of subsequent surveys on the same sample or on subsample to collect focused information	Rise *in itinere* costs of the analysis	A second or third wave of the same survey to the same groups of firms could provide several information vital for researchers.
Sensitive data	Asking (monetary, quantitative) information on economic performance, costs and investments	High rate of missing values	Ranges instead of precise values
Simultaneity	Simultaneous links between innovation and performance, as well as between policies and innovation, etc.	Risk of endogeneity and consequently attributing effects of other drivers to environmental policies. Similarly, risks of respondent sample being determined by environmental policies,	Lags: different adoption periods (e.g. CIS2009 for EMS adoption in 2 periods). Cognitive capacity to temporally locate innovations and performance should be pre tested
Analysis			
Endogeneity - Simultaneity	Most surveys are cross-section with limited ability to control for potentially relevant factors	Requires the elicitation of rich array of information to be used as instrumental variables which may be problematic	Questions to be used as instruments in empirical analysis. In a study on the effect of environmental policy on EI performances, a section of questions on the determinant of EI could provide useful instrument in a sequent IV-2SLS analysis.
Endogeneity - Unobserved heterogeneity	Relevant information not available due to missing variables that could potentially determine the causal link	Biased results due to the omission of relevant variables in the econometric analysis	All variables which could be correlated with the dependent have to be included in the analysis. (If the dependent is EI, not asking questions on regulation would omit a relevant part of the story)
Selection bias	A not randomly selected sample of firms	Biased results due to non-representative population	Avoid filters in the survey
Response rate	Low response rate	Non representative sample	Pre-testing. Designing questions to avoid missing responses (precision, sensitivity)

3.1 Community Innovation Survey (CIS)

The nature, structure, objectivity, sample and response rate of already implemented surveys are heterogeneous. One of the most frequently exploited is the Community Innovation Survey (CIS), conducted every 2 years by European Commission to measure innovation activity in enterprises (EEA (2014). CIS is conducted by EU member states on a harmonised questionnaire that allows comparability

over countries, but compilation is on voluntary basis so that different waves face different countries involved.[12]

The survey generally provides information on the different types of innovation and on various aspects of the development of an innovation, such as objectives, sources of information, public funding and innovation expenditures.

Although with some exceptions (e.g. Spain or France) data are available in an anonymised form, so that it is not feasible to track firms over time. In the 2006-2008 wave the CIS has been appended by a section on innovation with environmental benefits, in which firms were asked to report the adoption of different types of environmental innovations and the motivations behind this choice. The target population was the subset of enterprises with more than 10 employees in the NACE Rev. 2 sections A to M, stratified by country, size and sector. Data collection depended on the collecting country and has been performed both through census or sample surveys, often through mail surveys.[13]

Whereas CIS is still in place, the section on innovation with environmental benefits has not been included in any subsequent wave. As it is the first EU wide survey to provide information on EI which is comparable across countries, CIS has been considered a precious survey for analysing both the drivers of EI (Horbach 2008; Horbach et al., 2012) and their economic effects (Cainelli et al., 2011; Ghisetti and Rennings, 2014).

A positive aspect of the **CIS administered in 2009 (CIS 2006-2008**) is the comprehensive definition of EI provided, reducing potential 'definitional problems', which included innovation leading to: reduced material use per unit of output; reduced energy use per unit of output; reduced CO_2 'footprint' (total CO_2 production); replaced materials with less polluting or hazardous substitutes; reduced soil, water, noise, or air pollution; recycled waste, water, or materials; reduced energy use; reduced air, water, soil or noise pollution and improved recycling of product after use.

The role of policy is assessed in two ways. First, the role of innovation policy is tested by asking whether, from 2006 to 2008, the enterprise received any public financial support for innovation activities from different levels of government, including financial support via tax credits or deductions, grants and loans.

Secondly, in asking for the motivations that drove firm decisions to adopt EI, the survey asked specifically about the role of policy. The question was formulated as follows: "During 2006 to 2008, did your enterprise introduce an environmental innovation in response to existing environmental regulations or taxes on pollution or environmental regulations or taxes that you expected to be introduced in the future?"

Although such a formulation seems correct, it hides a serious methodological issue that hinders the possibility of exploiting such information to investigate the role of regulation in inducing EI adoption. In

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12. CIS2002-2004 covers 25 EU Member States plus Iceland, Norway, Bulgaria and Romania. CIS 2004-2006 covers 25 EU Member States plus Norway, Bulgaria, Romania, Croatia and Turkey. CIS 2006-2008 covers 26 Member States (all except Greece), Iceland, Norway, Croatia and Turkey. CIS2008-2010 covers EU 27 Member States (except Greece), Iceland, Norway, Croatia, Serbia and Turkey.

13. The Methodological annex of the CIS 2006-2008 does not make a distinction among countries a mail collection method or "other" methods. It is only reported that responses were often collected through mail. Furthermore, information on precise response rates by countries is not available, but it is specified the required checks in case non-respondents exceed 30% of the sample. In such cases, it is required to select a random sample of at least 10% of the non-respondents and to run a non-response survey in order to verify the absence of a bias in the respondents.

asking environmental innovators only for the role of regulation, no information is available for non-environmental innovators. In other words, a serious bias arises when trying to exploit such regulatory variables in any empirical analysis, as we only know whether regulation affected already eco-innovative firms, while nothing is known about the role environmental regulation had in influencing behaviours of non-eco-innovative firms. The innovation policy variable presented above is only available for innovative firms, as well as the majority of the variables in the CIS. More precisely, firms which do not report having adopted any product, process or any innovative activity are asked to jump directly to the end of the questionnaire and do not provide any answer to the majority of the questions, such as those on innovation policy described before. The drawback that emerges is that any econometric analysis on this data-source is mainly performed on a sample of innovative firms (sample selection). In principle, a proper selection model (e.g. Heckman) might be performed to model the probability that a firm has to be included in the sample under scrutiny. The CIS 2006-2008 structure, however, does not allow modelling such a selection as no exploitable variables remain out of the above described filter to build the exclusion restriction, thus making it impossible to control for the probability of firms to be included or excluded in the analysis.

Hottenrott et al. (2012) seek to explain the probability to adopt CO_2-reducing innovations at the firm level as well as the productivity effects of such adoption. They use the above "regulation" responses (measured as the sectoral mean) as a proxy for environmental stringency. A potential endogeneity arises if firms with better organisational quality ("clever managers") are more likely to see the opportunity linked to innovation adoption, and consequently higher productivity effects – in which case the effects would be overestimated for the average firm. To overcome such problems, they use the objective of increasing market share (as a motivation behind innovation adoption) response and alternatively the sectoral mean of EI adoption as an instrument for EI.

Another drawback in this survey is the anonymisation process of the respondents. This is clearly made to guarantee respondents of the anonymity of their answers, but from a researcher's point of view it raises some concerns. The bigger one is the impossibility of merging it with external datasets (e.g. balance sheets data to combine information and answer deeper research questions). This seriously constrains the analysis of the circular link among policy, R&D, innovation and performance. In this case, a second best would be to use discrete data or data formulated as value on a Likert scale. Another option could be the use of variables as a proportion of a continuous quantitative variable such as information on economic performance. Such denominator variables, as employment, profit and productivity trends, may then be elicited in a specific part of the survey, in the event that some sensitive information on quantitative aspects is not provided by many firms thereby inflating the missing values rate. However, exploiting different kinds of data sources could allow the reconstruction of past and expected trends in objective variables, thereby providing an empirical basis to test the full chain of links.

3.2 2004 OECD Survey

Another survey that has been extensively exploited is the facility-level **OECD 2004 survey**, mainly focused at analysing management (also environmental) systems, environmental performance and impacts, environmental policy design and effectiveness, motivations and stakeholders as well as firm and facility characteristics. It covers over 4,000 manufacturing firms and facilities in 7 OECD countries, with an average response rate of 25% (with considerable cross-country variation). As in the CIS, a question on whether regulation is a motivation to adopt environmental practices was formulated, and allowed a broader understanding of the magnitude of regulatory compliance through a 1-4 scale variable. Moreover, it allowed investigating environmental policy through a set of instruments:

- Input bans
- Technology-based standards (e.g. abatement equipment)
- Performance-based standards (e.g. emission levels)

- Input taxes (including energy
- Emission or effluent taxes or charges
- Tradable emission permits or credits
- Liability for environmental damages
- Demand information measures (e.g. eco-labels)
- Supply information measures (e.g. recognition programs)
- Voluntary / negotiated agreement
- Subsidies / tax preferences
- Technical assistance programmes

Lastly, the stringency of existing regulation was assessed in two ways. Firstly by a self-reported perception of the environmental policy regime, which ranged from "not particularly stringent" to "very stringent". Secondly, through a more objective indicator, which asked the number of inspections by public environmental authorities in the last three years.

As in the case of CIS, the simultaneity problem is somewhat unavoidable given the cross-section nature of the data. The definitional problems were mainly avoided given the detailed questions, also on policy perception, although on this point the information on policy stringency at firm level can be misleading. Firms of a same country may face different regional or local policies or facilities of a same big company that are located in different regions of the world face different types of environmental policy. Unless the information on policy is complemented by some kind of geographical reference that could also be used to retrieve at least rough information on the policy the firm is subjected to (by using geo-referenced policy indicators, see Cainelli et al., 2015), it becomes cumbersome to investigate the link self-reported policy stringency and innovation.

Furthermore, the formulation of some questions may need different elucidation in order to infer clearer correlations.

For instance question 1.3 asks "While purchasing and/or marketing goods and services, does your facility regularly consider the following measures?". Answers to this question can be more informative if a causality were suggested, to understand if the lack of environmental attitudes in (suppliers concretely constituted a limit for firm's partners choice or not. The formulation of the question renders it difficult to understand if and how suppliers' environmental attitudes concretely affected firm behaviours, since only the perceived importance of these elements can be inferred.

3.3 UK DEFRA Survey

Demirel and Kesidou (2011) exploited the Department for Environment Food and Rural Affairs (DEFRA) Government Survey of Environmental Protection Expenditure by Industry (EPE) in 2006.[14] The objective of this survey was to gather firm-level data on environmental protection expenditure across industrial sectors only in UK. It gives interesting hints on how to better design a survey in this field. It not only it raised questions on capital environmental expenditure, the existence of environmental management systems, environmental research and expenditures and their motivation for environmental expenditure, but also gives direct data on environmental research and development expenditures. Even though this type of question directly measures environmental R&D, it is also likely to give rise to definitional issues and

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14. The survey is specifically tailored around environmental investments. A distinction is only made between "in-house" and "externally" paid operating costs and between "operating costs" and "capital investments". *www.gov.uk/government/uploads/system/uploads/attachment_data/file/372986/2013_Final_Questionnaire_v3.pdf*

potential misreporting. The survey also asked the motivations behind firm investments in environmental protection.

A relevant positive element for this survey is that DEFRA runs it annually. Currently, the "Government Survey of Environmental Protection Expenditure by Industry: 2013" is ongoing.[15] This survey provides interesting insights as well. It makes a distinction between operating expenditures for environmental protection and capital environmental protection expenditures.

The first covers in-house expenditure associated with the operation of pollution control or abatement equipment and payments to external organisations for environmental services, including waste management and waste disposal costs.

The second proposes a differentiation for end-of-pipe capital investments,[16] integrated investments, cost saving process innovations and environmental management systems.

Elements of originality that deserve consideration are:

It quantifies end-of pipe vs integrated investments for environmental protection

It allows to measure, in percentage, which are the expenditures for each category among waste, water, air, soil, noise, nature protection and residuals. In other words it allows on the one side to identify the types of EI adopted and, on the other side, to quantify firm investments towards them.

A drawback of the DEFRA surveys is that not only the set of sampled firms, but also sectoral coverage and questions have changed along the waves. This does not allow a full exploitation of the data in terms of proper panel analysis as firms, sectors and sometimes questions differ.

3.4 ANTIPOL

Similarly to the DEFRA – EPE survey, the INSEE – Business Statistics Division implemented in France the ANTIPOL survey on investments and current expenditure to protect the environment in 2010.[17]

It covers the extraction and manufacturing industry and establishments in electricity, gas, steam and conditioned air production and distribution. The reference population is of 18,662 establishments whereas sample size is 10,000 and the number of responses collected 8,217; 7,571 of which were usable. It is a compulsory survey collected online or via mail.

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15. Firms have completed the response process to the survey - via mail or e-mail responses, in November 2014. No further information is available yet on results.

16. End-of-pipe' equipment is defined as those "used to treat, handle, measure or dispose of emissions and wastes from production, but not equipment which is used in, or as part of, production processes or installations. Examples of 'end-of-pipe' equipment include effluent treatment plant and exhaust air scrubbing systems." (DEFRA EPE Survey, 2013).

17. In 2011 INSEE has also conducted the Enquête sur les entreprises et le développement durable (EnDD). It covers French extraction activities; manufacturing; electricity, gas, water, steam and air conditioning production and distribution; construction and other key sectors. It conducted at the firm level, for firms above 10 employees (500 for corporates). The relevant sample covers some 11 000 entities, is qualitative and aimed at investigating of adoption and application of approaches towards corporate social responsibility and sustainable development. It can be merged with economic data from other sources. An update is planned for 2016.

This survey, used by Huiban and Musolesi (2013) and Huiban et al. (2014) differentiate between current expenses and investments. They exploit this difference to investigate the Porter hypotheses. Current expenses are defined as 'operating expenses associated with equipment specifically dedicated to environment installed before, including maintenance, energy costs, fees and taxes, environmental management and others' investments are defined as the purchase of 'buildings, land, machinery or equipment to treat, measure, control or limit'.

3.5 CEP Survey

Another survey that provides interesting suggestions was the carried out by the *Centre for Economic Performance* (**CEP**) by phone in 2009 to gather information on both the effectiveness and the competitiveness effects of climate change policies, particularly of the EU ETS, on a random sample of European manufacturing firms.

After establishing whether a firm was registered under EU ETS or not,[18] the survey asked how stringently the emission cap quota was imposed, the measures put in place to comply with the cap, the annual cost burden of being part of the EU ETS and the details about firms' trading of allowances. Moreover, the expectations on the stringency, allowances and sanctions of the last EU ETS phase were assessed. This survey also featured two extremely useful questions that were not targeted to a specific policy instrument.

First, firms were asked to indicate the fraction of their Research and Development expenditure towards climate change, which is, as previously described, an interesting question targeted at specifically measuring environmental rather than general R&D. Second, firms were asked whether the existence of a carbon price would lead them to outsource part of their production abroad or to close down completely.

Given the debate on the "pollution haven hypothesis" according to which regulation may be detrimental on firms' and countries' competitiveness and can encourage production to be moved to countries with lower environmental standards, asking firms directly if this is the case provides precious information. However, firms could also answer strategically to such a question, reporting that regulation would be highly detrimental for competitiveness even when they know that the negative effect on competitiveness could be weak.

3.6 Schmidt et al. (2012) Survey

The role of EU ETS is also tested in a survey presented in Schmidt et al. (2012), in which the EU emissions trading schemes effects in the 3 different phases are tested, together with EU and national policies promoting R&D and innovation, and the policy framework regarding renewable and the reduction targets for greenhouse gases by 2020. This survey was conducted only for the electricity sector in 7 European countries. The sector specificity may be a positive aspect, because it allows focusing on well-known sector characteristics and considering sector-specific policies, avoiding to some extent definitional issues. However, the focus on a single sector hampers the possibility of conducting analysis on spill-over effects between sectors and also prevents the assessment of the effects of a policy on the entire economy.

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18. 57% of the respondents are ETS firms. Anderson et al (2011) acknowledge that EU ETS firms are different from non-ETS firms, and empirically confirmed that interviewed firms are not significantly different from non-interviewed firms with respect to observable characteristics.

3.7 PACE survey

The US' Census Bureau's **PACE survey** on Pollution Abatement Expenditures and Costs also played a relevant role in empirical contributions (e.g. Brunnermeier and Cohen, 2003; Jaffe and Palmer, 1997; Gray and Shadbegian, 2003; 2007). It was focused on plants in manufacturing, mining and electric utility industries and provides statistics on capital expenditures and operating costs for pollution prevention and pollution treatment. The pro of this survey is its wide geographical and sectoral coverage. However, it has two main drawbacks. First, it only measures plant expenditures for environmental protection, which is not informative of the effective efforts towards innovation. Such expenditure may include expenditure on R&D, adoption of new production processes or end-of-pipe technologies. Nothing is known about the effective adoption of environmental innovations and, consequently, nothing can be inferred on their economic and environmental effects. The second drawback is the lack of continuous and current data. It was conducted annually from 1973 to 1994, with the exception of 1987, then was interrupted and re-started, no longer annually, in 1999, and was completely terminated in 2005.

3.8 Regionally Focused Surveys

Finally, a non-negligible role could be played by regionally-focused surveys (Eurostat NUTS2 geographical units). Regional innovation systems have been quite recently recognised as places where the interactions among market actors and institutions can trigger innovation (e.g. D'Allura, Galvagno, Mocciaro Li Destri, 2012). For example, the survey on Emilia-Romagna region in Italy collected information from over 555 manufacturing firms with at least twenty employees. It took CIS2009 as a benchmark and inspiration.

It is worth noting that the focus was not only on environmental innovation, but on several innovation strategies such as technological and organisational innovations, information and communication technologies adoption, training activities and internationalisation strategies.[19] The basic idea was to collect information on innovation strategies in order to verify the potential complementary links that related such strategies and that boost economic performance. In particular, the synergies in organisational innovations and human resource management practices in triggering the propensity to adopt environmental innovations have been assessed (e.g. Antonioli, Mancinelli and Mazzanti, 2013) in recent studies.

3.9 How to improve existing surveys

In this last section we briefly summarise how to improve existing surveys.

Suggestion 1: How can CIS be improved or expanded?

The CIS represents a precious source of data, improvements in the structure of the survey might be made in order to make its information fully exploitable in empirical analysis as well. Among others:

- Avoiding nested innovation and eco-innovation set of questions, to have also control variables available for both eco-innovative and not eco-innovative firms
- Improve the accessibility of micro data in various EU countries
- Ease data mergers both with external data sources and with previous waves of the same survey

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19. This allows investigating more in depth the various (complementary) links among innovative strategies. The section on internationalisation and offshoring is relevant to include within the set of economic performance some factors such as exports, FDI, offshoring, etc. and account for some key 'drivers' of EI, which interact with the role of policies, such as foreign ownership. Some policy effects may be transmitted by the link to multinationals which capture various policy realms (country of origin and beyond, see Cainelli et al., 2011).

- Include monetary environmental R&D expenditures
- Include spatial information (firm location in a EU region, province)
- Avoiding nested eco innovation motivations set of questions (within the EI section) to circumvent endogeneity (nested questions will most likely mean that particular characteristics of firms which are not innovating will not be collected, and hence it will not be possible to control for their role in the analysis)
- Distinguish between product and process EI, radical and incremental (new to the market, new to the firm)

Future surveys might take the core CIS as basis and enlarge or improve it according to EI related research questions.

Suggestion 2: How can OECD 2004 Survey be improved or expanded?

If the OECD 2004 survey were to be used as a basis for gathering firm and facility level information, it could be improved to address some of the issues:

- Set more type-specific and non-binary questions on economic performances (Lanoie et al., 2011), to allow more robust and varied econometric assessments.
- Set questions to elicit information on both invention (patents) and innovation adoption/diffusion. Within EI adoption questions, distinguish between product and process EI, radical and non-radical (new to the market, new to the firm)
- Change question formulation to more directly suggest causalities
- Add an open question to evaluate which is the most effective environmental innovation adopted by the firm, to understand the magnitude of its environmental impacts
- Ask firms to quantify investments towards environmental innovations and distinguish between end-of-pipe investments and integrated cleaner production ones (as in DEFRA–EPE, 2013).

Table 4. Positive and negative aspects of surveys on the main issues highlighted in Table 3

		Issues in setting the survey					Issues for the analysis	
		Taxonomy and Definitional issues	Sampling	Follow-up information	Sensitive data		Simultaneity, Selection bias and/or Unobserved heterogeneity	Response rate
1. CIS 2006-2008		V	V	X	V		X	V
2. OECD 2004		V/X	V	X	V		X	V
3. DEFRA- EPE 2006 and 2013		V	V	V	X		V/X	V (2006)/n.a. (2013)
4. ANTIPOL		n.a.	V	V	V		n.a.	V
5. CEP (Anderson et al. 2011)		V	V	V	V		X	X
6. Schmidt et al 2012		V	X	V	X		X	V/X
7. PACE		V/X	V	V	V		n.a.	V
8. UNIFE (University of Ferrara)		V	V	V	V		X	V
9. IAB-Betriebspanel		V	V	V	X		V/X	V
10. WEF World Economic Forum's (WEF) 'Executive Opinion Survey'.		n.a.	n.a.	X	X		V/X	n.a.
11. EMPIRE		V	V/X	X	X		X	V/X
12. TNO ecoinnovation futures survey		V	V/X	V/X	V		X	V/X

Positive: V; Negative: X; Mixed Positive and Negative: V/X

Table 5.   List of surveys

Survey	Country Coverage	Sectors	Questions on environmental policies	Main task of survey	Statistical unit	Survey implementation relevant details
CIS 2006-2008	EU	NACE Rev. 2 A to M. (>10 empl.)	Q1: During 2006 to 2008, did your enterprise introduce an environmental innovation in response to: Existing environmental regulations or taxes on pollution or environmental regulations or taxes that you expected to be introduced in the future (Y/N) Q2 on Innovation POL: During the three years 2006 to 2008, did your enterprise receive any public financial support for innovation activities from the following levels of government? Include financial support via tax credits or deductions, grants, subsidised loans, and loan guarantees. Exclude research and other innovation activities conducted entirely for the public sector under contract.	Enterprise's innovations and innovation activities between 2006 and 2008. Other Q on: Product, process, organisational innovations Firm structural characteristics	Firm level	Mixed types of answers: Multiple choice or binary answers; continuous variables (e.g. turnover) Usually web and postal implementation, but depends on each country's statistical office. Germany for instance performed also phone calls; Uk had only a postal questionnaire Response rates vary across Member States and are not available It is repeated over time but firms are anonymised so that no merge is possible with previous/subsequent waves
Schmidt et al 2012	7 EU countries: France, Germany, Italy, Poland, Slovakia, Spain, UK	Electricity	Q1: To what extent is your company negatively or positively affected by the EU emissions trading in the 3 phases? Q2: To what extent is your company negatively or positively affected by EU & national policies promoting R&D and innovation Q3: "To what extent is your company negatively or positively affected by the policy framework regarding renewable energies over the last five years? Q4: To what extent is your company negatively or positively affected by long-term European and global reduction targets for greenhouse gases as in 2020?"	Analysing EU policies and the perception of their effects for the firm. Other Q on firm characteristics; demand conditions	Firm level	Mixed types of answers: Multiple choice; ordinal; continuous; dummy Phone contact and then web-implementation tool Response rate of 14.6% for power generators and 13.1% for technology providers Not repeated over time
OECD 2004	OECD: Canada, France, Germany, Hungary, Japan, Norway and the USA	Manufacturing	Q1: How important do you consider the following motivations to have been with respect to the environmental practices of your facility? Motivation: Regulatory compliance (1-4 scale) Q2_Please assess the following environmental policy instruments in terms of their impacts on your facility's production activities: Input bans Technology-based standards (e.g. abatement equipment) Performance-based standards (e.g. emission levels) Input taxes (including energy) Emission or effluent taxes or charges Tradable emission permits or credits Liability for environmental damages Demand information measures (e.g. eco-labels) Supply information measures (e.g. recognition programs) Voluntary / negotiated agreement Subsidies / tax preferences Technical assistance programmes Other policy instrument (please specify)_____ Q3: Do the regulatory authorities have programmes and policies in place to encourage your facility to use an environmental management system? If Yes which one? Q4 How would you describe the environmental policy	Management (also environmental) systems Environmental performance and impacts Motivations and stakeholders Environmental policy design and effectiveness Facility characteristics Firm characteristics	Facility level	Mixed types of answers: Multiple choice, ordinal, binary and open questions 4186 respondents of the 7 countries from a random sample of only 50 + employees firms Not repeated over time

			regime to which your facility is subject? Not particularly stringent, obligations can be met with relative ease Moderate stringency, requires some managerial and technological responses Very stringent, has a great deal of influence on decision-making within the facility Q5: How many times has your facility been inspected by public environmental authorities (central, state/province and municipal governments) in the last three years?			
WEF World Economic Forum's (WEF) 'Executive Opinion Survey' 2012-2013	148 countries	Business leaders are asked to respond the survey, no indication on the sectors chosen	Q1_ Stringency of environmental policy How would you assess the stringency of your country's environmental regulations? [1 = very lax ; 7 = among the world's most stringent]	2012–2013 weighted average Q2 How would you assess the enforcement of environmental regulations in your country? [1 = very lax ; 7 = among the world's most rigorous]	2012-2013 weighted average	The Executive opinion survey is part of the global competitiveness Report. Inside the survey, perceptions of managers regarding several aspects, including environmental policy, are assessed	Managers, Data at country level	94.7 managers, respondents per country in mean (absolute values, not as a percentage) Repeated over time on different respondents
Department for Environment Food and Rural Affairs (DEFRA) Government Survey of Environmental Protection Expenditure by Industry in 2006 (EPE)	UK	Manufacturing firms with high environmental protection expenditures	capital environmental expenditure, environmental management systems, environmental research and development expenditure, motivation for environmental expenditure, general information on firm characteristics such as employment and turnover Firm invested in environmental protection? Why?: Parent company or owner policy of CS Because equipment upgrade Customer environmental requirements Firm has implemented environmental management scheme Environmental operating costs Environmental capital costs	The objective of the survey was to gather firm-level data on environmental protection expenditure across industrial sectors in the UK	Firm level	Mixed types of answers: Multiple choice or binary answers; continuous variables (e.g. environmental operating costa, capital costs) Postal implementation Response rate of 20.4% Repeated over time but with different sectors and different questions
DEFRA EPE 2013	UK	Relevant sectors according to the expenditure for EP	In addition to the questions outlined for 2006 wave: it asks firms to estimate operating and capital expenditures by type of investments: end-of-pipe vs cleaner production vs cost reducing vs management schemes adoption It estimates the percentage of investment by type of environmental domain (e.g. water, waste, air, noise etc.)	The objective of the survey was to gather firm-level data on environmental protection expenditure across industrial sectors in the UK	Firm level	Mixed types of answers: Multiple choice or binary answers; continuous variables (e.g. environmental operating costa, capital costs) Postal implementation Response rate not disclosed yet As above repeated over time but on different questionnaires and samples
CEP Wagner et al, described into Anderson et al 2011 WP	Belgium, FR, DE; Hungary, Poland, UK	Manufacturing	Is your company registered under EU ETS? Since when? How many of your European business sites are covered by the EU ETS? How tough is the emission cap/quota currently imposed by the EU ETS on your production site? (low mid high) Can you describe some of the measures you put in place to comply with the cap What is the annual cost burden of being part of the EU ETS? example, monitoring, verification and transaction costs; the cost of buying permits or reducing emissions. Is EU ETS compliance managed on the production site or elsewhere? Dis you buy or sell allowances on the market? How frequently? Many details on ETS trading How stringent do you expect the next phase of ETS? c) Will it be tough for your firm to reach such a target? Can	Objective of the survey was to analyse firm performance effects related to emissions and climate change policies, including the U ETS	Firm level	Instead of proposing multiple choices, interviews were conducted as an open dialog and then responses have been translated into ordinal performance scores by analysts according to a methodology proposed by (Bloom and van Reenen, 2007; Bloom et al., 2009, 2010) Telephone implementation From a (random) selected sample of 1,451 contacted firms in the six countries, 770 firms responded, leading to a response rate of 52% of the randomly selected sample. Not repeated over time

			you describe some of the measures you would have to put in place? (d) Do you believe the allowances will be distributed through an auctioning mechanism? (e) Is it likely that sanctions for non-compliance will become more stringent? Do you expect that government efforts to put a price on carbon emissions will force you to outsource parts of the production of this business site in the foreseeable future, or to close down completely? (a) Globally, is your company currently trying to develop new products that help your customers to reduce GHG emissions? (b) Can you give examples? (c) What fraction of your Research & Development funds are used for that? (Less than 10%, more than 10%?) Can you tell me what measures you have adopted in order to reduce GHG emissions (or energy consumption) on this site? UK Specific questions How stringent is the target imposed by the CCA(Climate Change Assessment)?			
EMPIRE (Testa et al. paper) 2009	3 EU Regions Italy, the Netherlands and France	Building and construction sector	Number of inspections Q to assess a set of environmental policy instruments in terms of their impact on their own production activities: The proposed set of environmental policy instruments included direct regulations (technology and performance-based standards), economic instruments (i.e. emissions and input taxes) and soft instruments (i.e green public procurement and demand information measures).	Survey ad hoc to analyse the effect of environmental regulation on competitive Performance in the building and construction sectors	Firm level	Mixed typologies of answers Not specified how the survey was implemented A random selection of 100 firms from Amadeus has been performed, of which 78 have been interviewed. We could not find information on the overall population of firms in that sectors for those regions to compute a response rate. Not repeated over time
UNIFE (University of Ferrara) 2009	Italian Region: Emilia-Romagna	Manufacturing	Q about the introduction of environmental innovations and the motivations; Types of environmental innovations asked: e.g. to reduce CO_2 emissions; to improve energy efficiency. Motivations at the basis of environmental innovations introduction: e.g. binding legislation; market demand.	Survey on firm level innovations strategies: linking firms innovation strategies and their economic performance	Firm level	Mixed typologies of answers with a prevalence of qualitative questions CATI survey Stratified random sample on the basis of firm geographical location (NUTS 3 level), sector and size. 555 interviews (response rate of 13.64%) Not repeated over time
PACE (Pollution abatement Costs and Expenditure) 2005	US	Manufacturing, mining and electricity	Q on amount of pollution abatement costs and expenditures	Collect industry data for pollution abatement activities. EPA uses it to Environmental Protection Agency use these data to monitor the impact of environmental programs and to estimate cost projections for its regulatory impact analysis for proposed pollution regulations	Plant level	n.a.
Antipol	France	Extraction, manufacturing industry and electricity, gas, steam and conditioned air production and distribution	Environmental protection expenditure and investment	Collect industry data on current and investment expenditures to protect the environment	Plant level	The reference population is of 18,662 establishments (20 employees and above) whereas sample size is 10,000 and the number of responses collected 8,217. It is a compulsory survey collected online or via mail.

4. ISSUES AT STAKE IN SURVEY DESIGN

Adequate survey design to investigate links between policy, innovation and performance at the firm level is somewhat complex and several of the drawbacks of existing surveys should and can be avoided, budget permitting.[20] Some flaws are partially unavoidable because they are linked to the nature of the data or because they are related to the specific topic of the survey. Finally, in some cases the extension or enrichment of the survey might reduce some flaws, but introduce others. Risk management is an issue in this case (e.g. costs and benefits of introducing monetary and quantitative questions on R&D and economic performances; better data, lower response rate and coverage). Pilot surveys may help to assess risks ex ante.

4.1 Taxonomy and Definitional issues

A.   *EI question*

When asking whether firms introduce any type of EI, possibly out of a list of EIs, as it is in the CIS 2006-2008 survey, it might be worth adding an **EI question** to elicit the understanding of the relevance of such innovation for the environment. This can be done in two ways. The first is asking firms for the low-medium-high level of environmental benefits associated with the innovation introduced – as the Mannheim Innovation Panel 2006-2008 does. This has the advantage of being easily interpreted, but the eventual flaw is that it can lead to subjective rather than objective answers. The second way is to ask firms to describe in detail, in an open question, the best innovations they have introduced, including description of the 'radicalness' and 'novelty'. The pro of this method is that it enables full understanding of the magnitude and relevance of each answer. The cons are that the information is not easily analysed; wording-oriented instruments are needed and in some cases experts are required to screen and understand it.[21] Having said that, the definition of EI is problematic itself and the respondents may not have the full knowledge to understand and recognise what EI encompasses.

B.   *Broader EI: Eco-Management Schemes*

Together with the question on the adoption of EI we suggest to ask whether the firm has some sort of eco-management and audit scheme certification, as this **organisational innovation is strongly related to EI**. Furthermore, we suggest asking firms whether they have these eco-management certifications (compulsory or not) and to verify if the adoption of this type of eco-management lead them to EI introduction.

Questions on the current green-oriented training programs and on future jobs or skills that the firm will recruit provide key information within the management section.

C.   *Innovation phases and related policies*

The survey should be clear in choosing whether to focus on the **adoption, invention or diffusion phase of the innovation process**, as different policy implications are derived from the different stages.

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20. We here want to point out the interesting survey conducted in Spain which aim to assess the country environmental performance (OECD, EPR of Spain, 2015)

21. This expert driven screening is recently used in the analysis of patents data (to understand whether green patents are really green oriented). See Crespi, Cerci and Costantini (2013) in Costantini and Mazzanti (2013).

D.   Patents

Following C, the inclusion of questions on **patenting activities and patents** developed by the firm in environmental realm is also in our opinion an important element of originality which would lead to interesting quantitative and qualitative analysis.[22] For instance, as discussed, it might be worth asking firms to describe the most important patent (from their perspective). Similarly, it might be interesting to ask if patenting is a relevant activity in their technological field or if firms tend to seek intellectual protection in other ways and if the first (or first three) more relevant environmental innovation generated by the firm has been patented. Alternatively, the survey can ask firms whether they applied for patents, or quantitatively how many patents they have been granted or they have applied for. If the identifier of the firm is known it is possible to extract information on patent filed or granted by that firm through external dataset, e.g. PATSTAT database. In this last case, qualitative question like the present ones may add a value on the simple total patent counts.

E.   Environmental R&D

A question on environmental R&D is a crucial. If firms may lack information or willingness to reveal environmental R&D, one should start from a question on overall R&D, then asking which share of that is oriented to environmental purposes in a sort of 'iterative' and nested approach.

F.   Subsidies as an element of green policies

Borrowing from the CIS survey, not only the role of regulation, but also the one of **subsidies** in spurring the adoption of innovation should be included. In particular we suggest asking firms to quantify the subsidy they received and to indicate whether it was locally, nationally or internationally (e.g. EU) funded.[23]

G.   Environmental policies

A critical definitional issue is that of **measuring environmental policies**. Knowing how previous surveys and studies dealt with this subject may be of help in choosing appropriate questions to be included in the survey (see Annex A for a discussion of how environmental policies have been measured so far).

Summing up

Summing up sections are drawn in relation with the decision tree nodes of Figure 3.

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22. The OECD HAN database merges ORBIS commercial data (firm balance sheets) and patents information from PATSTAT.

23. We cannot exclude a priori that EIs are also introduced on a voluntary basis, by the firm, possibly without any meaningful economic reason. However, we expect that the adoption of EIs that is not driven by economic reasoning is very rare.

Figure 3. Sampling strategy and survey characteristics: Choices subject to budget constraint and objectives of the analysis
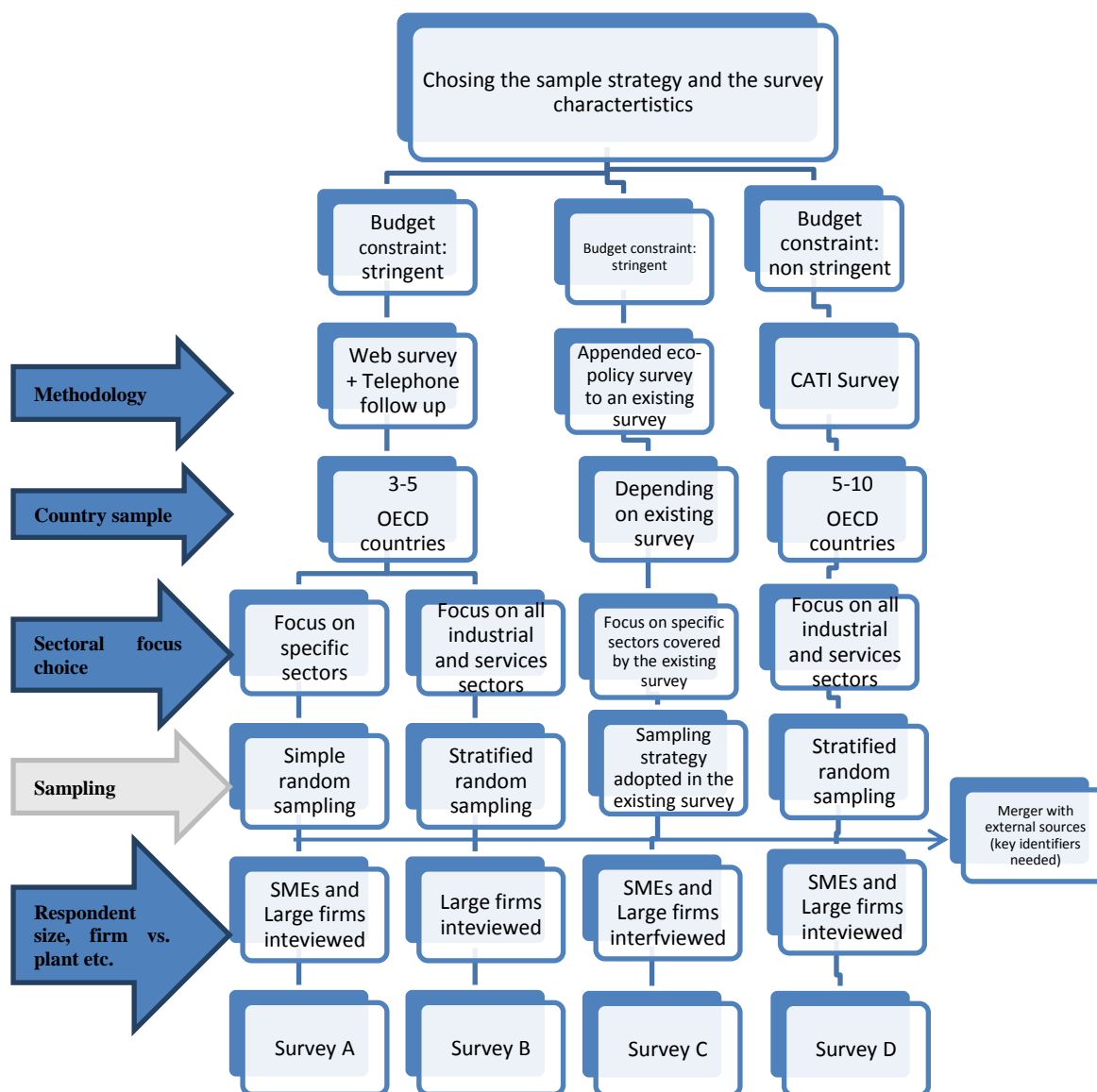
A.   Defining concepts and formulating questions on environmental innovations and environmental policies strongly hinge upon the objective of the survey as well as the budget constraints.

B.   A restricted budget should imply fewer questions. However, according to the objectives it can be optimal to go for general questions or for few, in depth and specific questions. In the latter case the definitional problems could be much more serious: asking for monetary environmental R&D for example could generate a not negligible amount of non-responses. The more the question is specific the higher the probability of non-responses, essentially for lack of knowledge of the respondent. An additional component is the objective of the follow-up empirical analysis, as focused surveys may be better at assessing effects of particular policies but suffer from the lack of generality of conclusions.

C.   A web survey could be more suitable than the CATI survey to deal with definitional issues. A web survey allows the respondent to acquire the information and then fill in the questions, but the web

survey still remains risky in terms of response rate, which is generally lower than that of a CATI (though Wagner, 2013; achieves a 30% rate through online surveys).

D.   The responses to questions on environmental policies, EI effects and effects of environmental policies will depend on firm size. Large firms are likely more able to answer these kind of questions than the small firms, which may also lack of strategic plans to comply with the policies. In the case of repeated surveys, in order to construct panel data or time series data, a good way to proceed would be that of preserving questions of general relevance and 'easy' for the respondent, to repeat in each survey. This will provide an information basis with few missing data. Specific and different questions could be included year by year. This strategy would be more consistent with a repeated web survey than a repeated CATI survey, especially at the light of some stringent budget constraint. The potential pitfall of constructing an unbalanced panel may be overcome ex post using appropriate techniques of analysis.

4.2 Sampling

In terms of sampling strategy there is no single choice suitable for all projects and objectives.

A.   *Extended option: all or many sectors*

A first option is to cover all economic sectors, from agriculture to services (or narrowly manufacturing and service sectors only). The main reason is that economies have witnessed increased sector integration over the years, one signal being the increasing relevance of intermediate goods trade. This would give the possibility to investigate the policy impact in terms of 'policy and knowledge spillovers' (e.g. the spillovers on other sectors, generated by a policy targeted on specific sectors, say manufacturing, given the presence of push and pull economic effects between sectors, e.g. between services and manufacturing). Although service sectors may be directly less polluting than manufacturing sectors, they represent more than 2/3 of GDP and evidence based on input output tables show that they indirectly pollute as much as manufacturing (EEA, 2014). Thus, even if it is true that environmental policies mainly bear on manufacturing and energy, it could be useful in some cases to cover the economy as a whole and analyse sector interactions, and the role of policy with respect to that, namely the extent to which policies implemented on heavier sectors are transmitted by innovation and economic spillovers to other sectors (Cainelli and Mazzanti, 2013; EEA, 2013; 2014). This analysis would require the merger of survey and input output data through NACE codes, at various level of disaggregation.

B.   *Narrow option: manufacturing and heavy sectors*

A second and more usual strategy would be to focus on the most regulated sectors, which are also usually the most polluting ones (e.g. manufacturing, or even narrower EU ETS sectors as examples). Most studies in the literature adopt this approach. The clear advantage is related to cost reduction with respect to the first option, but it might be less informative because it is not possible to disentangle some issues such as spillover effects. A weakness of this type a survey is related to the generality of conclusions that can be drawn from a specific sector or set of sectors. A trivial trade-off is between the potential reduced length of the questionnaire as the number of firms increase due to sector or geographical coverage extensions. On the basis of choice A or B, we may then choose to focus on both SMEs and large firms (corporates) or treat them in separate surveys. It is trivial to say that decisions are driven by budget and research hypotheses related issues.

We remark the usefulness of introducing questions on geographical location and specific sector classification in surveys, to ease and allow merging with other external data. This is concretely relevant for policy reasoning since policies are potentially (I) geographically and sector specific, (ii) spillovers may

exist across space and sectors, which one can analyse by spatial statistics and econometrics to assess if and how policy effects are 'diffused'.

Summing up

The strategy of covering both industry and service sectors is far more expensive than a more conservative strategy addressed to cover specific sectors. However, the higher cost may be compensated by the possibility to analyse spill overs, industry-service interactions and the service sector per se.

A second point concerns the unit of analysis: the choice is between firms or plants. In principle, environmental effects (e.g. such as local pollution) may be better and more sensibly measured at the plant level. A similar case may apply for production technologies, some aspects of management practices etc. Moreover, plant-level survey may result in more accurate data because respondents may have a clearer idea of the plant strategy and performance, especially when the firm is a large multi-plant. On the other hand, a large part of economic and financial data will make more sense and be better captured at the level of the firm – which can be crucial when aiming to merge environmental with e.g. accounting data. Moreover, in large scale cross-country surveys it is difficult to have the information to properly distinguish single plants. In addition, firm level census may be the base for constructing the relevant sample of the survey (with the potential pitfalls in dealing with registry data), however, plant level data have the advantage of providing information on single unit of production that are subject to specific legislation, while multi-plant firms, not to mention multinational firms, are subject to very different green policy regimes, according to the country location of each plant. Hence, we are in presence of pros and cons related to the choice of the firm or plant as unit of analysis. Overall, this choice is likely to be driven by the exact question of interest.

In terms of sampling strategy, both simple random sampling and stratified random sampling are viable alternatives. The sectors and countries have to be chosen carefully if the analysis of policy impacts is the main objective. In particular, it would be helpful to construct a set of 'treated' firms (firms covered by the policy) and a set of 'counterfactual firms' (firms not covered by the policy). If this strategy is feasible, the year of policy introduction is known and the merger with external data allow having information before and after the policy introduction, then some very informative analysis could be conducted.

4.3 Follow-up information and sensitive data

The assessment of policy-induced **economic performance** is cumbersome: many confounding factors (exogenous and endogenous) can stand in between policy and economic performance. Some survey enrichments would call for a questionnaire with firm identifiers[24] that may allow merging the future dataset with other datasets providing, for example, accounting information for the surveyed firms. Adding accounting data to subjective data (survey data) would make the analysis more robust to critiques (e.g. respondent perception on the economic performance may be biased) and allows for sensitivity testing[25]. In addition, it could avoid the direct inclusion in the questionnaire of questions addressed to capture the respondents' perceived performance, which tend to generate missing values.

A.   *Merger with objective data*

Methodologically, the first suggestion that we have is to thus develop a questionnaire which can be fully merged with other already existing surveys or data sources[26]. The **identifier of the firm** is a key

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24. The firm identifier could be already in the dataset used to extrapolate the sample of firms. E.g. it may come from a census, it could be the tax code. CIS survey in its full version has firm identifiers.

25. Check whether the relationship between policy-innovation and performances is valid in the two cases.

26. Mergers usually refer to balance sheets data –e.g. using AMADEUS-Bureau VanDijk.

element that should be provided. A clear example emerges if it is required to understand the linkages between EI – policy and competitiveness. In such a case **objective information on turnover or profitabilit**y would be preferred than letting firms subjectively self-report it, especially in a binary way. Trade-offs are obviously strong in this case. This point is highlighted by Martin and Wagner (OECD, 2009), who call for a 'novel method' linking interview to performance data. They suggest coping with the bias coming from the stated preference method (eliciting performance data from managers) by matching interview results with 'hard' micro data coming from facilities.[27] On the one hand, we obtain (1) more robust data that (2) are analysable through a broader set of techniques, given the variable is continuous.[28] However, it is possible to run into a twofold problem when the merger has to be done with registry data: the first stems from the data quality, which can be low, and the second from the sensitivity of the data, which may prevent their full and adequate collection.

B.   *Quantitative and qualitative data from the questionnaire*

An alternative to A (external data) (Likert scale, binary question on 'improvement', see Lanoie et al., 2011) is to elicit some **quantitative data out of the survey on economic performance**. The risk we face in terms of response rate decay may be tested through a wide and robust pilot study.[29] Mohnen and Hall (2013) sharply suggest increasing the use of quantitative data of innovation rather than yes/no information to get more meaningful results on the innovation→ outcome link.

C.   *Composite indicators*

Extending the reasoning on 'performance' one should notice that some key indicators such as **labour productivity and environmental and resource efficiency** (environmental output on value added or vice versa) are actually composed. They may hide very different dynamics and impacts of policy and innovation: emissions, economic value and employment move in various directions. Policy-innovation effects may then be further specified to better understand the dynamic of 'productivity' indicators.[30]

D.   *Spatial issues and techniques*

An additional enrichment which poses issues regarding 'sensitive' data is the **location of the firm**. The more precise the better. Past and current EI analyses have not benefited from the use of **spatial (econometric) techniques**, that highlight the relevance of economic and geographical spill-over effects. Namely, firm decisions on EI are eventually influenced by the presence of EI, environmental conditions and environmental policy in contiguous areas or in 'similar' sectors (cognitive distance).[31] The omission of

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27. This approach follows papers by Bloom and van Reenen (2007) and Bloom, Sadun and van Reenen (2007) who match interview data with real performance data to explain productivity dispersion across firms and counties.

28. Even towards semi and non-parametric techniques that may be applied both to innovation function and production function levels (Musolesi et al., 2014).

29. A Recent example which is not strictly in the EI realm is Fuji et al (2014), who merge productivity data with two waves of R&D survey data. As it happens, the sample is shrunk to 352 firms, but the analysis is panel and on real performance data (Online at http://mpra.ub.uni-muenchen.de/57996/MPRA Paper No. 57996, posted 18. August 2014 10:07 UTC).

30. Many examples are possible. Trivially, emission efficiency may decrease only because economic value increases, with stable or even increasing emissions. Labour productivity may well increase through job destruction; green job creation can associate with lower labour productivity of the related economic value increases less than proportionally.

31. See Corradini et al. (2014) for some EU sector evidence on R&D and abatement spatial spillovers, Costantini et al. (2013) on emission and innovation spillovers in Italian sectors, Antonioli et al. (2014), who exploit survey data to assess whether adoption of EI is also spatially influenced, and at what level. In the US, a seminal interesting

spatial situations is similar to the omission of relevant variables. It distorts the estimation of the policy-innovation-performance links and exaggerates the direct effect, for example, of innovation, which may pass through various indirect spatial dynamics.

Summing up

Here different nodes of the decision tree are involved. At first, the preliminary choice of selecting firms for which an unequivocal identifier present across databases (e.g. AMADEUS) can be assigned is of crucial importance for the analysis and the subsequent potential merger between the survey data and external data. For example, the use of external data to measure firm performance is helpful in different ways: it mitigates the problem of misreporting information on the economic performance and ialso allows the use of several performance indicators that permit investigating the policy-innovation-performance relationship with respect to different performance dimensions (productivity, profitability, employment) in different periods of time.[32] The decision to construct a dataset with a key identifier and sensitive data may lead to a decrease in the response rate.

Another issue related to the follow up is also directly linked to the budget constraints and the objectives of the analysis. If some of the objectives can be measured with a dynamic analysis, exploiting panel or time series information, then specific follow up strategies may be envisaged.[33] A conservative strategy, due to strict budget constraints, would be to focus on specific questions in the follow up questionnaire, possibly for a limited number of sectors or countries of interest. This would still make it possible to test for the policy impacts on competitiveness. In particular, the merger with external data sources can be helpful in accounting for exit and entry of firms.

4.4 Endogeneity and selection bias

A. To circumvent **endogeneity due to simultaneity**[34], surveys should try to elicit information on different time layers, for example (i) past policies and (ii) future performance. Past performances are also useful as a potential IV and control. This augments complexity, but offers more meaningful ways to analyse the dynamic links and various lagged effects (e.g. CIS5 asks whether EMAS was introduced before 2006-2008, the EI period of reference). Two to three periods of time such as 2 or more years each seem feasible.

B. Notwithstanding the usual budget constraint issue, as **much different and varied information** as possible is to be elicited to avoid omission of relevant variables and provide a good IV set. This is highly relevant in cross section constrained environment. The IV set should be defined in the survey from the beginning.

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paper is Gray and Shadbegian (2007), which uses plant-level EPA and Census data to examine spatial factors affecting environmental performance, as measured by air pollutant emissions and regulatory compliance. They find significant effects for compliance, but not for emissions. Compliance is positively spatially correlated, partly explained by spatial correlations in observed plant characteristics, suggesting influences of industry agglomeration.

32. External account data are on average more flexible and available on a yearly basis. Surveys questions on future expected performances permit the investigation of the effects without waiting for data to be produced.

33. Mohnen and Hall (2013, p. 62) conclude: '(…) be worth constructing a panel dataset that would allow to correct for unobserved heterogeneity and to examine dynamic aspects of the relationship'.

34. Endogeneity due to omission of key variables is managed by exploiting the rich information one may have.

C.   A+B allow setting sound **two or three stages models with lags** (1) innovation function, (2) production or productivity function, etc.

D.   Measurement errors are another source of explanatory variables endogeneity. The way to circumvent the problem is relying on IV when available, so point B is relevant also in this case.

E.   A further practical suggestion is to **avoid the introduction of filters** in the survey that made responses not comparable between groups of innovators and not innovators. This avoids generating a **selection bias** directly given by the questionnaire structure.

The specific issue of unobserved heterogeneity follows point B above, with some more insights. The effect of policies on performance, in addition to the intermediate step that passes through the core effect of innovation adoption and invention, could be relevantly mediated by other innovation-related factors, namely factors that drive or are complements to EI.

F.   We suggest **widening the questions to different types of innovation strategies**, beside the environmental one. Although the latter would remain the backbone of the questionnaire along with the information on environmental policy, the interrelatedness among environmental innovations and other types of innovations would be captured as well. In particular, organisational changes and managerial practices that may help in fully deploying the environmental innovations, calls for the introduction of questions on other innovations strategies. The role of complementarities and synergies among innovation strategies (e.g. regulation-induced environmental innovation and firm level organisational changes) in determining higher economic performance should not be neglected. EIs are correlated and can complement or substitute other techno-organisational innovations. The survey and the analysis should recognise and address this broader view of EI as an element within a set, as well environmental policy interacts with other policy realms.[35]

It is worth noting, in relation to point. A above, that background definitions of EI are generally broad, including 'unintended environmental effects'. This reinforces the option to investigate whether environmental policy impacts innovation and on innovation adoption (or acquisition) in various directions: technological EI, organisational EI, non and also strictly EI in kind – with in addition analyses of 'correlation' and complementarity among the aforementioned innovation factors.

G.   The aforementioned factors suggest that EI adoption, and then performance, are highly dependent upon the territory in where the firm is located, including factors such as agglomeration density, local knowledge spill-overs, social capital (following the 'Putnam' idea; Cainelli et al., 2007). Those generally support diffusion, though some local institutionally aspects might also act as a brake (e.g. the role of unions might be supportive or constraining eco-innovation and performance (Mazzanti et al., 2006[36])). We provide some more insights below as well.

H.   An obvious strategy to tackle endogeneity is the **creation of a structured survey repeated through years**, which can result in a two or more year panel dataset. The advantage of such a procedure, despite its high costs, is manifold. Firstly, the bias due to unobserved heterogeneity can be drastically reduced by the inclusion in the final analysis of firm/plant level fixed effect.[37] Secondly, the possibility to

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35. And different environmental/energy policies may be characterised by complementary or substitution effects. This is a consolidated fact in the economics of innovation following Mohnen and Roller (2005).

36. Organisational innovations, human resources and firm performance: The Emilia-Romagna food sector M Mazzanti, P Pini, E Tortia, The Journal of Socio-Economics 35 (1), 123-141

37. An interesting work is Huiban and Musolesi (2013) and Huiban et al (2014), who explore the impact of pollution abatement investments on firm level productivity by augmenting with knowledge capital a production function.

exploit both between and within variance would provide more accurate estimations. Thirdly, more interesting descriptive statistics can be produced, in order to account also for the time dimension. Attention must be paid in this case to question design, and a dichotomous format should be avoided as they would be correlated with fixed effect with a consequent loss of informative power.

Summing up

Endogeneity has several causes, ranging from simultaneity to unobserved heterogeneity – both meaning that environmental policies may be accredited effects which they do not cause in reality. Proper data collection can go long way in reducing endogeneity. Collecting information on the firm or plant structure/characteristics may reduce the problems of relevant unobservable variables. The same aim can be accomplished using external sources of data, which can also provide diachronic information with respect to the survey, mitigating the simultaneity between policy introduction and firm or plant performance. Extending the questions on several types of policy interventions helps in identifying the 'effects' of specific policies when controlling for other ones, both environmental and non-environmental that potentially influence, at first, innovation and, then, the economic performance. The potential problem of reverse causality in studying environmental policy adoption and growth can be solved with the availability of time series or long panel data, whose construction may be a long term objective of the survey project. Although the collection of many data on several levels (e.g. firms characteristics, respondent characteristics, environmental and non-environmental policies that potentially influence the economic performance of the firm, EIs and other innovation strategies) and the merger with external sources represents a huge burden on the budget, it seems the best way to properly conduct sound difference-in-difference matching procedures to detect the environmental policy impact on the economic growth.

A pitfall in structuring a complex questionnaire that tries to incorporate all the necessary information without relying on external data is the bounded ability of the respondents to answer all the specific questions included in an extended questionnaire. In particular, quantitative information on the economic performance of the firm or plant could be difficult to provide in a telephone interview. This limitation may counterbalance the difficulties of assigning an identifier in order to use also external sources.

4.5 Response rate

The low response rate is a widespread issue.

A. **A clear survey design, with focused questions** and a relatively **modest questionnaire length** (which can be tentatively defined as a 15 minutes length telephone survey) should be enough to avoid a low response rate, which worsens when coupled with distortion of the sample with respect to the population.

B. The **option of appending the questions on EI and on environmental policies to some existing survey** could be useful in avoiding low response rates provided that the pre-existing survey an adequate response rate. Linking the environmental policy survey to an existing survey has the disadvantage of not allowing the choice of countries and sectors to be covered.

C. **Addressing the right respondent in the firm may be a further challenge.** Employees willing to devote time to responding to a survey may not be fully aware of all aspects of environmental and economic performance, environmental innovation, environmental policies etc. Detailed question

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They elaborate on a firm's based panel dataset of the Food Industry, which stems from a merger of three French datasets: a survey on pollution expenditures, an R&D survey and a survey on economic performances. It is worth noting as such mergers are pretty rare, that they achieve an unbalanced dataset of 8260 observations over 1993-2007, wherein 999 firms are observed for at least 2 years.

may also pose a challenge to respondent capacity and discourage responses. Pre-testing the survey on a varied sample of firms can help in this respect.

Summing up

There is a trade-off between the length of the questionnaire and the response rate: the longer the questionnaire the lower the response rate. However, the shorter the questionnaire, the weaker the capacity to mitigate the endogeneity problem in the phase of analysis, since the information base on potential alternative causes of the effects found will be limited.

The respondent choice may vary in accordance to the sample targeted. For large firms (more than 250 employees) it might be suitable to select an environmental manager supported by a CEO or by another manager knowing the general firm's strategies; for small firms a single respondent should have all the information required[38].

4.6 Suggested new contents to be included in the survey

Beyond the suggested solutions to the issues raised in section 2 we further propose **extensions to the existing surveys** in terms of content. More original and insightful evidence could be drawn from a questionnaire including some of the following contents.

They relate to the eventual inclusion of 'spatial' phenomena that, if still partially overlooked in environmental economics, are usual elements of study in the economics of innovation, economic geography and regional studies field, among others.

A. An interesting strand of research that would require data is the role of **firms' cooperation and networking** towards EI and the role that innovation policies have in inducing behavioural changes (behavioural additionality) in firms to cooperate with themselves or universities and research organisation in order to develop greener version of their products or new green products. On this point, since the main objective of the survey is to test the policy impact it should be considered the necessity to properly build a control group in evaluating environmental 'policy additionality'.

B. A further extension would be to capture the role of **technological and knowledge spillovers** as a driver of EI and outcomes, namely the extent to which geographical issues and cognitive proximity might play a role – in addition or as a complement to policies. This is in general term the role of 'cooperation' an intangible factor behind innovation and performance, which might extend to foreign ownership and (SMEs) links to multinationals and to local agglomeration forces (see Cassiman and Veugelers, 2004; Mancinelli and Mazzanti, 2009; Cainelli et al., 2012a): global and local factors might interactively play a role in 'mediating' the effects of policies on innovation and then finally performance.

C. Linkages along the vertical axis are also interesting elements to be captured. Is the firm improving its performance because of its **inter-sectoral relatedness**? In other words, is the firm adopting EI because it is a supplier for some firms that require to (see Mazzanti et al., 2014, who test the effect of policy on EI by using EU sector data taking into account sector relationships)? If the surveys ask firms about their 'position' in the value chain (e.g. supplier, sub-contractor etc…), the

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38. See Wagner (2013): 'the surveys were addressed to the environmental manager or managing director of the firm, but it was asked that the most suitable person would answer the question. Especially in smaller firms oftentimes the managing director responded, whereas in larger firms next to environmental managers and HR managers provided responses' (p.447).

relevance for what regards policy effects is analysable (e.g. interacting policy indicators with those features).

4.7 An alternative to a stand-alone survey

Collecting information on green policies and EIs without relying specifically on a new survey can also be an interesting alternative. Since OECD collaborates with national statistical offices, which usually conduct surveys on industrial and service firms and also take censuses periodically, it could be envisaged the possibility of including some relevant questions on green policies and on EIs in already existing structured surveys.

Although less informative than a specific survey or the inclusion of a section on environmental issues in a survey already existing, another option could be that of merging firm and facility level data, from existing surveys carried out by national statistical offices, with environmental data also collected at the firm and facility level. For example, this could rely on existing data collection tools for pollutant releases in place in many countries (e.g. the Toxic Release Inventory and the National Emissions Inventory in the US, the European Pollutant Release and Transfer Registries, Canada's National Pollutant Release Inventory). These tools collect information on emissions of specific pollutants at the plant level, for emitters above a certain threshold. Although the data are not perfectly harmonised across countries, such revealed data on pollution could be merged with national manufacturing surveys to produce data on joint environmental and economic performance and gauge the effect of environmental policies (see Levinson, 2014). Challenges remain regarding confidentiality, the level of aggregation, definitions and cross-country comparisons. However, attempts to explore such options are already underway, e.g. in Canada, and OECD could contribute to a more widespread approach which would yield valuable inputs for research. Such attempts could take the form of a distributed data analysis, so that the confidentiality of data remains preserved – as in the case of OECD initiative such as DynEmp and MultiProd, which so far do not include environmental information. Similarly, firm data could be combined with external data sources on patenting, as in the OECD ORBIS-PATSTAT database, to yield insight on EI outcomes.

The immediate pro of one of these further strategies has to do with the budget: no severe burden on it would emerge following these ways. A pitfall relies on the sensitivity of some information that the national statistical offices should provide: sensitive data are usually difficult to collect because of legal rules on confidentiality.

ANNEX A. METHODOLOGICAL ISSUES AND SUGGESTIONS ON POLICY AND PERFORMANCE QUESTIONS DESIGN FOR FUTURE RESEARCH

A.1 Economic performances and environmental policies: insights for surveying firm's

To administer a survey which is primarily aimed at assessing the link:

Performance(economic or environmental) → (R&D + **policy)** → innovation → economic performance, with a narrower focus on **policy** → innovation → economic **performance.**

a broad survey would cover EI adoption and motivations, (co)-related aspects innovation and high-performance work practices (e.g. ICT strategies, training and human resources investments, other technological processes and organisational change (Antonioli et al., 2013).

To analyse the drivers and effects of EI, it is important to include a section on FDI, foreign ownership and offshoring (international section) and a section on regional/local issues (e.g. agglomeration). To fully exploit regional information and spatial analysis it is relevant to know where the firm is located with some precision.

Economic performance might be elicited both through the survey (past and future expectation) and by merging the survey to official data. This requires knowledge on firm's identification code for research purposes (one alternative as in CIS EU CD rom data is to average information across groups of firms to protect firms anonymity).

Policy information might well be recovered as well both from inside the survey and from external sources. The use of within survey and outside survey data could also provide room for sensitivity analysis of results and variegate the tested effect (sector varying policy indexes, geo-varying indexes, etc.).

Because of the crucial importance of the possibility to merge the survey data with other sources of data (e.g. accounting data from AMADEUS for EU countries), in order to measure (in the future) the effects of the policy on the economic performance, the focus on firms, for which it is easier to find accounting data, rather than plants, is recommended. The survey information would remain exploitable and relevant for several years after the survey completion in consideration of the time lag needed by innovation introduction to show the effects on economic indicators (e.g. productivity, profitability).

The firm size crucially depends on the objectives of the analyst. Assuming that the size is measured by the number of employees, not by the turnover (measure equally exploitable), and assuming budget constraints that prevent to address the questionnaire to firms of all size, it is important to answer the following questions in order to determine the most suitable types of firms to be interviewed in terms of size: is it more relevant to test the policy effects on large firms or on SMEs?; are SMEs or large firms the most diffused in the countries of interest?; would be interviewing a census of large firms and a sample of SMEs the best solution?

In what follows, we propose the type of potential questions to be included in the questionnaire in order to gather information on firms/plants performance and policies without relying on external sources.

Economic performance

The first set of necessary questions relate to the firms/plants performance. The most straightforward types of questions are direct questions, as those in the CIS, which aim to collect quantitative information. For example:

Can you monetise the following performance variables in the year T?

Performance	T (replicable for different years/periods)
Turnover	
Employment	
Investments (Physical, intangible, human capital)	
Labour productivity (turnover per employee)	
Profits	
Mark up	

The same table can be used to collect direct quantitative information on R&D, both general and directed toward EIs.

This is a list that could eventually be extended to other indicators (hybrid, composite, etc..). Some other 'intermediate' performance to include may be employee satisfaction (Wages, workers conditions) and corporate image (Wagner, 2013). We note that key 'output' indicators of performance are turnover, revenues, labour productivity. The latter is a key indicator of competitiveness, which is strictly linked to wage dynamics. One could also analyse labour productivity and the dynamics of the indicators that compose it, turnover and employment, as very different trends may explain the rise of decrease of the key labour productivity indicator (Cainelli et al., 2011).

Mark up is included as firms may tend to increase market power through innovation (patenting). This is linked to the role of environmental policy. Some firm reactions may lead to reduced competition in the market and thus increased mark-up, which could also increase wages as a consequence.

The relationship between environmental policy and mark-up is analysed in a recent paper by Marin et al. (2015), who after having analysed the sources of market power correlated to the EU ETS, investigates 'whether the EU ETS is inducing or amplifying market power of participating companies in the output market and we identify a causal relationship between the introduction of the EU ETS[39] and market power'[40].

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39. Hahn (1984) writes: "The appeal of using markets as a means of allocating scarce resources stems in large part from the assumption that a market will approximate the competitive ideal. When competition is not a foregone conclusion, the question naturally arises as to how a firm might manipulate the market to its own advantage". Among these studies, Convery and Redmond (2007) calculated the Herfindahl-Hirschman Index in the permits market and they did not find evidence of any company having market power in the allowances market. Hintermann (2013) found that the Herfindahl-Hirschman Index (HHI) in the allowances market suggests "relatively high competition among few large firms (…). However, the HHI increases when excluding permits allocated to installations that never traded and therefore were effectively not part of the market".

40. Their final dataset is final dataset is the result of the combination of 2 datasets: the "Ownership links and enhanced European Transaction Log dataset project" database (Jaraite et al., 2013) and the Amadeus database developed by Bureau van Dijk.

According to Ambec et al. (2013), market power can be a consequence of environmental policy and, in this case, it can be considered a theoretical explanation of the strong Porter Hypothesis; if there is market power due to environmental policy, firms are more profitable.

This type of question provides the most useful information, however the drawback is related to the scarce propensity of the respondents to provide this information and to the likely possibility that the respondents have a limited knowledge about the precise figures.

A way out can be given by asking less direct information on the economic performance. A typical question could be designed as follows:

How was your performance in the following years? (very negative ☹☹, negative ☹, neither positive nor negative ☺, positive ☺, very positive ☺☺)

Performance	T					T+1					T+2				
	☹☹	☹	☺	☺	☺☺	☹☹	☹	☺	☺	☺☺	☹☹☹	☹	☺	☺	☺☺
Turnover															
Employment															
Investments															
Labour productivity															
Profits															
Mark up															

The table might be also extended and used to get information on 'intermediate outcomes', such as corporate image, employee satisfaction, quality of staff recruited (including wages offered and paid), in the pursuit of corporate social responsibility strategies (Wagner, 2013).

The same question can be designed using a reference year to evaluate the trend of the indicator. Moreover the different years (T, T+1, T+2) can be thought of as years already passed or as years to come. Indeed, asking a respondent to forecast the trend of economic indicators of the firms has some limits, but this is the only viable solution if we want a time lag between the policy implementation, the potential innovation policy-induced and the subsequent economic performance of the firm to be linked to the policy-induced innovation strategy. The answer is devised in terms of a (Likert) scale ranging, as in the example proposed, from very negative to very positive. On the one hand, this type of information has some limits, especially in the way it can be used in the analysis and in exacerbating potential problems related to the self-reported judgement on the performance trends. On the other hand, it may be easier to collect information on the economic performance trend, without relying on external sources.

The last type of question aimed at providing some hints on the economic performance can be of a binary nature and could be formulated in the following way:

✓ *Did your turnover rise in the last year? Yes/No*

The same type of question can be used to gather information on the future (as e.g. in the Eurobarometer):
✓ *Do you think the turnover of your firm/plant will rise in the next year? Yes/No*

The last questions undoubtedly have the advantage of reducing at the minimum the non-response rate due to lack of the respondent knowledge: having a glimpse of the market trend and firm/plant strategic position

it is suffice to answer the binary questions. However, this come at a cost: the information is far from providing a precise figure of the firm/plant's economic performance trend.

Environmental Policy

We here propose a set of questions related to policies, recalling the pros and cons of eliciting policy features (stringency, certainty, etc.) within the survey or linking the survey to external sources. A description of approaches used in the literature follows in Annex A2.

1. Is your firm obliged to comply with one (or more) existing environmental regulations? (more than one answer possible)[41]
    - o   Yes, international
    - o   Yes, national
    - o   Yes, regional/local
    - o   None

    Could you state which are the most relevant ones (e.g. in terms expected targets, etc.)?
    _____

2. Regarding the most relevant environmental regulation you have to comply with, do you perceive such regulation as:

	Yes	No
Costly for your firm		
Stringent for your firm		
Stable over time		
With a credible/severe sanctioning system		
With an high enforcement system		
Coherent with other existing policies: there is a systemic view of existing regulations		

The diversified information on policies the survey elicits can be then aggregated to set up synthetic continuous indexes (Box 3).

Box 2. Other possible policy indicators: aggregating policy elements - continuous indexes

Most studies in the literature rely on sector and macro data as policy levers in firm's studies due to data unavailability. A possible option, which requires however further investigation and a *proper survey design,* is the inclusion of a broad set of questions related to environmental policy and the subsequent aggregation of such items in a single indicator. A single composite indicator that does account in a more complete way for different aspects of environmental policies can be constructed. This set of questions can cover different aspects of environmental policy, like stringency, the ability of the instruments to reduce investment uncertainty, the coherency of the policy framework (with firms' expectations and with the general policy mix), the enforcement level, the severity of the sanctioning system etc.

A nice option is to allow all these items to be constructed in a x-point Likert scale (x=7, 9).

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41. Defined by realms: climate change, energy, waste, resources, water, pollution, etc.

There are several techniques for the aggregation of multiple variables, which range from *confirmatory factor analysis* to a more simple analysis of the Cronbach's alphas, according to the complexity of the questionnaire and the researcher objective.

The more questions are included in the survey more information can be gathered. Obviously, increasing the number of items in fact increases the cost of the survey and make it more difficult to construct a single indicator (a factor analysis could, for instance, generate two different factors, i.e. two different indicators).

Methodologically, a sound implementation of this procedure has the advantage of deriving a single index capable of synthesising several aspects of environmental policies. Having a single index is often a requirement in empirical analysis, especially if researchers have to deal with endogeneity, in which case instrumenting a single indicator is simpler and less demanding than instrumenting several policy variables. The pros and cons of aggregation highly depend upon the aims of analysis.

A drawback of aggregation is the impossibility to test specific effects (e.g. stringency, stability, etc.).

Another risk is the existence of one general factor accounting for most of the variance in (policy) data (Common Method bias, see Wagner, 2013). *Ex ante* measures which revolve around question order and re-scaling are implementable (Podsakoff et al., 2003). *Ex post* tests assess whether there is one single factor accounting for most of the variance in data. For instance, in the pre-test of the survey question order can be counter-balanced and scale items can be improved, to ensure that the questions are easily understandable and the completion time is acceptable (as in Wagner, 2013).

ANNEX B. MEASURING ENVIRONMENTAL POLICY

Some critical issues however arise when trying to construct an indicator for measuring environmental policy.

A. The first critical issue is understanding whether it makes sense to construct a policy indicator at firm level. To ask firms in a survey on the stringency of the regulation, is somewhat subjective as self-reported. Moreover, regulations might act at the sector-region-national level, but rarely at the firm or facility level, namely many firms could be subject to the same exogenous policy.
Thus, the (non-strictly alternative) options are:

- Eliciting subjective information on various policy stringency aspects.

- Constructing firm based or sector based indicators by using firm/sector data. An example among others might be the ratio between CO_2 emissions and allocated ETS allowances (Borghesi et al., 2012) at the establishment/firm/sector level, depending on what data are available. Such (sensitive) information can be included in a 'policy section'.

  The aforementioned options may be complemented by other sectoral or geographical data recovered from other surveys, including that on different policy implementation (e.g. ETS, non-ETS) and policy stringency (e.g. level of energy taxation). Location information is again precious (Cainelli et al., 2014).

B. The second concerns the behavioral additionality. The attempt to evaluate the environmental policy impact on a set of firm outputs, using micro data, is not straightforward, as the environmental policy is not designed to induce a specific behavior, the firms may satisfy the requirements of the policy through a multiplicity of behavioural changes. Moreover a first order link would be probably policy/innovative performance and a second order link would be probably policy/economic performance of the firm, which is likely to be mediated by the innovative activities of the firm. The evaluation of policy impacts must be based on carefully selected sets of firms (treated and counterfactual) or, if the policy involves the entire population, it should be known the firm performance on the relevant outcomes before and after the policy implementation. In general, policy evaluation is data demanding.

In what follows we highlight how previous literature has dealt with the issue of measuring regulation. US based studies have mostly adopted US Pollution Abatement Costs and Expenditures (PACE) survey and more generally environmental protection expenditures as a proxy for the stringency of environmental regulation (e.g. Gray and Shadbegian, 2003). In other cases a measure of environmental protection expenditure scaled by value added has been adopted (Costantini and Crespi, 2008; Ghisetti and Quatraro, 2013). However, Koźluk and Zipperer (2013) outlined that this measure suffers from poor comparability across countries and time, as well as of problems of lack counterfactuals situation that would allow for evaluating the policy. Furthermore, costs of abatement can be incompletely measured (Berman and Bui, 2001).

Other studies have used environmental or related performance data as a measure of policy stringency. Environmental performance indicators in terms energy intensity (Cole and Elliot, 2003) or in terms of pollutant intensity, either at a micro, meso or macro level of analysis belong to this category (Cainelli et

al., 2013). These measures might, however, suffer of reverse causality as can be affected by factor prices, technology and industrial structure more than by environmental regulation (Koźluk and Zipperer, 2014).

Alternatively a measure of the perception rather than the objective regulatory stringency might be used. The World Economic Forum (WEF) Likert scale data on managerperceptions, at country level, of the stringency perceived of the environmental policies were exploited in several studies (e.g. Kalamova and Johnstone, 2011 and Johnstone et al., 2010). However, the adoption of such a measure has some drawbacks. At first they depend on the respondent's perception. Secondly, they depend on the business cycle and are thus area context-specific, making the data difficult to be compared (Nicoletti and Pryor, 2005; Koźluk and Zipperer, 2014).

All in all, once a measure for policy stringency is found, there exist four obstacles that need to be assessed: *multidimensionality* - regulations cannot be accounted for by one only measure of stringency; *simultaneity* – some countries (stronger or highly pollutant) may impose the most stringent regulations; *industrial composition* – the industrial composition of some countries might be on average more pollution intensive thus raising the measure of policy stringency chosen; *capital vintage* - new sources of pollution tend to be more regulated than already existing ones, and this impacts on the measure of stringency as well (for a deeper discussion refer to Brunel and Levinson, 2013).

The construction and use of environmental policy stringency (EPS) composite indicators across OECD countries goes into this direction. As proposed by Botta and Koźluk (2014) an energy sector based EPS indicator and a broader economy wide EPS indexes can help capturing the multidimensionality of policy instruments and overcome the above mentioned obstacles.

Table B.1 - How policy is captured in previous empirical contributions

Paper ref.	How they look at policies	Data
Becker, Pasurka and Shabdegian, 2013	Establishment data on pollution abatement expenditure	PACE Survey
Borghesi, Cainelli and Mazzanti, 2012	ETS dummy, ETS continuous indicator by sector (out of survey)	CIS Italy
Brunnermeier and Cohen, 2003	Pollution control operating costs	PACE survey
Cainelli, D'Amato and Mazzanti, 2014	Geographical related policies (regions) (out of survey)	CIS Italy
Carriòn-Flores and Innes, 2010	Industry-level measure of regulated toxic air releases in chemicals	Chemicals regulated under NESHAPS and TRI Core Chemical list
Costantini and Crespi, 2008	Environmental protection expenditure on VA	Regional ISTAT data
Costantini and Crespi, 2013	Sum of three costs: current environmental protection expenditures (public and private) as a percentage of GDP; share of environmental tax revenues on GDP; amount of public investments in R&D on environmental protection as a percentage of GDP.	OECD Account Stats and EUROSTAT National Environmental Accounts
Crespi, 2008	Sectoral data on compound annual rate of change in CO_2 and acidifying gases emissions intensity (emissions on VA)	EU NAMEA accounts
De Vries and Withagen, 2005	Test 3 different policy stringency variables: 1) Ratification of international agreements that limit transboundary air pollution: the Helsinki protocol, and the Oslo protocol 2) A composite index based on countries' acidification 3) stringency treated as a latent variable	Acidification index extracted from Cagatay and Mihci (2003)

Dechzelepretre, Glachant and Meniere, 2013	Count of the number of climate change related policies in place in each country	International Energy Agency Climate Change Policies and Measure database
Frondel, Horbach and Rennings, 2007	Self-reported perception of the stringency of environmental policy	OECD 2004 survey
Ghisetti and Quatraro, 2013	Environmental protection expenditure on VA	Regional ISTAT data
Gray and Shadbegian, 2003	plant's pollution abatement operating costs divided by its peak shipments	PACE survey
Gray and Shadbegian, 2007	Inspections at the plant (e.g., inspections, emissions monitoring, stack tests) directed towards this plant and other nearby plants; Pollution abatement expenditures	Envirofacts and PACE
Hascic, Johnstone and Kalamova, 2009	Self-reported data on perceived policy stringency	WEF
Hemmelskamp, 1999	Branch policy variable from survey: how companies were affected by environmental policy	German chambers of commerce (IHKs)
Jaffe and Palmer, 1997	Regulatory compliance costs	PACE survey
Johnstone,Hascic and Kalamova, 2010	Self-reported data on perceived policy stringency	WEF
Johnstone, Hascic and Popp, 2009	Binary variables constructed for the different policy types, e.g. tax measures, investment incentives, bidding systems, voluntary programs, and quantity obligations. Continuous variables on national public R&D expenditures, feed-in tariffs, and renewable energy certificates (REC)	IEA Energy Research and Technology Database
Johnstone, Hascic, Poirier, Hemar and Michel, 2012	Self-reported data on perceived policy stringency	WEF
Kalamova and Johnstone, 2011	Country self-reported policy stringency perceived	WEF data mean 2001-2007
Kerr and Newell, 2003	Stringency of lead regulation is measured inversely to the average amount of lead allowed per gallon, which in turn depends on the stringency of the standard for leaded gasoline and on the share of leaded gasoline in total gasoline.	State level p of gasoline from Petroleum Marketing Monthly
Kesidou and Demirel, 2012	Firms' abatement costs on ECORD (green R&D)	Survey
Lanjouw and Mody, 1996	Countries pollution abatement expenditures	OECD
Lanoie, Lucchetti, Johnstone and Ambec, 2011	Self-reported data on policy stringency in the survey OECD	OECD,2004
Levinson, 1996	Pollution abatement expenditure, establishment levels	PACE survey
Mazzanti and Zoboli, 2005	Presence of emission and waste policy and the number of years since the policy was introduced	Own surveys Emilia Romagna Region – 2002 and 2004 wave
Mazzanti and Zoboli, 2008	direct environmental costs linked to current expenses and all financial burdens deriving from policies, excluding expenses for safety and security obligations, as a percentage of turnover; Presence of emission and waste policy and the number of years since the policy was introduced	Own surveys Emilia Romagna Region – 2002 and 2004 wave
Peukert et al., 2013	Self-reported data on policy stringency	WEF
Ryan and Doran, 2012	CIS question on regulation	CIS
Schmidt et al., 2012	Self-reported perception on stringency of EU ETS in the 3 different phases	Own survey on 7 EU countries in electricity
Testa, Iraldo and Frey, 2011	Stringency: number of inspections (only building and construction sector), own data EMPIRE project	Own Survey (built following OECD 2004 survey)
Verdolini and Galeotti, 2011	Government expenditures in R&D targeting energy efficiency, fossil and renewable sources and storage technologies	IEA Energy Technology R&D Database

Figure B.1 Dynamic innovation induced effect of a tax on the environment
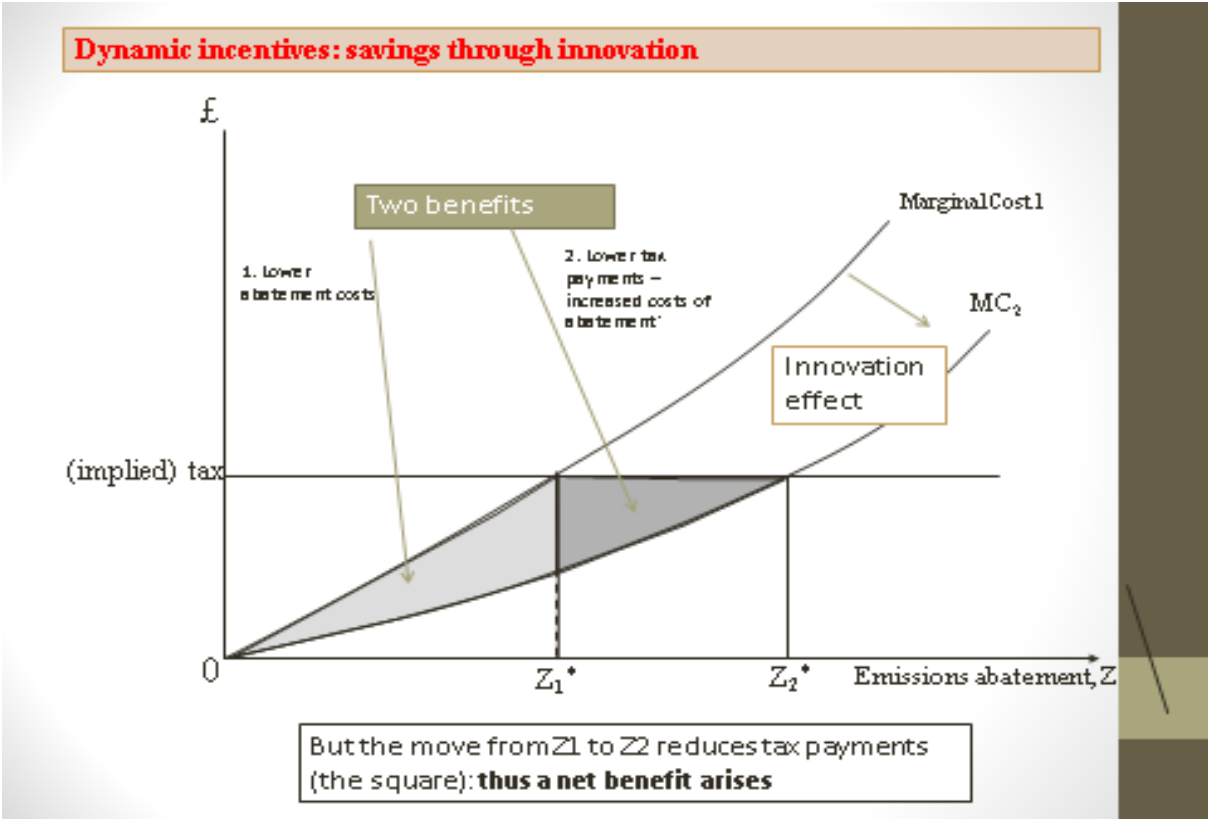
REFERENCES

Albrizio, S., T. Koźluk and V. Zipperer (2014), "Empirical evidence on the effects of environmental policy stringency on productivity growth", OECD Economics Department Working Papers n. 1179.

Ambec, S. et al. (2013), "The Porter hypothesis at 20: can environmental regulation enhance innovation and competitiveness?", *Review of Environmental Economics and Policy*, Vol. 7/1, pp. 2-22.

Antonioli D. et al. (2015) (forthcoming), Outsourcing and firm productivity in local production systems, Growth and change.

Antonioli, D., S. Mancinelli and M. Mazzanti (2013), "Is environmental innovation embedded within high-performance organisational changes? The role of human resource management and complementarity in green business strategies", *Research Policy*, Vol. 42/4, pp. 975-988.

Antonucci T. and M. Pianta (2002), "Employment effects of product and process innovations in Europe", *International Review of Applied Economics*, Vol. 16/3, pp. 295-307.

Arimura, T. H., A. Hibiki and H. Katayama (2008), "Is a voluntary approach an effective environmental policy instrument?: A case for environmental management systems", *Journal of Environmental Economics and Management*, Vol. 55/3, pp. 281-295.

Baumol, W. J. and W.E. Oates (1988), *The theory of environmental policy*, Cambridge University Press, Cambridge, England.

Becker, R.A., C. Pasurka Jr. and R.J. Shadbegian (2013), "Do environmental regulations disproportionately affect small businesses? Evidence from the Pollution Abatement Costs and Expenditures survey", *Journal of Environmental Economics and Management*, Vol. 66/3, pp. 523-538.

Berman, E. and L.T. Bui (2001), "Environmental regulation and productivity: evidence from oil refineries", *Review of Economics and Statistics*, Vol. 83/3, pp. 498-510.

Bloom, N. et al. (2010), "Modern Management: Good for the Environment or Just Hot Air?", *Economic Journal*, Vol. 120/544, pp. 551–572.

Bloom, N., R. Sadun and J. van Reenen (2009), The Organziation of Firms Across Countries. NBER Working Paper n. 15129.

Bloom, N. and J. van Reenen (2007), "Measuring and Explaining Management Practices across Firms and Countries", *Quarterly Journal of Economics*, Vol. CXXII/4, pp. 1351–1406.

Bogliacino F. and M. Pianta (2010), "Innovation and employment: a reinvestigation using revised Pavitt classes", *Research Policy*, Vol. 39/6, pp. 799–809.

Borghesi, S., G. Cainelli and M. Mazzanti (2012), "European Emission Trading Scheme and environmental innovation: an empirical analysis using CIS data for Italy", *Giornale degli Economisti*, Vol. 71/1, pp. 71-97.

Botta, E. and T. Koźluk (2014), Measuring Environmental Policy Stringency in OECD Countries: A Composite Index Approach, *OECD Economics Department Working Papers*, No. 1177, OECD Publishing, Paris, *http://dx.doi.org/10.1787/5jxrjnc45gvg-en.*

Bresson G., J.M. Etienne, and P. Mohnen (2014), "How Important is Innovation? A Bayesian factro augmented productivity model on panel data", UNU MERIT wp 52.

Brunel,C. and A. Levinson (2013), "Measuring Environmental Regulatory Stringency", *OECD Trade and Environment Working Papers*, No. 2013/05, OECD Publishing, Paris, *http://dx.doi.org/10.1787/5k41t69f6f6d-en.*

Brunnermeier, S.B. and M.A. Cohen (2003), "Determinants of environmental innovation in US manufacturing industries", *Journal of Environmental Economics and Management*, Vol. 45/2, pp. 278-293.

Bushnell, J.B., H. Chong and E.T. Mansur (2009), Profiting from regulation: an event study of the EU carbon market. NBER Working Paper No. 15572.

Cainelli G., A. D'Amato and M. Mazzanti (2015), "Adoption of waste-reducing technology in manufacturing: Regional factors and policy issues", *Resource and Energy Economics*, Vol. 39, pp. 53-67.

Cainelli, G. and M. Mazzanti (2013), "Environmental innovations in services: Manufacturing–services integration and policy transmissions", *Research Policy*, Vol. 42/9, pp. 1595-1604.

Cainelli, G., M. Mazzanti and S. Montresor (2012), "Environmental Innovations, Local Networks and Internationalization", *Industry and Innovation*, Vol. 19/8, pp. 697–734.

Cainelli, G., S. Mancinelli and M. Mazzanti (2007), "Social Capital and innovation dynamics in district based local systems", *Journal of Socio-Economics*, Vol. 36/6, pp. 932-48.

Cainelli, G. M. Mazzanti and R. Zoboli (2013), "Environmental Performance and Firm Growth in Manufacturing Sectors. Empirical evidence on structural factors and dynamic relationships", *Environmental Economics and Policy Studies*, Vol. 15/4, pp. 367-387.

Cainelli, G., M . Mazzanti and R. Zoboli (2011), "Environmentally oriented innovative strategies and firm performance in services. Micro-evidence from Italy", *International Review of Applied Economics*, Vol. 25/1, pp. 61–85.

Calel, R. and A. Dechezleprêtre (2012), Environmental policy and directed technological change: evidence from the European carbon market. FEEM working paper series n 22.

Carrión-Flores, C.E. and R. Innes (2010), "Environmental innovation and environmental performance", *Journal of Environmental Economics and Management*, Vol. 59/1, pp. 27–42.

Cassiman, B. and R. Veugelers (2002), "R&D cooperation and spillovers: some empirical evidence from Belgium', *American Economic Review*, pp. 1169-1184.

Christiansen, V. and S. Smith (2015), "Emissions Taxes and Abatement Regulation Under Uncertainty", *Environmental and Resource Economics*, Vol 60, p. 1.

Cleff, T. and K. Rennings (1999), "Determinants of environmental product and process innovation", European Environment, Vol. 9/5, pp. 191-201.

Cole, M.A. and R.J. Elliott (2003), "Determining the trade–environment composition effect: the role of capital, labor and environmental regulations", *Journal of Environmental Economics and Management*, Vol. 46/3, pp. 363-383.

Consoli D. and F. Rentocchini (2013), Multi industry labour force skills: structure and dynamics, presented at the 35th DRUID Conference, Barcelona 17-19 June 2013.

Convery, F.J. and L. Redmond (2007), "Market and price developments in the European Union emissions trading scheme", *Review of Environmental Economics and Policy*, Vol. 1/1, pp. 88-111.

Costantini, V. and F. Crespi (2008), "Environmental regulation and the export dynamics of energy technologies", *Ecological Economics*, Vol. 66/2, pp. 447-460.

Costantini, V. and F. Crespi (2013), "Public policies for a sustainable energy sector: Regulation, diversity and fostering of innovation", *Journal of Evolutionary Economics*, Vol. 23/2, pp. 401–429.

Costantini, V., F. Crespi and Y. Curci (2014), "A keyword selection method for mapping technological knowledge in specific sectors through patent data: the case of biofuels sector", Economics of Innovation and New Technology, DOI:10.1080/10438599.2014.942583.

Costantini, V. and M. Mazzanti (2012), "On the green and innovative side of trade competitiveness? The impact of environmental policies and innovation on EU exports", *Research Policy,* Vol. 41/1, pp. 132–153.

Crespi, F. (2012), "Environmental policy and induced technological change in European industries", in V. Costantini, M. Mazzanti and A. Montini (eds.), *Hybrid Economic Environmental Accounts*, Routledge, London.

Crespi, F. (2013), "Environmental policy and induced technological change in European industries", in *The Dynamics of Environmental and Economic Systems*, Springer Netherlands, pp. 143-157.

D'Allura, G.M., M. Galvagno and A. Mocciaro Li Destri (2012), "Regional Innovation Systems: A Literature Review", *Business Systems Review*, Vol. 1/1, pp. 139-156.

Dechezleprêtre, A. and M. Glachant. (2013), "What Drives the International Transfer of Climate Change Mitigation Technologies?", Empirical Evidence from Patent Data, pp. 161–178.

De Loecker, J. (2011), "Recovering markups from production data", *International Journal of Industrial Organization*, Vol. 29/3, pp. 350-355.

De Loecker, J. and F. Warzynski (2012), "Markups and firm-level export status", *American Economic Review*, Vol. 102, pp. 2437-2471.

Delmas, M.A. and S. Pekovic (2013), "Environmental standards and labor productivity: Understanding the mechanisms that sustain sustainability", Journal of Organizational Behavior, J. Organiz. Behav. 34, pp. 230–252 (2013).

Del Río González, P. (2009), "The empirical analysis of the determinants for environmental technological change: A research agenda", *Ecological Economics*, Vol. 68/3, pp. 861-878.

Demirel, P. and E. Kesidou (2011), "Stimulating different types of eco-innovation in the UK: Government policies and firm motivations", *Ecological Economics*, Vol. 70/8, pp. 1546-1557.

De Marchi, V. (2012), "Environmental innovation and R and D cooperation : Empirical evidence from Spanish manufacturing firms", *Research Policy*, Vol. 41/3, pp. 614–623.

De Vries, F.P. and C. Withagen (2005), "Innovation and environmental stringency: the case of sulfur dioxide abatement", CentER Discussion Paper Series No. 2005-18.

Doran, J. and G. Ryan (2012), "Regulation and firm perception, eco-innovation and firm performance", *European Journal of Innovation Management*, Vol. 15/4, pp. 421-441.

EEA (2014), "Resource efficient green economy and EU policies", http://www.eea.europa.eu/publications/resourceefficient-green-economy-and-eu

Frondel, M., J. Horbach and K. Rennings (2007), "End-of-pipe or cleaner production? An empirical comparison of environmental innovation decisions across OECD countries", *Business Strategy and the Environment*, Vol. 16/8, pp. 571-584.

Frondel, M., J. Horbach and K. Rennings (2008), "What triggers environmental management and innovation? Empirical evidence for Germany", *Ecological Economics*, Vol. 66/1, pp. 153-160.

Ghisetti, C. and F. Quatraro (2013), "Beyond inducement in climate change : Does environmental performance spur environmental technologies ? A regional analysis of cross-sectoral differences", *Ecological Economics*, Vol. 96, pp. 99–113.

Ghisetti, C. and K. Rennings (2014), "Environmental innovations and profitability: how does it pay to be green? An empirical analysis on the German innovation survey", *Journal of Cleaner Production*, Vol. 75, pp. 106-117.

Ghisetti C. et al. (2015), "Do financial constraints make the environment worse off? Understanding the effects of financial barriers on environmental innovations", SEEDS working paper 1/2015, SEEDS, Ferrara.

Gilli, M., S. S. Mancinelli and M. Mazzanti (2014, "Innovation complementarity and environmental productivity effects: Reality or delusion? Evidence from the EU", *Ecological Economics*, Vol. 103, pp. 56–67.

Gray, W.B. and R.J. Shadbegian (1993), "Environmental regulation and manufacturing productivity at the plant level", National Bureau of Economic Research NBER working paper No. w4321.

Gray, W.B. and R.J. Shadbegian (2003), "Plant vintage, technology, and environmental regulation", *Journal of Environmental Economics and Management*, Vol. 46/3, pp. 384–402.

Gray, W.B. and R.J. Shadbegian (2007), "The Environmental performance of polluting plants: a spatial analysis", *Journal of Regional Science*, Vol. 47/1, pp. 63–84.

Grubb M. (2014), *Planetary Economics: Energy, climate change and the three domains of sustainable development*, Routledge.

Hahn, R.W. (1984), "Market power and transferable property rights", *The Quarterly Journal of Economics*, pp. 753-765.

Haščič, I., N. Johnstone and M. Kalamova (2009), "Environmental policy flexibility, search and innovation", *Czech Journal of Economics and Finance (Finance a uver)*, Vol. 59/5, pp. 426-441.

Hemmelskamp, J. (1999), "Innovationswirkungen der Umweltpolitik im Windenergiebereich", in: Klemmer, P. (ed.), *Innovationen und Umwelt*, Analytica-Verlag, Berlin, pp. 81–112.

Horbach, J. (2008), "Determinants of environmental innovation — New evidence from German panel data sources", Vol. 37, pp. 163–173.

Horbach, J., C. Rammer and K. Rennings (2012), "Determinants of eco-innovations by type of environmental impact — The role of regulatory push/pull, technology push and market pull", *Ecological Economics*, Vol. 78, pp. 112–122.

Horbach, J. and K. Rennings (2013), "Environmental innovation and employment dynamics in different technology fields. An analysis based on the German Community Innovation Survey 2009", *Journal of Cleaner Production*, Vol. 57, pp. 158–165.

Hottenrott, H. et al. (2012), "Green innovations and organizational change: Making better use of environmental technology", ZEW Discussion Papers n.12-43.

Huiban, J.P. and A. Musolesi (2013), Pollution abatement investments, knowledge capital and firm productivity in the French food sector, mimeo.

Huiban, J.P. et al. (2014), The impact of pollution abatement investments on technology: Porter hypothesis revisited, mimeo.

Inoue, E., T.H. Arimura and M. Nakano (2013), "A new insight into environmental innovation: Does the maturity of environmental management systems matter?", *Ecological Economics*, Vol. 94, pp. 156–163.

Jaffe, A.B. and K. Palmer (1997), "Environmental regulation and innovation: a panel data study. Review of economics and statistics", Vol. 79/4, pp. 610-619.

Jaraite, J. et al. (2013), Matching ET ETS Accounts to Historical parent companies: A technical note. European University Institute, Florence, 2013. Available online at *http://fsr.eui.eu/CPRU/EUTLTransactionData.aspx*.

Johnstone, N. et al. (2012), "Environmental policy stringency and technological innovation: evidence from survey data and patent counts", *Applied Economics*, Vol. 44/17, pp. 2157-2170.

Johnstone, N., I. Haščič and D. Popp (2010), "Renewable energy policies and technological innovation: evidence based on patent counts", *Environmental and Resource Economics*, Vol. 45/1, pp. 133-155.

Johnstone, N., I. Haščič and M. Kalamova (2010), "Environmental Policy Design Characteristics and Technological Innovation: Evidence from Patent Data", *OECD Environment Working Papers*, No. 16, OECD Publishing, Paris, *http://dx.doi.org/10.1787/5kmjstwtqwhd-en*.

Kalamova, M. and N. Johnstone (2011), "Environmental Policy Stringency and Foreign Direct Investment", *OECD Environment Working Papers*, No. 33, OECD Publishing, Paris, *http://dx.doi.org/10.1787/5kg8ghvf85d5-en*.

Kemp, R. (1997), *Environmental policy and technical change*, Edward Elgar Publishing.

Kemp, R. and P. Pearson (2007), Final report of the MEI project measuring eco innovation, UNU MERIT, Maastricht.

Kerr, S. and R.G. Newell (2003), "Policy-Induced Technology Adoption: Evidence from the US Lead Phasedown", *The Journal of Industrial Economics*, Vol. 51/3, pp. 317-343.

Kesidou E. and P. Demirel (2012), "On the drivers of eco-innovations: Empirical evidence from the UK", *Research Policy*, Vol. 41, pp. 862-870.

Koźluk,T. and V. Zipperer (2013), "Environmental Policies and Productivity Growth: A Critical Review of Empirical Findings", *OECD Economics Department Working Papers*, No. 1096, OECD Publishing, Paris, *http://dx.doi.org/10.1787/5k3w725lhgf6-en*.

Lanoie, P. et al. (2011), "Environmental policy, innovation and performance: new insights on the Porter hypothesis", *Journal of Economics and Management Strategy*, Vol. 20/3, pp. 803-842.

Lanjouw, J.O. and A. Mody (1996), "Innovation and the international diffusion of environmentally responsive technology", *Research Policy*, Vol. 25/4, pp. 549-571.

Levinson, A. (1996), "Environmental regulations and manufacturers' location choices: Evidence from the Census of Manufactures", *Journal of Public Economics*, Vol. 62/1, pp. 5-29.

Levinson, A. (2014), " A Direct Estimate of the Technique Effect: Changes in the Pollution Intensity of US Manufacturing 1990-2008", NBER Working Paper No. 20399, NBER, *www.nber.org/papers/w20399*.

Malerba, F. (ed.) (2004), *Sectoral systems of innovation: concepts, issues and analyses of six major sectors in Europe*, Cambridge University Press.

Mairesse, J. and P. Mohnen (2010), "Using innovation surveys for econometric analysis", *Handbook of the Economics of Innovation*, Vol. 2, pp. 1129-1155.

Mancinelli, S. and M. Mazzanti (2009), "Innovation, networking and complementarity: evidence on SME performances for a local economic system in North-Eastern Italy", *The Annals of Regional Science*, Vol. 43/3, pp. 567-597.

Marin, G., M. Marino and C. Pellegrin (2015) (forthcoming), "The impact of the European Union Emission Trading Scheme on market power: an empirical analysis", working paper series *www.sustainability-seeds.org*.

Marin, G. and M. Mazzanti (2013), "The evolution of environmental and labor productivity dynamics", *Journal of Evolutionary Economics*, Vol. 23/2, pp. 357-399.

Marin, G. (2014) Do eco-innovations harm productivity growth through crowding out? Results of an extended CDM model for Italy. Research Policy, 43(2), 301-317.

Martin, R., M. Muûls and U.J. Wagner (2013), The Impact of the EU ETS on Regulated Firms: What is the Evidence after Eight Years? (November 14, 2013). Available at SSRN: *http://ssrn.com/abstract=2344376* or *http://dx.doi.org/10.2139/ssrn.2344376*.

Mazzanti, M. and R. Zoboli (2005), "The drivers of environmental innovation in local manufacturing systems", *Economia politica*, Vol. 22/3, pp. 399-438.

Mazzanti, M. and R. Zoboli (2008), "Waste generation, waste disposal and policy effectiveness: evidence on decoupling from the European Union", *Resources, Conservation and Recycling*, Vol. 52/10, pp. 1221-1234.

Mazzanti, M. and R. Zoboli (2009), "Embedding environmental innovation in local production systems: SME strategies, networking and industrial relations: evidence on innovation drivers in industrial districts", *International Review of Applied Economics*, Vol. 23/2, pp. 169-195.

Mazzanti, M. and R. Zoboli (2010), "The Environment as a Driver of Innovation and Economic Change", *Economia Politica*, Vol. 27/2, pp. 237-246.

Mazzucato, M. and C. Penna (2015), *Mission-Oriented Finance for Innovation: New Ideas for Investment-Led Growth*, Rowman & Littlefield.

Mehlac C. and A. Recoules (2014), "La certification environnementale des établissements industriels s'acompagne de la diminution des pressions environnementales ", Commissariat Général au Développement Durable, Études et documents, No 118, Décembre 2014.

Mohnen P. and B. Hall (2013), Innovation and Productivity: an update, Eurasian Business Review, Vol. 3/1, pp. 47-65.

Mohnen, P. and L.H. Röller (2005), "Complementarities in innovation policy", *European Economic Review*, Vol. 49/6, pp. 1431-1450.

Nicoletti, G. and F.L. Pryor (2006), "Subjective and objective measures of governmental regulations in OECD nations", *Journal of Economic Behavior and Organization*, Vol. 59/3, pp. 433–449.

Oberndorfer, U. et al. (2013), "Does the stock market value the inclusion in a sustainability stock index? An event study analysis for German firms", *Journal of Environmental Economics and Management*, Vol. 66/3, pp. 497-509.

Pavitt, K. (1984), "Sectoral patterns of technical change: towards a taxonomy and a theory", *Research Policy*, Vol. 13/6, pp. 343-373.

Pessoa, J.P. and J. Van Reenen (2014), "The UK productivity and jobs puzzle: does the answer lie in wage flexibility?", *Economic Journal*, Vol. 124, pp. 433-452.

Peuckert, J. (2014), "What shapes the impact of environmental regulation on competitiveness? Evidence from Executive Opinion Surveys", *Environmental Innovation and Societal Transitions*, Vol. 10, pp. 77–94.

Podsakoff, P.M. et al. (2003), "Common method biases in behavioral research: a critical review of the literature and recommended remedies", *Journal of Applied Psychology*, Vol. 88/5, pp. 879.

Porter, M.E. (1991), "Towards a dynamic theory of strategy", *Strategic Management Journal*, Vol. 12/S2, pp. 95-117.

Porter, M.E. and C. Van der Linde (1995), "Toward a new conception of the environment-competitiveness relationship", *The Journal of Economic Perspectives*, pp. 97-118.

Rehfeld, K.M., K. Rennings and A. Ziegler (2007), "Integrated product policy and environmental product innovations: an empirical analysis", *Ecological Economics*, Vol. 61/1, pp. 91-100.

Rennings, K. and C. Rammer (2011), "The impact of regulation-driven environmental innovation on innovation success and firm performance", *Industry and Innovation*, Vol. 18/03, pp. 255-283.

Rennings, K. and R. Rexhauser (2011), "Long-term impacts of environmental policy and eco-innovative activities of firmsz", *International Journal of Technology, Policy and Management*, Vol. 11/3, pp. 274-290.

Rexhäuser, S. and C. Rammer (2014), "Environmental innovations and firm profitability: Unmasking the Porter Hypothesis", *Environmental and Resource Economics*, Vol. 57/1, pp. 145-167.

Schmalensee, R. (2012), "From "Green Growth" to sound policies: An overview", *Energy Economics*, Vol. 34, pp. S2-S6.

Schmidt, T.S. et al. (2012), "Environmental Innovation and Societal Transitions The effects of climate policy on the rate and direction of innovation : A survey of the EU ETS and the electricity sector" *Environmental Innovation and Societal Transitions*, Vol. 2, pp. 23–48.

Testa, F., F. Iraldo and M. Frey (2011), "The effect of environmental regulation on firms' competitive performance: The case of the building and construction sector in some EU regions", *Journal of Environmental Management*, Vol. 92/9, pp. 2136-2144.

Testa, F. et al. (2014), "EMAS and ISO 14001: the differences in effectively improving environmental performance", *Journal of Cleaner Production*, Vol. 68, pp. 165-173.

Triguero, A., L. Moreno-Mondéjar and M.A. Davia (2013), "Drivers of different types of eco-innovation in European SMEs", *Ecological Economics*, Vol. 92, pp. 25-33.

Vachon, S. and R.D. Klassen (2008), "Environmental management and manufacturing performance: the role of collaboration in the supply chain", International Journal of Production Economics, Vol. 111/ 2, pp. 299-315.

Van den Bergh, J. (2008), "Environmental regulation of households: An empirical review of economic and psychological factors", *Ecological Economics*, Vol. 66/4, pp. 559-574.

Verdolini, E. and M. Galeotti (2011), "At home and abroad: An empirical analysis of innovation and diffusion in energy technologies", *Journal of Environmental Economics and Management*, Vol. 61/2, pp. 119-134.

Veugelers, R. (2012), "Which policy instruments to induce clean innovating?", *Research Policy*, Vol. 41/10, pp. 1770–1778.

Veugelers, R. and B. Cassiman (2005), R&D cooperation between firms and universities . Some empirical evidence from Belgian manufacturing", *International Journal of Industrial Organization*, Vol. 23, pp. 355–379.

Wagner, M. (2007), "On the relationship between environmental management, environmental innovation and patenting: Evidence from German manufacturing firms", *Research Policy*, Vol. 36/10, pp. 1587-1602.

Wagner, M. (2008), "Empirical influence of environmental management on innovation: evidence from Europe", *Ecological Economics*, Vol. 66/2, pp. 392-402.

Wagner, M. (2013), "'Green' Human Resource Benefits: Do they Matter as Determinants of Environmental Management System Implementation?", *Journal of Business Ethics*, Vol. 114, pp. 443–456.

Ziegler, A. and J. Seijas Nogareda (2009), "Environmental management systems and technological environmental innovations: Exploring the causal relationship", *Research Policy*, Vol. 38/5, pp. 885-893.

Ziegler, A. and K. Rennings (2004), "Determinants of Environmental Innovations in Germany: Do Organizational Measures Matter?", ZEW-Centre for European Economic Research Discussion Paper, pp. 04-030.