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Measuring Environmental Policy Stringency in OECD Countries: A Composite Index Approach

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ABSTRACT/RÉSUMÉ

Measuring Environmental Policy Stringency in OECD Countries-A Composite Index Approach

Cross-country analysis of the economic effects of environmental policies is limited by the lack of reliable, comparable measures of the stringency of environmental policies. This paper attempts to fill this gap, by constructing new quantitative indexes of environmental policy stringency (EPS). Selected environmental policy instruments, primarily related to climate and air pollution, are scored and aggregated into composite EPS indexes. Two EPS indexes are proposed – one for the energy sector, and an extended one to proxy for the broader economy ("economy-wide"). They cover most OECD countries over 1990s-2012. While a simplification of the multidimensional reality of environmental policies, the EPS indicators are a first tangible effort to measure environmental policy stringency internationally over a relatively long time horizon. They show relatively high and significant correlations with alternative proxies of EPS used in the literature, such as measures of perceived stringency based on surveys, measures based on environmental outcomes and a composite policy-based measure with no time series. The paper describes some additional features of the EPS indicators and sketches out possible future extensions.

JEL classification codes: Q58, Q48, Q50.

Key words: Environmental policies, environmental regulation, environmental policy stringency, composite indicators.

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Mesurer la sévérité des politiques environnementales dans les pays de l'OCDE : approche fondée sur des indices composites

L'analyse des effets économiques des politiques environnementales dans une optique internationale est entravée par le manque de mesures fiables et comparables de la sévérité de ces politiques. Ce document vise à combler cette lacune en construisant de nouveaux indices quantitatifs de la sévérité des politiques environnementales (SPE). En l'occurrence, une note est attribuée à certains instruments de la politique de l'environnement – liés principalement au climat et à la pollution atmosphérique – et les notes sont agrégées sous forme d'indices composites de la SPE. Deux indices de SPE sont proposés : un pour le secteur de l'énergie et un, élargi, destiné à couvrir l'économie dans son ensemble (« macro-économique »). Ces indices couvrent la plupart des pays de l'OCDE pour la période allant des années 90 à 2012. Même s'ils dressent un tableau simplifié de la réalité protéiforme des politiques environnementales, les indicateurs de SPE sont l'aboutissement d'un premier effort tangible visant à mesurer la sévérité de ces politiques dans une optique internationale sur une période relativement longue. Ils laissent apparaître des corrélations relativement fortes et significatives avec d'autres mesures indirectes de la SPE employées dans les travaux publiés, comme celles issues d'enquêtes sur la sévérité perçue, celles reposant sur les résultats environnementaux et une mesure composite fondée sur les politiques pour laquelle il n'existe pas de série temporelle. Le document décrit plusieurs autres caractéristiques des indicateurs de SPE et esquisse de possibles prolongements à venir.

Classification JEL: Q58, Q48, Q50.

Mots clés: Politiques environnementales, réglementations environnementales, sévérité des politiques environnementales, indicateurs composites.

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MEASURING ENVIRONMENTAL POLICY STRINGENCY IN OECD COUNTRIES-A COMPOSITE INDEX APPROACH

By

Enrico Botta and Tomasz Koźluk [1]

1. Introduction

1. Empirical research on the economic effects of environmental policies relies heavily on the non-trivial task of evaluating the stringency of these policies. Stringency can be defined for individual policy instruments as well as for overall environmental policy, as the "cost" imposed on polluting or other environmentally harmful activity. At the same time, the complexity of measuring this elusive variable across countries and time is one of the main problems inhibiting the use of cross-country variation for policy inference (Brunel and Levinson, 2013; Koźluk and Zipperer, 2014). This paper attempts to fill this gap by providing a policy-based composite index. The approach followed is the construction of a measure turning quantitative and qualitative information contained in normative instruments (laws and regulations, primarily in the energy sector) into a comparable country-specific measure of environmental policy stringency (EPS).

2. The paper is organised as follows. First, it reviews the major challenges to construct indicators of environmental policy stringency (Section 2). Then, it describes the methodology used to build measures of environmental policies (Section 3). The fourth section shows the performance of OECD countries along the measures of stringency across time, in particular showing the evolution of market-based and non-market policies, and compares the results with other measures of stringency available in the literature as well as with selected indicators of environmental and economic performance. A conclusion follows. The Appendixes present some robustness checks and data sources.

2. The challenges of building a measure of environmental stringency

3. The main challenges in measuring the stringency of environmental regulation are: multi-dimensionality, sampling, identification (and enforcement) and the lack of data (Brunel and Levinson, 2013; Koźluk and Zipperer, 2014). Each of these aspects and the challenges related to it, are described in more detail in the following paragraphs.

4. *Multi-dimensionality* is determined by the intersection of the various planes of environmental regulations (environmental multi-dimensionality) with the multitude of possible policy instruments (policy design multi-dimensionality):

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1. This working paper is the result of joint work between the Economics Department and the Environment Directorate. This paper has been prepared by Enrico Botta and Tomasz Koźluk as part of the project on Environmental Policies and Productivity Growth. An earlier version of this paper has been discussed at WP1, WPIEEP and EPOC meetings in the course of 2014. Enrico Botta is currently working at the Global Green Growth Institute (GGGI). Tomasz Koźluk works for the Economics Department/Environment Directorate of the OECD. The authors would like to thank Jean-Luc Schneider, Simon Upton, Giuseppe Nicoletti, Shardul Agrawala, Silvia Albrizio, Vera Zipperer, Nick Johnstone, Ivan Haščič, Jehan Sauvage and Jean Fauquembergue, for their useful comments and suggestions. Special thanks go to other OECD staff and delegates who provided feedback and input. Finally, the authors would like to thank Sarah Michelson for editorial support. This project has benefited from voluntary contributions from the Danish and Swiss governments.

- Governments regulate various environmental media (air, water, soil, etc.) and different pollutants (SO_x, NO_x, Hg, etc.) per each media. A full evaluation of stringency of environmental policies would need to weigh and aggregate the policy stance in each of these dimensions.

- A multitude of environmental policy instruments are used (e.g. pricing, command and control instruments, voluntary approaches) and possible design features vary as well. Legislators may not only regulate emissions of a single pollutant through different instruments (e.g. both a tax and a performance standard on NO_x emissions), but often also discriminate the application of regulations according to the sector where a firm operates (e.g. by international trade exposure), capital vintage (e.g. certain regulations apply only to plants that started to operate after a given year), location of activity (e.g. urban area) or technologies deployed by firms.[2] This aspect of multi-dimensionality is further exacerbated by the different levels of government which often retain legislative power on this subject matter.

5. *Sampling* is linked to multi-dimensionality and arises from the fact that the sample of industries subject to policies may be driven by the policies themselves. For example, more polluting industries may have a lower share in a country subject to stringent policies precisely because the policies lead to a specific industrial structure. Sampling also concerns the possibility that in sectors indirectly affected by stringent environmental policies (e.g. through high electricity prices), these effects are not likely to be correctly assessed as resulting from environmental policies. Such sectors may constitute a large part of the sample in service-based economies.

6. *Identification* can be framed as the difficulty in correctly assessing the degree to which the expected consequences of stricter regulations (e.g. abatement expenditures by firms or observed pollution intensity) can be actually attributed to environmental policy stringency. Observed environmental outcomes can also be determined by other regulatory instruments (related, for instance, to labour and capital) and country-specific characteristics: market imperfections, skills, level of development, technology access, or trade openness and outsourcing. Moreover, all these features tend to interact with each other, making it difficult to link measures of relative environmental performance (or abatement expenditures) to actual environmental policies. Further effects may come from the provisions accompanying the environmental policies (e.g. to smooth the transition) and policy uncertainty.

7. A peculiar facet of identification is linked to the various degrees of law enforcement across countries, which further complicates the measurement of the impact of regulations. Enforcement issues are a problem of discrepancy between the legal and the actual stringency of policies. They may be related to the transposition of laws into government actions, low fines for and lax pursuit of violations. Enforcement may be of particular importance in countries with lower quality of institutions or large unofficial economies.

8. The last (but surely not least) issue is the *lack of data*. This element is often quoted as one of the reasons for preferring one type of measure of stringency over others.

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2. For example, different emission limit values are often enforced for electric arc furnace and a blast furnace in the steel industry or for chemical and mechanical pulp making for the pulp and paper industry.

2.1 A review of existing measurement approaches

9. Different approaches have been taken to measure environmental policy stringency, including: single policy change measures; composite measures of environmental regulation; surveys on the perceptions of stringency; survey-based data on firm or plant-level pollution abatement expenditures; estimated "shadow prices" of pollution; and environmental or related performance data (Koźluk and Zipperer, 2014; Box 1). Less direct proxies, such as counts of international environmental treaties ratified or number of environment-related inspections have also been used.

Box 1. Existing cross-country measures of environmental policy stringency

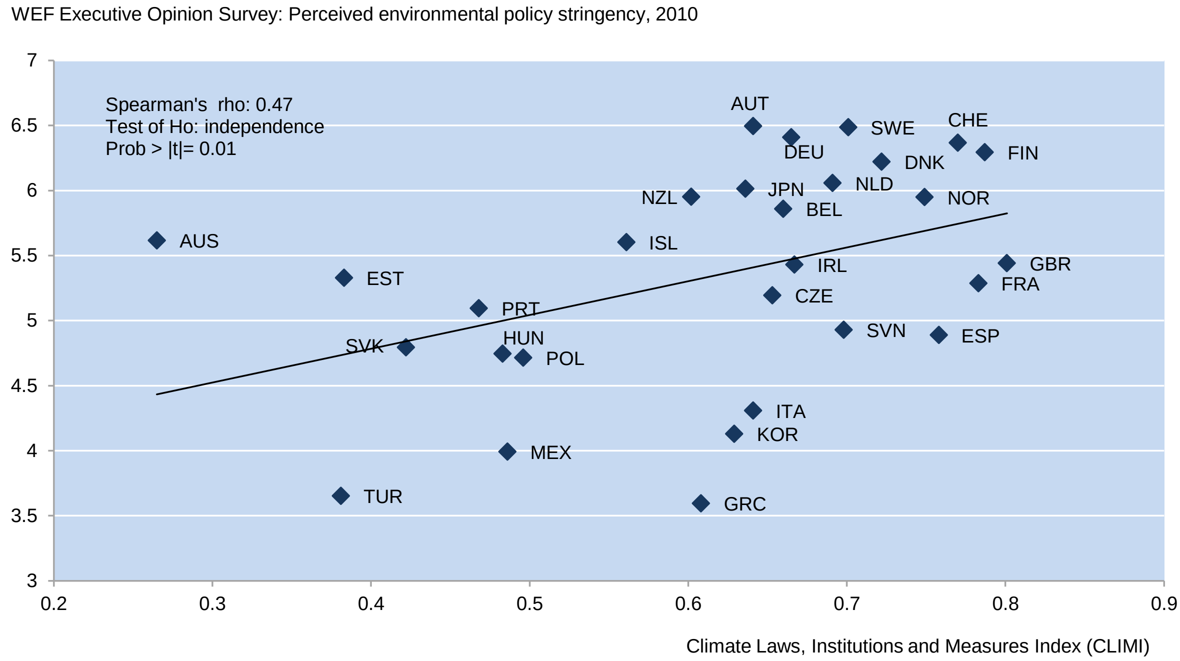
A handful of attempts to measure environmental policy stringency across countries have been undertaken in the past, but the lack of a sufficient time-series dimension has limited their empirical application. Dasgupta et al. (1995) developed an index of environmental regulations based on the reports prepared for the United Nations Conference on Environment and Development.[a] These reports were filled by countries' officials and complemented by responses from several NGOs in the attempt to make the data less exposed to biases from self-reporting. Dasgupta et al. (1995) assessed the answers to 25 questions in relation to four media (air, water, land, and wildlife), five economic sectors, and along five different environmental dimensions: awareness, scope of policies, scope of legislation, control mechanisms and implementation. Using the same methodology, Eliste and Fredriksson (2002) extended the database to cover another 31 countries for the agricultural sector only.

A second major attempt of building an environmental policy index was undertaken by the EBRD in 2011. Similar to the index developed by Dasgupta et al. (1995), the EBRD's "Climate Laws, Institutions and Measures Index" (CLIMI) index builds on the UN country reports, as well as on the National Communications to the United Nations Framework Convention on Climate Change (UNFCCC), which include information of climate adaptation and mitigation measures adopted by national governments. The components of the CLIMI index have been aggregated into four thematic areas: international cooperation; domestic climate framework; sectoral, fiscal or regulatory measures or targets; cross-sectoral fiscal or regulatory measures. The CLIMI index was developed for 95 countries and thus allows comparing climate change mitigation legislation of the year 2010 across a wide range of countries(EBRD, 2011).[b]

In an attempt to measure perceptions of business executives, the World Economic Forum (WEF) poses a number of questions relative to environmental regulations within its annual survey. The respondents are asked to rate the national environmental regulatory stringency and the enforcement of these regulations on scale from one to seven where seven represents the most stringent setting (WEF, 2011). These data have been used by Esty and Porter (2005), together with information on the broader economic and legal context drawn from the Environmental Sustainability Indicators (ESI) project, to develop a measure that summarises the overall environmental regulatory system in a country (Environmental Regulatory Regime Index – ERRI). The ERRI index measures the following aspects of a country's environmental regulatory system, of which some aspects measure more than solely policy stringency: standards, sophistication of regulatory structure and the extent of subsidisation of natural resources, enforcement and quality of environmental institutions.

A direct comparison among the above-mentioned stringency measures is only possible between the WEF and the CLIMI index for 29 countries in 2010, this being the only year where the two indicators overlap. By definition, WEF and CLIMI measure slightly different things. The former assesses the perception of *de facto* environmental stringency in all domains, from water abstraction to waste management, while the latter focuses only on *de jure* climate policies. The correlation between the two is 0.47 (Figure 1), significant at 5%. Unsurprisingly, the WEF and the ERRI, which is an extension of the WEF, are also highly correlated (0.89 significant at 99%). Instead, correlation between the WEF data and measures of pollution abatement expenditures is zero (Brunel and Levison, 2013).

Figure 1. WEF perceived environmental policy stringency and CLIMI policy-based index



Note: Both indicators measure EPS in 2010.

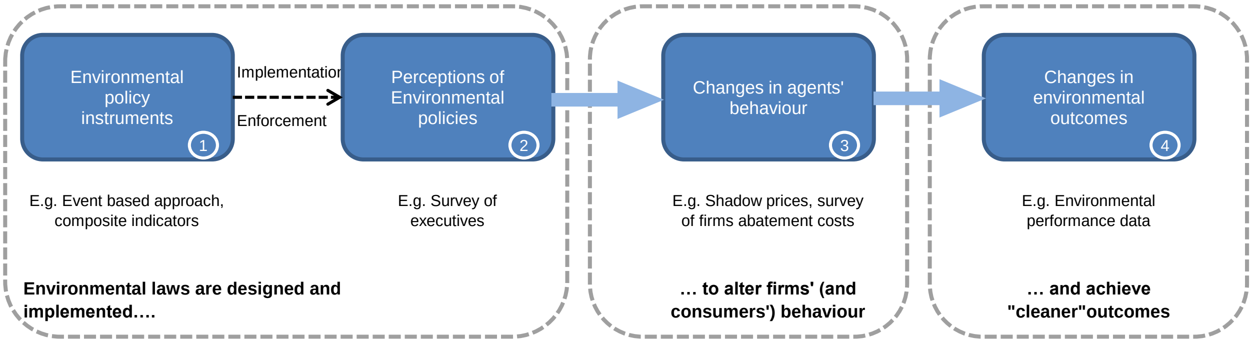
Source: EBRD (2011), WEF (2011).

a. Out of 145 countries that sent the report to the UN, Dasgupta et al. (1995) randomly select 35, of which only six are OECD countries (Switzerland, Finland, Germany, Netherlands, Ireland, and Korea). Given the small number of countries and reference to 1992 reports, the correlations are not reported here.

b. According to the EBRD Special Report on Climate Change “all assessments and data” are based on information as of early March 2011. As such, the index is considered representative of national regulation as of 2010.

10. The existing approaches differ in many dimensions, but it is possible to classify them according to “where” they attempt to measure environmental stringency (Figure 2). Single policy change events and composite measures of regulation build on the assumption that it is possible to directly observe environmental regulations, or at least representative elements of them, and therefore that it is possible to represent a country stance on environmental regulation by summarising measures of the enforced laws (Figure 2, bubble 1). The second group of measure - surveys on stringency - attempt to measure perceived regulations (bubble 2). Third, shadow prices for environmental inputs or environmentally-related expenditures (e.g. on pollution control) focus on the first-level consequences of regulation, namely firms’ cost and production choices (bubble 3). Environmental performance approaches look at the second-level consequences of instruments, that is, the variation in environmental performance of firms, sectors or countries, in order to evaluate the stringency of the policy itself.

Figure 2. Approaches to the measurement of stringency



Source: Authors' elaboration

11. The choice of *where* to measure stringency involves trade-offs among the magnitude of the different types of challenges. If stringency is measured by the laws themselves, there is a higher risk of neglecting important elements of regulations, of over-simplification or of failing to address potential large gaps between *de jure* and *de facto* law enforcement. On the other hand, the problems of identification are substantially reduced, as policies are directly observable. Conversely, measures of stringency closer to the consequences of policies should capture the combined effects of all regulations enforced (and relative designs), and dealing with sampling and the identification of the actual environmental policies may prove cumbersome. Each of the proposed measurement approaches has specific strengths and weaknesses with respect to the challenges identified (Table 1):

- *Single policy event measures* indicate the introduction or change of a certain policy. They are powerful in looking at direct effects, particularly at the micro-level where other variables can be controlled for, differenced-out or ignored. If the research question is specific (e.g. the impact of a single norm), then multi-dimensionality can be largely assumed away. However, this is done at the cost of the generality of conclusions and therefore the utilisation of the chosen variable as a measure of overall environmental stringency may be problematic. Furthermore, such measures are often dummy variables (Van der Vlist *et al.*, 2007; Curtis, 2012) and therefore rarely allow for testing the actual influence of particular aspects of the policy change (e.g. phase in, accompanying measures, design characteristics, policy interactions). Still, in empirical applications they have the advantage of linking effects directly to policies, reducing the issues of identification. In principle, they do not suffer from the lack of data, but are exposed to the risk of divergence between *de jure* and *de facto* regulation.

- *Composite measures* summarise directly observable laws and are also widely affected by multi-dimensionality. They reduce the visible size of a set of information into a synthetic, representative measure by aggregating individual indicators into a single measure on the basis of an underlying model. For this reason, they might be able to provide a more complete description of overall environmental legislative settings, but their sensitivity to the process of selecting and scoring policy instruments, deciding on the aggregation structure and relative weights adds uncertainty to the validity of the resulting variable. In fact, composite indicators can be highly misleading, if poorly constructed. They may disguise serious failings in some dimensions, if some sides of policies which are difficult to measure are ignored (OECD, 2008) – that is, if the selected and aggregated policies actually turn out not to be representative. Regarding identification, similar to single policy change measures, they are based on directly observed policies. Hence such measures usually are purely *de jure*. In such case, an additional complication may come from the fact that a number of policies may be characterised by little variance across countries - given that international guidelines often drive a process of homogenization of regulations (e.g. WHO guidelines for drinking water, EU Directives; see also Sauvage, 2014), while implementation may differ significantly. On the other hand, these measures present higher potential for recreating history, based on past rules and legal acts, though in practice this may be painstaking. For instance, the most notable efforts such as Dasgupta (1995) and EBRD (2011) only present a snapshot of the regulative stance of countries at a specific point in time.

- *Surveys of perceived stringency*, such as the WEF, are affected by multi-dimensionality in a rather implicit way. In fact, weights of policy instruments, media, and pollutants are decided implicitly with the choice of the sample. Even a random selection of respondents is disputable, in particular as a large part of economic actors (and hence survey-respondents) may not be directly exposed to environmental policies. Sampling problems are relevant, as the sample of respondents may actually be a result of environmental policies. Simultaneity and identification are important issues, as respondents might perceive environmental regulation as more or less stringent depending on the business cycle (e.g. during economic downturns labour regulation might top the agenda, while during expansive periods environment might become more a focus of concerns, Brunel and Levinson, 2013).[3] They may also be capturing the overall quality of institutions, rather than solely environmental policy stringency (Kalamova and Johnstone, 2011) – as suggested by the high correlation between the WEF measure of environmental stringency and the WEF measure of enforcement (.93 over 2004-2011) and by the high correlation with regulatory quality as measured by the World Bank Governance Indicators[4] (0.78 over 2004 - 2011). Using perception surveys in cross-country comparisons implicitly assumes that respondents are knowledgeable of the level of environmental stringency in other countries and that answers do not reflect perceived stringency relative to other domestic regulations (e.g. labour, financial and product market). The preference given to managers of large[5] firms probably helps in this regard, but might also strengthen the sampling bias. Data wise, WEF surveys have the benefit of covering several years (early 2000s to 2013), but it is not possible to recreate historical values.

- For *firm or plant surveys*, such as the US pollution abatement and control expenditure (PACE) survey, multi-dimensionality is more of an implicit problem, as firms tend to report all environmentally related expenditure. Identification is probably the major concern, as these measures do not distinguish effects of environmental policies from those of other policies, firms' decisions (e.g. marketing, efficiency/profit seeking investments in capital and R&D with collateral improvement in environmental performance) and knock-on effects are ignored – e.g. as a result of regulation a firm may choose to outsource dirty production rather than invest in cleaning it. Additionally, these measures suffer from sampling issues since countries whose economies are characterised by a large presence of heavy industries are more likely to register higher level of pollution and higher expenditures in abatement technologies (Brunel and Levinson, 2013). At the same time, for example, service-based economies will have lower pollution and lower environment-related expenditures even if the exact same norms are enforced. On the other hand, enforcement is not an issue, given that the effects of policies are considered. Data availability is patchy in terms of both countries and years. Furthermore, the data is reported

3. An argument supported by the finding of Kahn and Kotchen (2011) that public support for environmental policies falls when unemployment rates rise.

4. Reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.

5. The survey sample guidelines highlight each year the need to have a sample with a large portion of large companies since these companies have a better knowledge of the business environment. WEF EOS 2009-2010 & EOS 2011-2012

only for existing firms, which may be a source of bias if the population is actually determined by environmental policy stringency. The most popular measures, (US PACE data) have commonly known definitional and self-reporting problems, suffer from poor comparability across time and with other countries and from endogeneity (see Koźluk and Zipperer, 2014; for a discussion).

- *Shadow prices* of pollution can be estimated from production functions, reflecting the fact that environmental policies put an implicit price on pollution (Brunel and Levinson, 2013). Multi-dimensionality is again implicit, and by focusing on the outcomes, these measures have no issue of instrument-related multi-dimensionality. They also capture the *de facto*, rather than *de jure*, policy stance. Measurement issues arise from the fact that the observed outcomes are the result of the interaction of other policies (labour, product market, etc.) and market imperfections – making effects of environmental policies cumbersome to identify. Data are potentially available and historical series can be gathered, if there is sufficient information on pollutants. Such measures are also vulnerable to the strong assumptions made on the functional form of the production function which is used for their estimation.

- *Measures based on environmental outcomes*, such as relative pollution intensity (Brunel and Levinson, 2013), have the virtue of limiting multi-dimensionality on both the policy instrument and industry composition side. This is done by focusing on the joint outcome (*de facto*) of a pollutant in a given medium. Environmental multi-dimensionality remains, since a decision needs to be made on the aggregation of different pollutants and media to construct a measure of general environmental policy stringency. Also, although they tend to be straightforwardly comparable for a global environmental issue, such as GHG emissions, the bulking of "intensities" of local pollutants may be less meaningful, as it will focus on the country-wide effect rather than the effect where it matters. Identification issues are particularly acute, since, performance-based measures are not able to directly filter out the effects of other policies (financial market, competition, labour), costs of factors of production (e.g. energy, labour, capital) and other factors such as technological advancement, market structure etc. Data availability is also a problem, in particular for developing countries, even if there is some potential for generating past time series.

Table 1. Approaches to the measurement of stringency: advantages and disadvantages

<table>
<tr><th></th><th>Multi-dimensionality (and sampling)</th><th>Identification</th><th>Enforcement (De jure vs de facto)</th><th>Data issues</th></tr>
<tr><td>Single policy change event</td><td>▪ Depending on the research question. Powerful in looking at direct effects at a micro-level where other variables can be controlled for or ignored.
▪ Utilisation as proxy of overall country stance on environmental regulation relies on assumptions that selected policy events can represent the general legislative setting.</td><td rowspan="2">▪ In principle policies are well identified, though the weighting and aggregation structure imposes assumptions on the interactions among environmental policies that may not be valid. Empirical applications may face problems of different time lags in reactions to policies.</td><td rowspan="2">▪ Practically fully de jure.</td><td>▪ Depending of the event chosen. For instance, the date of signing international agreements (e.g. Kyoto) is easier to collect than implementation data of national legislations. Being often dummy variables, they can be used in international comparison only if the same policy is introduced (e.g. Kyoto, EU Directives, etc.)</td></tr>
<tr><td>Composite indicators of policies</td><td>▪ Linked to the process of scoring, aggregation and weighting of diverse instruments which is challenging. The underlying assumption is that a sufficient set of “representative” instruments is informative on the overall policy stance.</td><td>▪ Theoretically they give potential for recreating historical time series. Data gathering may be particularly cumbersome for some developing countries. Once data are gathered, comparing and quantifying policies may not be straightforward.</td></tr>
<tr><td>Surveys of perception</td><td>▪ Implicit – different dimensions are implicitly weighted via the surveyed sample.
▪ Sample self-selection is a major issue.</td><td rowspan="4">▪ Distinguishing effect of overall environmental policies or individual environmental policies from the effects of other polices (labour, competition, financial market) and of other factors (economic developments, available technologies, market structure, trade etc.) is tricky.
▪ May focus on direct effects, rather than total effects, e.g. outsourcing.</td><td>▪ De facto</td><td>▪ Few surveys are conducted consistently across countries.</td></tr>
<tr><td>Firm/plant level environment-related expenditures</td><td rowspan="3">▪ Focusing on consequences circumvents the part of multi-dimensionality due to different instruments and their design. In this sense, they also include policies that are normally difficult to score or obtain information on, e.g. soft policies, voluntary approaches (VAs).
▪ Environmental multi-dimensionality remains a major issue.
▪ Sample self-selection is a major issue.</td><td rowspan="3">▪ De facto</td><td>▪ Several datasets, even if sometime discontinuous, are available (e.g. US – PACE, EU – EPER, etc.), but not easily comparable internationally. Measurement and definitional issues.</td></tr>
<tr><td>Shadow prices</td><td rowspan="2">▪ Environmental performance data are available for most OECD countries on a restricted set of media/pollutants (mainly GHG). Shadow prices prone to assumptions on the production function.</td></tr>
<tr><td>Environmental Performance/outcomes</td></tr>
</table>

Source: (i) Authors elaboration, (ii) Koźluk and Zipperer, (2014), (iii) Brunel and Levinson, 2013

3. The proposed approach – a composite policy index

12. Composite indicators of policies result from the aggregation of individual indicators into a single measure on the basis of an underlying analytical model. Notwithstanding the challenges involved in constructing such indicators, the under-exploitation of composite indicators as a measure for environmental policy stringency is somewhat surprising given that analogous attempts have been performed in other fields of regulation which are equally characterised by a considerable degree of complexity and multi-dimensionality. Examples include product market regulation, employment protection legislation (Nicoletti and Scarpetta, 1999), financial sector regulation (Čihák and Tieman 2008) or competition law and policy (Hoj, 2007; Alemani et al., 2013) and the burdens to businesses (the World Bank's Doing Business Indicators or the WEF's Global Competitiveness Index).

13. This section outlines the definition of environmental policy stringency used in this paper, followed by a description of the sectoral and instrument coverage of the indicator. Furthermore, it describes the methodology for the construction of the two new composite indexes of stringency of environmental regulation.

3.1 Defining environmental policy stringency

14. In the context of developing the EPS indicator in this paper, policy stringency, both for individual policy instruments as well as for overall environmental policy, is defined as a higher, explicit or implicit, cost of polluting or environmentally harmful behaviour. This is straightforward for instruments like taxes – where a higher price on a unit of pollutant implies higher stringency. Lower (stricter) emission limit values have a similar interpretation. For subsidising instruments, such as feed-in tariffs or subsidies to R&D, a higher subsidy is also interpreted as more stringent environmental policy – such subsidies increase the opportunity costs of polluting and can be assumed to be paid by the bulk of tax payers or consumers, hence providing an advantage to "cleaner" activity.

3.2 Sectoral coverage and the potential for an economy wide indicator

15. This paper develops two composite indicators of environmental policy stringency. As a first step, an EPS indicator is built which focuses on the energy sector. In a second step, the first indicator is extended to include three additional policy instruments from outside the energy sector in an attempt to proxy the economy-wide stance of environmental policy stringency.

16. The energy sector, as base for the first indicator, is identified as selected activities that pertain to the production, transmission and distribution of electricity, gas and steam (ISIC rev. 4 code D 35). In practice, the indicator focuses on policies applied to electricity generation, though many of them are also applied to other sectors. This sector is chosen due to several structural features, primarily driven by data availability:

- First of all, the main objective is to obtain a policy stringency measure with the broadest possible time and country coverage. This requires focusing on a sector that is present and of broadly similar importance in all countries.

- Second, while the production of electricity might take place as a secondary activity within different sectors, electricity-generating firms tend to perform primarily this function, i.e. are rarely directly affected by policies concerning other activities (even taking combined heat and power generation into account). This allows the (strong) assumption that the stringency of environmental regulation for this sector can be estimated by looking only at the selected policies affecting electricity generation. Admittedly, not all technology types could straightforwardly be included – for instance nuclear or hydro energy and related environmental policies are missing from the analysis, primarily due to the high complexity of the regulations concerning these and interactions e.g. with public safety policies. Overall, the indicator remains a proxy and cannot possibly cover all environmental policies in the energy sector, but in turn includes the broadest possible range of policies regarding electricity generation, based on the cross-country available data.

- Third, the electricity sector is a key contributor to the emissions of greenhouse gases in most countries and also contributes to air pollution. The recent focus of international literature on how to design policies to contain emissions allows building on a large body of analysis and starting the data collection process from a solid base of data (e.g. national communications to UNFCCC, IEA policies and measures databases, OECD\EEA Environmental Policies Database, etc.). Moreover, climate externalities are global, hence at least in principle more comparable across countries.

- Fourth, environmental regulations for this sector are consistently framed across countries in order to differentiate technologies according to the fuel used to generate electricity and the size of the plants. Thus, selection rules can be designed fairly simply and are applicable to the whole sample. Specifically, when regulations differed across fossil fuel electricity generation technologies the focus was set on regulations affecting utility scale coal-burning plants. When regulations discriminated according to year of entry into operation, only regulations for newly built plants were considered.

17. Clearly, the above criteria constitute a strong simplification of reality since the focus on emission limit values for coal fired plants overlooks important differences across countries (e.g. coal is only one of the most common fuels used to generate electricity and its importance in the generation mix varies).[6] Additionally, in every given year, the portion of new plants starting operation is (except under exceptional circumstances) a small fraction of the whole generation capacity. While regulations for existing plants are often tightened at the same time that rules are established for newly built plants, the extent to which rules that apply to new plants are representative of those affecting the whole industry is uncertain.

18. As discussed above, focusing on regulation that mitigates GHG and air pollutant emissions reduces the set of policies, but it overlooks other areas of regulations that have an impact on the energy sector. For instance, the nexus between water and energy (IEA, 2012: DOE, 2006) in the terms of the need for clean water for energy generation and of the impact of energy generation on water resources, is not considered.

19. A number of instrument types have been ignored in the analysis, including voluntary approaches (VAs), land use regulations and other “soft” policy instruments.[7] The main issue with this type of instruments is the high level of site specificity. For instance, land use regulation is likely to be implemented at lower levels of governments while voluntary approaches are often negotiated between single facilities and local authorities. This heterogeneity, together with the possibility of regulatory

6. Consequently, emission limit values for other types of plants, such as gas-fired plants, are not included in the indicator. While the main reason is linked to data limitations, this approach may also be justified by the fact that coal plants are typically considered to produce higher amounts of air pollutants (SO_x, NO_x) per unit of energy.

7. The OECD Environment Directorate is currently planning an analysis on land use regulations.

capture, makes even more problematic the comparative assessment of stringency.[8] The omission of certain types of instruments weakens the generality of the composite indicator since these instruments are common in some countries, like Japan, where voluntary approaches represent a large share of the tools implemented for environmental protection (OECD, 1999; Welch and Hibiki, 2002).

20. The second indicator attempts to move from an energy sector based index to a broader measure of environmental policy stringency. The main objective in developing the economy-wide EPS index is to preserve the time dimension of the data, which poses a trade-off with respect to potential sectors and policy instruments to be included. Ideally, the indicator would replicate the analysis of environmental regulations undertaken for the energy sector, as described above, for all key sectors or activities of the economy. However, due to limitations in historical data availability, this is infeasible in the context of this project, limiting the number of additionally included policies to three for the moment.

21. Available data allows supplementing the energy sector information with a small number of instruments applying to the transport sector and a dummy on the existence of deposit and refund schemes. This can potentially increase the representativeness of the indicator on the economy wide level under the assumption that selected instruments are representative of the diffusion (and stringency) of environmental policies elsewhere in the economy.[9] In particular, data included in the extended ("economy-wide") indicator complement the information on market-based instruments outside the energy sector.[10] These additions increase the breadth of coverage of environmental policies; nevertheless the indicator remains a proxy of overall stringency and is not comprehensive as such.

3.3 The challenge of multi-dimensionality

22. Accounting for the multi-dimensionality of activities, environmental media and pollutants is particularly difficult at the level of the whole economy, but, if the relative stringency of environmental regulations for specific sectors is to be estimated, the number of dimensions is sensibly reduced. In fact, each economic activity (or sector) produces a different set of main environmental externalities. For instance, fossil-fuel based electricity generation are key contributors to greenhouse gas emissions and air pollution, while they scarcely pollute water (at least in terms of effluents); the opposite can be said for food processing or textiles where the main direct pollution is generated in the form of effluents and waste. As such, strict air control limits might be extremely burdensome for the former, but less relevant for the latter. Adopting a sectoral approach implicitly assumes that the overall stringency of environmental regulations can be approximated by looking at policy instruments that regulate environmental externalities in selected sectors. The underlying assumption is that policy

8. A number of attempts to describe key features of the design of voluntary approach practices across a number of OECD countries have been made (OECD, 1999 and 2003). Such characteristics include e.g. the presence of BAU scenario, type of monitoring, public disclosure of results and sanctions. However, available data does not allow to robustly comparing these elements – the responses to the OECD questionnaire indicate that in most countries there is no national inventory of such agreements (Koźluk, 2014).

9. This cannot be tested directly, but some indication is provided in Appendix IV, in particular using emission limit values and effluent limit values in other sectors and regarding other pollutants. These have been collected for the purpose of the project but are not included in the EPS because data are patchy across time and countries.

10. Note that many of the pricing instruments implemented before the mid-1990s, like taxes on fuels, were not primarily environmentally motivated but are nonetheless included due to their potential relevance for addressing negative externalities.

control of environmental externalities in a given sector (e.g. energy, transport) implies a similar degree of policy control for the same externalities in other sectors. While this may not always be the case due to political economy issues (e.g. lobbying power of sectors) or international obligations, it is a reasonable approximation.

23. A second key aspect of multi-dimensionality is linked to the multitude of instruments that can be used to regulate a given sector (policy design multi-dimensionality). To this end, the taxonomy developed by De Serres *et al.* (OECD, 2010) is used as a map to navigate the variety of possible instruments (Table 2). Additionally, the taxonomy can ease the process of policy advice since the optimal combination of instruments is dependent on the predominant market failures, costs of implementation and the structure of the sector to be regulated. For instance, trading schemes (especially if requiring continuous monitoring) are often considered as more effective where few large sources of pollution are present (e.g. energy sector), while standards might be more useful in tackling environmental externalities arising from a dispersed base of small sources where monitoring cost might be too high. To this end, information that a country is strongly unbalanced towards a category of instruments compared to others, together with insights on environmental and economic outcomes might suggest there is room for reviewing policies.

24. The third aspect of multi-dimensionality relates to instrument design, such as the degree of differentiation according to vintage, size or technology exploited in production. For instance, it is not uncommon for countries to set standards of varying strictness for existing and new installations or small and large units (e.g. coal-fired power plants) or to have different air emission standards for coal and gas-fired power plants. In this paper, the issue is dealt with by designing sampling rules that can be applied uniformly across the sample (e.g. focusing on regulations for new plants).

Table 2. Taxonomy of policy instruments

	Name	Example in the database
Market-based instruments	**Taxes and charges directly applied to the pollution source.**	Tax on emissions of NO_x
	Taxes and charges applied on input or output of a production process.	Diesel tax
	Trading scheme	Emissions Trading Scheme for CO_2, Renewable Energy Certificates
	Subsidy for environmentally - friendly activities	Feed-In Tariffs
	Deposit-refund systems	Deposit Refund Scheme for beverages
Non-market instruments	**Command – and - control regulations**	Emission Limit Value for NOx for large size coal-fired plants
	Technology - support policies	Government R&D expenditures (% GDP, Renewable energy)
	Voluntary approaches	Not covered

Source: De Serres et al. (2010)

3.4 Construction of the EPS index

25. The actual construction of the indicators entails two main steps: *i)* selection and scoring of single instruments and *ii)* aggregation of the information.

3.4.1 Selection and scoring

26. The instruments included in the analysis have been selected in order to cover, as broadly as possible, both market and non-market approaches to environmental policies (Table 3). All variables considered in the analysis represent law-based elements of regulations (e.g. emission limit value for a given substance, percentage of renewable energy to be procured, tax rate for emissions of NO_x) except for emission trading schemes for CO_2 and SO_x, where the simple yearly average of allowance prices has been used, and for government R&D expenditures, where the annual total public budget allocated for R&D on renewable technologies (as percentage of GDP) has been used.

Table 3. Instruments included in the energy sector indicator

Instrument	Information considered for scoring	Rules for addressing capital vintage or technological composition
Emission Trading Scheme(CO_2)	Price of one CO_2 allowance	n.a.
Renewable Energy Certificates Trading Scheme	% of renewable electricity that has to be procured annually	n.a.
Energy Certificate Emission trading Scheme	% of electricity saving that has to be delivered annually	n.a.
Emission trading Scheme for SO_2	Price of one SO_2 allowance	n.a.
CO_2 tax	Tax rate in EUR/ tonne	n.a.
NO_x Tax	Tax rate in EUR/ tonne	n.a.
SO_x Tax	Tax rate in EUR/ tonne	n.a.
Feed In Tariff for wind	EUR/kWh	n.a.
Feed In Premium for wind	EUR/kWh	n.a.
Feed In Tariff for solar	EUR/kWh	n.a.
Feed In Premium for solar	EUR/kWh	n.a.
Particulate Matter Emission Limit Value for newly built coal-fired plant	Value of Emission Limit in mg/m^3	ELV for newly built large scale coal fired plants
SO_x Emission Limit Value for newly built coal-fired plant	Value of Emission Limit in mg/m^3	ELV for newly built large scale coal fired plants
NO_x Emission Limit Value for newly built coal-fired plant	Value of Emission Limit in mg/m^3	ELV for newly built large scale coal fired plants
Government R&D expenditures for renewable energy technologies	Expressed as % of GDP	n.a.

Source: see source table in the Appendix IV.

27. The extended (or "economy-wide") indicator of stringency embodies three additional time series of instruments in order to develop a broader representation of countries' environmental regulations (Table 4). By construction, the extended indicator remains largely focused on the electricity sector, but the additional instruments and the fact that some of the policies included in the energy sector indicator are also applied beyond the electricity sector itself (e.g. EU ETS, taxes on air pollutants), imply it can be seen as an extension to a broader coverage of the economy. Similarly, it remains largely focused on policies addressing greenhouse gases and air pollutants, proxying for a broader set of environmental policies.

Table 4. Additional policy instruments included in the economy-wide indicator

Instrument	Information considered for scoring	Rules for addressing capital vintage or technological composition
Tax on diesel for industry	Total tax for a litre of diesel used in transport for industry	n.a.
Deposit & refund scheme	Dummy for presence of a Deposit Refund Scheme	n.a.
Maximum content of sulphur allowed in diesel	Value dictated by the standard	n.a.

Source: see source table in the Appendix IV.

28. All the nominal values of market instruments for the energy sector have been normalised using the electricity price paid by industrial users in order to account for the different impact of nominal tax rates across countries. This applies to all tax rates, FITs and ETS prices. The tax on diesel fuel has been normalised by the national pre-tax price paid by industry for diesel.

29. This approach results in having the tax rates for the energy sector expressed as MWh/tonne of pollutants. The intuitive interpretation is an equivalent of a shadow output to input ratio which increases in stringency as they increase in value.[11] More precisely, the more MWh a plant is to produce per tonne of CO_2 (NO_x, SO_x), the more stringent the instrument is (equation 1).

(1)
$$\frac{Tax\ rate}{Price\ of\ electricity} = \frac{\frac{€}{ton}}{\frac{€}{MWh}} = \frac{MWh}{ton}$$

30. For federal countries, where some of the key instruments for the energy sector are applied at the sub-national levels, these instruments are also considered (e.g. US States, Canadian Provinces). In this case, they have been weighted by the State's share of a country's total generation (or demand). In case of emission limit values, due to the problematic averaging, the emission limit value for the most populated State or Province was adopted.

31. The process of scoring starts with the creation of instrument–specific measures of stringency - i.e. cardinal measures increasing in value as the stringency increases. The information for each policy instrument across the entire sample is used to identify seven classes of increasing stringency. It is assumed that the sample represents the entire population, therefore for each instrument-specific indicator both 0 (not existing) and 6 (most stringent) are assigned with the thresholds for each class chosen based on the in-sample distribution of values on each instrument.[12] In other words, the cross country (and time) ranges of policies are standardised across instruments. Countries' performance is

11. In terms of units, the tax instrument is hence expressed in units (MWh/tonne) that are the inverse of a common unit of emission limit values). For example in the United States, new Emission Limit Values (ELVs) are expressed as pounds of carbon dioxide (CO2) per megawatt-hour (MWh) of electricity generated.

12. The use of in-sample distribution can have some disadvantages. For instance, adding new countries and years to the sample may require a re-attribution of bin thresholds or increase in the number of bins and therefore lead to a reattribution of scores.

scored for each year according to how they perform against the individuated classes. A value equal to zero is assigned each time the instrument is not implemented (e.g. CO_2 Emission Trading Scheme in Germany in 1997). Examples are given in Table 5.

Table 5. Examples of scoring for NO_x taxes and Emission Limit Values

A. Categorical scoring for NO_x taxes		
Tax rate MWh/tonne (deflated by EUR/MWh)	Score assigned	Impact on indicator of stringency
=0	0	-
0<x<=.03	1	+.03
.03<x<=.5	2	+.06
.5<x<=1	3	+.09
1<x<=2	4	+.13
2<x<=4.5	5	+.16
X>4.5	6	+.19

B. Categorical scoring for NO_x Emission Limit Value		
ELV in mg/nm[3]	Score assigned	Impact on indicator of stringency
=0	0	-
X>350	1	+.06
300<x<=350	2	+.13
250<x<=300	3	+.19
200<x<=250	4	+.25
150<x<=200	5	+.31
0<x<=150	6	+.38

32. The same methodology is applied to all instruments except deposit and refund schemes (DRS) - the only qualitative variable included. This is coded as a binary measure (dummy) with value zero (no DRS) or one (the presence of a deposit and refund scheme).[13]

33. The scoring procedure is based on the comparison of the stringency of each instrument against the distribution of values for the same type of instrument across countries and time. It reflects the relative stringency – that is the country's position on each instrument relative to the other countries (and years). It is less meaningful for comparing the relative stringency across instruments. Additionally, this procedure alters the variability of policies (e.g. the sample of NO_x emission limit values moves from a distribution with mean of 282 and standard deviation of 273 to one centred at 2.4 and with a standard deviation equal to 2.3).

3.4.2 Aggregation method

34. The aggregation procedure, which is the same for both the energy and broader indicator, follows a two-steps approach. First, the instrument-specific indicators (e.g. taxes on SO_x, NO_x and CO_2) are aggregated into mid-level indicators according to their type (e.g. environmental taxes). Second, the obtained mid-level indicators are grouped into the two broad categories of market- based and non-market instruments. Subcomponents can be used and aggregated in various ways, for example to obtain "stick" and "carrot" versions of the indicators, where the former represents policies punishing environmentally harmful activity (e.g. taxes on pollutants), while the latter policies reward "environmentally-friendlier" activities (e.g. subsidies). At each level of aggregation, equal weights are applied, which reflects the lack of priors in this respect (Figure 3 and 4).[14] Some robustness tests of the aggregation approach are provided in Appendix I.

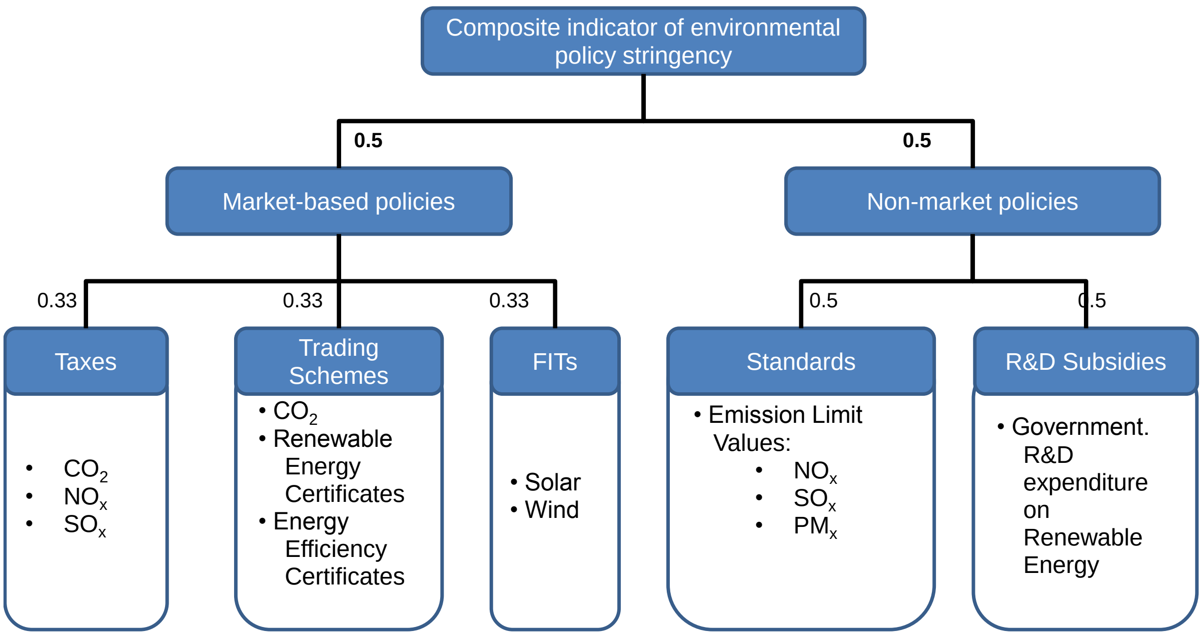
35. Caution is necessary due to potentially different statuses of policies – but in general, instruments within a certain type (e.g. taxes or ELVs) are more likely to be implemented jointly within

13. Then, the value is multiplied by 6 to rescale.

14. The only instrument type which receives a lower weight than its peers is white trading scheme due to its novelty and lower diffusion.

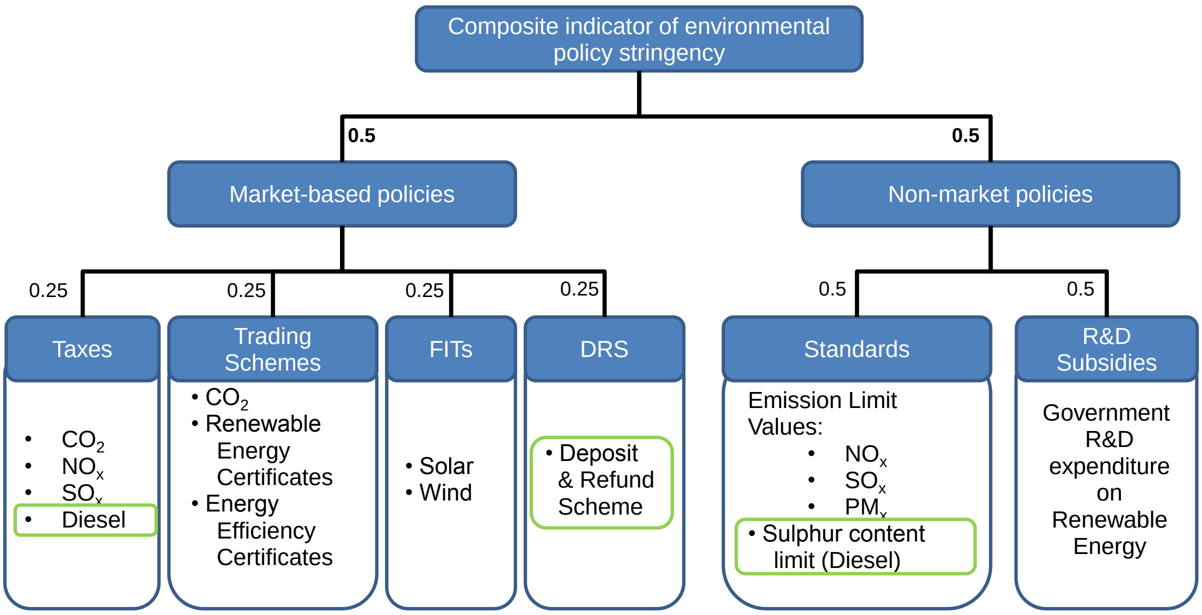
a country. This might be due to a preference for a given approach to regulation or cumulative experience in designing and enforcing a certain typology. On the other hand, instruments of different types, but within the same category (e.g. a tax on CO_2 emission and a CO_2 emission trading scheme are different types of market-based instruments) are more likely to be substitutes conditional on the same pollutant and activity covered.[15] An exploratory factor analysis seems to support this argument (Appendix I).

Figure 3. Structure of the energy sector indicator



15. However, it should be noted that from a theoretical perspective, combinations of instruments focusing on the same pollutant are possible and reasonable. This can be the case in the presence multiple policy objectives (in the like of the Tinbergen's principle). For instance, a carbon tax can be used as floor price for a CO2 ETS, as an emission limit value can be implemented, even in presence of SOx pricing, under the argument that higher confidence has to be created for investors (see Hood, 2013 for further discussion).

Figure 4. Structure of the extended (economy-wide) indicator



4. Results and analysis

36. This section analyses how countries score on the two indexes over time.[16] It first focuses on the indicator of environmental policy stringency for the energy sector, and then looks at the extended measure, which is used in the empirical analysis in Albrizio et al. (2014) and OECD (2014). Comparisons with other measures of environmental policy stringency and other relevant variables are provided as well.

4.1 Environmental policy stringency in OECD countries

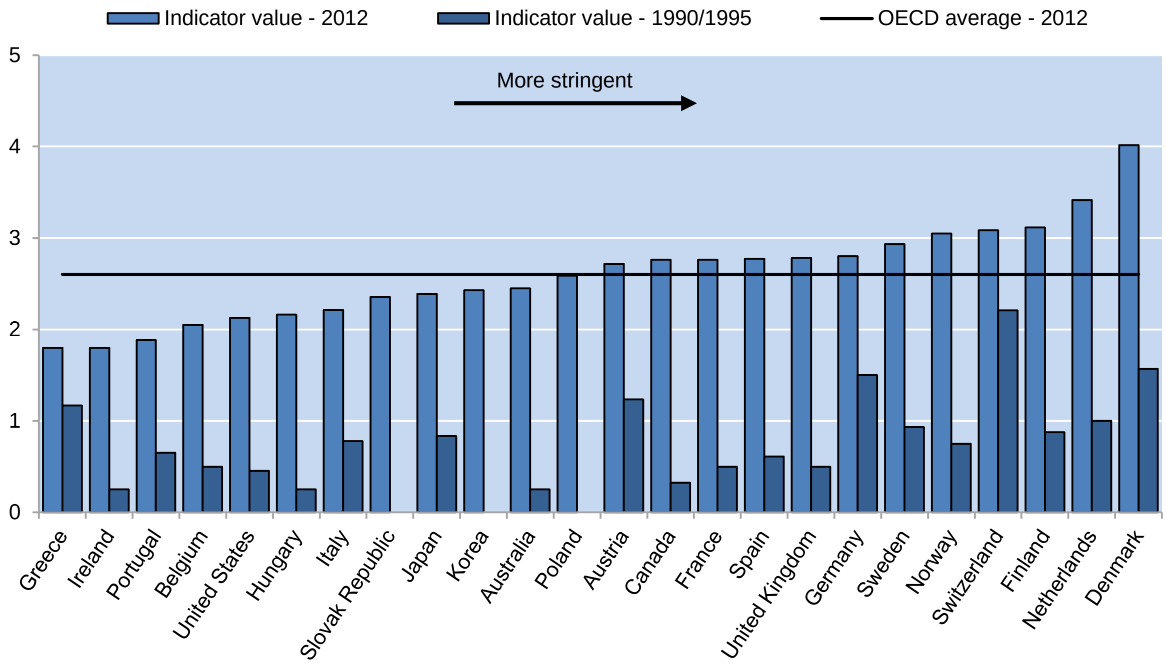
37. The new indicators represent the stringency of environmental policy on a scale from 0 to 6 with higher numbers being associated with more stringent environmental regulation. The range of values taken by the indicators across countries is narrower than the initial 0-6 scale because of the aggregation - no country scores least (or most) stringent on all instruments at any point in time.

4.1.1 Environmental policy stringency based on policies in the energy sector

38. First, the energy-sector based EPS is built, according to the structure laid out in Figure 3. For 2012, three country groups can be distinguished with regard to their aggregate regulatory stance, although incremental differences are relatively small (Figure 5): at the lower end of the spectrum, Greece, Ireland and Portugal; above the OECD average the Nordic countries, the Netherlands and Switzerland; the rest of the countries score close to the average.

16. With respect to previous versions of this paper, New Zealand was excluded from the analysis in this paper, as due to specific aspects of New Zealand environmental policies it was not possible to arrive with a satisfactory proxy under the time constraints. Work is underway to include New Zealand (and other countries) in a later, extended vintage of the EPS.

Figure 5. Environmental policy stringency in 2012 – Energy Sector

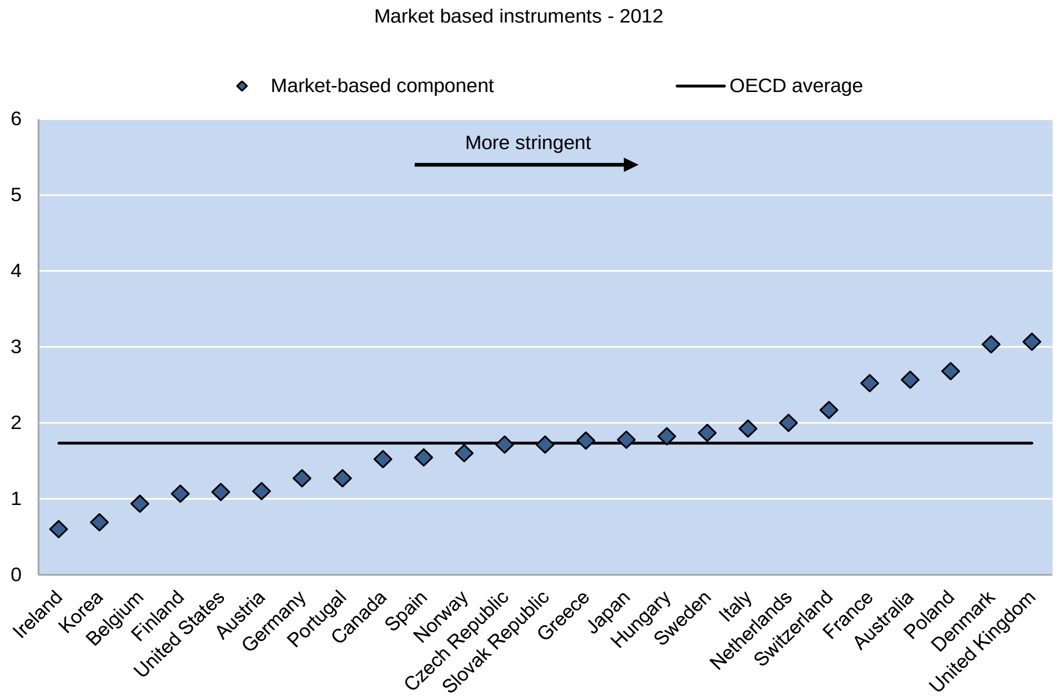


Source: OECD calculations.

39. As for the main components of the aggregate indicator, in 2012, countries show higher scores for non-market than for market-based regulation (Figure 6 and 7). This may be partly due to the variable construction, as the non-market measure covers primarily ELVs for different pollutants, which tend to be complements, while a large part of the market-based measures can be rather regarded as substitutes – for instance in the case of ETS based prices and taxes regarding the same pollutant.[17] The second domain, "non-market regulation", is characterised by a slightly higher variance in the same year.

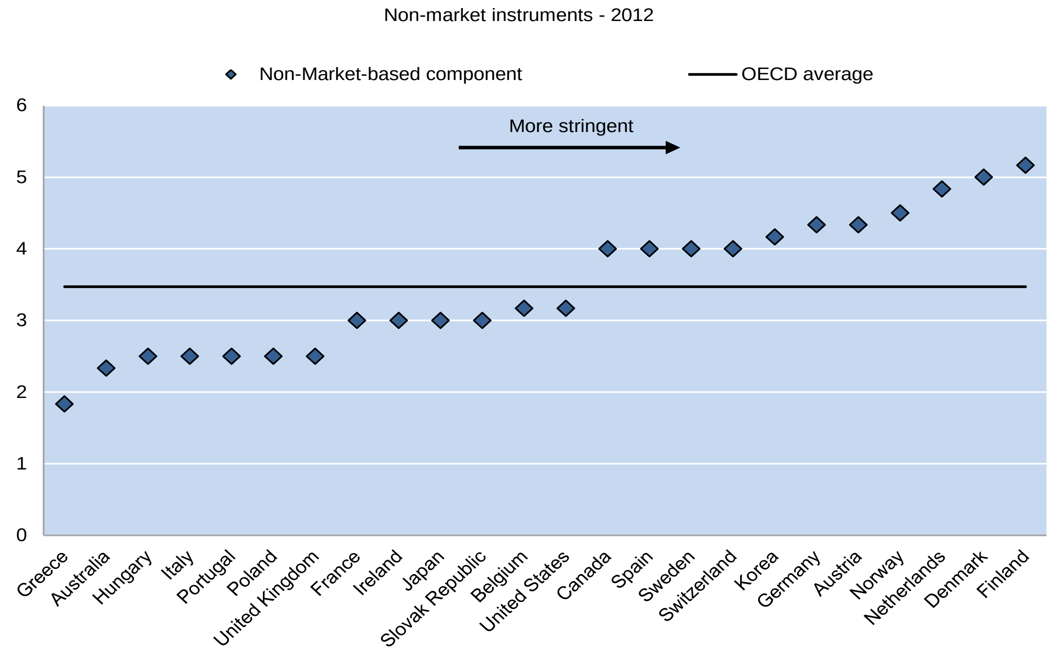
17. Each country implemented at least one of the market-based instruments included in the analysis. This includes the New Zealand recent ETS and the carbon tax in British Columbia (Canada).

Figure 6. Stringency of market based instruments in 2012 - Energy sector



Source: OECD calculations.

Figure 7. Stringency of non-market instruments in 2012 - Energy sector

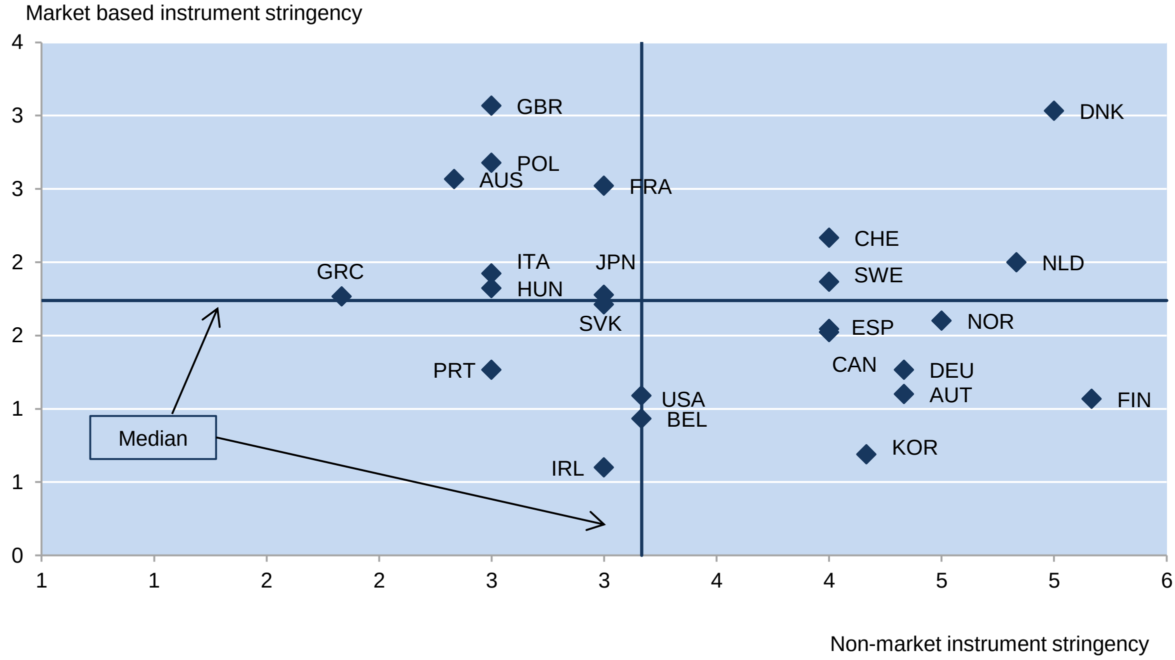


Source: OECD calculations.

40. The relative position of countries varies across the two main regulatory domains (Figure 8). For instance, the relative stringency of market-based instruments seems to be higher in Australia, Poland and the United Kingdom, than elsewhere among OECD countries, while non-market instruments appear to play a relatively more important role in Austria, Finland, Germany and Korea.

Figure 8. Relative importance of different approaches to environmental policies - Energy sector indicator

2012



Source: OECD calculations.

4.1.2 An "economy-wide" environmental policy stringency

41. The extended, "economy-wide" indicator is constructed by incorporating information on two policy instruments regarding pollution from the transport sector and one waste-oriented policy instrument to the energy sector structure (Figure 4). It is hence strongly correlated with the energy sector indicator (Table 6). For example, country rankings for 2012 hardly change (Figure 9). Nevertheless, it provides some additional information especially regarding the market-based side of regulation.[18] In fact, while the correlation between the two indicators is very high (Table 6), it is somewhat lower for the market-based component. This is likely to be due to the higher number of instruments added to this side of the indicator, including the introduction of a new category (DRS). Interestingly, the correlations between market-based and non-market instrument stringency in 2012 is notably higher than for the energy sector indicator (Figure 10).

18. In practice many of the instruments already included in the energy sector EPS have broader application – e.g. the EU ETS covers a significant share of European industrial activity.

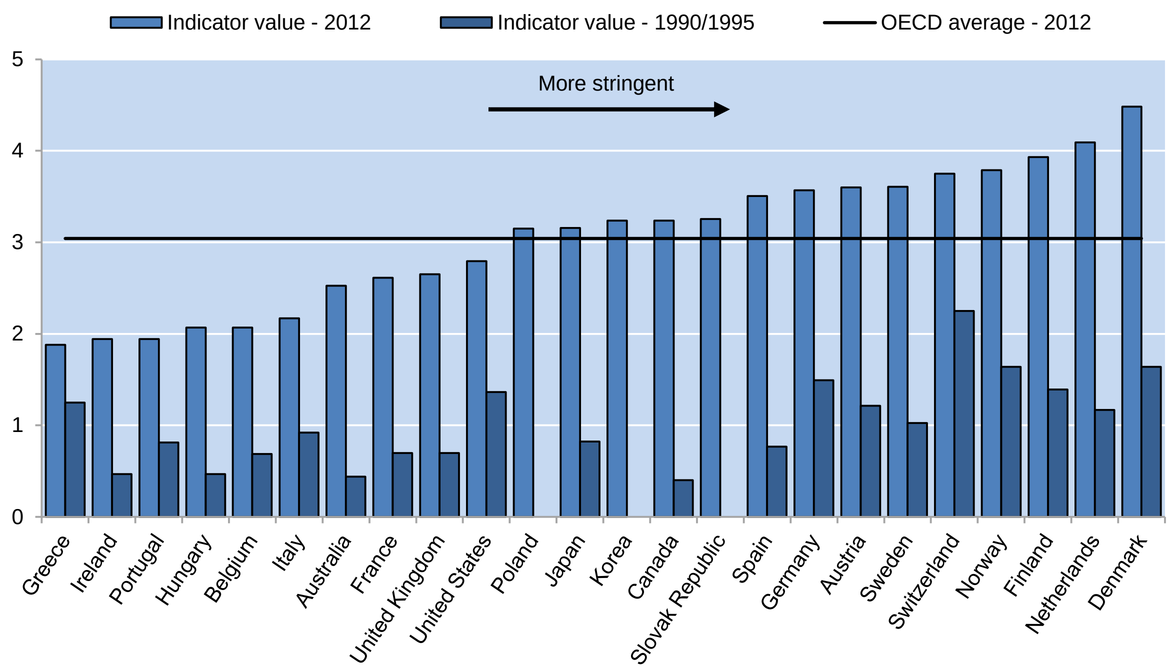
Table 6. Correlations between energy sector and extended (economy-wide) indicator

		Extended economy-wide Indicator		
		Overall Stringency	Market-based	Non-market
Energy sector Indicator	Overall Stringency	**.94*** **	.76***	.92***
	Market-based	.68***	**.76*** **	.51***
	Non-market	.90***	.59***	**.99*** **

Note: *** indicate significance at 1% level. Full sample 1990-2012.

Source: OECD calculations

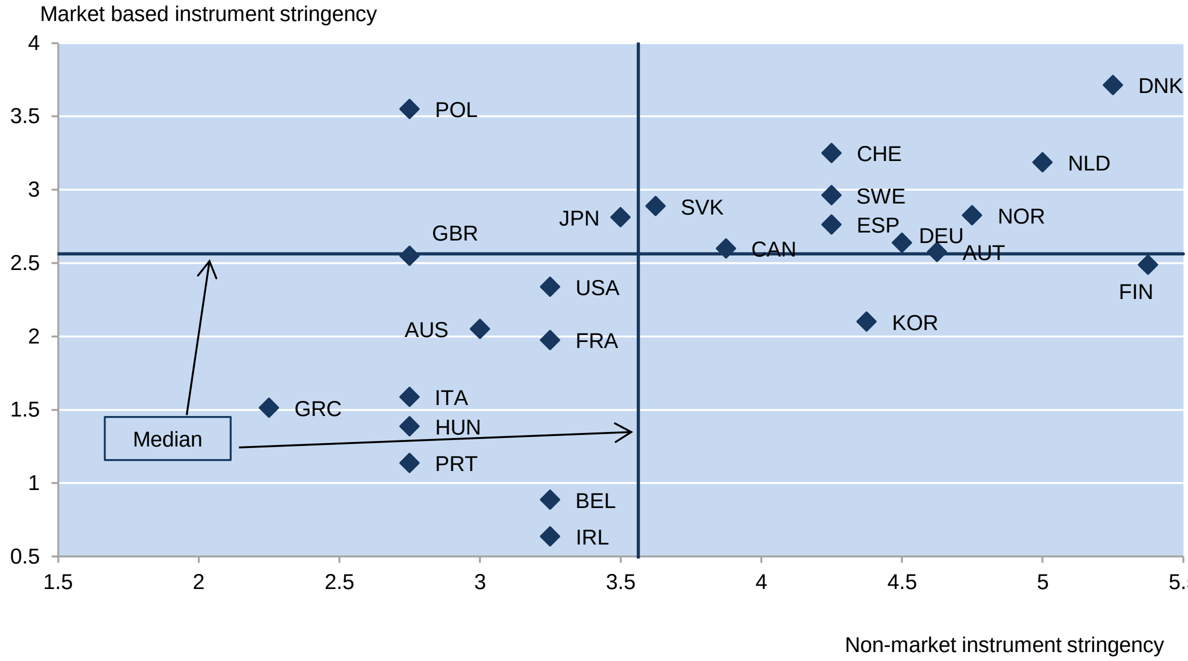
Figure 9. Stringency of environmental policies in 2012 - Extended (economy-wide) indicator



Source: OECD calculations.

Figure 10. Relative importance of different approaches to environmental policies - Economy-wide indicator

2012



Source: OECD calculations.

4.2 The evolution of environmental policy stringency

42. Since the 1990s there is a trend towards an EPS tightening both at the aggregate level (Figure 11) and individually across countries (Appendix II). This has been accompanied by increasing dispersion across countries (Figure 12). This trend is visible for both categories of instruments, but it is especially strong for market-based instruments. Furthermore, market-based instruments show significant variation year on year due to introduction of the ETS in EU countries in 2005 and relative swings in allowances prices (Figure 13). For instance, the decline in 2012 is due to the collapse of EU ETS prices.[19] This creates some endogeneity in the measure of environmental regulation to economic outcome and shows how stringency might vary without changes in underlying laws if instruments based on markets are put in place.

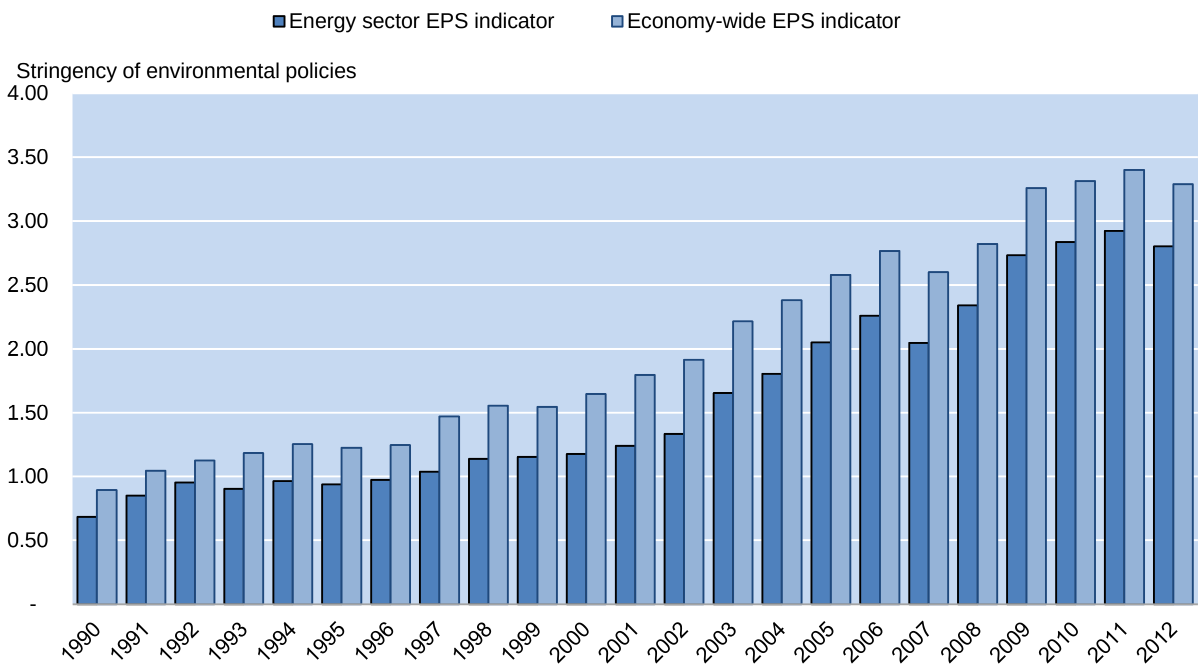
43. A key feature of the economy-wide indicator is that the market-based instruments for the transport sector (fuel taxes) were introduced earlier than those in the energy sector. Thus, it provides a more complete representation of environmental policy stringency since the early 1990s than the energy sector indicator. In the 2000s, the market-based index reflects the first wave of regulations for the energy sector (mainly taxes aiming at reducing emissions from combustion plants), while the non-

19. Instead, the fall in 2007 is due to the collapse of price between the first and the second phase of the scheme due to the impossibility to bank permits to the next stage and also to the discovery that permits have been over-allocated.

market index is influenced largely by a wave of tightening of ELVs (Figure 13). The recent increase in market-based stringency is due to a big wave of policy instruments in the EU (around 2005) characterised by the diffusion of trading schemes (the EU ETS and green trading schemes).

Figure 11. Average environmental policy stringency over time

Fixed subsample of OECD countries

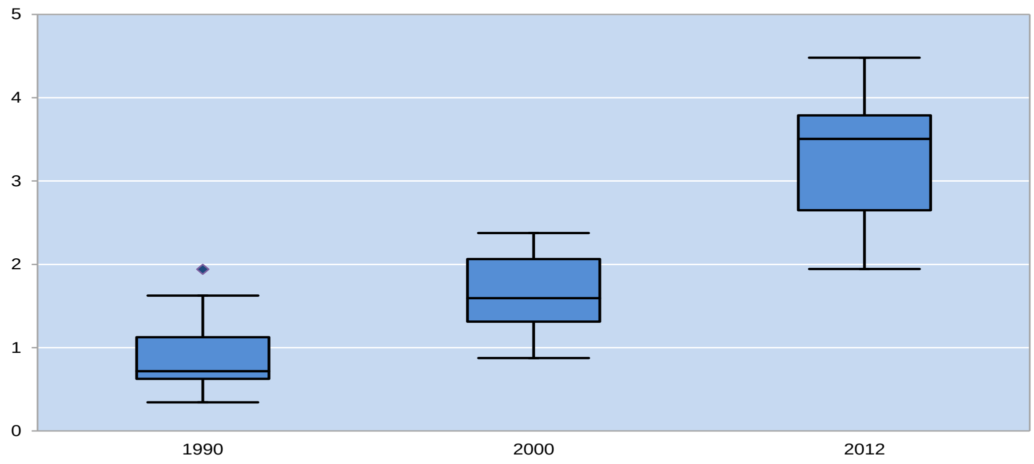


Note: Constant sample of countries.

Source: OECD calculations.

Figure 12. Box plots: the economy-wide indicator

Selected years, constant sample of countries



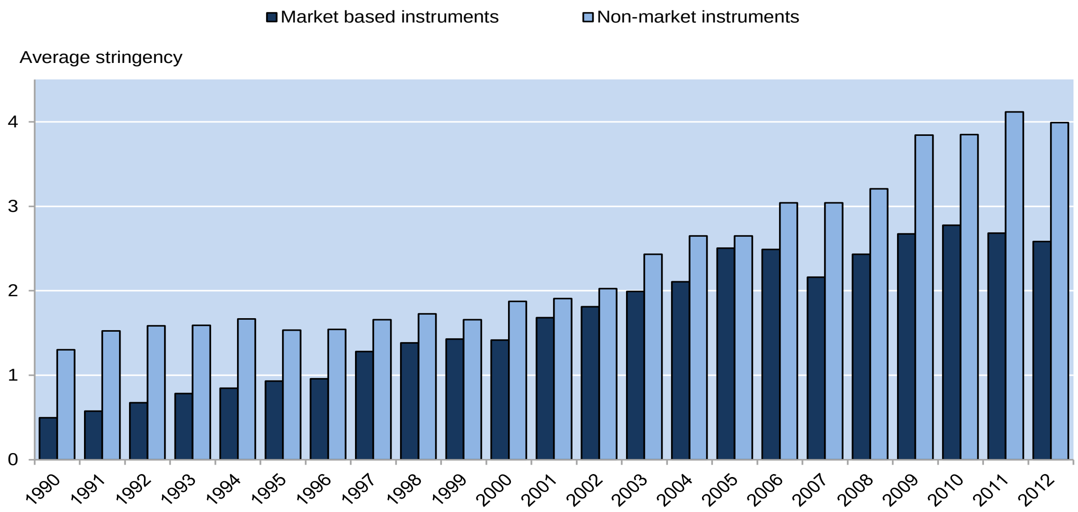
Note: Boxes represent ranges between the 25th and 75th centile of the distribution, Horizontal line in the box represents the median, while whiskers range from minimum to maximum values, excluding outliers (defined as 3/2 of lower/higher quartile), Outliers are indicated by dots,

Source: OECD calculations,

44. The number of instruments (among those included in the analysis) leveraged to mitigate the environmental externalities of the energy sector shows an increase during the past two decades driven mainly by a broader adoption of market-based instruments (Figure 13). Most of the non-market instruments were already in place in the 1990s and only increased in stringency over time.

Figure 13. Average stringency per component – Economy wide

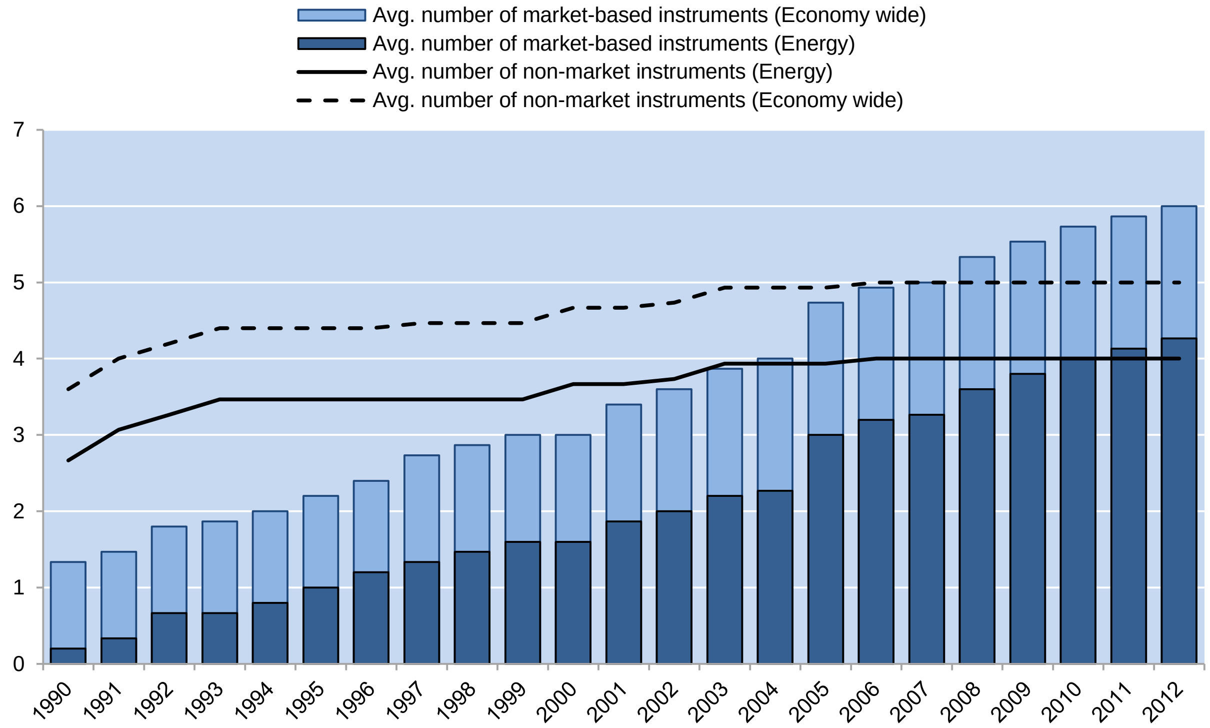
Average over fixed OECD subsample



Source: OECD calculations.

Figure 14. Average number of instruments

Fixed subsample of OECD countries



Source: OECD calculations.

4.3 Correlations with other indexes of environmental policy stringency

45. The energy sector EPS correlates well with the EBRD measure of climate policies (CLIMI) and less so with the WEF index of perceived stringency (Table 7). This may be due to the fact that climate policies captured by the CLIMI index tend to be also major contributors to the energy sector index, while the WEF survey indicator (potentially) covers all sectors and all environmental policies. Secondly, both the OECD and EBRD indexes are based on policy data, while the WEF index measures perceptions.

Table 7. Correlations with other measures of stringency

	2004	2005	2006	2007	2008	2009	2010	2011	Over the period
Energy Sector									
Perceived stringency (WEF)	.45 (.02)	.29 (.16)	.24 (.25)	.22 (.29)	.29 (.15)	.40 (.04)	.28 (.19)	.35 (.09)	.26 (.00)
CLIMI							.54 (.01)		
Economy-wide indicator									
Perceived stringency (WEF)	.60 (.00)	.51 (.01)	.49 (.01)	.49 (.01)	.45 (.02)	.53 (.00)	.44 (.03)	.45 (.03)	.44 (.00)
CLIMI							.56 (.01)		

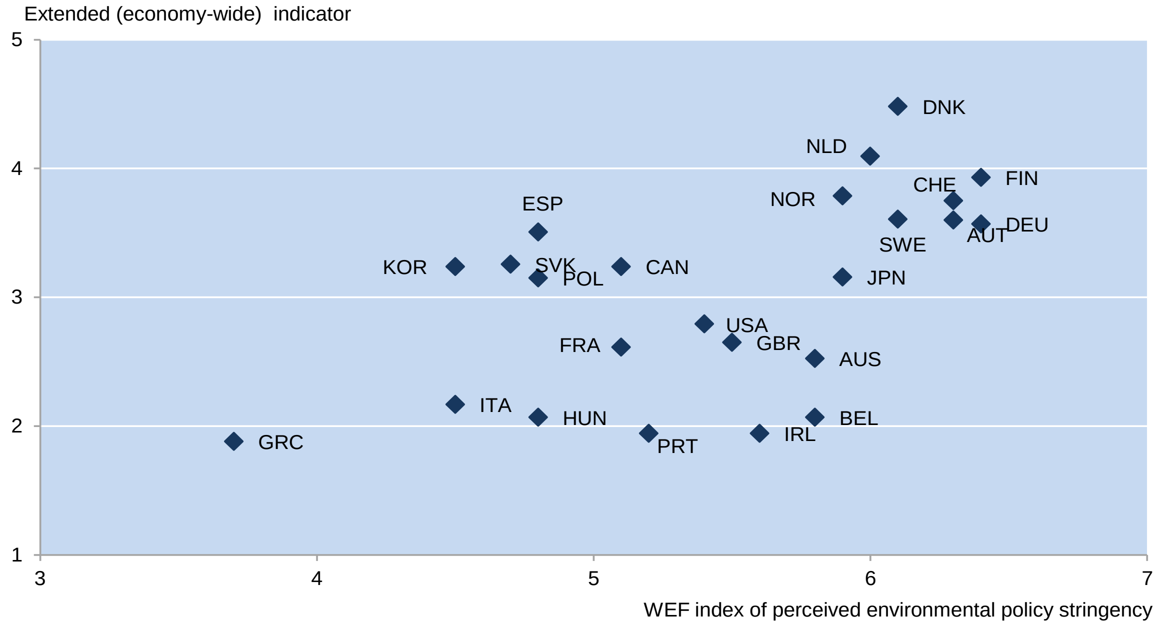
Note: Significance levels in brackets.

Source: Authors' elaboration, EBRD (2011), WEF (EOS reports, various years).

46. For the economy-wide indicator the correlation with the WEF index is markedly higher and more significant, possibly due to wider coverage, while the correlation with CLIMI is not affected (Table 7). A scatter plot of the most recent available values shows a correlation of 0.56 (Figure 15).

Figure 15. Environmental policy stringency measures - WEF and the economy-wide indicator

Most recent years available (2011/2012)



Source: OECD calculations.

47. Additionally, the economy-wide indicator is correlated with environmental policies of two other sectors to check the validity of proxying general environmental policy stringency of a country with the EPS indicator. Data on standards for leather (effluent limit values for BOD5) and PM emission limit values for the steel industry are collected. However, no time-series data is currently available for these policies and hence the correlation with the EPS indicator only covers the year 2012. The correlation with the effluent limit values and the economy-wide EPS indicator is significantly high (0.6). The correlation with the PM limit of the steel industry is slightly lower (0.5) and significant. Moreover, correlations of two variables used as proxies for environmental policy stringency by Sauvage (2014), the share of wastewater treatment and the landfill rates of municipal waste, show a highly significant correlation with the extended "economy-wide" EPS indicator. This correlation suggests that, despite the limited coverage of policies included in the extended indicator, it nonetheless can be seen as a strong proxy for overall environmental policies. More details on the data used as well as detailed results are presented in Appendix IV.

48. The decomposition of the indexes into market and non-market subcomponents shows a lower correlation of the market-based components with the CLIMI and particularly the WEF measures for the energy sector indicator (Table 8). Among many, an explanation of this difference can lie in the fact that emission limit values might be perceived as more stringent as they affect more directly production possibilities than taxes that "simply" alter relative prices and leave the choice of optimal mix to the firm. This pattern is not visible for the economy-wide indicator.

Table 8. Correlations with other measures of stringency: market and non-market instruments

	Correlation table: Perceived stringency (WEF)									**CLIMI**
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Over the period**	**2010**
Market-based instruments	.03	.08	.03	-.11	.04	.11	.08	.12	0.05	.17
Energy Index	(.87)	(.67)	(.86)	(.54)	(.82)	(.57)	(.57)	(.51)	(.41)	(.38)
Market-based instruments	.32	.31	.15	.09	.21	.26	.23	.18	.29	.35
Economy wide Index	(.09)	(.10)	(.46)	(.63)	(.26)	(.17)	(.22)	(.34)	(.00)	(.08)
	Correlation table: Perceived stringency (WEF)									**CLIMI**
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Over the period**	**2010**
Non-market instruments	.61	.53	.54	.54	.46	.56	.48	.57	.46	.58
Energy Index	(.00)	(.01)	(.01)	(.01)	(.02)	(.00)	(.01)	(.00)	(.00)	(.00)
Non-market instruments	.62	.54	.56	.58	.48	.59	.50	.58	.47	.54
Economy wide Index.	(.00)	(.01)	(.00)	(.00)	(.02)	(.00)	(.01)	(.00)	(.00)	(.01)

Note: Significance levels in brackets.

Source: Authors' elaboration, EBRD (2011), WEF (EOS reports, various years)

4.4 Correlations with other variables

49. Well-designed environmental policies might increase innovation, or at least redirect it towards a more environmentally-friendly direction (Porter, 1991; Hicks, 1932; Koźluk and Zipperer, 2014). While the constructed indicators do not provide insights on the quality of instruments design, they are positively correlated with counts of patents (European Patent Office, EPO, patents in energy generation from renewable and non-fossil sources)[20] and the Green Patents Index[21] (Table 9). Interestingly, the correlation is significantly higher for the market-based component, which may be a sign of the higher effectiveness of market-based instruments to stimulate "green" innovation (as in Johnstone et al., 2010; OECD, 2010).

50. Additionally, the indicators display a high positive correlation with GDP and are negatively correlated with CO_2 emissions per unit of GDP (both measured in nominal and PPP values) and per KWh of electricity generated. The correlation with a measure of environmental performance (the Yale Environmental Performance Index - EPI), is also found to be positive and significant (Table 10).[22]

Table 9. Correlations with "green" innovation proxies

	Green Patents Index	Green Patents Index (t+2)	Patents (RE)	Patents (RE) (t+2)
Energy Index	**.45 (.00)**	**.36 (.00)**	**.20 (.00)**	**.21 (.00)**
Market-based instruments	.53 (.00)	.47 (.00)	.23 (.00)	.24 (.00)
Non-market instruments	.30 (.00)	.20 (.00)	.13 (.02)	.14 (.02)
Extended E-W Index	**.42 (.00)**	**.32 (.00)**	**.29 (.00)**	**.27 (.00)**
Market based instruments	.39 (.00)	.32 (.00)	.30 (.00)	.27 (.00)
Non-market instruments	.37 (.00)	.27 (.00)	.18 (.00)	.19 (.00)

Note: Significance levels in brackets.Spearman rank correlations.

Source: (i) Authors' elaborations, (ii) OECD patent database.

20. Data refer to patents granted by EPO, using applicant's residence and priority date (application date).

21. Data refer to patent applications filed under the Patent Cooperation Treaty (PCT), using inventor's residence and priority date (date of application). Total "green" patents (GG_E17) is the sum of patents on electric and hybrid vehicles (GG_E19), energy efficiency in buildings and lightning (GG_E110), renewable energy generation (GG_E111), air pollution abatement (from stationary sources, GG_E112), water pollution abatement (GG_E113) and waste management (GG_E114).

22. The EPI tracks outcome-oriented indicators based on ten policy categories that support the two broad objectives of environmental health and ecosystem vitality.

Table 10. Correlations with GDP, emission intensity and environmental performance

	GDP per Capita (PPP)	CO_2/GDP	CO_2/GDP(PPP)	CO_2/KWh	EPI
Energy Index	.31 (.00)	-.24 (.00)	-.32 (.00)	-.19 (.00)	.38 (.00)
Extended E-W Index	.43 (.00)	-.22 (.00)	-.26 (.00)	-.26 (.00)	.44 (.00)

Note: Significance levels in brackets.

Source: (i) OECD Stat (ii) CO_2 Emissions from Fuel Combustion (2012 Edition), IEA, Paris. Note: GDP Per Capita, Annual, Constant Prices and Constant PPPs (in USD, 2005) (iii) Environmental performance Index (2012 edition), Yale University.

5. Concluding and moving forward

51. This paper describes the construction of new quantitative indexes that allow comparison of countries' environmental policy stringency. The proposed measures are a simplification of the multidimensional reality of environmental policies, and *de facto* cover a small part of country policies – primarily GHG and air pollutant related policies, with a particular focus on the energy sector. Still, while care is warranted when applying such proxies, the proposed indicators have a number of virtues which make them suitable for cross-country analysis:

- Firstly, they constitute the first tangible effort to measure environmental policy stringency internationally over a relatively long time horizon. While imperfect, they can provide a basis for empirical cross-country analysis.

- Secondly, they show relatively high correlation with measures of perceived stringency, in the sample over which the measures overlap, implying these policy-based measures are quite in line with business' perceptions on environmental policy stringency. They also show high correlations with a number measures proxying EPS in specific environmental domains, such as wastewater management and landfill rates.

- Thirdly, the measure appears to have the expected correlation signs with GDP, a number of environmental performance measures and environmental innovation proxies.

52. There is ample room to further improve the indicator in the future. Nevertheless, the costs of gathering further data and combining stringency measures for other, less common or less easily quantifiable, instruments and industries needs to be weighed against the benefits this can provide. Regarding further work in this area, there are several potential next steps that can be envisaged:

- Broadening the coverage to the remaining OECD countries and BRIICs. Extending the indexes to the latter will be challenging due to the potential prevalence of different types of tools, larger discrepancies between enforcement and legislation and the large share of the unofficial economy in some of these countries.

- Including additional instruments, in particular instruments regarding other sectors, pollutants and media. A number of these have been already collected for the most recent period, but have proven difficult to extend coverage back in time.[23] Information on these efforts is

23. For this purpose, the authors have established contacts in OECD member states' Ministries of Environment and Environmental Agencies, although for most industry-instrument activities in question it was only possible to recreate the history for a limited number of countries.

provided in Appendix IV. The inclusion of less easily quantifiable instruments, such a VAs, "soft" policies or environmental aspects of land use regulation, would require further investigation on these policies, in particular on ways to directly assess their stringency. Some of this work is planned in the OECD Environment Directorate.

- Corroborating with environmental performance-based measures, such as those whose construction is proposed in Brunel and Levinson (2013), to gain insight on the relationship between the indexes and effects of policies, and potentially gain further insights on the time discrepancy between legislation and environmental outcome based measures.

- Further research on policy design, rather than pure policy stringency, such as flexibility, predictability and competition-friendliness (as laid out in Koźluk, 2014).

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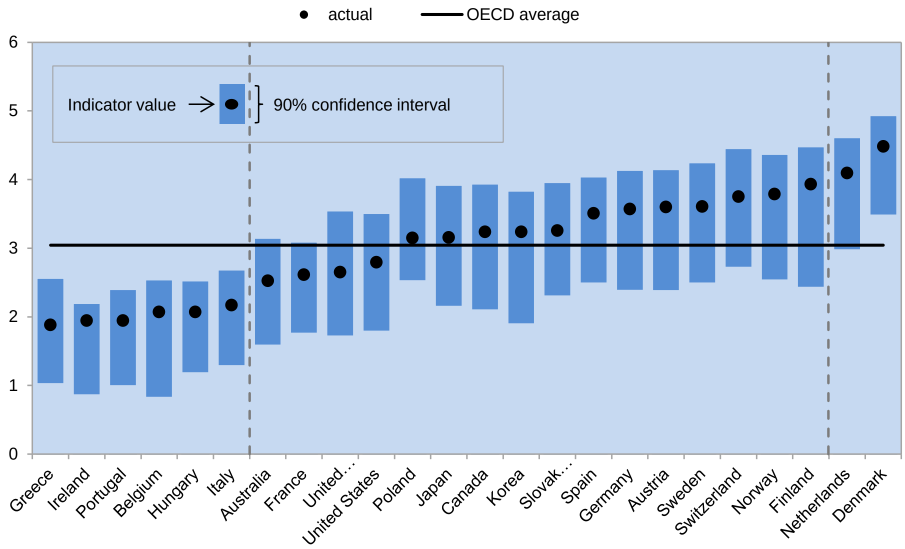
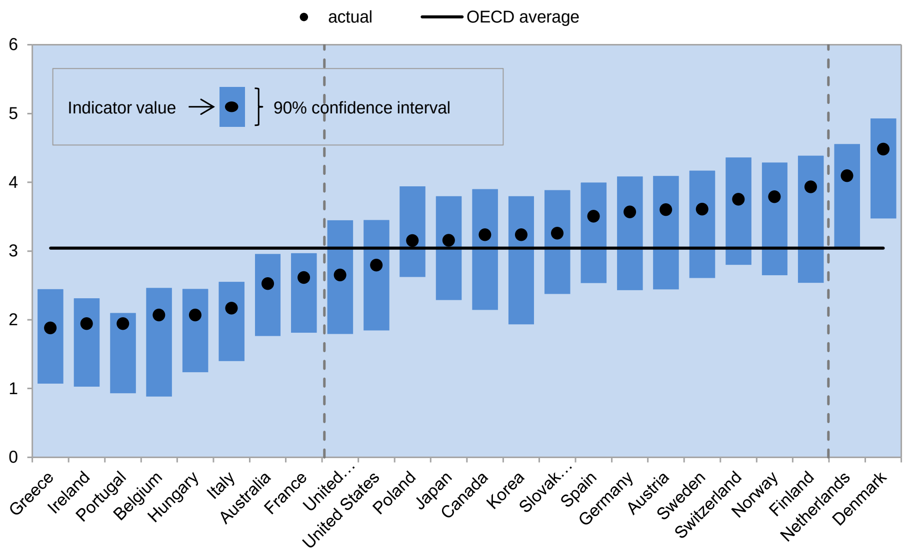
APPENDIX I– ROBUSTNESS OF THE INDICATOR

1. To verify the stability of country scores to different weights, the random weight approach is applied. Essentially, random weights from 0 to 1 are generated and are then used to aggregate the low and mid-level indicators into a new Index of EPS to verify what would happen to countries' scores if the assumption of equal weighting of instrument is dropped. Based on 10,000 randomly generated weights, a distribution of the EPS score is obtained, and then the 5^{th} and 95^{th} percentile are used to obtain the 90% confidence intervals.

2. The results (Figure A1.1), computed for 2012, show a general stability of the final score with some exceptions – when the actual EPS value lies far from the middle of the confidence interval – indicating preference to some type of instruments. A number of countries (Greece, Ireland, Portugal, Belgium, Hungary, Italy and Australia) score significantly below the OECD average with France being a border case. Denmark and the Netherlands score significantly above.

Figure A1.1 Result of application of random weights – Extended (economy-wide) indicator



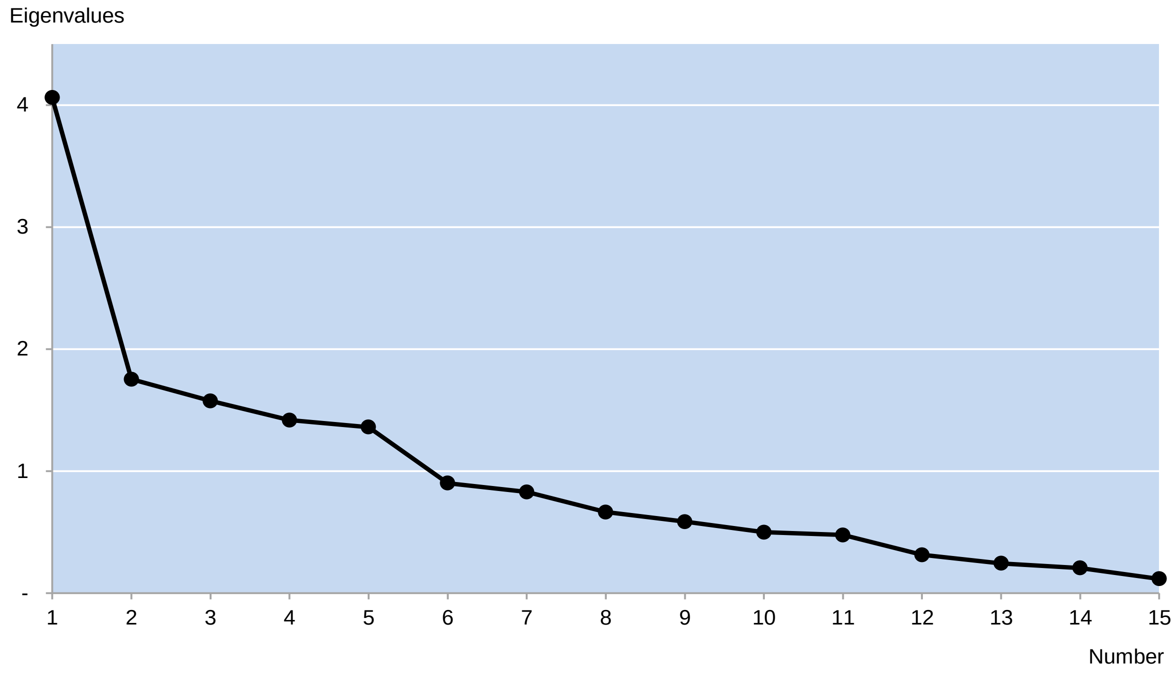


Note: Top figure displays the results of a random weights exercise within the instrument categories, i.e. where random weights are only applied to the low level indicators. The bottom figure displays the results of random weights applied at all levels of aggregation.

Source: OECD calculations.

3. A principal component analysis (PCA) is also run on the policy instrument variables. Eigenvalues greater or equal to one and cumulative explained variance equal to 0.7 suggest selecting five to six factors (cumulative variance explained equal .69 or .76 respectively) which seems consistent with the scree plot (Figure A1.2). Ultimately, five factors are retained for the rotation analysis.

Figure A1.2 PCA scree plot



Source: OECD calculations.

Table A1.1 Factor eigenvalues

Factor number	Eigenvalue	Difference	Proportion	Cumulative
Factor1	**4.06073**	**2.3082**	**.27**	**.27**
Factor2	**1.75253**	**.17816**	**.12**	**.39**
Factor3	**1.57437**	**.15671**	**.11**	**.49**
Factor4	**1.41766**	**.05752**	**.09**	**.59**
Factor5	**1.36014**	**.45942**	**.09**	**.68**
Factor6	.90072	.07187	.06	.75
Factor7	.82884	.16520	.06	.80
Factor8	.66364	.07802	.04	.84
Factor9	.58562	.08723	.04	.88

Source: Authors' elaboration

4. A first interesting result is that instruments of the same type (e.g. emission limit values, trading schemes or feed in tariffs) tend to correlate highly with the same factor, except for the tax on diesel and tax on CO_2 (Table A1.2). This means they tend to be introduced or tightened together or that countries are consistently higher (lower) on groups of such instruments. On the other hand, R&D subsidies, deposit and refund schemes, diesel taxes and NOx taxes tend to have loadings less consistently distributed.

5. Factors 2 and 4 are almost entirely dedicated to FITs and trading schemes respectively, robustly supporting their aggregation as unique variable. Taxes are less consistent, falling mainly on factors 3 and 5. The selection of five factors leaves three variables with an unexplained variance equal to almost 0.5 which might suggest some cautions in explaining their relation with identified factors.

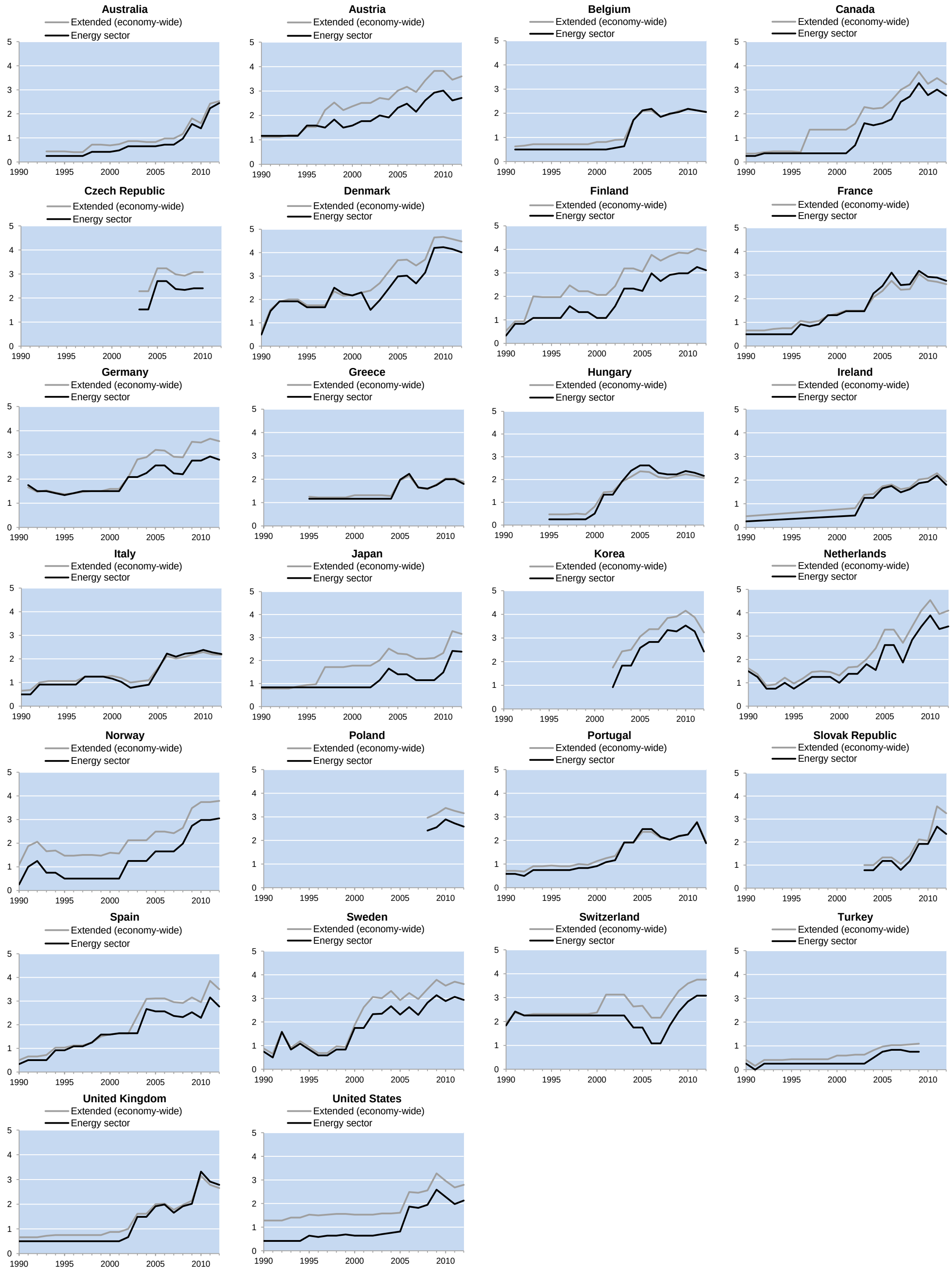
Table A1.2 Factor weights

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Uniqueness
ELV NO_x	.8380	.1275	-.0960	-.1042	.1389	.2421
ELV SO_x	.8675	.1371	.0816	.0707	.1085	.2052
ELV PM	.6665	.2024	.0263	.0357	.5381	.2233
Sulphur Diesel cont.	.7740	.2041	.3292	.1331	.0831	.2263
R&D RE	.4161	-.0253	.0266	-.5375	-.1513	.5137
CO_2 TS	.7484	.0989	.0657	.1235	-.2758	.3345
Green TS	.4793	-.3276	.0399	.5642	-.0273	.3422
White TS	.2679	.1260	.0110	.6680	-.1072	.4545
CO_2 tax	.0991	.0275	.0459	-.0487	.8656	.2356
NO_x tax	.2787	-.1015	.4177	.2685	-.3118	.5683
SO_x tax	-.0544	.1365	.8455	-.0248	-.0123	.2628
FiT Solar	.3040	.8114	.1015	.0497	.1003	.2264
FiT Wind	.1008	.8771	-.0242	-.0203	-.0051	.2195
Tax Diesel	-.3590	.1627	-.6098	.0345	-.1892	.4358
DRS	.4539	-.1320	.4106	-.4847	.1700	.3441

Source: Authors' elaboration

APPENDIX II – COUNTRY GRAPHS

Figure A2.1 EPS countries' score over time



Source: OECD calculations.

APPENDIX III – CORRELATION TABLE AMONG SUB-INDICATORS

	EW Ind.	Mkt Cmp	Nmkt Cmp	Tax	FiT	Trad Sch.	DRS	ELV	RD	CO_2 T.S.	REN T. S.	E. eff.	CO_2 Tax	NO_x Tax	SO_x Tax	Dies. tax	Fit solar	Fit Win.	Elv Nox	Elv Sox	Elv PM	Sulp. dies.
EW Index	1																					
Mkt Cmp.	.88 **	1																				
Nmkt Cm.	.92 **	.62 **	1																			
Tax	.24 **	.39 **	.12 **	1																		
Fit	.44 **	.51 **	.28 **	.01	1																	
Trad. Sch.	.54 **	.47 **	.49 **	.08 **	.22 **	1																
DRS	.69 **	.82 **	.46 **	.32 **	.1 **	.17 **	1															
ELV	.82 **	.64 **	.81 **	.04	.4 **	.64 **	.4 **	1														
RD	.62 **	.3 **	.77 **	.1 **	.08 *	.15 **	.31 **	.25 **	1													
CO_2 T.S.	.56 **	.49 **	.52 **	.06 *	.27 **	.89 **	.19 **	.63 **	.2 **	1												
Gr. TS.	.26 **	.23 **	.23 **	.04	-,01	.66 **	.1 **	.35 **	.02	.26 **	1											
E Eff.TS	.16 **	.12 **	.16 **	.07 *	.17 **	.43 **	-,09 **	.23 **	.02	.21 **	.39 **	1										
CO_2 Tax	.23 **	.2 **	.21 **	.46 **	0	-,04	.16 **	.09 **	.12 **	-.01	-.07 *	-.05	1									
NO_x Tax	.24 **	.32 **	.19 **	.73 **	-.01	.26 **	.22 **	.16 **	.1 **	.22 **	.22 **	.1 **	.3 **	1								
SO_x Tax	.24 **	.38 **	.1 **	.72 **	.02	0	.38 **	.05	.06	0	-.02	.05	.24 **	.4 **	1							
Diesel tax	-.37 **	-.26 **	-.32 **	.16 **	.01	-,19 **	-,22 **	-,33 **	-.08 **	-.21 **	-.09 **	.02	-.14 **	-.13 **	-.16 **	1						
Fit solar	.47 **	.53 **	.32 **	.03	.92 **	.27 **	.15 **	.45 **	.08 *	.31 **	.04	.2 **	.01	-.01	.04	-.01	1					
Fit Win.	.31 **	.4 **	.19 **	.03	.92 **	.12 **	.03	.27 **	.07 *	.17 **	-.04	.11 **	-.02	-.01	0	.1 **	.69 **	1				
Elv Nox	.75 **	.55 **	.76 **	-.02	.33 **	.5 **	.39 **	.9 **	.29 **	.49 **	.28 **	.19 **	.05	.09 **	-.05	-.18 **	.35 **	.25 **	1			
Elv Sox	.72 **	.58 **	.7 **	.02	.34 **	.63 **	.38 **	.94 **	.14 **	.64 **	.32 **	.23 **	.01	.19 **	.05	-.35 **	.38 **	.23 **	.82 **	1		
Elv PM	.62 **	.46 **	.63 **	.04	.36 **	.42 **	.25 **	.8 **	.18 **	.41 **	.25 **	.1 **	.29 **	.01	.04	-.24 **	.38 **	.27 **	.63 **	.69 **	1	
Sulp.diesel content	.74 **	.63 **	.68 **	.15 **	.47 **	.62 **	.35 **	.83 **	.25 **	.59 **	.36 **	.25 **	.09 **	.24 **	.18 **	-.27 **	.5 **	.33 **	.6 **	.7 **	.62 **	1

Source: Authors' elaboration. Note **,* indicates significance at 5% and at 10% levels respectively.

APPENDIX IV – DATA SOURCES AND ADDITIONAL COLLECTED DATA

1. The following databases, together with desktop research and personal communications with Member Countries Delegates to the OECD, have been used as main sources for data on policy instruments:

- IEA Clean Coal Centre emission standards database.
- IEA, Policy and Measures database.
- OECD/EEA, database on economic instruments used for environmental policy and natural resources management
- OECD (2013) Renewable Energy Policy Dataset, version March 2013. Compiled by the Empirical Policy Analysis Unit of the OECD Environment Directorate (Johnstone, N., Haščič, I., Cárdenas Rodríguez M., Duclert, T.) in collaboration with an ad hoc research consortium (Arnaud de la Tour, Gireesh Shrimali, Morgan Hervé-Mignucci, Thilo Grau, Emerson Reiter, Wenjuan Dong, Inês Azevedo, Nathaniel Horner, Joëlle Noailly, Roger Smeets, Kiran Sahdev, Sven Witthöft, Yunyeong Yang, Timon Dubbeling).
- UNFCCC, National Communications to the United Nations Framework Convention on Climate Change (several years).

2. In addition to the data used in the analysis, a number of data on different policy instruments have been collected but it has proven difficult to recreate a time series and therefore have not been used in the analysis. These are briefly listed in Table A4.1.:

Table A4.1 Additional collected data

Policy instruments	N. countries	Year
Selected Emission limit value for gas-fired utility scale plants	21	Currently enforced (2012) and limited time series
Selected Emission limit value for steel manufacturing	22	Currently enforced (2012) and limited time series
Selected Emission limit value for cement manufacturing	20	Currently enforced (2012)
Selected Effluent limit value for food processing	16	Mainly currently enforced (2012)
Selected Effluent limit value for leather manufacturing	24	Various years (1990-2012)
Selected Effluent limit value for paper and pulp manufacturing	16	Mainly currently enforced (2012)

Source: Authors' elaboration

3. A preliminary analysis on correlation between the 2012 EPS indicator and an indicator summarising standards for leather (effluent limit values for BOD5, most recent ELVs available, scored in order to range from 0 to 6 as all other variables) shows a significant positive correlation for the overall EPS and insignificant positive correlations for lower level EPS indicators (Table A4.2). The correlation with PM emission limit values for steel industry (steel-making with electric arc furnace, most recent ELVs available, scored in order to range from 0 to 6) is positive significant for the economy wide EPS and for non-market instruments. Overall, in all cases the cross-section sample is small, and no complete time-series exist, limiting conclusions. Finally, correlations of two variables used as proxies for environmental policy stringency by Sauvage (2014) are reported. Both capture environmentally-related outcomes: the share of wastewater treatment and the landfill rates of municipal waste. In both cases correlations are significant, high and of expected sign.

Table A4.2 Correlations with other instruments

	Extended Economy-wide indicator	**Non market component. economy wide**	**Emission limit values component**	No. obs. included
Effluent limit value – Leather manuf. (2012)	.60*	.49	.10	16
Emission limit value – steel industry (2012)	.49*	.51*	.14	14
Outcome-based measures (Sauvage, 2014)				
Wastewater treatment shares	.50***	-	-	205
Landfill rates for waste	-.55***	-	-	377

Note: Spearman rank correlations. Emission limit values component includes ELVs for NO_x, SO_x, PM and sulphur content in diesel. * and *** indicate significance at 10% and 1% levels respectively.

Source: Authors' elaboration. (i) Data from Sauvage (2014).

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(forthcoming)

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