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POLICY STRINGENCY AND (ECO)-INNOVATION PERFORMANCE: A CROSS COUNTRY ANALYSIS

Políticas rigorosas e desempenho em eco-inovação: uma análise Inter países

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Abstract: Policymakers have an important role in enabling eco-innovation. To assess the effectivity of these interventions, it is necessary to characterize policies, namely the level of policy stringency. The present study contributes to extant empirical literature by performing a cross-country assessment of the impact of policy stringency on the outcomes (rather than the inputs) of the eco-innovation process. Contrasting with extant evidence, results fail to evidence the relevance of policy stringency for eco-innovation performance. Notwithstanding, policy stringency emerged indirectly as a potential critical determinant. Indeed, the possibility to save costs is often driven by policy instruments that punish pollution intensive firms.
Keywords: eco-innovation; policy stringency; environmental regulation; Porter's hypothesis; competitiveness

Resumo: Os decisores políticos têm um papel importante na promoção da eco-inovação. Para avaliar a eficácia destas intervenções, é necessário caracterizar as políticas, nomeadamente o nível de rigor das políticas. O presente estudo contribui para a literatura empírica existente através da realização de uma avaliação inter-país do impacto do reigor da política sobre os resultados (e não sobre os inputs) do processo de eco-inovação. Em contraste com as evidências existentes, os resultados não evidenciam a relevância da rigidez das políticas para o desempenho da eco-inovação. Não obstante, o rigor surgiu indiretamente como um potencial determinante crítico. Na verdade, a possibilidade de economizar custos é muitas vezes motivada por instrumentos de política que punem as empresas com poluição intensiva.
Palavras-chave: Eco-inovação; Rigor da política; Regulação ambiental; Hipótese de Porter; Competitividade.

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INTRODUCTION

The rising urgency and accumulation of environmental related problems is inducing policymakers to strive towards sustainable development (Millennium Ecosystem Assessment, 2005). The concept of sustainable development was first introduced in 1972 at the United Nations Conference on the Human Environment. The United Nations World Commission on Environment and Development (WCED) defines sustainable development in its 1987 report 'Our Common Future' (WCED, 1987: 41) as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

The European Commission has identified eco-innovation as one of the key tools to achieve this sustainable development and has developed the Eco-Innovation Action Plan (EC, 2011).

Policymakers play an important role to make eco-innovation possible because unlike in traditional innovation economics, policy intervention is required to overcome externality problems related to eco-innovation (Rennings, 2000). Environmental policies are needed to create incentives and reduce costs involved in technological, social and institutional innovation to stimulate eco-innovation (Khanna et al., 2009).

The available empirical studies that have examined the influence of policy stringency – i.e., the degree in which countries implement regulations to pressure industry to develop environmentally compatible production processes (Costantini and Crespi, 2008) - on eco-innovation performance mainly applied methodologies on firm level based on survey data (e.g., Frondel et al., 2008; Horbach, 2008; Kesidou and Demirel, 2012). The few empirical studies that involved country level analysis focused on the relation between policy stringency and bilateral trade flows (van Beers and van den Bergh, 1997; Costantini and Crespi, 2008) or the number of inventions (Johnstone et al., 2011), not directly assessing the impact of policy stringency on countries' eco-innovation performance. Therefore, the aim of the present study is to examine at cross-country level the impact of policy stringency on (eco)-innovation performance, resorting to econometric techniques and data recently released by the Eco Innovation Observatory.

[1]Various analogous notions for the term eco-innovation have been used, most notably, 'ecological innovation', 'environmental innovation', 'green innovation' or 'sustainable innovation' (Schiederig et al., 2012). According to Schiederig et al. (2012) these terms can be used interchangeably because of the large commonalities between the different definitions. First of all, they consist of an innovation object that fulfills a market need: a product, service, process or method. Secondly, all concepts include the reduction of negative environmental impacts. Thirdly, the intention for innovation does not need to be strictly ecological, it can also be economic.

This study is structured as follows. In the next section (Section 2), the literature review on eco-innovation determinants and the importance of policy stringency is performed. Then, in Section 3, we detailed the methodology. In Section 4, we present the empirical results and, in the final section, the conclusions, including the main points raised by the present study as well as its main limitations and paths for future research will be mentioned.

ECO-INNOVATION DETERMINANTS AND THE IMPORTANCE OF POLICY STRINGENCY: A LITERATURE REVIEW

Several researchers have proposed frameworks to categorize the determinants of eco-innovation performance (Pereira and Vence, 2012). Horbach et al. (2012) divide those determinants into four categories: firm specific factors, technology, market, and regulation.

For the society, in general, and policymakers, in particular, it is important to understand the relation between the nature of policy, most notably policy stringency, and the eco-innovation outcomes. This might enable policymakers to develop more effective policies.

A common characterization of the nature of environmental policies relates to command-and-control and market-based approaches (Jaffe et al., 2002).

Stavins (2002: 5) defines market-based instruments as "regulation that encourage behaviour through market signals rather than through explicit directives regarding pollution control levels or methods". Examples of market-based instruments are tradable permit systems, charge systems, subsidies and taxes. Market-based environmental policy instruments create incentives for organizations to change its behaviour and actions.

In contrast, command-and-control regulations tend to force firms to undertake actions that reduce the caused environmental burden (Stavins, 2002). These regulations consist of setting standards that firms need to meet. Usually if they fail to comply with the imposed regulations, a penalty will apply.

Both types of instruments have the potential to induce some sort of technological change because they impose a certain behaviour that firms, under normal circumstance, would not autonomously exhibit. (Jaffe et al., 2002)

Typically, cocktails of market based and command and control instruments are used to address environmental issues (Vollebergh, 2007). Hence, it is adequate to assess policies by distinguishing general characteristics such as stringency, predictability or flexibility. In the present study merely policy stringency is addressed.

Policy stringency is a concept that is mainly used in the field of ecological economics. Despite its frequent usage, the definition of the concept receives little attention throughout extant literature. Merely a few studies devoted a paragraph on defining the concept. Costantini and Crespi (2008) defined policy stringency as the degree in which countries implement regulations to pressure industry to develop environmentally compatible production processes. According to Haščič et al. (2009), policy stringency indicates how ambitious the environmental targets are in reference to the 'baseline' trajectory. More stringent policies increase opportunity costs involved in polluting and therefore create incentives for innovation.

Harring (2008: 25) defined environmental policy stringency as "the scope and success in implementation of environmental policy". The success of implementation is dependent on factors such as governance ability, political rights and civil liberties (Torras and Boyce, 1998). Similarly, Magnani (2000) suggests that the efficacy of environmental policy is determined by well-defined property rights, democratic voting systems and respect for human rights, in short, institutions.

Originally, Hicks (1932) formulated the 'induced innovation hypothesis' which states that a change in the relative price factors of production will encourage firms to innovate. Innovating will help firms to economize the use of factors which have become relatively expensive. Applied to the case of environmental policy such argumentation implies that if governments are able to influence the price of production factors, they can increase the firm's incentive to innovate their production technologies. Johnstone et al. (2011) therefore argued that if more stringent regulations lead to a relative increase of these price factors (such as the use of environmentally harmful resources), they create incentives to (eco)-innovate.

Porter and van der Linde (1995) suggested that, besides stimulating eco-innovation, policy stringency can also improve commercial competitiveness. This became to be known as the 'Porter hypothesis'. The rationale behind this hypothesis is that more stringent regulation pushes industry to create new environmental friendly products and processes that can drive firms to become leaders in green markets (Rothfels, 2000). This is also known as the first mover advantage and can contribute to the firm's competitiveness.

Additionally, more stringent regulations act as an impetus to search for inefficiencies in current production processes and eliminate them (van Soest et al., 2006). Subsequently, this leads to higher cost efficiency of the production processes.

Empirical literature that has tried to provide evidence for this relationship between policy stringency and (eco)-innovation performance has remained rather limited (Vollebergh, 2007; Popp et al., 2009). Actually, it can be stated that the relationship between policy stringency and eco-innovation performance has still not been addressed properly. Extant empirical literature uses input (e.g., R&D expenditures) rather than output measures of the innovation process (Jaffe and Palmer, 1996; Hamamoto, 2006), or intermediate output measures such as patent count (Brunnermeier and Cohen, 2003; Popp, 2006; Johnstone et al., 2011).

Studies that directly relate policy stringency to the outputs of the eco-innovation process and thus eco-innovation performance have not yet, to the best of our knowledge, been empirically explored.

Existing studies which address this relation using input or intermediate measures of eco-innovation applied to different countries mostly found a significant positive correlation between policy stringency and eco-innovation performance (Brunnermeier and Cohen, 2003; Popp, 2006; Hamamoto, 2006; Johnstone et al., 2011) – see Table 3. The only exception was a study of Jaffe and Palmer (1996). These authors examined the impact of policy stringency both on R&D expenditures and successful patent application and solely found a significant and positive result for R&D expenditure.

[2] Flexibility of policy is defined as the extent to which a regime lets innovators free to decide how to meet their own objectives. Predictability is the degree in which governments stick to their original policy plan (Haščič, 2009).

The present study contributes to the empirical literature in two ways. Firstly, and in contrast with existing studies (Jaffe and Palmer, 1996; Brunnermeier and Cohen, 2003; Popp, 2006; Hamamoto, 2006; Johnstone et al., 2011), we use output measures for eco-innovation performance. Secondly, and in order to have a macroeconomic perspective of the relation between policy stringency and eco-innovation performance, we perform a cross country analysis instead of resorting to firms-related analysis. It should be noted that, like most other studies, our study is also primarily based on self-perception indicators of policy stringency.

METHODOLOGICAL CONSIDERATIONS

In accordance with the literature review (cf. Section 2), four major groups of factors are expected to determine eco-innovation performance (the 'dependent variable') at the country level: regulation (the main focus of the present study); firm characteristics; technology and market. Thus the general empirical model specification is as follows:

$$ECO\_INN\_PERF_{it} = \beta_1 + \boldsymbol{\beta_2 Regulation} + \boldsymbol{\beta_3 Firm} + \boldsymbol{\beta_4 Technology} + \boldsymbol{\beta_5 Market} + \mu_{it}$$

Within each factor, the following empirical 'model' specifies the relevant variables:

$$\begin{aligned} ECO\_INN\_PERF_{it} = & \\ &= \beta_1 + \beta_2 Reg_{Stringency} + \beta_3 Firm_{Age} + \beta_4 Firm_{Size} + \beta_5 Firm_{EMS} + \beta_6 Technology_{R\&D} \\ &+ \beta_7 Market_{Dem} + \beta_8 Market_{Ben} + \beta_9 Market_{Sec} + \mu_{it} \end{aligned}$$

where i indexes country and t indexes time, ECO_INN_PERF represents the eco-innovation performance of a country; $Reg_{Stringency}$ represents the environmental policy stringency of a country; $Firm_{Size}$ represents the proportion of large firms in a country; $Firm_{Age}$ denotes the proportion of aged firms; $Firm_{EMS}$ represents the intensity of implemented environmental management systems; $Technology_{R\&D}$ denotes the expenditures in environmental R&D; $Market_{Dem}$ refers to customer demand; $Market_{Ben}$ represents customer benefits; $Market_{Sec}$ denotes the proportion of pollution intense sectors, and μ_{it} is a residual error term capturing all other effects.

The data for the present analysis is gathered from a database supplied by the Eco Innovation Observatory [3] that contains eco-innovation information for all EU member states over a time-period of 4 years (2008-2013), although for most of the relevant variables, data only exists for one unique year within this period.

Table 4 describes the indicators for the dependent and independent variables.

[3] The database can be accessed at http://www.eco-innovation.eu/, accessed on 01-04-2015.

Table 3: Overview of dependent and independent variables

Group Determinant	Variable	Reference year	Proxy of the relevant variable	Source
Dependent variable: eco-innovation performance	1.Green exports	2012	Share of eco-industry exports in total export (in %).	EUROSTAT
	2.Employment eco-industries	2012	The share of employment in eco-industries as a percentage of the total work force.	Thomson One
	3.Turnover eco-industries	2012	The share of turnover of eco-industries as a percentage of total GDP	Thomson One
Policy stringency	4.Present environmental regulations	2008	The share (in %) of total companies declaring environmental regulations as relevant for pursuing eco-innovation.	CIS data from EUROSTAT
	5.Expected environmental regulations	2008	The share (in %) of total companies declaring regulations or taxes to be introduced in the future as relevant for pursuing eco-innovation	CIS data from EUROSTAT
	6.Green taxes	2008	The share of green taxes, including energy taxes, transport taxes, pollution taxes, and resources taxes, as a percentage of total GDP.	EUROSTAT
	7.Availability of government grants	2008	The share (in %) of total companies declaring government grants, subsidies or other financial incentives as relevant for pursuing eco-innovation.	CIS data from EUROSTAT
Firm specific factors	8.Firm size	2008	The share (in %) of NSC-5 firms among the total number of enterprises. (NSC-5 firms typically contain more than 250 employees)	The OECD Statistics Directorate
	Firm age	2013	The average number of established years of firms.	The OECD Statistics Directorate
	9.Procedures to reduce environmental impact	2008	The share (in %) of total companies with procedures in place to regularly identify and reduce environmental impacts (e.g. ISO 14001, environmental audits, etc)	CIS data from EUROSTAT
	10.EMAS certificates	2008	The share (in %) of total firms that possess an EMAS certificate.	EUROSTAT
	11.ISO 14001 certificates	2008	The share (in %) of total firms that possess an ISO 14001 certificate	The ISO survey 2008
Technology	12.Environmental R&D	2008	The Government Budget Appropriations or Outlays on environmental R&D in percentage of total GDP.	EUROSTAT
Market	13.Customer demand	2008	The share (in %) of total companies declaring current or expected market demand as relevant for pursuing eco-innovation.	CIS data from EUROSTAT.
	14.Cost savings	2011	The share (in %) of firms that estimates an increase in prospect material costs.	Q3 from the Eurobarometer No.315.
	15.User benefits	2008	The share (in %) of total companies with innovations leading to reduced energy use by the end-user	CIS data from EUROSTAT.
	16.Sector	2008	The share (in %) of total companies which are operating in pollution intense sectors such as the machinery and equipment sector and the motor vehicles sector	The OECD Statistics Directorate

Note: For eco-innovation performance measures the analyzed eco-industries subsectors are: air pollution control, water pollution control, waste disposal, monitoring equipment, other environmental equipment, solar thermal, photovoltaics and hydropower.
Source: Authors' own elaboration.

1. ECO-INNOVATION PERFORMANCE

Until very recently, data on eco-innovation performance was unavailable and therefore the majority of extant empirical literature adopted input (e.g. Jaffe and Palmer, 1996; Hamamoto, 2006) and intermediate input (e.g. Brunnermeier and Cohen, 2003; Popp, 2006; Johnstone et al., 2011) measures for eco-innovation instead of output measures.

Current definitions of eco-innovation commonly encompass the development of new ideas, products or processes that result in a reduction of environmental burden. An appropriate output measure should therefore represent these dimensions of eco-innovation. The Eco Innovation Observatory database contains such measures (under categories: 'Socio-economic outcomes' and 'Resource efficiency outcomes') and allows separate access to them. However, the 'Resource efficiency outcome' indicators only contain data for the year 2008. This frustrates analysis with the indicators for policy stringency as any effect of policy stringency on eco-innovation performance can only be observed after a certain time period. Therefore it is advisable to consider a time lag between eco-innovation performance and the independent variables. Costa et al. (2014) showed that, although in another context, usually time lags of 2-4 years between decisions and performance are adequate. Since the earliest data for the independent variables are from 2008, we opted to consider the latest available data for eco-innovation performance, i.e., from 2012. As such, the following eco-innovation performance indicators were included in the analysis: (1) exports of products from eco-industries (% of total exports), (2) employment in eco-industries[4] (% of total employment across all companies), (3) revenue in eco-industries (% of total revenue across all companies).

[4]The analyzed subsectors are: air pollution control, water pollution control, waste disposal, monitoring equipment, other environmental equipment, solar thermal, photovoltaics and hydropower.

2. ENVIRONMENTAL POLICY STRINGENCY

To be able to study the influence of policy stringency on eco-innovation performance it is necessary to find an adequate measure for policy stringency. A frequently used proxy for policy stringency is the Pollution Abatement Costs and Expenditures (PACE) (Jaffe and Palmer, 1996; Brunnermeier and Cohen, 2003; Hamamoto, 2006; Kesidou and Demirel, 2012). PACE provides a general indication of a country's financial efforts to implement control measures and undertake compliance costs against pollution (OECD, 2007).

It is argued that these expenditures lead to measures that protect the environment and therefore create incentives for clean production technologies to be developed (OECD, 2007).

However, the studies that use PACE as a measure for policy stringency received a lot of criticism (van Soest et al., 2006; Haščič et al., 2009; Johstone et al., 2011). Johnstone et al. (2011) argue that policy stringency has an impact on opportunity costs which, in turn, translates into increased costs of production factors. This creates an incentive for firms to innovate in a manner to reduce costs associated with these factors. They argue that the increase in costs of production factors caused by stricter policy is not captured by the proxy PACE.

As a consequence, Johnstone et al. (2011) decided to use perceived policy stringency as a proxy. This data was extracted from the World Economic Forum's (WEF) 'Executive Opinion Survey' in which research departments in firms and universities assessed the perceived policy stringency on a Likert scale (1= lax compared with other countries, 7 = among world's most stringent countries). Subsequently, Johnstone et al. (2011) compared the results from this survey with available PACE data from these countries and found a significant negative correlation. They argue that this confirms their supposition that PACE data is not a reliable source to measure environmental policy stringency. Though they do not go as far as to say that this result also implies the opposite, namely that survey data is not reliable.

Van Soest et al. (2006) also contend that PACE data is an inadequate proxy for policy stringency. They showed that PACE data is only available for the U.S and does not allow cross-country comparisons. Therefore, they propose to use the difference between a polluting input's shadow price and its purchase price as an indicator for policy stringency.

Similarly, Haščič et al. (2009) argue that the heterogeneity of used definitions and large number of missing observations make PACE an inadequate measure for policy stringency. Hence, they also decided to use perceived policy stringency as a proxy. Van Beers and van den Berg (1997) adopted a measure for environmental policy stringency that is aligned with the Polluter Pays Principle. They proposed a composed measure based on a set of output-oriented indicators, including: protected areas as percentage of national territory in 1990; market share of unleaded petrol in 1990; recycling rate of paper in 1990; recycling rate of glass in 1990; percentage of people connected to sewage treatment plant in 1991; change of energy intensity during period 1980-1991; and the level of energy intensity in 1980. While PACE is considered as an input-oriented measure, the measure proposed by van Beers and van den Berg (1997) can be regarded as an output-oriented indicator. According to Beers and van den Berg (1997) the advantage of using such a measure is that they reflect the concrete results of environmental regulations. Therefore, they consider it as a better proxy for environmental policy stringency, assuming that better environmental performance is a result of stricter environmental regulations.

As shown in Section 2.3.1, environmental policy commonly exists as a cocktail of command-and-control and market based instruments. An ideal measure for policy stringency should therefore contain elements of both types of instruments. Unfortunately, such a composed indicator is not available yet. The database of the Eco Innovation Observatory only contains macroeconomic data on market based instruments (e.g. percentage of revenue generated from environmental taxes in comparison to the total amount of taxes). Although, this is a limitation, other available measures (such as PACE data) do not represent policy stringency, as it is defined here, more accurately. Besides that, they possess other limitations as has been previously discussed.

A second proposed measure is to use perception-based data - percentage of total firms in a country that declare existing (or future) environmental regulations (command-and-control) or/and taxes (market-based instruments) as relevant for pursuing eco-innovation. This measure has been used by Johnstone et al. (2011). An advantage of using this measure is that it encompasses both dimensions of the definition of policy stringency. The downside of this type of indicators is that it is based on questionnaires in which firms are asked to self-evaluate. As a result, this measure is subject to response bias or social desirability bias (Nederhof, 1985).

A third measure proposed here is the share of total companies declaring government subsidies, grants, or other financial incentives as relevant for pursuing eco-innovation. Similar to the previous measure, this indicator is also based on self-perception data and is therefore subject to biases. Furthermore, the measure only illustrates the proportion of implemented market-based instruments and disregards the importance of command-and-control instruments in environmental policy.

3. OTHER CONTROL VARIABLES' MEASURES

As stated previously, in order to be able to examine the effect of the independent variables (policy stringency, firm specific factors, technology factors and market factors) on eco-innovation performance in 2012, and due to data availability limitations, we introduce a time lags of four years[5.]

Firm specific factors

Firm size

The literature review (see Section 2) suggests to control for the ratio of larger firms, when assessing the relationship between policy stringency and eco-innovation performance on country level. The OECD Statistics Directorate contains a wide range of firm specific factors on country level, among which firm size. In the database firms are divided into 5 size classes, with each class containing a specific range of number of employees. For the purpose of this study we decided to use an indicator that illustrates the share of NSC-5 class firms (NSC-5 class firm typically contains more than 250 employees) as a percentage of the total number of enterprises (in 2008).

[5]In their case study of a public transport operator in Portugal, Costa et al. (2014) showed that usually time periods of 2-4 years apply to observe the effect of decisions on performance levels.

Firm age

For this variable, The OECD Statistics Directorate only contains data for the year 2013 and has only few countries in common with the rest of the indicators. This lack of appropriate data inhibits the use of firm age in the empirical model.

Environmental Management Systems (EMS)

The literature review (cf. Section 2) suggests that EMS is a potential determinant for eco-innovation at the country level. The Eco Innovation Observatory database contains three different indicators for the relative presence of EMS per country: (1) a measure that illustrates the share of total companies *with procedures in place to regularly identify and reduce environmental impacts, (2) a measures that illustrates the percentage of total firms that possess an EMAS certificate, and (3) a measure that illustrates the percentage of total firms that possess an ISO 14001 certificate.*

As the definition of EMS suggests, EMS help companies in identifying opportunities to eco-innovate, and reduce environmental impact. This dimension of the definition is captured by the first measure. The second measure illustrates the proportion of firms that have a voluntary environmental management system (EMAS). This is therefore a direct indicator on the proportion of EMS in total. The third measure illustrates the proportion of ISO 140001 certificates. This type of certificate assists companies in establishing its own environmental management system. It is expected that firms which possess such certificates are more likely to also have its own environmental management system. This is the reason why this indicator is also regarded as an adequate indicator. Additionally, all indicators have data available for the year 2008.

Technology factors

Environmental R&D

The Eco Innovation Observatory contains data on Government Budget Appropriations or Outlays on R&D (GBAORD). This data shows the governmental support to R&D activities in specific R&D areas, in this case environmental R&D. The proposed measure illustrates the share of environmental GBAORD as a percentage of total GDP for the year 2008.

Market factors

Customer demand

Customer demand illustrates the share (in %) of total companies declaring current or expected market demand from customers for eco innovations as relevant (in 2008). The data for this indicator is gathered through questionnaires. As mentioned before, the validity of questionnaires are often controversial due to response biases (Nederhof, 1985).

Cost savings

The indicator for cost savings illustrates the share of firms that estimates an increase in prospect material costs. The data is derived from question Q3 from the Eurobarometer No.315. The Eurobarometer survey No.315 targets the attitudes of European entrepreneurs towards eco-innovation. 5222 managers from small and medium sized enterprises from 5 different NACE sectors have been interviewed at the beginning of 2011.

Unlike other control variables, data for this determinant is not available for the year 2008. Solely appropriate data for the year 2011 was found. This forms a substantial methodological limitation. Nevertheless, it is decided to keep cost savings as control variable in the model estimations. Current measurement instruments are insufficient and therefore impose inevitable methodological limitations. Since our study is the first to examine how the prospect of increasing costs affects eco-innovation performance at the country level, it is still of clear usefulness to estimate the empirical model. Furthermore, it could be argued that cost savings are capturing a structural phenomenon, which will not result in radical changes on short time frames.

User benefits

The literature review identified energy savings as one of the product attributes that provide end-users with an extra reason to purchase the product (see Section 2). The Eco Innovation Observatory contains an indicator that illustrates exactly this, namely the share (in %) of total companies with innovations leading to reduced energy use by the end-user.

Sector

The literature review identified several pollution intense sectors. These sectors are more likely to eco-innovate. Among these sectors are the machinery and equipment sector, and the motor vehicles sector. To illustrate the proportion of pollution intense sector per country, the indicator consists of the share (in %) of total companies which are operating in pollution intense sectors such as the machinery and equipment sector and the motor vehicles sector.

EMPIRICAL RESULTS AND DISCUSSION

For the 27 countries under analysis, on average, 0.45% of the total exports are of products from eco-industries (e.g. air pollution control, water pollution control, waste disposal, monitoring equipment, other environmental equipment, solar thermal, photovoltaics and hydropower). The cross country differences are substantial, ranging from a minimum 0.03% for Malta to a maximum of 1.23% for Luxembourg.

Some of the proxies for our independent variables are highly correlated which result in multicollinearity problems. To overcome multicollinearity, we estimate several alternative specifications (cf. Table 6). [6]

Despite this omnipresent empirical evidence of policy stringency as a determinant for eco-innovation, the present study did barely find any statistical significant results to support this importance. As can be seen in Model B3, in Table 9, at the country level, merely the share of green taxes as a percentage of total GDP shows a significant and positive coefficient in determining the turnover of eco-industries. However, in the same model we also found a higher significant positive correlation for EMAS certificates, indicating that counties that present higher shares of firms possessing an EMAS certificate tend to outperform the other countries in terms of eco-innovation turnover. Models B1 and B2 also demonstrate the importance of EMAS certificates in determining the turnover generated by eco-industries.

[6] In Table A1, in the Appendix, we present the procedure that resulted in the 31 specifications estimated.

In this context, and assuming that a government seeks to increase the turnover of eco-industries, such a result suggests that, besides imposing green taxes, it might be more effective to invest in policies that foster a larger EMS presence among firms. EMS are known to stimulate eco-innovation directly by introducing measurable goals, management structures as well as programs to achieve them (Coglianese and Nash, 2002), and, indirectly, by provoking organizational learning (Melnyk et al., 2003). Extant empirical literature (Frondel et al.,2008; Kammerer, 2009; Kesidou and Demirel, 2012) has only examined to what extent the presence of EMS impacts eco-innovation on firm level. Frondel et al. (2008) did not find a correlation between the presence of EMS systems among firms, and the changes in production technologies that firms undertake to reduce environmental impacts. In contrast, Kammerer (2009) and Kesidou and Demirel (2012) both identified the presence of EMS as a significant determinant, using respectively the ratio of firms with eco-product innovations, and environmental R&D expenditures as measures for eco-innovation. As far as we know, macro-economic studies that examine the relationship between EMS presence and eco-innovation at the country level do not exist. In comparison to the results of firm level studies (Frondel et al., 2008; Kammerer, 2009; Kesidou and Demirel, 2012), our results show similar ambiguities because only few models identify EMS presence as a significant determinant.

Still, regardless of the relation between the share of EMAS certificates and policy stringency in determining the turnover of eco-industries, it remains rather odd that policy stringency is barely identified as a determinant for eco-innovation in the present study, while a vast amount of empirical evidence has proven otherwise. A possible explanation is that aforementioned existing studies are examining the relation between eco-innovation and policy stringency on firm or sector level. As a consequence, the used measures differ substantially. Where firm-level studies employ self-perception measures to represent eco-innovation (often acquired through surveys), the present study has used macro-economic data. In addition, some of the studies mentioned above use input measures for eco-innovation such as environmental R&D activity (Demirel and Kesidou, 2012), while the present study uses output measures such as the share of green exports.

To get a better understanding on how the level of scale might influence the obtained results, it is interesting to compare our findings with the scarce amount of studies that also conducted research at the country level (Popp, 2006; Johnstone et al, 2011). Johnstone et al. (2011) developed an empirical model to test the impact of policy stringency on eco-innovation. They used the number of patent applications in certain areas of environmental technology (air and water pollution, solid waste management) as measure for eco-innovation. This type of measure is regarded as an intermediate output, not an output, measure of the eco-innovation process. Johnstone et al. (2011) found that policy stringency has a highly significant and positive impact on environmental patent activity, among OECD countries. Popp (2006) also used patent count as a measure for eco-innovation and found that an increase in emissions standard leads to an increase in foreign patents in the US and Germany. In contrast, and as mentioned before, our results do not identify policy stringency as an important determinant. Despite the fact these studies do conduct analysis on country level, the used measures for eco-innovation differ substantially, not measuring the outcome but rather an intermediate stage of the innovation process.

Regarding the remaining determinants, some other interesting results emerged. For the green export model estimations (Models A1-12, in Table 8), firm size and cost savings are ubiquitous in determining eco-innovation performance. Larger firms are known to have more capacity to adopt an eco-innovation strategy (del Río González, 2008) and the prospects of savings costs encourage firms to pursue eco-innovation (Cohen and Klepper, 1996). Extant empirical literature has only considered the relationship between these variables and eco-innovation (performance) at the firm and sector levels. For firm size, current empirical studies are not consentient. Some studies found a positive correlation (Horbach, 2008; Rave et al., 2011; Kesidou and Demirel, 2012), whereas others found a negative or no correlation at all (Wagner, 2007; Horbach, 2008). Although all our significant results showed a positive correlation with the share of green exports, we have also found plenty insignificant results for the other measures of eco-innovation performance. In that sense, our findings are in line with the ambiguity of previous studies: different indicators for eco-innovation lead to different findings. However, this is the first time that evidence is provided at the country level. For policymakers, such results might not be of great use given the difficulty that policymakers have in directly, though relevant policies, influencing the size of firms.

Regarding the prospect of cost savings, numerous studies have confirmed its role in determining eco-innovation (Frondel et al., 2007; Horbach, 2008; Horbach et al., 2012). As far as we know, only Frondel et al. (2007) found a result other than positive, namely zero. Our study is the first study to examine how the prospect of increasing costs (and thus the opportunity to save costs) impacts eco-innovation performance at the country level. Interestingly, the prospect of rising costs is identified as the most important determinant for the share of green exports. Apparently, firms acknowledge eco-innovation as a tool to avoid further increase in costs of production factors. However, it is peculiar that while theory explains that the prospect of saving costs leads in particular to eco process innovation (Cohen and Klepper, 1996), in our estimations, we find that the prospect of increasing costs is a significant and positive determinant of eco product innovation, i.e. the export of products from eco-industries (% of total exports). A possible explanation for our results is that eco-industries in particular are subject to stringer policies. This creates an incentive for them to pursue eco-innovation to reduce the costs involved in the manufacturing process. As a result, firms in these industries might increase their productivity and gain competitive advantage in favor of firms operating in countries with minor policy stringency. This might lead to an increase in the export of their products. Another explanation is that this measure for cost savings is intertwined with the measures for policy stringency. Stringer environmental policies punish firms that have a relatively high negative impact on the environment. This creates an incentive to start eco-innovating and simultaneously save costs. This could suggest that a part of the effect of stringer policies can be included in the cost savings variable. In reality the effect of cost savings might therefore be less then demonstrated by our results.

Another interesting result is the positive coefficient of environmental R&D (Models C1-3) in determining employment within eco-industries and, to a smaller extent, for fostering eco-innovation exports (Model A3). According to Pereira and Vence (2012), R&D is a prerequisite to obtain the necessary knowledge to be able to develop innovations. Numerous empirical studies have identified R&D as an important driver for eco-innovation (Mazzanti and Zoboli, 2006; Frondel et al., 2007; Rehfeld et al., 2007; Horbach, 2008).

All these studies have in common that they are conducted at the firm level, but they are using different measures for eco-innovation outputs and data from different countries. Frondel et al. (2007) analyzed to what extent type of technologies are implemented within the organization as a result of market, technology and firm specific factors. The authors distinguished two types of technologies: end-of-pipe and cleaner production technologies. They identified R&D as a significant determinant for cleaner production technologies but not for the implementation of end-of-pipe technologies. Rehfeld et al. (2007) also divided eco-innovation into two categories: eco-product and eco-process innovation. They found that firms that conduct R&D are more likely to realize eco-product innovation. At the same time no positive correlation with eco-process innovation was found.

Table 7: Determinants of eco-innovation performance – OLS estimations (dependent variable: Country's share of green exports as a percentage of total exports)

Group Determinant	Variable	Model A1	Model A2	Model A3	Model A4	Model A5	Model A6	Model A7	Model A8	Model A9	Model A10	Model A11	Model A12
Policy stringency	Present environmental regulations	-0.113 *(0.694)*											
	Expected environmental regulations		0.170 *(0.526)*	0.256 *(0.272)*	0.338 *(0.318)*	0.347 *(0.210)*							
	Green taxes						0.216 (0.270)	-0.094 (0.740)	-0.094 (0.730)	-0.158 (0.602)	-0.166 (0.591)	-0.301 (0.361)	-0.266 (0.389)
	Availability of government grants												
Firm specific factors	Firm size	0.571* *(0.055)*	0.539* (0.065)				0.497** (0.022)	0.557* (0.086)	0.588* (0.065)				
	Procedures to reduce environmental impact			-0.181 *(0.438)*						-0.049 (0.913)	-0.336 (0.419)		
	EMAS certificates				0.011 *(0.977)*		0.228 (0.289)					0.081 (0.827)	
	ISO 14001 certificates	-0.459 *(0.154)*	-0.268 *(0.327)*			-0.074 *(0.775)*		-0.436 (0.222)	-0.449 (0.207)				-0.139 (0.656)
Technology	Environmental R&D	0.140 *(0.620)*	0.261 *(0.338)*	0.336* *(0.089)*	0.126 *(0.652)*	0.140 *(0.598)*	0.078 (0.700)	0.127 (0.645)		0.129 (0.624)			
Market	Customer demand								0.019 (0.952)		-0.152 (0.704)	0.012 (0.970)	0.106 (0.695)
	Cost savings			0.407** *(0.048)*	0.611* *(0.069)*	0.601** *(0.047)*				0.550* (0.071)	0.588* (0.075)	0.623 (0.102)	0.567* (0.075)
	User benefits							0.061 (0.857)		0.212 (0.627)			0.174 (0.577)
	Sector	0.459 *(0.204)*					0.175 (0.401)	0.383 (0.257)	0.440 (0.206)	0.154 (0.565)	0.199 (0.466)	0.111 (0.729)	0.155 (0.621)
	Constant	0.139 (0.497)	0.097 (0.729)	-1.313 (0.201)	-1.988 (0.122)	-1.945* (0.083)	-0.161 (0.565)	0.288 (0.637)	0.330 (0.571)	-1.372 (0.265)	-0.874 (0.449)	-1.266 (0.248)	-1.192 (0.277)
	N	13	13	19	13	13	19	14	13	14	13	13	14
	F-stat: p-value	0.237	0.238	0.019**	0.195	0.188	.048**	.296	.274	.289	.289	.336	.271
	Adjusted R^2	0.216	0.172	0.398	0.217	0.224	0.345	0.171	0.177	0.177	0.162	0.118	0.196

Note: p values in brackets; grey cells indicate statistically significant estimates; ***(**)[*] statistically significant at 1%(5%)[10%].

Source: Authors' own computations.

Table 8: Determinants of eco-innovation performance – OLS estimations (dependent variable: Country's turnover and employment of eco-industries)

		Turnover eco-industries			Employment eco-industries		
Group Determinant	Variable	Model B1	Model B2	Model B3	Model C1	Model C2	Model C3
Policy stringency	Present environmental regulations	-0.454 (0.162)					
	Expected environmental regulations		-0.389 (0.227)				
	Green taxes			0.505* (0.088)	-0.355 (0.107)	-0.161 (0.536)	-0.390 (0.104)
	Availability of government grants						
Firm specific factors	Firm size	-0.312 (0.318)	-0.206 (0.479)	-0.203 (0.473)	-0.086 (0.692)	-0.304 (0.276)	
	Procedures to reduce environmental impact						
	EMAS certificates	0.689* (0.086)	0.705* (0.071)	0.711* (0.067)	0.161 (0.490)		0.116 (0.637)
	ISO 14001 certificates						
Technology	Environmental R&D	0.031 (0.921)	0.097 (0.743)		0.494** (0.039)	0.539* (0.060)	0.504** (0.036)
Market	Customer demand			0.019 (0.948)			
	Cost savings						0.056 (0.819)
	User benefits					0.149 (0.603)	
	Sector	-0.025 (0.941)		-0.056 (0.856)	-0.277 (0.231)	-0.166 (0.535)	-0.274 (0.238)
	Constant	0.564* (0.062)	0.513* (0.081)	-0.406 (0.378)	1.239* (0.065)	0.643 (0.351)	0.812 (0.648)
	N	13	13	13	19	15	19
	F-stat: p-value	0.339	0.297	0.247	0.134b	0.307b	0.139b
	Adjusted R^2	0.116	0.119	0.205	0.216	0.115	0.210

Note: p values in brackets; grey cells indicate statistically significant estimates; ***(**)[*] statistically significant at 1%(5%)[10%].

Source: Authors' own computations.

Horbach (2008) examined which factors resulted into new or improved products by suppliers of environmental goods/services. He also identified R&D as a highly significant and important factor. Thus, albeit the importance of R&D is widely spread throughout extant empirical literature, our results are less conclusive. Only for a few models significant and positive results are obtained.

A possible explanation might be that in our study completely different measures for both eco-innovation and R&D are used. Instead of merely analyzing whether firms are conducting R&D activities, our study has used Government Budget Appropriations or Outlays on environmental R&D in percentage of total GDP as measure for R&D. This measure does not say anything about the number of firms that conduct R&D activities but it represents the amount of investment a government puts into environmental R&D activities (for example research institutions). As measures for eco-innovation the share of green exports, the share of turnover and the share of employment of eco-industries are used. Although the latter is generally considered as an input measure in traditional innovation literature, governments often regard increasing domestic employment as an end-goal in itself. 5. Conclusions

MAIN RESULTS AND CONTRIBUTION OF THE STUDY

Over the past 50 years mankind has been damaging eco-systems faster than any period in human history before. The accumulated damages are to a great extent irreversible, and will prevent future generations from deriving the same benefits as current generations (Millennium Ecosystem Assessment, 2005). Smart solutions such as eco-innovations are needed to shift towards a more sustainable future (Millennium Ecosystem Assessment, 2005). Unlike in traditional innovation economics, policy intervention is required to overcome externality problems related to eco-innovation.

Given the relevance of policy intervention in realizing eco-innovation, it is crucial to study how past and present policies affect eco-innovation and its diffusion (Mickwitz et al., 2007). Commonly, environmental policies are therefore characterized by its stringency to enable and facilitate analysis. Current empirical literature on the role of policy stringency in determining eco-innovation, abounds with examples that policy stringency acts as a key determinant, both at the micro- and meso-levels. Still, to a large extent due to the lack of available data, empirical evidence at the macro-economic level does either not exist, or assesses the relation of policy stringency with indicators such as environmental patent counts. Although this type of indicator is widely available, patent counts are considered to be an inadequate measure for eco-innovation performance, since they are measuring intermediate outputs of the (eco)-innovation process instead of outputs.

To the best of our knowledge, this is the first study that uses output indicators for eco-innovation performance, most notably the share of green exports, the share of turnover from eco-industries, and the share of employment in eco-industries. Given the relevance for policymakers to understand to what extent and which factors are determining eco-innovation performance, our preliminary efforts to devise and estimate empirical models to determine the importance of policy stringency with respect to other relevant factors at the country level are of clear usefulness.

Based on a small sample of countries (13-19), cross country linear regression estimates showed that policy stringency (using four different measures), did not emerge as a significant determinant for eco-innovation performance. The only exception was the share of green taxes in determining the share of turnover of eco-industries. Given that the importance of policy stringency in determining eco-innovation is ubiquitous in extant empirical literature (Mazzanti and Zoboli, 2006; Rehfeld et al., 2007; Horbach, 2008; Horbach et al., 2012; Demirel and Kesidou, 2012), it is odd that policy stringency is barely identified as a determinant in our study.

Other determinants, nevertheless, evidenced a stronger impact on several dimensions of eco-innovation performance. In particular, the prospect of increasing costs, and the percentage of large firms proved to be more important determinants for eco-innovation performance in terms of eco-industry exports. In extant empirical literature the prospect of cost savings frequently emerged as a significant determinant for eco-innovation at firm/sector level (Frondel et al., 2007; Horbach, 2008; Horbach et al., 2012), whereas for firm size existing findings are more ambiguous (Wagner, 2007; Horbach, 2008; Rave et al., 2011; Kesidou and Demirel, 2012).

The measures for policy stringency and cost savings used in this study are based on self-perception data. This implies that firms in countries with higher eco-innovation performance (in terms of eco-industries exports), apparently perceive cost savings as more important than policy stringency. However, in practice, the possibility to save costs is often (partly) driven by policy instruments that punish pollution intensive firms. So in reality, firms that indicate that the prospect of cost savings is relevant to them for pursuing eco-innovation, therefore indirectly acknowledge that policies are also relevant to them. As a result, a proportion of the policy stringency effect might be observed through the variable cost savings. This provides an additional explanation for why policy stringency did not emerge as an important determinant

Besides cost savings and firm size, our results also pinpointed the share of EMAS certificates and environmental R&D as significant positive factors in determining respectively the turnover of eco-industries and employment in eco-industries. However, in comparison to cost savings and firm size, the results are less conclusive since only a few models identify these variables as significant determinants. Along similar lines, the available empirical evidence on the presence of EMS at firm level, also suggests ambiguity (Frondel et al., 2008; Kammerer, 2009; Kesidou and Demirel, 2012).

In contrast, extant empirical literature on environmental R&D provides ample examples of the crucial role that R&D plays in determining eco-innovation (Mazzanti and Zoboli, 2006; Frondel et al., 2007; Rehfeld et al., 2007; Horbach, 2008). As mentioned, our results deal with policy stringency on a macro-level. To the best of our knowledge, a study with the macro-level as the focal point of research had up to date not been conducted. Yet, comparisons with available evidence only concern the micro and meso level.

1. IMPLICATIONS FOR MANAGERS AND PUBLIC POLICY AUTHORITIES

Regarding the implications for policymakers, two major and several minor conclusions can be drawn from our results. First of all, our results seem to suggest that policy stringency plays a lesser role in determining eco-innovation performance than anticipated beforehand. As a consequence, policymakers should reconsider increasing general environmental policy stringency to improve eco-innovation performance. Secondly, and to elaborate on the first implication, other variables such as cost savings, firm size, environmental R&D, and EMS presence are identified as more significant determinants. In particular, the findings on the relation between cost savings and eco-innovation performance (in terms of green exports) are convincing. Apparently, countries where firms expect a higher increase of costs perform better in terms of eco-innovation. Given the importance of policy instruments in increasing these costs (associated with the use of environmentally harmful resources) governments possess the powerful ability to indirectly increase eco-innovation performance. It is recommended that governments leverage this ability by explicitly designing policies that fulfill this purpose. Researchers have an important role in providing the necessary knowledge to support governments in creating these instruments. Originally, theoretical literature claimed that more stringent policies result into higher costs of production factors, consequently reducing profit margins and decreasing the competitive advantage. However, since the introduction of Porter's hypothesis (Porter and van der Linde, 1995) it widely accepted that more stringent policies can also improve commercial competiveness. Along similar lines, our results show that the prospect of increasing costs can also increase international competitive advantage (in terms of exports of eco-industries).

Perhaps less novel but also relevant, our results indicate that public investments in environmental R&D form the most important determinant for increasing employment in eco-industries and to a smaller extent for fostering green exports. Hence, if governments are seeking to increase domestic employment in eco-industries or green exports, additional investments in environmental R&D constitute a good option.

Finally, the share of EMAS certificates emerges as the most important determinant in driving the turnover of eco-industries. This result suggests that countries with a higher presence of EMS have a relatively higher turnover of eco-industries. For corporate management in eco-industries this creates an incentive to invest in EMS. Also, at country level, governments should attempt to design policies that encourage the development of EMS among firms. In designing these policies, a strong cooperation between governments and researchers is required to come to effective policies. The role of future research in this cooperation is discussed later in this section.

2.LIMITATIONS OF THE STUDY

Due to the small sample size (13-19 countries) our results are volatile and adding more countries to the dataset might lead to a significantly different model fit. This induces a severe limitation to the original purpose of this study. Nonetheless, we find it justified to keep the empirical model as the focal point of this research because this type of multivariable analysis has not been conducted at the country level before. Despite the high volatility, the results give initial insights into how the different factors impact eco-innovation performance with respect to each other at country level. Still, the results should be interpreted with care, in particularly by policymakers.

Apart from statistical/methodological issues, there are several other limitations that have to be taken into consideration. First of all, the measures we have adopted for policy stringency are not entirely adequate. Ideally, a measure for policy stringency would contain characteristics of both dimensions of environmental policies: command-and-control and market-based instruments. Unfortunately, due to a lack of appropriate data, our measures are either perception based (derived from surveys), or are only representing market-based instruments. Substantial methodological differences in compiling databases between countries frustrate the usage of objective universal data. Therefore cross country studies still rely on survey data which is known to be subject to biases. On a more critical note, one could even wonder how useful it is to use a general measures such as policy stringency. In the end, an important role of researchers is to help governments in designing effective policies. While overall policy stringency is not identified as significant determinant in our study, it is possible that individual instruments emerge as an important determinant. However, since studies such as our use such a generic measure, we fail to point to and distinguish between effective and ineffective individual policies. In macro-economic studies, it remains a big challenge to determine measures that are adequately representing the theory. This also applies to the other measures used in the present study.

Another limitation concerns the introduced time gap between the dependent variable and independent variables in the models. Due to constraints introduced by the data, we were forced to adopt a time lag of four years. Extant empirical literature does not address this issue and therefore there seems to be no compelling reason to argue that a time lag of four years is perfectly adequate. Moreover, our study merely observes one point in time. As a consequence, the present study fails to capture the dynamic character of the innovation process. Furthermore, the database merely consists of European countries and does therefore not give an accurate and full scope global perspective.

3. FURTHER AVENUES FOR FUTURE RESEARCH

In the first part of this conclusion we stated that researchers have an important role in supporting governments to create effective policies. But what is the role that we have in mind for future researchers?

Our results indicate that increasing policy stringency does not lead to better eco-innovation performance. Due to a lack of a reference frame (scarcity of studies at the country level) and due to several severe limitations, it is unclear how reliable our results are. That is why it is necessary to conduct more studies on the influence of policy stringency (and the other determinants) on eco-innovation at the country level, before policymakers start drawing clear-cut conclusions from our study.

However, before researchers can conduct any meaningful research, two limitations should be tackled: first, the number of countries for which data is collected is insufficient. Hence, in an absolute sense, more data is required. Second, and perhaps more importantly, at this moment, the measurement instruments are very generic and limited. In the case of policy stringency, it would be interesting to understand what the effect of specific policies on eco-innovation performance would be. At this very moment, this type of information is not available and as a result, a conclusion with clear implications for policy-makers is hard to draw. Besides merely doing more research, developing more specific measurement instruments is therefore highly recommended.

If more detailed data on environmental policy and eco-innovation is available, it will open up a lot of opportunities for future research. At firm and sector level multiple studies distinguish different types of eco-innovation (i.e. product/process, end-of-pipe/cleaner production technology) and examine how factors affect these different types. To the best of our knowledge this has not been done at the country level before. More (detailed) data will enable future research to conduct this type of study. It will help to gain more insight to what extent regulatory pressures help improving different dimensions of eco-innovation. Countries that perform poorly in certain aspects of eco-innovation but well in others can benefit from these insights. It enables them to create more targeted policies. Another interesting avenue for future research is to examine to what extent stringer environmental policy is leading to the prospect of rising costs of production factors. Our sample suggests that cost savings play a key role in determining eco-innovation performance (measured in green exports). So if governments are able to influence this aspect by creating certain policies it possibly entails a huge potential. More knowledge on what types of policies play an important role in this process can yield significant benefits. Finally, more advanced cross country empirical models can be established that are not subject to the same limitations of the present study. This type of research will greatly contribute to extant empirical literature since currently macro level studies are severely under-represented.

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