

A tailored method for eco-innovation strategies and drivers (in the South)¹

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Paper submitted to the DIME International Conference “Innovation, sustainability and policy”, 11-13 September 2008, GREThA, University Montesquieu Bordeaux IV, France.

Abstract

A positive perception of the use of eco-innovations and cleaner technologies has been established throughout the years. In the present decade, there is an increasing need to understand those driving forces and variety of eco-innovation strategies adopted by firms – both for developed and developing nations. In spite of its importance, no single body of literature has succeeded in providing a comprehensive framework for the study of eco-innovations strategies and drivers as a tool for sustainability. There is an evident need to perform internationally comparable sectoral ‘eco-innovation’ studies in less advanced economies (e.g. namely advanced developing countries). In order to do so, the use of different indicators to measure environmental innovation strategies and drivers based on the experience of studies from developing countries is highly beneficial. Unfortunately, the necessary data sources are not always available. More critically, there is a lack of standard methods for performing such a comparison. This paper contributes to filling this gap in the literature.

The main objective of this paper is to provide a ‘tailored’ methodological contribution to identify eco-innovation strategies and drivers from micro-innovation data from a small scale surveys (e.g. firm-based). Moreover, the proposed tailored method aims to propose a viable alternative for measuring eco-innovation at the time it reduces biased and trivial choices for the identification of eco-innovative firms. Unlike previous studies, the main methodological proposition regarding the construction of eco-innovation indicators is based on the assumption that different levels of eco-innovation can be identified. Related to this, the present work aims to introduce three qualitative eco-innovation indicators build by quantitative methods (RCC, BEH, EI) which can be used to measure different level of eco-innovativeness or strategic positioning of firms.

Key words: eco-innovation, eco-innovation strategies and drivers, eco-innovation indicators, innovation, resources, capabilities and competences, advanced developing countries

¹ This paper drafts the main findings from my PhD research at the University of East Anglia, School of Development Studies. The author would like to acknowledge the financial support from the UAM-CONACYT Project 37896-S during the fieldwork stage. I am very grateful to Prof Rhys Jenkins and Prof Michael Stocking for their supervisory role during my PhD research. I greatly appreciate the constructive comments of Dr Lars Coenen, Dr Carlos Montalvo, Dr Roger Few and Dr Daniel Villavicencio regarding this work. The usual disclaimer applies.

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Introduction

In the present decade, one of the major challenges that public authorities, industry leaders and civil society face is the alignment/coordination of industrial policies and strategies with the principles of sustainability. This may be one of the reasons why the topic of environmental sustainability has gained importance in the agenda of innovation policies/ strategies studies (Fukasaku 2000). Studies in this area have acknowledged the need to create systemic information about what drives firms to innovate with positive environmental benefits (Fukasaku 2005). Clearly, there is an increasing need to understand those driving forces for environmental innovations (eco-innovations). In addition, insights into the type and variety of eco-innovation strategies adopted by firms is greatly needed – both for developed and developing nations.

The economic perception of the use of eco-innovations and cleaner technologies has changed throughout the years. Nowadays, environmental costs are being seen by large and important firms as an important variable that must be internalised. Business opportunities have been driven by the emergence and use of environmental innovations that nowadays represents not only a factor for firm's competitiveness, but also as a mechanism to achieve a better image with clients, communities and the government. The use and promotion of eco-innovations has traditionally been used to address environmental challenges. Furthermore, it constitutes a core opportunity for alternative modes of cooperation and partnership between the different stakeholders in the different dimensions of sustainability (Diaz Lopez 2008).

In spite of its importance, no single body of literature has succeeded in providing a comprehensive framework for the study of eco-innovations strategies and drivers as a tool for sustainability. Although important steps have been achieved, there is still a plethora of inconclusive definitions, case-study evidence, government initiatives, and claims from social groups related to eco-innovation (Diaz Lopez 2008). Berkhout (2005) noted that eco-innovations studies should follow two main objectives: to establish the methods, drivers, sources and direction of technological and organisational eco-innovations; and, to set up the context for the relationship of eco-innovations within institutions and markets. This paper expects to contribute to the first type of studies.

Because of the (relative) novelty of the field, different bodies of knowledge, tools, methodologies, indicators and explanatory variables have been tested in order to understand and interpret its driving forces. On the one hand, innovation studies have provided relevant theoretical and methodological expertise that could be used for modelling and understanding 'eco-innovation' strategies and driving forces. On the other hand, environmental performance and strategic environmental management studies have also contributed to the accumulation of knowledge for understanding firm environmental dynamics and its relationship with firm performance (Diaz Lopez 2008). This paper expects to provide sound and comprehensive methods for the study of eco-innovations making use of the best of both strands of literature.

Clearly, there is an evident need to perform internationally comparable sectoral 'eco-innovation' studies in less advanced economies. In order to do so, the use of different indicators to measure environmental innovation strategies and drivers based on the experience of studies from developing countries would need to be carefully contextualised. Unfortunately, the necessary data sources are not always available. To date, the list of on-going projects in the field seems to be limited and the amount of specific data sources is even smaller (especially in advanced developing countries). This paper contributes to filling this gap in the literature. In particular, this paper makes a contribution to the field of eco-innovation by proposing an integrated method for identifying strategies and drivers based on micro-innovation data.

The main objective of this paper is to provide tailored methodological contributions to identify eco-innovation strategies and drivers from micro-innovation data from a small scale surveys (e.g. firm-based). Moreover, the proposed tailored method aims to introduce a viable alternative for measuring eco-innovation at the time it reduces biased and trivial choices for the identification of eco-innovative firms. Unlike previous studies, the main methodological proposition regarding the construction of eco-innovation indicators is based on the assumption that different levels of eco-innovation can be identified. Related to this, the present work aims to introduce three qualitative eco-innovation indicators build by quantitative methods (RCC, BEH, EI) which can be used to measure different level of eco-innovativeness or strategic positioning of firms.

It is important to establish that this paper is based on a doctoral research on drivers and strategies for eco-innovation in the context of an advanced developing country (Diaz Lopez 2008). In particular, this study aimed to analyse the case of eco-innovation strategies and drivers in the Mexican chemical industry (CI), as an example of an ‘advanced developing countries’. This study had also the aim to provide empirical evidence of the strategic role of micro-data obtained from innovation surveys for ‘environmental innovation’ measurement.

The following paragraphs provide a definition of eco-innovation; an overview related to the state of the art in eco-innovation methods is subsequently provided. This is followed by a section where the contribution of innovation studies for informing methods and data sources for eco-innovation is acknowledged; immediately after, some aspects of the nature of indicators and data sources are briefly discussed. Subsequently, the main elements and components of the proposed method for the identification of eco-innovation strategies and drivers are detailed. In the conclusion, the main methodological contributions of this paper are outlined.

Understanding eco-innovations

The term environmental innovation or ‘eco-innovation’ is not a new term and there is an on-going academic debate on what it really means.³ As suggested by Skea (1995), a large amount of concepts have arisen to describe the use of technologies associated to improve the environmental performance of firms (see Diaz Lopez 2008 for a summary of definitions). Different authors have recognised the need to provide an operational definition of environmental innovation as this type of innovation is different from the general notion of innovation suggested by the Oslo manual (e.g. Rennings 2000).⁴ A

³ The term *eco-innovation* was promoted since early 1990s by Claude R. Fussler former Vice-President of DOW-Europe and the WBCSD (Nuiji, 2001). Despite of not becoming a mainstream concept in its early years, Fussler (1996) introduced a notion of the term *eco-innovation* accompanied with a set of practical tools for firms to achieve it. He created an eco-efficiency compass based on six strategies due the success of its implementation in DuPont. However, this author neither provided a concise definition of eco-innovation, nor explained the factors that made it part of eco-efficiency nor its drivers. To date, there is still a plethora of definitions in the literature and the policy environments. Currently, both the European Commission and the European Parliament have commissioned expert advice for solving the definitional issue of eco-innovation (e.g in the ‘Measuring eco-innovation’ project, <http://www.merit.unu.edu/MEI/>)

⁴ The ‘Schumpeterian’ notion of innovation is related to gain profits and to be introduced in the market so a minimal return or investment rate can be maintained. Environmental innovation’s aim is also extended to contribute to protect the environment and gain social benefits for the firm, in a direct or indirect way. It can be driven by factors such as regulations, business philosophy, consumer demands, industrial or transport accidents, etc (Arundel, Kemp, et al 2007). There are substantial differences between the purposes and drivers of ‘general innovations’ and ‘eco-innovations’. It is generally accepted that firms’ incentives to engage in ‘general innovation’ activities are normally associated with expectations of profit increases and market share. Conversely, as suggested by Arundel, Kemp et al (2007) and other authors (e.g. Rennings, 2000), environmental innovation may be driven by other factors rather than merely economic and business opportunities, as this type of innovation is normally associated with a ‘double externality’ effect. Environmental innovations not only produce the general spillovers like general innovations, it also creates less environmental external costs.

similar case has occurred when defining an ‘eco-innovative’ firm, since motivations and drivers for environmental innovation can be different from general innovations. This paper uses the general notion of *environmental innovation* provided by Arundel, Kemp et al (2004: 4).⁵

“[...] consists of new and modified processes, equipment, products, techniques and management systems that avoid or reduce harmful environmental impacts. A substantial fraction of environmental innovation is based on the simple adoption of new technology, although firms may need to adapt the technology to their own production processes. A smaller fraction of environmental innovation is probably based on the firm’s own creative activity. In some cases, reducing environmental impacts may be the sole purpose of an environmental innovation. In other cases, the environmental benefit may be a fortuitous by-product of other innovation activities...Environmental innovation is ‘technical’ when it involves new equipment, products and production processes and ‘organisational’ when it involves structural change within the organisation to institute new habits, routines, orientation and practices [...]”

From the eco-innovation definition above, it is important to note that a core aspect is related to the application of knowledge. This knowledge can be applied to technical, organisational or managerial areas in order to reduce environmental harm. Additionally, the *intentionality*, *effects* and *type* of innovation is noted in all the eco-innovation definitions. Its development can be driven by a combination of factors different from environmental protection, but having in the end a positive impact on the environmental performance of the firm (VINNOVA 2001). Additionally, depending on the technology level and maturity of the firm and the sector, some environmental innovations may not be new to the world and the markets, but new to the firm. In other words they have a different *novelty degree*. In this way, a gradual introduction of any type of innovation would help the firm to develop higher competences and capabilities, as it involves learning and knowledge creating processes; an aspect that has been extensively analysed in literature of technological capabilities in developing countries (e.g. Bell 1984; Lall 1992).⁶

The influence of OECD publications for the study of eco-innovations

The systems of innovation approach have greatly influenced innovation studies and policies in the last decade. In recent innovation studies the evident influence of the

⁵ The author is aware of the latest definition given by these authors in the context of the “Measuring Eco-innovation” project (in Kemp, et al 2008). However, this novel definition is not discussed in this paper as it is subject of a separate topic.

⁶ It is important to note that some of the current problems of this definition derive from the fuzzy clarity of the dichotomy between intentionality and effects of eco-innovations. A problem derived from focusing on the effects of eco-innovations arises when deciding in practice which innovations reduce environmental impacts (VINNOVA, 2001). Another problem comes with the intentionality of eco-innovation; unintentional eco-innovations may not be close to the market since it may be originated from other motivations than commercialisation or environmental performance (i.e. product and process efficiency). These aspects should be clearly attended in further research.

OECD publications and guidelines regarding the nature of the innovation process and what they understand as an innovative firm are evident (e.g. OECD 1997; 1999; 2002). In particular, the Oslo Manual provides a general framework for the understanding of the innovation process. This manual provides definitions (e.g. technological product innovation, technological process innovation, and organisational innovation), their novelty degree (e.g. new to the firm, industry, market, world), nature of innovation (e.g. radical or incremental, the methods for data collection, and some considerations and implications for the stage of data analysis. It promotes the use of innovation surveys to collect micro-data for the analysis of innovation activities of firms. However, the contribution for the explicit understanding eco-innovations is limited, as it is clearly not its purpose.⁷ Nonetheless, its methodological contributions are outstanding (i.e. by using innovation surveys). In this case, some conceptual and empirical modifications need to be made in order to gain positive benefits from using this framework and methods (e.g. in Diaz Lopez 2008).

Measuring eco-innovation strategies and drivers: overview of methods

For the study of environmental innovations, it seems not to be any standard method to measure its performance, drivers or strategies in firms –both for developed or developing countries (Diaz Lopez 2008). Alternatively, in order to choose data variables or the type of indicator a high degree of freedom has been suggested. According to Arundel, Kemp et al (2007: 20):

“[...] there is not one best type of indicator research for environmental innovation. All have a role to play to study the very heterogeneous issue of environmental innovation [...] studies should differentiate between different types of environmental innovation [...] using micro-data for innovation and detailed sector data for environmental policy.”

On the one hand, the lack of a rich set of internationally comparable environmental innovation indicators has had severe implications for the policy makers and their task to create integrated environmental and innovation policies (Fukasaku 2005). On the other hand, firms could benefit from the use such indicators by means of benchmarking

⁷ In the Oslo manual (first and second versions) the role of environmental variables for innovation surveys was merely restricted to: (1) The recognition of the role of other policy areas (besides innovation policy) to foster (or restrict) industrial innovations. Between these ‘other’ innovation policy areas the manual cites: *environmental regulation*, health standards, intellectual property rights, quality controls, and standardisation methods. (2) To develop *environment-friendly products* and to *reduce environmental damage* as part of the economic objectives of innovation. (3) The measurement of the expenditure on innovation. This manual suggests the collection of R&D and non R&D expenditures. The later one includes in particular: the expenditure for tooling up, industrial engineering, industrial design and production start-up. *Satisfying environmental regulatory requirements* is included in the case of tooling-up expenditures of firms.

practices with other firms and to develop more accurate environmental and innovation strategies (Arundel, Kemp et al. 2007). Fukasaku (2005) suggested that at least two types of information is necessary for better policy making in the field: the first one is public and private environmental R&D expenditures; the second one is related to the determinants of environmental innovation in industrial firms, how firm assess their cost/benefits, what the types of environmental innovations are and how the knowledge required by them is developed. This research intends to provide evidence for the second type of information for advanced developing countries.

Table 1 presents a summary of methodological aspects for environmental innovation measurement from selected studies (Green, McMeekin et al. 1994; Florida 1996; Cleff and Rennings 1999; Theyel 2000; Montalvo 2002; Bartolomeo, Kemp et al. 2003; Ramus 2003; Horbach 2006; Mazzanti and Zoboli 2006; Pujari 2006; Rennings, Ziegler et al. 2006).⁸ The studies in this table aim to present aspects that are important to approach environmental innovation measurement in the cases from developed countries, and have no apparent limitation to be adapted to the case of less advanced countries and different industrial sectors.

It is important to note that a particular difference between the proposed method and most of the studies described in table 1 is based on the fact that the proposed method focuses on “advanced developing countries”. From the studies presented in this table, only the work of Montalvo shares this condition of studying an advanced developing country (Mexico).⁹ Table 1 also presents the studies from Jaffe & Palmer (1996) and Brunnermeier & Cohen (2003). However, I decided not to follow these studies to build the empirical model due to their differences with the proposed approach; mainly from our different use of data sources and analytical techniques.¹⁰ More specifically, the

⁸ It is convenient to mention that all of these studies were based on the use of innovation surveys as main data source and presented cases from developed countries. Only the works of Florida (1996) and Theyel (2000) were not influenced by and did not base its survey methods on OECD guidelines (Oslo Manual). Conversely, they were immersed in the tradition of strategic environmental management, but their methods and theoretical framework showed comparability with the rest of the studies classified as part of this ‘new generation’ of eco-innovation studies. Table 2.3 presents a description of prior studies, authors, study scope, sector, location, methods for data collection, methods for analysis, and the dependent variables employed.

⁹ I also reviewed the work of Lustosa (2000) on eco-innovation in the Brazilian manufacturing industry, which used innovation data from a local survey dated from the year 1996. However, the only paper available describing this study did not provide enough material to describe all the elements in table 2.3. Nonetheless, this study was acknowledged to provide some basic comparison with the results of my own research.

¹⁰ The work from Jaffe & Palmer used two different measures of innovative effort as dependent variables: industry-wide R&D expenditures and, the total number of successful (general) patent applications. The expected relationship between its dependent variables and environmental innovation was expected by the introduction of pollution abatement cost and expenditures (PACE) into the explanatory variables. Accordingly, the work from Brunnermeier & Cohen (2003) measured environmental innovation by the number of successful environmental patents applications granted to US manufacturing industries. In a similar way to Jaffe & Palmer, Brunnermeier & Cohen also introduced PACE into their explanatory variables. In addition to this, they expected to find

works from Jaffe & Palmer (1996) and Brunnermeier & Cohen (2003) were excluded from the final selection of variables regarding eco-innovation drivers due the fact that they used input and throughput indicators based on the use of R&D expenditures, patents and pollution expenditures. In addition to this, both researches found mixed evidence on the relationship between regulation, enforcement and innovative output and strategies. Nonetheless, their explanatory variables were considered for the stage of selection of potential explanatory drivers for environmental innovation (see below)

The ‘new’ generation of eco-innovation studies provide many important theoretical aspects on the use of indicators. More importantly, they provide important aspects related to data sources and analytical techniques. It could be inferred that a common (methodological) pattern was followed by most of these eco-innovation studies prior to their statistical / econometric analysis. Firstly, they made assumptions in order to define what they consider as an ‘eco-innovative firm’. As a second step, these studies created indicators and dealt with the issue of how reliable their dependent variable(s) were. Finally, defining a given set of explanatory and control variables aimed to be introduced into the selected statistical or econometric technique. These were basic inputs for further empirical (statistical or econometric) analysis enabling the identification of significant explanatory variables. Their relevant methodological aspects of these studies can be summarised in the following points:

- A common practice was to ask firms specific questions that enabled the researchers to define whether or not they could consider them as ‘eco-innovative’. In this category we find firms that: (1) were located in a particular sector that could be related to environment innovation (i.e. environmental services); (2) introduced any sort of technological change with environmental benefits in products and processes; or (3) considered themselves as eco-innovative.
- Among the selected dependent variables used as a proxy for environmental innovation we account different (qualitative and quantitative) output and input measures such as: experience with environmental R&D, experience with environmental (product and process) innovation projects, introduction of different types of environmental innovations, etc. These studies used different

some significance of the variable related to the number of air and water pollution inspections. Evidently, these two studies did not deal with the fact of identifying ‘eco-innovative’ firms (as it is not a characteristic of studies that are not based on innovation surveys).

‘formats’ of dependant variables mainly as binary variables (yes/no type) and synthetic indices (either continuum or fixed).

Data sources and methods for eco-innovation measurement: the contribution from innovation studies

It seems to me that, so far, ‘eco-innovation’ studies have followed a very similar methodological pattern to ‘general innovation’ ones. Just to cite one example, Flor & Oltra (2004) suggested that the use of (general) innovation indicators enables the identification of innovative firms as a first step in studies aiming to characterise their behaviour and results. In a similar way to sectoral/ industry studies aiming to understand drivers of ‘general’ innovation, eco-innovation studies have been pursuing similar aims and followed similar methodological patterns. For the case of recent innovation studies, the Oslo Manual has provided a clear framework to understand what ‘innovation’ and ‘innovative firm’ are. In the case of ‘eco-innovation’, there is an open debate on the concept of eco-innovation, what sort of indicators and which empirical methods should be used for its measurement. However, it seems that the working ‘eco-innovation’ definition from the IMPRESS project has gained more and more credibility (see the definition provided above).¹¹

There are some implications of the use of similar methods to measure ‘eco-innovation’ compared with ‘general innovation’ studies:

- First of all, we need to take into account that ‘eco-innovations’ are different in nature from ‘general innovations’. The former type of innovation has normally been associated with a double ‘externality’ effect, due to its environmental and economic effects and it is extremely important to understand this concept.
- The availability of data sources and the quality of data collected (discussed later in this paper)
- The need to use relevant and accurate indicators that truly reflect the dynamics and nature of ‘eco-innovation’ in firms, and not a limited adaptation of ‘general innovations’ data or methods. Proxy variables for environmental innovation can

¹¹ The description of the IMPRESS project can be found in Bartolomeo, Kemp, et al (2003)

only be relevant if they are supported by the use of sound data and methodology.¹²

- It is also very important to bear in mind the novelty degree of (process and product) innovations of firms in the context of developing countries. Empirical evidence on innovation dynamics from Latin American countries (e.g. Pirela, Rengifo et al. 1993; Arvanitis and Villavicencio 1998) has suggested that firms in these countries have mostly experience with incremental (process and product) innovation new to the firm and country.
- Finally, the interpretation of variables affecting environmental innovation in developing countries when compared with the ‘state of the art’ in developed ones. Different levels of ‘eco-innovativeness’ would imply different strategic approaches for public policies and business strategies in different countries/sectors/firms.

The importance of the identification of eco-innovative firms

Following on from the above, one of the first and most important aspects to consider for environmental innovation measurement is related to a proper knowledge of what an ‘eco-innovative firm’ can be. A partial or limited understanding of the concept of ‘eco-innovative firm’ could lead to biased results and interpretation of any empirical findings. In order to avoid this, the notion of an ‘eco-innovative firm’ aligned with the general notion of ‘innovative firms’ and ‘innovation’ as described in the Oslo Manual would be desirable. This is due to the fact that this definition has gained wide acceptance, is comprehensive, and can be easily adapted as a dependent variable from data taken from innovation surveys. Studies based on this notion have shown the use of sound methodology, good sample adequacy, and the use of high quality data (or *strong data*, in statistical *argot*). Correspondingly, the statistical and/or econometric methods employed had theoretical and methodological advantages during their empirical analysis. For example, by defining a ‘no/yes’ type question as main data source to define a dependent variables a binary probit model could be easily employed

However, it is my view that, in particular circumstances, some of the ‘eco-innovation’ studies have had only partially reflected a realistic nature of an ‘eco-innovative firm’.

¹² It may be possible that some empirical research using R&D expenditures and patents as eco-innovation indicators probably failed to produce conclusive results, among many other factors, due the fact of lack of sound data on environmental R&D and environmental patents at a more disaggregated level (i.e. Jaffe & Palmer 1996; Brunnermeier & Cohen, 2003).

This may especially be the case when adapted to the context of developing countries. This could be true since such a view, in particular circumstances, does not necessarily recognise that there might be different levels of ‘eco-innovativeness’ between firms (in the same industrial sector). The exclusion of firms that might not have experience, according to the researcher’s judgement, is risky as it implicitly denies that such a firm could be gradually developing the capabilities to innovate. Innovation studies have shown, with greater empirical evidence from both developed and developing countries, that the gradual accumulation of capabilities depends to a great extent on internal technological, organisational, and managerial processes inside the firm (Teece, Pisano et al. 1997; Kim and Nelson 2000). Correspondingly, firms could accumulate ‘dynamic capabilities’ that eventually would enable them to reach their highest level of ‘eco-innovativeness’ (conditioned by their technological paradigm and industrial sector).

In my opinion, the current criterion for identification of ‘eco-innovative firms’ (and its use as dependent variables) when applied to developing countries could have some important limitations. This could be due to the following aspects:

- It is complex to know *ex-ante* whether the experience of firms with ‘environmental innovations’ involves successful cases with full economic and environmental impacts/ benefits (double externality).
- Some firms could be failing to be truly ‘eco-innovative’ in those cases when they may just be suppliers of ‘end-of-pipe’ technologies or have experience only as recipients of technology (i.e. from north-south technology transfer). A similar case would occur when they have failed to integrate aspects of innovation, R&D and environmental management as vital components of the firm’s strategy.
- Similarly, asking firm managers whether they consider themselves as ‘eco-innovative’ could be easily biased by each respondent. This could be the case for firms considering themselves as eco-innovative with a single or unique case of product innovation, but that may have been unsuccessful in the end or had never reached the market. Another case would occur for companies facing problems of credibility, so they could claim to be ‘eco-innovative’ only to recover prestige.
- A final limitation could be that concepts used mean different things to academics guiding the research and managers or engineers responding to the questionnaires (when using survey questionnaires).

Nature of the inputs for the study of eco-innovations

As it can be noted from the content in table 1, a crucial aspect in eco-innovation studies has been to consider the nature of the dependent variables to build indicators that measure environmental innovations. In general, innovation studies have informed eco-innovation studies on the use of used input, throughput and output innovation indicators (e.g. Meyer-Krahmer 1984; Kleinknecht, Van Montfort et al. 2002). Table 2 shows different potential innovation indicators and its relationship to a different aspect of the innovation process (input, throughput, and output). Analogically, a set of ‘eco-innovation indicators’ derived from the eco-innovation studies reviewed for this work are included. These eco-innovation indicators will aim to illustrate two stages of a hypothetical ‘green box’ of the ‘eco-innovation process’ –from inputs to outputs.

Following on from the above, two important aspects can be discussed: (1) the type of indicator to be constructed (categories, variables used as proxies or indices). Mazzanti & Zoboli (2006) claimed that the use of synthetic indices is a better alternative compared to the use of classifications for environmental innovation measurement. These authors claimed that (p. 16):

“[...] a (synthetic) index on different innovation adoptions ranging from 0 to 1 is a preferable alternative to count-like specifications of the dependent variable when we observe a number of innovation typologies over a range (necessarily) defined by the researcher [...].”

Nonetheless, Mazzanti & Zoboli (2006) also recognised that this methodological issue is open to debate and subject to further investigations. (2) A final aspect to consider is the dimensionality of the indicator, since single-dimensional and multi-dimensional indicators can be created. In this regard, Horbach (2005) argued that in order to connect eco-innovation indicators with general systems of innovation, it is desirable to favour the use of multi-dimensional indicators because this approach may include all the driving forces and the relevant components that better reflect its nature.

It is relevant to recognise that the construction of ‘eco-innovation’ indicators that capture and explain all the possible scenarios leading to 100% reliability constitutes a very complex issue. This is probably why defining accurate indicators for

environmental innovation measurement for better policy making is still part of an ongoing debate (Fukasaku 2005)..

As a consequence of what has been described above, researchers and practitioners in the field face a challenge to generate fitting data, and to standardise the available methods for (environmental) innovation measurement. In such a case, one of the main challenges is to eliminate the trivial choices of (environmental) innovation indicators (Kleinknecht, Van Montfort et al. 2002). However, it is not a matter of adding complexity to the way eco-innovation is measured, but trying to identify different accurate methodologies and indicators in order to minimise possible bias induced by the researchers and their methods. Current and further empirical research could focus on testing different indicators for ‘eco-innovation’, and possibly evolve in a similar way to previous studies from ‘general innovations’. In particular, Horbach (2005) has warned that one of the main problems for their construction is the amount of data available. In this sense, Horbach adds, we need to avoid the problem that the available data itself determines the indicator

On the selection of data sources for measuring eco-innovation

In regard to data sources, Mohen, Mairesse et al.(2006: 1) made an important observation in terms on how to measure ‘general’ innovations which could be useful for the study of eco-innovations:

“So far, most of the work on science and technology indicators has been based on R&D, patent or bibliometric data. R&D data have been collected in a systematic fashion in OECD countries since the inception of the Frascati Manual (OECD, 1963). Patent grants have been recorded by patent offices around the world for a much longer time. Bibliometric data are also widely available in the form of publications and citations, or innovation announcements. All of these indicators have their shortcomings.”

For the case of ‘eco-innovation’ measurement, Arundel, Kemp et al. (2007) and Horbach (2005) reviewed five types of data sources to create indicators that have attempted to assess environmental innovation in different studies from developed countries – in a similar way as described by Mohen, Mairesse et al. (2006) in the quote above for general innovations. The four types of indicators are related to: financial indicators collected by governments, patents, literature-based innovation output techniques (bibliometric data), and, innovation surveys based on the Oslo Manual.

These authors also suggested that these indicators can help to identify: typologies of environmental innovation; motivation and drivers for environmental innovation; the economic effects of environmental innovations and sources of knowledge and barriers for its implementation.

Clearly, the choice of any of these data sources has methodological and theoretical implications for the study of eco-innovations, due to their advantages and disadvantages. The latter has been discussed elsewhere in the eco-innovation literature (e.g. Arundel, Kemp et al. 2007). For the purposes of the present study, I used data derived from innovation surveys. According to Mohen, Mairesse et al.(2006: 1):

“It is only recently that, under the guidelines of the Oslo Manual (OECD 1992), statistical agencies have started conducting surveys directly asking firms about their innovations. In these surveys, firms are asked to give information about the inputs, the outputs and the behavioural and organisational dimensions of their innovative activities. On the input side, we have data on R&D expenditures and on current innovation expenditures besides R&D (such as the acquisition of patents and licenses, product design, trial production, and market analysis). On the output side, we have the declaration of whether an enterprise has introduced a new product or process and the shares of sales due to incrementally, significantly changed, or entirely new products, which can be new to the enterprise or new to the market. As other dimensions of innovative activities, we have indicators of whether R&D is done on a continuous basis and/or in cooperation with others and categorical data on the sources of knowledge, the reasons for innovating, the perceived obstacles to innovation, and the perceived strength of various appropriability mechanisms.”

Arundel, Kemp et al. (2007) identified two sources of survey indicators. The first related to large surveys of thousands of firms collected by the government on a regular basis (the one described by Mohen, Mairesse et al in the quote above). The second related to smaller surveys performed by the academic community limited to a region or industrial sector. Both types of innovation surveys can contain relevant questions to determine in an indirect way relevant factors for environmental innovation. Equally, valuable information regarding environmental benefits or failures from the use and implementation of ‘general’ innovations can also be gained. Most of the work from Rennings, et. al. etc could be located into this second group.

An important quality of innovation surveys is that depending on the content of the questionnaire, it could help to obtain in-depth information of specific environmental innovations and its factors –as long as explicit questions are addressed. However, a limitation of small surveys could be the size of the sample. Official surveys receive

large amounts of responses while the proportion of responses in small-scale surveys could be more reduced and lead to induced errors due to missing data (Arundel, Kemp et al. 2007). More importantly, this data source seems to be extremely useful for the case of advanced developing countries, due to many logistical and empirical considerations (see e.g. Diaz Lopez 2008).

Drivers for eco-innovation (in the South): overview of the proposed method

The content of the sections above presented a comprehensive review of different aspects related to the measurement of eco-innovation strategies and drivers in the context of (developed and) advanced developing countries. Accordingly, the following subsection introduces the general proposed method to approach eco-innovation in a similar pace. Before doing some, box 1 contains referential material that explains the research context where the proposed methodological approach was inspired, built and assessed.

Box 1 A note of the case used as background for the study of eco-innovations

The research supporting this methodological paper aimed to identify drivers for environmental innovation in the chemical industry by analysing a sample of 70 firms in Mexico (as an example of an advanced developing country). The firm was selected as the unit of analysis.

The methods for data collection from quantitative sources were based on the use of data from an innovation survey in a sample of firms (UAMX-CONACYT innovation survey for the chemical sector, UCISC) based on OECD guidelines (OECD and EUROSTAT 1992; 1997; 2005) and the methodology and findings of Villavicencio, Arvanitis et al. (1995). The procedure of data collection lasted one year, from august 2003 to august 2004. During that period of time I performed a field visit to Mexico for completing the different stages of data collection (e.g. qualitative case studies not reported here). In spite that the UCISC was not specifically designed for the analysis of 'eco-innovations', one of its sections was specifically designed to obtain specific information on the influence of different environmental management related aspects on firm's innovativeness. By using a 'tailored' innovation survey based on the guidelines of the 'Oslo manual' that included relevant environmental information this research gained: international comparability, access to micro-data of the innovation dynamics of firms, information related to the influence of environmental factors on innovation activities, the interactions among actors and knowledge flows, and a deep understanding of structural, economic, organisational, managerial and environmental dynamics of participating firms. The UCISC questionnaire was logically structured and had clear definitions, instructions and questions. It was designed in the Spanish language so it was easily administered to each respondent. Its content was divided into seven sections as follows: general description of the firm's production and markets, productive process related issues, technological development and innovation management of the firm, firm's networks and alliances technological development, engineering and R&D management of the firm, human resources & knowledge management and empowerment activities and, environmental management, strategies and best practices of the firm. From all these sections, only the last one is not cited in the Oslo Manual to be included as part of an innovation survey-questionnaire. The data obtained from the innovation survey was used for obtaining the dependent and independent variables for the quantitative analyses (this paper).

In the overall, this empirical approach aims to explain the use of resources, capabilities, competences, behaviour and strategic approach of firms in the sample regarding environmental innovation adoption and development. For doing so, I used quantitative analytical methods in order to perform a statistical analysis of the data collected by the innovation survey.

The analysis of the collected quantitative data was based on the use of multivariate statistical techniques. In particular, the dependent variables (indicators) were built using multiple correspondence analyses (HOMALS) (Greenace 1984; Gifi 1990; SPSS-Inc. 2001). The HOMALS technique is widely used to quantify nominal data by assigning numerical values to each observation in order to create categories. After such categorisation, the use of other statistical techniques that requires numerical data can be used. The aim of this procedure is to describe the relationships between two or more nominal variables in a low-dimensional space. Homogeneity analysis is preferred over standard principal components analysis when linear relationships between the variables may not hold or when variables are measured at a nominal level. This method required the selection of variables (items) from the innovation survey based on theoretical and empirical considerations. Similarly, principal component analyses (PCA) (Kline 1994; Tabachnick and Fidell 2001; Costello and Osborne 2005) of selected items derived from the questionnaire were used as the statistical technique in order to extract (uncorrelated) components to be used as explanatory variables in a linear regression analysis (for significance testing). Principal component analysis (PCA) is a multivariate analytical method applied to single set of variables when the aim is to discover coherent subsets that are relatively independent from one another. Correlated variables in one subset but largely independent of other subset are combined into components. Components are thought to reflect underlying processes created by such correlations among variables. PCA produces linear combinations of observed variables. Such linear combination of variables can be used in other advanced statistical analysis as one approach to handling multi-collinearity in procedures such as multiple-regression.

In simplify, the multivariate statistics techniques provided the elements needed to unveil the explanatory variables and to measure eco-innovation. In such analysis, the consistency, quality and strength of the data collected by the innovation survey is fundamental. In addition to this, an adequate selection of variables and sound use of the statistical techniques is demanded. Finally, it is important to keep in mind that the findings of this research may be sector specific (e.g. in this case for chemicals and petrochemicals). Therefore, the use of the empirical evidence of this study would need to consider these particularities before being tested under different conditions (e.g. in other advanced developing countries).

Some considerations on the use of dependent and independent variables

Before starting with the construction of relevant ‘eco-innovation indicators’, there are some practical and theoretical aspects to consider related to the use of data collected from an innovation survey. Such data had to be carefully interpreted to avoid its misuse. These aspects are briefly described in this methodological paper. However, it is important to mention that innovation surveys deal directly with factors for the development and adoption of ‘general innovations’, and not specifically with factors for ‘environmental innovations’.

It is also important to remember that it is generally accepted that firms’ incentives to engage in ‘general innovation’ activities are normally associated with expectations of profit increase and market share. Furthermore, as suggested by Arundel, Kemp et al (2007) and other authors, environmental innovation may be driven by other factors rather than merely economic and business opportunities as this type of innovation is normally associated with a double externality effect. Finally, the aspect of temporality of innovation surveys should also be considered. This is due to the fact that innovation surveys tend to ‘capture’ the innovativeness of a sample in a particular period of time. Therefore, inferences for other particular conditions should be carefully managed.

The first challenge in dealing with ‘eco-innovation’ indicators imply avoiding the use of the traditional approach of prior studies that defined a single item from their questionnaires or asked firms whether or not they consider themselves as ‘eco-innovative’. Alternatively, the main task consisted in developing an alternative indicator that could reduce the bias and error introduced by the researcher when defining a ‘proxy variable’ from a single item from a questionnaire in order to define whether a firm was eco-innovative or not. For this purpose, the creation of ‘tailored’ classifications was proposed. This classification of firms would be used as an ‘eco-innovation indicator’. These classifications were created in order to identify sectoral characteristics and be able to create ‘natural’ groups of firms. The creation of such classifications followed the use of multivariate statistical techniques (HOMALS and PCA). As a result of the creation of these classifications, albeit is possible to distinguish between environmental innovation ‘leaders’ and ‘others’.

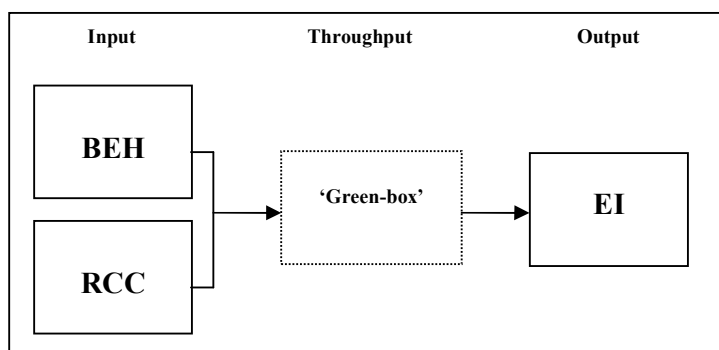
A second aspect to consider is the nature of the independent variables to be used to explain the drivers for environmental innovations of firms in the sample. In the present case, the ‘tailored’ classifications proved their utility as an input and output ‘eco-innovation indicator’. The proposed ‘eco-innovation indicators’ are therefore based on the strategic behaviour of firms towards environmental innovation (input indicator), the set of resources, capabilities & competences (input indicator), and the strategic approach of firms regarding environmental innovations (output indicator).¹³ These indicators constituted the first explanatory level of the empirical model, as observed in figure 3. Finally, it is important to clarify that although the proposed indicators are built using quantitative techniques (multivariate statistics), they are qualitative in nature. This is because they reflect qualities and firm characteristics and do not quantify the number of ‘eco-innovations’ that firms in the sample may have developed or adopted. I believe the proposed approach constitutes a viable alternative for other researchers when analysing ‘eco-innovative firms’ and ‘eco-innovations’ from data taken from innovation surveys from developing countries.

I propose the creation of eco-innovation indicators that would help to understand the drivers of firm’s ‘eco-innovation’ in the context of advanced developing countries. To date, some of the ‘eco-innovation indicators’ used in prior studies have been of a quantitative nature (see table 2). These indicators have been used to measure either inputs (i.e. using patents and R&D data) or outputs of eco-innovations (i.e. number of eco-innovations). However, there are clear limitations on the use of such approach (e.g. mislead definition of eco-innovative firms).

The proposed alternative quantitative approach is qualitative in nature: the proposed indicators aim to show different ‘qualities’ explaining on-going characteristics of firms with different levels of ‘eco-innovativeness’. Consequently, each variable (item) is allocated exclusively into one of these three groups (illustrated in figures 2.2 - 2.4). This is done according to their main orientation or its main contribution to different aspects of the firm’s strategy. Moreover, these indicators also serve as a way to classify firms according to their level of eco-innovativeness.

¹³ See the classification of ‘innovation indicators’ adapted to ‘possible eco-innovation indicators’ presented in table 2.

Figure 1 Nature of indicators for measuring eco-innovation drivers



Source: modified from Rosenberg (1982) and Meyer-Kremer (1984)

Below I describe some of the considerations for the creation of the different groups of variables used to build each indicator, illustrated in figure 1:

Input indicators: For the first indicator (BEH in figures 1-3), this category would need to show a contribution to the manager's perception on drivers for eco-innovation and their own disposition to eco-innovate. If this perception was positive, the managers could decide to favour an 'eco-innovative' strategic behaviour of the firm. In this sense, those internal and external influences/obstacles of the firm could be used and interpreted by managers as the starting point of their strategy towards innovation and the environment. Therefore, variables used to create this input indicator would need to be related to firm's *behavioural* variables somehow associated to the eco-innovation process. For the second indicator (RCC in figures 1-3), this category would need to show a parallel process of the firm that, once the managers would have decided to adopt an initial strategic approach towards eco-innovation, would be combined with a strategic use of the firm's resources, abilities, capabilities or competences in order to be more likely to 'eco-innovate'. The dynamism of technological and organisational capabilities would imply their gradual accumulation. Eventually, the firm would be able to combine them with the firm's resources and obtain results from this 'eco-innovative' process. As a result, variables selected to create this input indicator would be related to the *resources, capabilities and competences* of the firm, already developed or in the process of being developed.

Output indicators: The third indicator (EI in figures 1-3) would need to show results and consequences of a given combination of strategic inputs and the deployed resources,

capabilities, etc in order to achieve an ‘eco-innovative output’. In this sense, the results of the use of eco-innovation strategies (i.e. eco-efficiency & by-product synergy best practices), the results of the implementation of a given production approach (i.e. pollution prevention) and the results of the use of advanced ‘eco-innovative capabilities or competences (i.e. environmental R&D approaches, such as the design for the environment) would imply that some results have been already achieved by the firm or they are in an advanced stage.¹⁴

Building eco-innovation indicators (building taxonomies to be used as dependent variables)

The procedure to build ‘eco-innovation indicators’ can be expressed as follows: definition of category classifications (labels), selection of variables (items) that would be included in each category, reliability analysis of selected variables, homogeneity analysis of variables in order to create the indicators (HOMALS), and finally the analysis of the descriptive statistics and interpretation of each tailored classification.

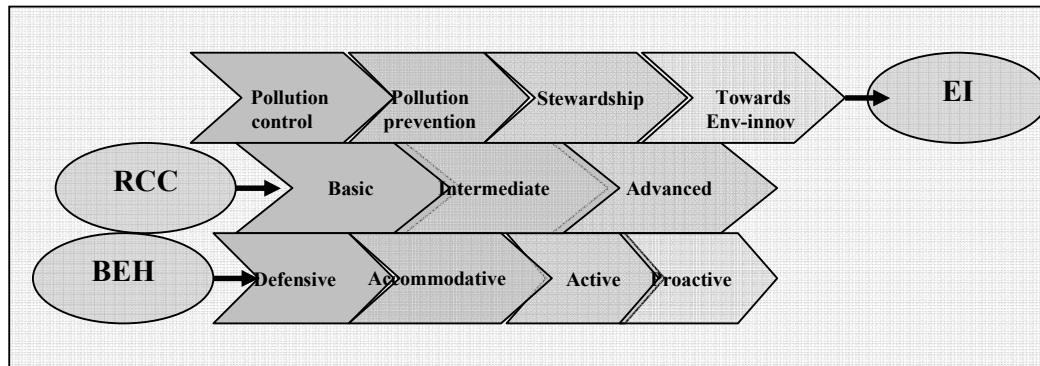
1) Definition of category classifications

The idea behind a classification of firms is that different levels of ‘eco-innovation’ strategies can be assessed. In addition to this, different approaches to eco-innovation indicators related to differentiated strategies can also be tested.¹⁵ Following a reduced form of Montalvo’s (2002: 49) selection of variables towards clean production development (willingness to innovate in cleaner technologies), I created the labels for three classifications of firms, namely environmental innovator; resources, capabilities and competences; and, strategic behaviour of firms (EI, RCC and BEH). Figure 2 shows each of these general classifications of firms.

¹⁴ It is important to bear in mind that I consider any ‘eco-innovative’ effort in the context of developing countries. Therefore, the novelty degree of firm’s ‘eco-innovativeness’ would be normally expected into the ‘new to the firm’ and ‘new to the country’ categories. This is also why I decided to label the last category of this indicator as ‘towards environmental innovation’ and not ‘environmental innovation’ or ‘sustainable innovation’ as the adjective ‘towards’ gives a sense of progress and in process to be achieved.

¹⁵ In this way, the information generated could be used to, eventually, favour the creation of differentiated policies and strategies that could be proposed for firms in less advanced stages of ‘eco-innovativeness’. However, it is not the purpose of my thesis to provide policy recommendations.

Figure 2 EI, RCC and BEH classification of firms according to their main strategic approach



Source: Diaz Lopez (2008)

A summarised description of the studies that contribute to modelling each classification is presented below. It is important to note that the authors used to build each classification are not merely for ‘labelling’ purposes. The empirical and theoretical contributions from these studies guide the selection of variables to be used as an input for building the indicator in the multivariate statistical method (see below).

Environmental innovators (EI): The categories for this indicator are based on contributions of the resource-based theory of the firm applied to the environment. In particular, the EI classification was based on the typologies suggested by the influential work of Hart (1995). The extended contributions of Russo and Fouts (1997), Sharma and Vredenburg (1998), Christmann (2000) and Buysse and Verbeke (2003) on the same grounds (within the field of corporate environmental responsiveness) are also considered. These later authors extended Hart’s ideas based on seminal works of corporate social performance from Carroll (1979) and Wartick and Cochrane (1985) – among some other authors. Finally, the works from Hart, Russo and Fouts & Christmann related the environmental best practices (or strategies) of the firm to the development of capabilities or resources to gain competitive advantage implicitly considering the importance of the learning process at the within the firm. In addition, it is important to note the contribution of two more influential perspectives of strategic management: corporate responsibility (related to orientation or values of the firm) and corporate responsiveness (related to the action phase of management and processes of the firm). Finally, the contributions from Hunt and Auster (1990), Azzone and Bertele (1994), Roome (1994) and Hass (1996), Aragon-Correa and Rubio-Lopez (2007) on the field of corporate environmental strategy are also considered for this classification.

In the end, this classification included an aggregate of the previous studies in the sense of: *pollution control, pollution prevention, stewardship and towards environmental innovation.*

Resources, capabilities and competences for eco-innovation (RCC): This classification was based on the contributions of the resource-view of the firms applied to the environment (Hart 1995) and the dynamic capabilities of the firm. For this indicator in particular I used the contributions from Teece, Pisano et al (1994; 1997) on dynamic capabilities' of the firm, the concept of core competences from Prahalad and Hamel (1990) and core capabilities and rigidities of Leonard-Barton (1992) –grounded in knowledge and learning processes. Teece, Pisano, and Shuen (1997) on competences and strategic management are also useful. Finally, the contributions from Tidd, Bessant et al. (2001) on innovation management of the firm are also important. The environmental complement was given by the seminal work from Hart (1995). More importantly, Lall's (1992) matrix of firm-level technological capabilities according to their degree of technological complexity was useful for shaping the proposed classification (*basic, intermediate, advanced*). This matrix is shaped particularly for the context of firms in developing countries.¹⁶

Behaviour of firms regarding eco-innovation (BEH): It follows Carrol's (1979) original classification of firms. In particular, *defensive* firms would look to do the necessary for environmental compliance, despite a small tendency to be a laggard; *accommodative* would be slightly progressive firms that have a discrete attitude and results regarding environmental innovation; *active* firms would be progressive firms that take actions towards being industry leaders. However, depending on what is convenient for them to achieve is their "strategic approach" or "final performance". Finally, *proactive* firms would be those forerunner firms committed to the adoption and achievement of the principles of sustainable development and using environmental innovation as part of their business strategy. These types of firms would not only look to be industry leaders

¹⁶ Basically, Lall's (1992) matrix of firm-level technological capabilities highlights three degrees of technological complexity: basic, intermediate or advanced. The selected categories were defined by their level of formality and the purpose they serve for the firm's technological efforts. In Lall's classification basic capabilities can be accumulated through simple production activity routines (e.g. learning by doing or experience-based mechanisms). Intermediate capabilities can be constructed upon adaptive duplicative activities, which are somehow purposely carried out. Finally, advanced capabilities can be developed through research-based activities and imply higher risks and uncertainty.

but they would also be fully recognised by their community, personnel and stakeholders.

2) Identification of variables to be included in each category

The second step for the construction of the classification of firms required the identification of items to be included as fundamental dependent variables. The pre-selection included 17 questions from the UCISC's questionnaire that assessed aspects on the influence of environmental factors on firm's innovative performance. Once the main descriptive statistics of the sample are obtained and analysed¹⁷, only 13 of these questions (set of items) are finally selected to build the three classifications of firms. Evidently, a careful selection and use of each subset of variables was performed in order to create each classification. The previous was done due the fact that they could not be based on the same variables in order to explain one by the other. The identification and allocation of these variables into different subgroups according to their main orientation (resources, capabilities & competences, behaviour or being an eco-innovator) and nature (input or output) is described in table 3.

The selected items (questions from the questionnaire) used to build each indicator required the performance of reliability analysis in order to ensure its applicability. The different subgroups of variables (questions) used to build each classification and its reliability should be reliable according to the Cronbach- α (C- α , for multiple scales) and Kuder-Richardson-20 (KR20, for dichotomous scales) tests.¹⁸

3) Application of the HOMALS method and descriptive statistics

The next step implies the use of the HOMALS method (see brief definition in box 1) (Greenace 1984; Gifi 1990; SPSS-Inc. 2001). The HOMALS method is based on the average response patterns of the inputted data and produces scores that can be easily assigned to a pre-defined category. In order to identify and create each group, a graphical inspection of the object scores graph was performed.

The results from an HOMALS analysis can suggest the presence of clearly defined patterns of the firms that integrated each category. As a result of this, the different

¹⁷ Available from the author upon request; alternatively, see Diaz Lopez, 2008.

¹⁸ The alpha/KR20 coefficients values for all the subgroups of variables integrating the EI, RCC and BEH indicators should be all high. A value of C- α /KR20 >0.6 represent high reliability of the scales used for each subgroup.

characteristic elements of each category are identified and analysed. From these results it is possible to identify the number of cases in each category. Firms with similar characteristics are gathered together. Alternatively, firms with un-related patterns can be discriminated. This method proved to be useful for the assessment of the different proposed categories for approaching eco-innovation: the strategic behaviour of firms, the resources, capabilities and competences of firms, and the eco-innovation approach of firms.

As a starting point for the creation of each indicator, several trials should be performed in an exploratory way –in order to ensure repeatability, stability and consistency of the results. Such an exploratory analysis could be performed in the SPSS programme or similar. The HOMALS method using SPSS[®] has the limitation of only accepting positive data as otherwise it considers them as ‘system missing’(SPSS-Inc. 2001). Therefore, all the variables to be introduced from a [no=0, yes=1] format should be recoded into a [1=no, 2=yes] format. In this way I would ensure the software would not consider them as ‘missing values’.

After introducing the right items, the HOMALS procedure in SPSS[®] is relatively simple to perform. However, the critical aspect of this method is the interpretation of the results since this is based on graphical techniques. The HOMALS output produces both graphic and numerical solutions showing such relation patterns between items.¹⁹ The use of a variation of a visual graphical technique for multivariate data analysis helps to the allocation of each individual case or object (firm) into each particular group (Everitt 1978; Meulman and Heiser 2001)²⁰. With this method it is possible to identify the characteristics of each particular firm in the general ‘picture’ of each classification (see Diaz Lopez 2008 for empirical examples of the application of this statistical method).

The last step includes basic statistical analysis of the recently created indicators (classification of firms), such as cross-tabulations and descriptive statistics. In this way,

¹⁹ By default, HOMALS using the SPSS[®] software analysed all of the introduced items for all of the cases (observations) and computed two solutions (dimensions). It then produced the frequencies for each variable (descriptive statistics), the eigenvalues for each dimension (two default dimensions), discrimination measures, category quantifications and finally the object scores for the data (values and plots).

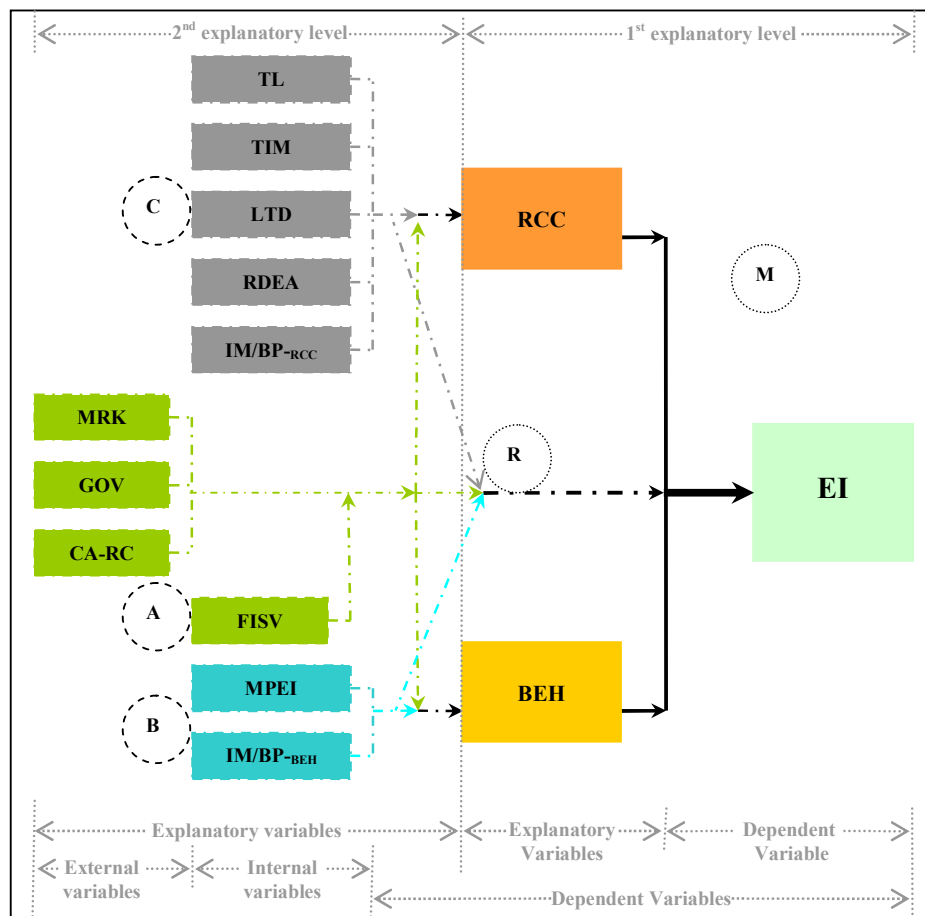
²⁰ Basically, the HOMALS procedure displayed the rows and columns of a data matrix (or, two-way contingency table) as points in dual low-dimensional vector spaces that need to be interpreted. These (x,y) coordinates or *object scores* were presented in both, a matrix form and *i*-dimensional display (graph) (Greenace, 1984). The use of one, two or three dimensions-solution is a standard procedure in HOMALS analysis (Meulman and Heiser, 2001), although SPSS[®] is automatically set to two dimensions. The obtained graph was presented in terms of a label for better identification.

interpretations of the sample can be drawn according to each level. More importantly, this method enables the identification of particular firms within each level.

Proposed empirical model for eco-innovation drivers (independent variables)

Following the construction of dependent variables was the selection of independent variables for empirical testing. The explanatory variables are used in an advanced statistical analysis in order to determine whether or not they are significant in regard to the dependent variables. The (expected) causal relationship between the selected groups of variables is presented in figure 3 followed by an explanation of the two analytical levels.

Figure 3 Empirical model for eco-innovation measurement and eco-innovation drivers: dependent variables (classifications) and corresponding groups of explanatory variables



Notes: (CIRCLE M) EI= strategic approach to environmental innovation (outcome); BEH= behavioural factors for environmental innovation; RCC= resources, capabilities and competences for environmental innovation. (CIRCLE A) FISV= firm's internal structural variables (size, ownership, age, technological maturity, etc); MRK = market influence (EU and NAFTA); GOV= government's support for technological development; CA-RC= membership to the chemical association and Responsible Care implementation. (CIRCLE B) MPEI= managers perception and willingness for environmental innovation; IM/BP-BEH= integrated management system's best practices (specific for BEH). (CIRCLE C) TL= technological learning activities of the firm (as a proxy to absorptive capacity); TIM= technology and innovation management of the firm; LTD= learning and collaboration networks of the firm for technological development; RDEA= R&D and engineering activities/capabilities of the firm; IM/BP-RCC= integrated management system's best practices (specific for RCC). (CIRCLE R)= reduced form for the analysis (all the explanatory variables vs. EI).

First explanatory level of the empirical model

The main theoretical contribution in this level of analysis was provided by Montalvo's (2002: 189), who suggested that only if three factors are combined in the right proportion –manager's attitude, social pressures and technological and organisational capabilities to innovate, firm's willingness to develop environmental innovations could be sparked.²¹ Following a reduced form of Montalvo's (2002: 49) selection of variables towards clean production development (willingness to innovate in cleaner technologies), I created the labels for the three classifications of firms (EI, RCC and BEH). These variables constituted the *first explanatory level* and it is represented in the **circle M** (on the right hand side) of figure 3.

These classifications (indicators) are created according to the firm's use of internal and external environmental innovation-related factors (EI/ pollution control, pollution prevention, stewardship, towards environmental innovation), resources, capabilities & competences -related factors (RCC/ basic, intermediate, advanced) and behavioural-related factors (BEH/ defensive, accommodative, active, and proactive).²²

Earlier in this paper I described the theoretical contributions for the creation of the different levels and the specific content for each subgroup of variables for this *first explanatory level* (see figure 2 and preceding discussion). For the same purpose it is also advisable to use information derived from descriptive statistics from selected items

²¹ Note that in my empirical model I did not include the "regulation" or "social pressure" variable. The CI is highly regulated, so I assumed that environmental compliance in chemicals (as a case of pollution-intensive industry) was positively driving industrial innovation, as suggested by Barton, Jenkins et. al (2006). I also supported this assumption based on the following reasons: (1) The chemical industry has a long tradition on developing environmentally friendly technologies [Clow and Clow, 1958; Eder and Sotoudeh, 2000]. (2) The toxic nature of chemicals manufacturing has made this industry to be severely regulated and under public scrutiny throughout the years. As a consequence of environmental incidents and regulations, the chemical industry has developed a cautionary manufacturing approach that supposes the use of pollution control and pollution prevention measures [Eder, and Sotoudeh, 2000; OECD, 2000]. (3) The chemical industry is considered one of the most advanced cases of corporate self-regulation. In spite of its limitations, the Responsible Care ® programme is considered as a promising model for voluntary initiatives for environmental responsibility [King and Lenox, 2000; Acutt and Medina, 2004]. (4) In environmental management, many tools and initiatives had their origins/had been proven in this industry. Examples of this are the pollution prevention programme from 3M, the 4Rs programme from DuPont, the cases of by-product synergy and industrial ecology (Chaparral Steel, Kalundborg, Tampico-Altamira Case), the green chemistry programme (Bristol Meyers), the zero emissions initiative (Ebara, Tokio University), etc. (5) In spite of mixed evidence and lack of agreement on this topic, relatively recent studies on the effect of regulation on innovation in this industry [Maglia and Rapisarda, 1999; Delgado, Fleischer, et al, 2000; Mahdi, Nightingale, et. al, 2002] have posited that the chemical industry is a case where environmental regulation have had a modulating effect on innovation, and the most successful firms in this industry tend to be highly innovative. New regulations may have an initial shocking effect that temporarily inhibits innovation. Several studies have supported the Porter and van der Linde (1995) hypothesis that compliance with strict environmental regulations in combination with proactive environmental strategies have lead to the adoption of eco-innovation solutions [Schmidheiny, 1992; Cleff and Rennings, 1999; Spinardi and Williams, 2001; Holliday, Schmidheiny, et al 2002; Rennings and Zwick, 2003; Diaz-Lopez, 2003].

²² It is important to note that these groups are merely indicative and it was also based on the names given to the different sections of the innovation survey. This is due the fact that the questionnaire was not entirely designed to measure environmental innovation, as explained in the methodological chapter. In this way, a distinction of each variable into a group of reference facilitated its interpretation and possible relationship with other groups of variables in the HOMALS and PCA methods. It also facilitated the clustering of variables in exploratory PCA. Most of the items included in each subgroup of variables were identified, added and standardised (converted to positive values via recoding) directly from specific questions from the questionnaire. However, a few more complex ones were constructed using the answers of each case to several questions.

from the sample (not discussed here), reports and transcripts from the case studies and interviews with managers and other experts in the field. Statistical tests for significance and correlation analyses also help to validate if individual variables should be included. The combination of different information sources helps to identify and classify the selected empirical variables that will be finally used to build each indicator.

In simplify, at the first explanatory level, RCC and BEH would be the explanatory variables for EI (circle M in figure 3). This (research) question was in an exploratory way by using statistical techniques and information derived from case studies (not reported here). The main proposition for this *first explanatory level* (based on the idea that environmental innovation strategies would be explained by the set of resources, capabilities and competences and a positive behaviour towards its development and/or adoption), was based on the following assumptions: Firstly, I assumed that all firms in the sample have developed a minimal degree of capabilities & competences. In addition to this, I assumed they possess a basic set of resources for environmental innovation. This is partly because of the technological maturity of the sector and the engineering expertise of firms.²³ Secondly, I assumed that the sample did not include a significant number of ‘non-complier’ firms: Lastly, I assumed that at least the stage of ‘pollution control’ was present in firms in the sample. Therefore, a minimal degree of positive strategic approach towards ‘eco-innovation’ was expected from firms in the sample. Please note that such assumptions are only valid depending on the nature of the sector under analysis (e.g. chemical and petrochemical industry). Otherwise, variables related to regulatory compliance should be included.²⁴

²³ In the context of the studied case (Diaz Lopez 2008), the chemical sector has a long history in environmental compliance due its historical social and legal pressures. As suggested in the introduction, this sector has always been the focus of attention due the risky nature of its activities so it has needed to ensure certain level of compliance with environmental legislation and standards (Hoffman, 1999). Firms would decide to comply with environmental legislation due government enforcement or due to business ethics (King and Lennox, 2000). In addition to this, regulators have often recognised that the Responsible Care programme has helped to foster attitudes for supporting legal compliance and facilitate their response to new regulations (Tapper, 1997). In this sense all the firms in the sample would have, in principle, the potential to perform positively in regards to its environmental behaviour. Several aspects covered in the innovation survey questionnaire were considered as ‘delicate’ and ‘commercially sensitive’ by some firm managers originally invited to participate to answer to it. As a consequence, some of these firms were reluctant to participate –members and not members of the chemical association. Therefore, I assumed that participating firms that answered the innovation questionnaire were certain about their own legal compliance. Therefore, respondent firms could be regarded as compliers firms.

²⁴ For the studies case (Diaz Lopez 2008), firms belonging to the Mexican chemical association and implementing RC are meant to ensure legal compliance with (Mexican) environmental legislation. Legal compliance with ‘pollution control’ would imply that firms would have a minimal level of production, engineering and innovative capabilities that could be used for that purpose, as suggested by the case of the Venezuela chemical industry (Mercado and Palma, 2001). The nature of the sector and the expertise of the Chemical Industry with the management of programmes like Responsible Care are notable and frequently recognised by regulators, media and environmental groups (Tapper, 1997). It would be expected that chemical association members would have implemented RC. Unfortunately in practice this condition has not been fully satisfied for the Mexican case as there may be different levels of implementation, as suggested by Medina-Ross (2002). Regardless of the degree of implementation of the RC programme, all the technical and organisational information of the programme is available to all the members of the Chemical Association, so ideally all ANIQ firms would have tools and information for ensuring a basic level of compliance

Second explanatory level of the empirical model

Following the left hand side of the figure 3, the *second explanatory level* refers to the set of independent variables to be used for empirical testing. A generic research question at this level of analysis could be expressed as follows: ***What are the capabilities-related and behaviour-related drivers for the development and use of environmental innovation strategies in firms?***

As it is described earlier, the selected statistical techniques are principal component analysis (PCA) followed by regression analysis. This empirical testing had two forms of analysis as follows:

1. The first analytical form implies testing the set of corresponding groups of variables against RCC and BEH. Variables of the **circles A and B** in figure 3 are empirically tested against BEH. In order to do so, PCA of the variables should be performed in order to extract the main uncorrelated components (from the items from the innovation survey) –so they could be used in a further linear regression analysis. Following, those extracted factors are tested for significance in a linear regression analysis. Correspondingly, the extracted components from the variables in the **circles A and C** would be similarly tested against RCC.
2. The second analytical form is a reduced form to measure the EI indicator. This means that EI would be directly tested against those variables aiming to explain RCC and BEH from the previous analytical form. In summary, circles A, B and C should be tested against EI using PCA and regression analysis. The **circle R** in figure 3 illustrates this relationship. As EI would be explained by BEH and RCC in the first explanatory level, it would be expected that the individual variables explaining BEH and RCC would also explain EI.

Identification of potential explanatory variables for the second level of analysis:

As noted in the introduction, it is difficult to identify *a priori* a single theoretical perspective to understand environmental innovation strategies and drivers at the firm level when compared to the industry level. The set of potential explanatory variables in different studies is large. Many of the variables used in different studies have been derived from areas such as strategic management, innovation management and environmental management variables. Control or marker variables have traditionally

included mostly the use of firm structural and firm performance variables (Mazzanti and Zoboli 2006).

Traditionally, innovation studies have highlighted what internal and external factors impact the techno-organisational dynamics of the firm. Traditional variables for assessing the drivers of innovation have included: size of the firm, technological capabilities, technological learning activities, elements from innovation management systems, R&D expenditures or budget, skill intensity, absorptive capacity, technology level, technological opportunity, innovative effort, market concentration, sector demand, R&D financed by government, appropriability of innovations, entry or exit barriers, exports, degree of diversification, internationalisation, government support, present and past levels of R&D, spillovers, geographical opportunities, investment rates, number of R&D staff/total staff, external linkages, patents, sectoral influence, number of innovations introduced, etc (Nieto and Quevedo 2005).

Based on the content of figure 2 and the evidence on eco-innovation drivers suggested by the studies presented in table 1, three main groups of internal and external potential explanatory variables can be identified. I must note that the allocation of variables to each group must not be by any means the outcome of a random process. It should be the product of a long and deep process of analysis on the potential influence of each variable on the proposed indicator. The influence of each variable must be assessed based on prior empirical evidence from the literature review, exploratory interviews, academic discussions, additional literature review (e.g. during the fieldwork stage), inspection of historical events related to those variables in the manufacturing activities (of the selected industry), analysis of results and discussion of prior environmental and innovation empirical analyses of the selected industry in a particular advanced developing countries, and the participation in forums, seminars and events of this industry.

In order to have a clear image of the potential use of each variable, it is advisable the creation of matrices with the two main groups of explanatory variables (BEH, and RCC) of EI (in the first level of analysis), and to allocate a number of potential explanatory variables into each group. The following step would imply to grant a number of theoretical and empirical considerations to each variable. The first evident

group to be created could be the one related to the marker variables, or variables with known properties. The amount of empirical research on innovation measurement based on the system of innovations approach is considerable, and there are variables with well known properties that could be easily allocated to the study of eco-innovations (i.e. size of the firm, ownership, skill intensity, corporate support, etc). For the case of the RCC group, the process should be greatly associated to the ‘technical nature’ of each variable. In addition to this, the contribution of the Oslo Manual for the identification of to be measured for innovation activities of firms also helps to create this group. In contrast, the BEH group suggests including variables with a ‘voluntary component’. Once the potential contribution to each group from each variable is analysed, it is recommended proceeding to triangulate this first assumption with the rest of the aspects described in the previous paragraph until finally reaching the definitive groups.

2) Selection of variables in the second explanatory level

Firm’s structural Variables (control variables): The studies presented in the table 1 use variables with known properties that could influence environmental innovation development/adoption at the level of the firm. Some of those variables can be used and interpreted as ‘marker variables’ (as suggested by the PCA technique). Empirical studies based on developing countries’ industrial development and innovation have extensively used variables related to internal factors of the firm in order to explain the construction on technological capabilities their effects on innovation. Additionally, an extensive set of literature of technological capabilities development in the context of developing countries has also suggested similar use of these ‘general’ variables (e.g. Katz 1987; Lall 1992; Romijn 1997).

This group of potential explanatory variables may include the following: size of the firm, ownership, corporate support (group membership), geographical location, technology level, production mode (production flexibility), level of process automation, age of the firm, skill intensity (of managers to workers and skilled to unskilled workers), influence of export markets, membership to an industrial association, implementation of voluntary industry programmes (e.g. Responsible Care®), and government support (participation in government’s support programmes for technological activities). These are variables with known properties that could influence

environmental innovation development/ adoption; these at the level of the firm (see table 4).

‘Behavioural’ subgroup of variables towards the development/ adoption of environmental innovations: Different eco-innovation studies have proposed explanatory variables that could be interpreted to have a ‘behavioural’ motivation or driver due the manager’s perception of the environmental performance/ management/ strategy/ innovation of the firm. Montalvo’s (2002) study was based on a behavioural theory adapted to the understanding of the role of individuals in decision making and their dispositional motivations leading them to develop/adopt cleaner technologies. It contributed to look at individuals (or firms, groups and organisations) as social actors seeking for changes and developing innovative activities towards clean production. It assumed that manager’s positive or negative expectations and outcomes from the development of clean technologies was a condition for innovative behaviour.²⁵ Environmental management literature has also been concerned with the firm’s approach towards a positive environmental performance. The role of managers and leaders for environmental preferences has been a recurrent topic in this field and provided important theoretical inputs to be considered in this group of variables (e.g. Cordano and Frieze 2000; Egri and Herman 2000; Sharma 2000).

This group included two main sub-groups of variables: those variables related to the manager’s attitude and perception of environmental innovation contribution to the firm competitiveness (MPEI); and the use of (integrated) environmental and quality management tools and best practices (IM/BP_{BEH}) (see table 5). The first sub-group,

²⁵ Montalvo’s understanding of the ‘behavioural’ or ‘attitudinal’ variables was defined as: “*the degree to which the firm’s managers expect positive or negative outcomes from the performance of such behaviour*” (p. 49). He defined as ‘behavioural’ those variables that were the result of those manager’s ‘beliefs’ or ‘relevant information’ in relationship with the adoption/ adoption of cleaner technologies. Such ‘beliefs’ would change the ‘strategic approach’ of the attitude of managers regarding ‘eco-innovation’ and would include: cost reductions, cycle investment timing, economic opportunities, anticipation of regulatory changes, improvement of value product and environmental performance, outcomes from environmental protection, etc. In contrast, I understood the ‘BEH’ variables as related to inputs for the manager’s perception of the (eco) innovative process and internal and external factors affecting it. I assumed that firms already were engaged into activities that could be potentially used for eco-innovation purposes (i.e. environmental management systems). Therefore, depending on each manager’s perception of such factors, they could define a strategy related to develop/use those capabilities/competences / resources regarding eco-innovation in a further step of the eco-innovation process (i.e. RCC or EI). It seemed to be a contradiction for my research to have used Montalvo’s notion of behavioural domains as for him they clearly reflected a ‘strategic approach’. However, this was not merely a matter of semantic but of the use of different theoretical approaches and different concepts. The ‘theory of planned behaviour’ as used by Montalvo emphasised the possibility of influencing behaviour of managers in order to feel motivated to develop ‘eco-innovations’. Alternatively, my use of the eco-innovation literature embodied in the ‘national systems of innovation’ approach was in relationship with the understanding of ‘eco-innovation drivers’ as a first stage of any strategic approach of the firms, given its current situation. Therefore, I understood ‘behaviour’ in a closer sense to the literature from ‘strategic environmental management and performance’. Clearly, Montalvo’s research dealt with eco-innovation governance (for policy making) and the understanding of general factors for ‘eco-innovation’ at the firm level. Meanwhile, my research was located within the ‘greening of business’ literature for ‘green strategic management’, it aimed to create valuable information for a shift from ‘reactive’ to ‘proactive’ strategies for eco-innovation at the level of the firm.

MPEI, was related to the following variables: managers' perception on sources of firm's competitiveness, on the influence of free trade agreements, on the contribution of pollution prevention, on positive and negative aspects for innovation, and on innovation barriers. The second sub-group, IM/BP_{BEH}, was related to the following variables: the use of environmental performance indicators, environmental training, use of elements from a design for the environment approach; the use of by-product synergy and eco-efficiency best practices, environmental impact evaluation for new product development and the use of quality management systems and tools. These are variables with unknown properties could potentially influence the use of resources, and the development/assimilation of capabilities and competences for environmental innovation development/ adoption; these at the level of the firm.

'Resources, capabilities & competences' subgroup of variables: Several empirical quantitative and qualitative studies based on developing countries' industrial development have used factors such as technological strategy, absorptive capacity, technology level and effort, learning mechanisms, strategic alliances, etc in order to explain the construction of technological capabilities and their effects on innovation. In addition to this, literature from the resource-view of the firm applied to environmental strategic management and performance has also used factors related to the use of the resources and development of capabilities for better environmental performance. The studies from the environmental innovation literature (presented in table 1) have included factors related to the development of firm's capabilities and competences to innovate with positive environmental effects. The explanatory variables presented in table 1 could be easily allocated into the areas of: innovation management, technology management, R&D management, engineering activities of the firm, and patent activities of the firm, learning capabilities, and the use of strategic alliances and networking for technological development.

The sub-groups of variables aiming to explain the resources, capabilities and competences of the firm in the research are integrated by: technology and innovation management of the firm (TIM); firm's linkages for technology development (FLT_D); firm's engineering and R&D activities and infrastructure (RDEA); and the use of environmental and quality management tools and best practices (IM/BP_{RCC}) (see table 6). I used these variables to explain specific technological capabilities, core

competences and resources used for environmental innovation. Regarding the TIM subgroup, the literature of innovation management provides a rich set of empirical evidence on this set of variables, and it included the different components of the process of management of innovations at the level of the firm. In particular: technological learning activities, sources of technological information, technology and innovation strategy of the firm, process technology sourcing, product innovation sourcing, the type of innovation introduced, and, intellectual property strategies. The FL included: firm's technological networks for new product development, process design, and technological assistance and formal strategic alliances for technological development. Regarding the RDEA sub-group, the amount of engineering and R&D personnel and its evolution, and the presence of in-house engineering and R&D units are the allocated variables. Finally, the subgroup of IM/BP_{RCC} was formed by: environmental audits, use of a pollution prevention, design for the environment, by-product synergy and eco-efficiency approaches in the business strategy and best practices derived from them; use of quality management systems, environmental training at the different levels of the organisation, and empowerment of employees.

Reduced form for 'Environmental innovators': The second analytical form would be a reduced form to measure the EI indicator. This means that EI would be directly tested against those variables aiming to explain RCC and BEH from the previous analytical form. In summary, the variables contained in circles A, B and C would also explain EI. Therefore, the firm's strategic output for environmental innovation (EI) would be explained by all the different variables already explaining BEH and RCC: the manager's attitude and perception of environmental innovation (MPEI); and the use of (integrated) environmental and quality management tools and best practices (IM/BP_{BEH/RCC}), technology and innovation management of the firm (TIM), firm's linkages for technology development (FL), and firm's R&D & engineering activities and infrastructure (RDEA). Summarising, the **EI group** of variables was an aggregate subgroup of variables from BEH and RCC (see table 7).

An important methodological clarification

It is important to note that some of the data derived from the questionnaire used as explanatory variables is also used to build the classifications (see tables 2-7). Evidently, a careful use of each of these items included in each subgroup of variables had to be

ensured, as they could not be based on the same variables in order to explain one by the other. Therefore, some of the variables from BEH and RCC should be excluded or modified when tested against EI, since it must be avoided using the same items that were used to build the indicator.²⁶

Verifying the significance of dependent and independent variables (empirical levels)

In order to validate the findings of the HOMALS analyses, cross-tabulation analyses can be performed. In particular, cross-tabulation analyses show patterns of association between two pair of variables, namely EI and RCC and EI and BEH. In addition to this, Pearson and Chi-square coefficients should be obtained with satisfactory values. The cross-tabulation analyses provide valid results for linear regression analysis (related to the EI indicator as dependent variable and RCC and BEH as independent variables). In a preliminary way, the results of such analyses can provide statistical evidence to substantiate or refute the main research question. These analyses correspond to the first explanatory level of the empirical model. Finally, regression analyses between the indicators created by the HOMALS analytical method, and the explanatory components unveiled by the PCA analytical method should be performed. In particular, the components revealed by the PCA analyses should be tested as explanatory variables of BEH, RCC and EI in regression analysis, depending of the corresponding group they belonged. The latter represents the second explanatory level of the empirical model, as described earlier.

Conclusions: methodological contributions to the eco-innovation field

At the outset of this paper I stated that one of the main methodological contributions would be related to an alternative method for measuring different levels of eco-innovation in firms. One of the main criticisms I made to prior studies measuring eco-innovation was the way they interpreted what an eco-innovative firm was. Following the tradition of innovation studies and the content of the Oslo Manual, the new generation of eco-innovation studies (table 1) provide many important theoretical and

²⁶ For example, EI would include all the individual variables of TIM and FL compared to RCC (see tables 6 and 7). The group of RDEA would also be basically the same used for RCC, but would include 5 items from the variable IRSD (infrastructure to support environmental innovation activities). The group of $IMBP_{EI}$ would use only 3 items from $BPEE_{EI}$ instead of 9 used in BEH and 6 used in RCC (see tables 5-7). This is because 6 items from BPEE were included in the HOMALS procedure to build the EI classification. Finally, the group of $MPEI_{EI}$ would add some items to the variable MPID to include a total of 20 items originally included in the questionnaire. This is due all the 20 items from MPID could now be tested against EI. This is due the fact that 6 items could not be tested earlier against BEH since they were used in the HOMALS procedure to build that classification. It would not be included either the MPPPC variable, since it was included to build the EI classification (see tables 5.-7). Finally, regarding to the average reliability value of these subgroups of variables, they must be satisfactory.

practical aspects on the use of eco-innovation indicators. However, most of these studies chose to define ex-ante what they would consider as an eco-innovative firm by posing a single question in a survey questionnaire. This method would inevitably introduce trivial choices for the identification of eco-innovative firms.

A tailored method, like the one proposed in this work, refers to the use of accurate eco-innovation indicators that truly reflects the nature of the eco-innovation process, and its double externality effect. Moreover, the main challenge is to design eco-innovation indicators that reduce the bias induced by the criteria of the researcher, without adding complexity to the way eco-innovation is measured. In order to do so, the use of strong data, sampling adequacy and sound methodology is a key ingredient. In the process of verifying the strength of the data used for measuring eco-innovation, especial care must be taken to the reliability analyses of the survey questionnaire and its constructs (as noted earlier). Only in this way, the problem of a sampling adequacy can be overcome, and data from low-scale surveys can be perfectly adequate (less than 100 observations, see explanation in Diaz Lopez 2008).

Another methodological contribution of this research is based on the unique characteristics of the indicators developed (BEH, RCC, EI). In spite of the issue that these indicators are built using quantitative techniques, they are qualitative in nature. Therefore, they can reflect qualities and characteristics of firms in a sample that can be related to a level of eco-innovativeness and the strategies adopted (see figure 2). Conversely, these indicators do not provide an account of the number of eco-innovations developed by firms, so they cannot be considered as a measure of 'output' in the same sense than R&D and innovation studies that account the number of innovations, patents or R&D expenditures per firm as a proxy of innovation performance (e.g. Meyer-Krahmer 1984; Saviotti and Metcalfe 1984; Brouwer and Kleinknecht 1999). In this way, the proposed set of eco-innovation indicators can measure different characteristics and levels of eco-innovativeness of firms. Hitherto, different levels of eco-innovation strategies of firms can be identified in regard to their strategic behaviour (reactive, accommodative, active and proactive), their use of resources, competences and capabilities (basic, intermediate, advanced) and their strategic positioning (pollution control, pollution prevention, stewardship and towards eco-innovation). The use of this method suggests that the selection of variables and

labels for each category requires especial attention. This alternative method to measure eco-innovation strategies indeed reduced the chances that firms with a single case of eco-innovation can be considered as eco-innovative –conversely, they can be located within a certain level of eco-innovativeness.

The chosen method to build qualitative/quantitative eco-innovation indicators using the HOMALS analysis is a viable alternative to diminish the bias of traditional methods. Since this method is based on average patterns of response to a survey, especial care must be considered for the quality of the data imputed. In addition to this, expertise in the use of variables that might reflect the nature of eco-innovations is a must. The proposed method can be particularly useful for the study of eco-innovation strategies in advanced developing countries, since the identification of different levels eco-innovation can lead to differentiated strategies for capacity building. Moreover, this method can provide information on the determinants of environmental innovation and how firms assess the different costs / benefits of their development (as suggested by Fukasaku, 2005). The proposed method can be successfully complemented with case study evident and provide evidence on the types of environmental innovations developed by firms and how the knowledge required by them was developed.

Earlier in this paper I stated several implications from the use of data derived from innovation surveys for measuring eco-innovation (and its strategies). In particular, this method acknowledged that the nature of eco-innovation is different from general innovations and its novelty degree. I also introduced different aspects for the debate of the use of different data sources for measuring eco-innovation (strategies). Different choices would have had methodological and empirical consequences. For example, (if available) I could have chosen to use patent date for measuring eco-innovation of a sample of firms. If I would have chosen patents as a proxy to eco-innovation strategies, I would have clearly obtained mislead results. Alternatively, the proposed method suggests that micro-innovation surveys are adequate source of information for measuring eco-innovation strategies. In spite that the Oslo Manual does not include enough aspects in their guidelines that can be used for measuring eco-innovation, it is important to consider additional inputs on the impact of environmental aspects on innovation and a specific section of environmental management and innovation (as the UCISC survey did). Eco-innovation studies using innovation surveys as data source

must take this aspect into consideration, so a richer data set can be created.²⁷ Such micro-innovation data had to be carefully interpreted to avoid its misuse, since innovation surveys deal directly with factors for the development and adoption of ‘general innovations’, and not specifically with factors for ‘environmental innovations’. Finally, the aspect of temporality of innovation surveys should also be considered. This is due to the fact that innovation surveys tend to ‘capture’ the innovativeness of a sample in a particular period of time. Therefore, inferences for other particular conditions should be carefully managed and more dynamic models should be explored

Finally and for comparative purposes with prior studies in other developing countries, a sound use of multivariate statistics has been used to study the innovative behaviour of the Venezuelan chemical industry (Pirela, Rengifo et al. 1993) and the Mexican chemical industry (Arvanitis and Villavicencio 1998), and the understanding of managers’ willingness to adopt cleaner technologies in the assembly-type industry in Northern Mexico (Montalvo 2002). Although these studies used multivariate statistics techniques, they did not use HOMALS for the construction of the indicators. They used clustering analysis and principal component analysis (respectively) in order to identify groups of factors (explanatory variables) that could, potentially, be affecting their dependent variables (single inputs derived from items from their questionnaires). It would be valid to say that the proposed approach to eco-innovation from micro-innovation data is a novel and sound methodological contribution derived from an adequate theoretical and empirical modelling. The proposed methodology offers an alternative in the field of eco-innovation for the process of methodological standardisation. In this way, additional studies related to the relation of innovation and the environment at the firm level can be addressed.

²⁷ Just to cite one example, Horbach (2005) suggested that information derived from environmental management systems was also a valuable input for measuring eco-innovation. This research included this information not because of Horbach’s suggestion, as his research was possibly contemporary to mine. The UCISC group (lead by Dr Villavicencio) included this environmental-related information in the survey questionnaire as a result of the work of a multidisciplinary team (year 2002). The results of the empirical analyses proved this approach to be right. Another example is the recent contribution of the MEI group which recognise the need to include eco-innovation related inputs in the Community Innovation Survey questionnaire.

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Table 1 Prior studies on drivers for environmental innovation, focus of study, data sources, analytical methods, dependent and independent variables

Authors	Level/Country /Sector	Data source/ Analytical method	Dependent variable	Explanatory Variables (Significant = \$)	
Green, McMeekin et al.(1994)	Firm/ Sector UK. Manufacture and services (machinery, chemicals, light manufacturing, electrical equipment, research/ consultancy, other sectors)	Innovation survey/ Descriptive statistics	Product and process environmental friendly innovation (R&D)	<ol style="list-style-type: none"> 1. Existence and anticipation of environmentally related regulations 2. Prospect green products (need to develop new materials/components) (\$) 3. Cost savings through better use of materials and energy 4. Collaboration with customer and suppliers (\$) 5. New plant investment 6. Need to increase training expenditures (\$) 7. Reorganisation of R&D aims (\$) 8. Increases in expenditure. 	
Jaffe and Palmer (1996)	Industry USA Chemical Industry	Panel data/ Factor analysis	Environmental regulation and innovative activity based on: Patents and R&D industry funded expenditures	<i>For patents:</i> <ol style="list-style-type: none"> 1. Number of successful foreign patent applications (\$) 2. Pollution control expenditures (PACE) (\$) 3. Industry value added (\$) 	<i>For R&D:</i> <ol style="list-style-type: none"> 1. Government R&D (\$) 2. Pollution control expenditures (PACE) (\$) 3. Industry value added (\$)
Cleff and Rennings (1999)	Firm/ industry Germany	Panel survey/ multivariate logit regression	Integrated product and process innovation in environmental protection: a) Waste recovery b) Waste disposal c) Soil decontamination d) Product integration e) Emissions control f) Process integration	Goals of environmental innovations: <ol style="list-style-type: none"> 1. Cost reduction 2. Market share (\$)^b 3. Environmental protection 4. Complying with legislation (\$)^f 	Importance of policy instruments for environmental innovation : <ol style="list-style-type: none"> 5. Charges(\$)^e 6. Soft instruments(\$)^{b,c,d,e,f} 7. Eco-labels(\$)^{a,b,d} 8. Medium instruments(\$)^{b,e} 9. Civil law(\$)^b 10. Size of the firm (\$)^{c,d} 11. Geographical location (\$)^{a,b,c,e} 12. Consumer goods
Florida (1996)	Industry USA Manufacture	Survey Descriptive statistics, cluster analysis & linear regression	Innovations in advance manufacture and green design	Advanced manufacturing practices and pollution prevention (PP)*: <ol style="list-style-type: none"> 1. PP and corporate performance 2. Zero emissions manufacturing 3. PP expenditures 4. Adoption of cleaner technology 5. 'Green' process improvements for production 6. Total quality environmental management 	Adoption of advanced manufacturing and green design: <ol style="list-style-type: none"> 1. Green product design(\$) 2. Total quality management(\$) 3. Quality-oriented design(\$) 4. Quality-oriented process improvements(\$) 5. Concurrent engineering(\$) 6. Ratio of managers to workers(\$) 7. Employment security(\$) 8. Supplier relations(\$)

Authors	Level/Country /Sector	Data source/ Analytical method	Dependent variable	Explanatory Variables (Significant = \$)
				7. Worker involvement in PP 8. Supply chain management and environmental performance 9. Electronic design interchange(\$)
Theyel (2000)	Firm/ Industry USA Chemical Industry	Survey Descriptive statistics & Pearson correlations	Environmental innovation in the form of: a) material substitution b) process change	(Eco-efficiency management best practices) 1. Employment 2. Organisational status (single or multi plants) 3. Industrial sector (\$) ^a 4. Waste audits (\$) ^b 5. Total quality management for pollution prevention (\$) ^a 6. Pollution prevention plan 7. Employee pollution prevention training programme 8. Total cost accounting (\$) ^{a,b} 9. Designated pollution prevention manager 10. In-house R&D for pollution prevention 11. Pollution prevention requirements for suppliers (\$) ^a 12. Life cycle analysis 13. Pollution prevention employee incentive programme.
Montalvo (2002)	Firm/Industry North of Mexico Assembly type (electronics mainly)	Innovation survey/ principal component analysis & linear regression	Clean technology development (willingness to develop clean technologies)	1. Environmental risk perception and acceptance (\$) ^a 2. Economic risk (\$) ^a 3. Market pressures (\$) ^a 4. Community pressures (\$) ^a 5. Regulatory pressures (\$) ^a 6. Technological capabilities (\$) ^a 7. Learning (organisational) capabilities (\$) ^a 8. Strategic alliances capabilities ^a 9. Networks of collaboration
Rennings and Zwick (2003)	Firm/ Sector Germany, Italy, Switzerland, UK, Netherlands Manufacture (manufacturing, electricity, gas & water, construction), and services (retail, hotels, transport, financial remediation and real state)	Panel data/ Factor analysis/ multinomial logit regression	Employment impacts of environmental innovation**	1. Type of environmental innovation (product (\$), service (\$), process, organisational, recycling, end-of pipe) 2. Goals of innovations (market share (\$), environment, cost reduction) 3. Innovation size (share of environment on total innovation expenditures) (\$) ^a 4. Size of the firm (\$) ^a 5. Government subsidies 6. Sales expectations (\$) ^a 7. Environmental regulation influence on changes to products and processes (\$) ^a 8. Competition factors (markets) 9. Level of education of workers (\$) ^a
Brunnermeier and Cohen (2003)	Sector USA	Panel data/ multivariate	Successful environmental	1. Private expenditures on R&D (\$) ^a 2. Number of successful patent applications

Authors	Level/Country /Sector	Data source/ Analytical method	Dependent variable	Explanatory Variables (Significant = \$)				
	Manufacture (this research used patents from the USPTO and did not detailed the manufacture sectors involved)	Regression analysis	patents***	<ol style="list-style-type: none"> 3. Number of government industrial inspections 4. Export intensity (\$) 5. Value of industry shipments (\$) 6. Industry concentration (\$) 7. Capital intensity 				
Ramus (2003)	Firm/Sector Europe	Survey questionnaire/	Eco-initiatives of employees (organisational eco-innovations)	<ol style="list-style-type: none"> 1. (Corporate) Environmental policies(\$) 2. Innovative behaviours of employees(\$) 3. Management of goals and responsibilities(\$) 4. Rewards and recognition(\$) 5. Information and dissemination of data 6. Environmental training and education(\$) 7. Environmental communication (\$) 8. General vs. environmental comparison of behavioural responses 				
Pujari (2006)	Firm Canada	Innovation survey/ factor analysis & hierarchical regression methods	Environmental new product development.	<ol style="list-style-type: none"> 1. Upfront proficiency 2. Cross-functional coordination (\$) 3. Supplier involvement (\$) 4. Design for the environment/ life cycle analysis (\$) 5. Market focus (\$) 				
Horbach (2006)	Sector Germany Manufacture and services (mining, food, textiles, chemical, ceramics, basic metals, machinery, electrical machinery, precision instruments, motor vehicles, furniture, recycling, energy & water, construction, retail, transport, data processing, R&D and consultancy, other services)	2 sources of panel data (IAB Survey & MIP Survey)	<p>Environmental innovation.</p> <p>For IAB: firms supplying environmental goods and services with product innovations</p> <p>For MIP: firms with innovations with relevant environmental or health effects</p>	<table border="0"> <tr> <td><i>LAB Survey:</i></td> <td><i>MIP Survey:</i></td> </tr> <tr> <td> <ol style="list-style-type: none"> 1. Age of firm 2. Size of the firm 3. Government's subsidies (\$) 4. Export intensity (\$) 5. R&D activities (\$) 6. Share of high qualified employees(\$) 7. Turnover expectations (\$) 8. Lagged economic performance 9. Overtime worked 10. Wage agreements 11. Use of environmental management tools (\$) 12. Region 13. Sector </td> <td> <ol style="list-style-type: none"> 1. Age of firm 2. Size of firms 3. Government subsidies (\$) 4. Exports (\$) 5. R&D activities (\$) 6. Investment in employees' further education 7. Workers with university degree (\$) 8. Cooperation dynamics 9. Cost saving strategies (\$) 10. Employment demand 11. Innovative firm 12. Introduction of new organisational structures(\$) 13. Region located (west vs. east Germany) 14. Regulations compliance (\$) 15. Market scope (regional vs. international) </td> </tr> </table>	<i>LAB Survey:</i>	<i>MIP Survey:</i>	<ol style="list-style-type: none"> 1. Age of firm 2. Size of the firm 3. Government's subsidies (\$) 4. Export intensity (\$) 5. R&D activities (\$) 6. Share of high qualified employees(\$) 7. Turnover expectations (\$) 8. Lagged economic performance 9. Overtime worked 10. Wage agreements 11. Use of environmental management tools (\$) 12. Region 13. Sector 	<ol style="list-style-type: none"> 1. Age of firm 2. Size of firms 3. Government subsidies (\$) 4. Exports (\$) 5. R&D activities (\$) 6. Investment in employees' further education 7. Workers with university degree (\$) 8. Cooperation dynamics 9. Cost saving strategies (\$) 10. Employment demand 11. Innovative firm 12. Introduction of new organisational structures(\$) 13. Region located (west vs. east Germany) 14. Regulations compliance (\$) 15. Market scope (regional vs. international)
<i>LAB Survey:</i>	<i>MIP Survey:</i>							
<ol style="list-style-type: none"> 1. Age of firm 2. Size of the firm 3. Government's subsidies (\$) 4. Export intensity (\$) 5. R&D activities (\$) 6. Share of high qualified employees(\$) 7. Turnover expectations (\$) 8. Lagged economic performance 9. Overtime worked 10. Wage agreements 11. Use of environmental management tools (\$) 12. Region 13. Sector 	<ol style="list-style-type: none"> 1. Age of firm 2. Size of firms 3. Government subsidies (\$) 4. Exports (\$) 5. R&D activities (\$) 6. Investment in employees' further education 7. Workers with university degree (\$) 8. Cooperation dynamics 9. Cost saving strategies (\$) 10. Employment demand 11. Innovative firm 12. Introduction of new organisational structures(\$) 13. Region located (west vs. east Germany) 14. Regulations compliance (\$) 15. Market scope (regional vs. international) 							
Mazzanti & Zoboli (2006)	Firm/Sector Italy	Innovation survey/ Descriptive statistics	Environmental innovation expressed as:	<ol style="list-style-type: none"> 1. Size of the firm 2. Environmental policy pressure (direct regulatory costs) (\$)^b 				

Authors	Level/Country /Sector	Data source/ Analytical method	Dependent variable	Explanatory Variables (Significant = §)
	Industrial district (ceramics, chemicals, food, pulp and paper, machinery, textile, other industries)	& multivariate probit analysis	a. Input index: environmental R&D innovation input b. Output index: total innovation (emission, waste, energy and total related innovation)	3. Environmental subsidies from the government (grants) (§) ^b 4. Auditing schemes (EMAS, ISO14000) (§) ^b 5. Industrial relations involvement in management strategies (§) ^{a,b} 6. Positive correlations between environmental innovations with other non-environmental technological and organisational innovations [total index of organisational innovation practices, total quality management, technological process and product innovation, formal training employee coverage, flatness of the organisational structure (§) ^{a,b}] 7. Networking activities associated to environmental R&D (§) ^a 8. Firm structural variables [share of revenue in international markets, share of final market production (§) ^a , complement to subcontracting production, chemical sector (§) ^{a,b} , ceramic sector, machinery sector, final market sector, corporate support (group membership) (§) ^b]
Rennings, Ziegler, et al (2006)	Sector Germany Manufacture	Survey/ Descriptive Statistics & probit analysis	Environmental innovation: a. Environmental process innovation b. Environmental product innovation	1. Maturity of EMS (§) ^a 2. Strategic performance of EMAS (§) ^a 3. Learning processes by EMS (§) ^b 4. Organisational scope of EMAS (participation of different departments) (§) ^a 5. Technical environmental innovations and environmental organisational measures (§) ^a 6. Environmental innovation targets (environmental improvement (§) ^a , image (§) ^b , compliance (§) ^a , anticipation of regulations, cost reduction, markets shares (§) ^b) 7. Importance of factors for economic performance (price (§) ^b , quality, customer satisfaction, innovation (§) ^{a,b} , environmental issues) 8. Age of the firm 9. Supplier to environmental protection market (§) ^b 10. Share of turnover with industrial customers (§) ^b 11. Size of the firm (§) ^a 12. Employee qualification (share of employees with university degree) (§) ^b 13. Share of turnover 14. Share of exports 15. Legal independence (§) ^a 16. Type of industry 17. Domestic region (country) 18. Use of environmental indicators (§) ^b

Notes: * This author employed descriptive statistics to explain... ** Although this research did not measure ... *** This was referred to environmental patents in the areas of: Toxic waste destruction or containment, waste recycling or reuse, acid rain prevention, solid waste disposal, alternative energy sources, air pollution prevention and water pollution prevention

Table 2 Classification of indicators used in 'innovations' studies adapted to the case of 'eco-innovations'

Type	Quantitative	Qualitative	Data Source
Input	Number of R&D personnel Environmental R&D expenses Ratio of Environmental R&D activities/total R&D (estimation of time) Acquired environmental technologies Pollution prevention expenditures	Market strategies Formal R&D department Competitors pressure Eco-innovation barriers Strategic behaviour regarding environmental innovations (BEH) Strategic use of resources, capabilities and competences for EI (RCC)	Innovation surveys Other type of surveys (labour, productivity, etc) Official statistics Reports from the Chemical Association Corporate Reports Case Studies
Throughput	Environmental patents solicited Revenues by technology management of environmental technologies	Recycling share Reuse share	Patent statistics Corporate Reports
Output	Environmental patents granted Environmental innovation intensity LBIOs Number of environmental innovations introduced Turnover of the eco-products introduced	Environmental innovation goals Environmental innovation strategies (EI) Environmental characteristics of new eco-products with respect to comparable products Eco-innovative activities of clients and suppliers	Innovation surveys Patent statistics Reports from the Chemical Association Case Studies Specialised magazines and industrial reports Sustainability indices

Source: modified from Horbach (2005) and Kleinknecht, Van Montfort et al (2002)

Table 3 Variables introduced in the HOMALS analyses for the creation of the three eco-innovation indicators

Nature of indicator	Label or group	Variables introduced for its creation
Input	BEH	Manager's perception on positive influences (related to environment) for firm's innovation, use and implementation of different types of environmental audits, training and motivational tasks for environmental issues (top level management, middle level management, operatives, clients, and providers), and firm's priority given to pollution prevention strategies and the identification of pollution prevention opportunities.
	RCC	Environmental impact evaluation on new product development, firm's R&D activities (proportion of R&D activities dedicated to product process, environmental and others), infrastructure to support environmental innovation activities (quality control lab, maintenance unit, pilot plant, customer service unit, environmental control unit), use of different types of environmental performance indicators, topics covered in an environmental training agenda for clients and suppliers (as an approach to green chain management), and the use of production best practices to support eco-innovation activities.
Output	EI	Use of elements from the design for the environment approach, pollution prevention contribution to firm's productivity & performance, and the use of eco-efficiency best practices to support environmental innovation activities.

Table 4 External (EFSV) and internal (ISFV) firm variables included as explanatory variables for the BEH, RCC and EI regression analyses

	#	Variable name	Acronym	Number of items	Type of variable	Codification description
EFSV	1	Influence of export markets	MRK	3	Discrete, ternary	0=no exports 1= e.g. exports to NAFTA 2= e.g. exports to the EU & others (South America & Asia)
	2	Membership to the Chemical Association & Responsible Care ²⁸ (RC) implementation	CA-RC	2	Discrete, ternary	0 = not a member 1= a member not implementing voluntary programmes 2 = a member implementing voluntary programmes
	3	Participation in government's support programmes for technological activities	GOV	5	Discrete, quaternary	0= no participation 1= support from at least one programme 2= support from two programmes 3= support from more than one programmes
ISFV	4	Size of the firm	SF	1	Continuous, interval	Natural logarithm of the number of employees
	5	Ownership	OWN	1	Discrete, binary	0 = domestic firm 1 = foreign firm
	6	Corporate support	CS	1	Discrete, binary	0 = does not belong to a corporate group; does not receive corporate services 1= do belong to a corporate group; do receive corporate services
	7	Geographical location	GL	1	Discrete, binary	0 = e.g. capital city 1 = outside the capital city
	8	Technology level	TL	1	Discrete, quaternary	0= does not know 1= older than foreign competitors 2= same level than foreign competitors 3= newer than foreign competitors
	9	Production mode	MP	1	Discrete, ternary	0=batch 1=continuous 2= both
	10	Level of process automation	AL	1	Discrete, ternary	0= manual 1= automatic as electromechanical 2= automatic as electrical
	11	Age of the firm	AF	1	Discrete	0 = created during the ISI period 1= e.g. new firms created after the liberalisation period
	12	Skill intensity managers to workers	SIMEU	2	Continuous, ratio	Number of managers and engineers / Number of unskilled blue collars (workers)
	13	Skill intensity skilled to unskilled workers	SISU	2	Continuous, ratio	Number of skilled blue collars (workers) / Number of unskilled blue collars (workers)

²⁸ The information of the implementation of RC and membership to the Chemical Association (CA-RC variable) was obtained directly from ANIQ's officers as it was not originally included in the UCISC. The first approach was to obtain the number of firms who have already implemented the RC programme. However, it was virtually impossible to do it by means of their webpage. One of the reasons for this is that not necessarily all the (new) members have implemented such programme. Equally, the composition of the industry has changed in the last few years so many firms have also changed its membership status to the chemical association.

Table 5 Explanatory variables included for the BEH regression analyses

	#	Variable name	Acronym	# of items	Type of variable	Codif. description
IM/BP_{BEH}	1	The use of environmental performance indicators	UEPI	5	Discrete, scaled	Sum of item scales >0
	2	Environmental training agenda for clients and suppliers	ETACS	5		
	3	Environmental impact evaluation for new product development	EIENPD	7		
	4	Use of elements from a design for the environment approach	DFE	4		
	5	The use of by-product synergy and eco-efficiency best practices	BP/EE _{BEH}	9		
	6	The use of quality management systems and tools	QMS	8		
MPEI	7	Managers perception on sources of firm's competitiveness	MPFC	7		
	8	Managers perception on problems related to production activities	MPPP	16		
	9	Managers perception on general production problems faced by firms	MPGP	7		
	10	Managers perception on innovation drivers	MPID _{BEH}	14		
	11	Managers perception on influence of free trade agreements	MPFTA	5		
	12	Managers perception on pollution prevention contribution to firm's performance	MPPPC	7		
	13	Managers perception on positive influences for innovation	MPPI	11		
	14	Managers perception on negative influences for innovation	MPNI	16		

Table 6 Explanatory variables included for the RCC regression analyses

	#	Variable name	Acronym	# of items	Type of variable	Codification description		
TIM	1	Technological learning activities	TLA	15	Discrete, scaled	Sum of item scales >0		
	2	Sources of technological information	STI	6				
	3	Technology and innovation strategy of the firm	TIS	8				
	4	Process technology sourcing	PTS	11				
	5	Product innovation sourcing	PIS	11				
	6	Type of innovation introduced	IRI	4				
	7	Intellectual property strategies	IPS	4				
FL	8	Firm's technological networks for new product development, process design, and technological assistance	TNNPD	11	Continuous, interval	Natural logarithm of the number of R&D employees		
	9	Firm's strategic alliances for technological development (with foreign firms)	SATD	3				
RDER	10	Expected evolution of engineering and R&D personnel in the following years	EERD	2				
	11	Firm possesses an engineering and R&D facility and personnel in the industrial facility	ERDU	3				
	12	Number of engineering and R&D employees of firm	ERDP	2				
IM/BP_{RCC}	13	Type of environmental audits implemented by firms	EA	6			Discrete, scaled	Sum of item scales >0
	14	Use of a pollution prevention approach	PP	2				
	15	Use of elements from a design for the environment approach	DFE	4				
	16	Use of by-product synergy and eco-efficiency best practices	BP/EE _{RCC}	6				
	17	Use of quality management systems and tools	QMS	8				
	18	Workers participation in decision making aspects for production and management systems	WP	5				
	19	Worker's environmental training and awareness	WET	5				
	20	Middle level management environmental training and awareness	MET	5				
	21	Top level management environmental training and awareness (directive level)	DET	5				
	22	Clients and suppliers environmental training and awareness	CSET	3				

Table 7 Explanatory variables included for the EI regression analyses (reduced form)

	#	Variable name	Acronym	# of items	Type of variable	Codification description		
TIM	1	Technological learning activities	TLA	15	Discrete, scaled	Sum of item scales >0		
	2	Sources of technological information	STI	6				
	3	Technology and innovation strategy of the firm	TIS	8				
	4	Process technology sourcing	PTS	11				
	5	Product innovation sourcing	PIS	11				
	6	Type of innovation introduced	IRI	4				
	7	Intellectual property strategies	IPS	4				
FL	8	Firm's technological networks for new product development, process design, and technological assistance	TNNPD	11	Continuous interval	Ln of the number of R&D employees		
	9	Firm's strategic alliances for technological development (with foreign firms)	SATD	3				
RDER	10	Infrastructure to support environmental innovation activities	ISR	5			Discrete, scaled	Sum of item scales >0
	11	Expected evolution of engineering and R&D personnel in the following years	EERD	2				
	12	Firm possesses an engineering and R&D facility and personnel in the industrial facility	ERDU	3				
	13	Number of engineering and R&D employees of firm	ERDP	2				
IM/BP-EI	14	Use of environmental performance indicators	UEPI	5				
	15	Environmental training agenda for clients and suppliers	ETACS	5				
	16	Type of environmental audits implemented by firms	EA	6				
	17	Use of a pollution prevention approach	PP	2				
	18	Environmental impact evaluation for new product development	EIENPD	4				
	19	Use of by-product synergy and eco-efficiency best practices	BP/EE _{EI}	3				
	20	Use of quality management systems and tools	QMS	8				
	21	Workers participation in decision making aspects for production and management systems	WP	5				
	22	Worker's environmental training and awareness	WET	5				
	23	Middle level management environmental training and awareness	MET	5				
	24	Top level management environmental training and awareness (DET	5				
	25	Clients and suppliers environmental training and awareness	CSET	3				
MPE _{EI}	26	Managers perception on sources of firm's competitiveness	MPFC	7	Discrete, scaled	Sum of item scales >0		
	27	Managers perception on problems related to production activities	MPPP	16				
	28	Managers perception on general production problems faced by firms	MPGP	7				
	29	Managers perception on innovation drivers	MPID	20				
	30	Managers perception on influence of free trade agreements	MPFTA	5				
	31	Managers perception on positive influences for innovation	MPPI	11				
	32	Managers perception on negative influences for innovation	MPNI	16				