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Innovation Processes and Environmental Safety

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Discussion Paper 141
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Abstract
In this paper, we propose a new index that is able to point out the important relationship between environmental protection and investments in innovation processes. We identify the index with the acronym EICI (Environmental Innovation Comparative Index). This new empirical tool can help to explain how the level of innovation can determine different levels of air pollution in the world. We use OLS models to investigate how this new index impacts the variations in greenhouse gas emissions, and we underline some fundamental policy implications. Considering the levels of the EICI and the empirical analysis of the role of this index then we conclude that enforcing new environmental agreements with some fundamental rules, as the incentive to reduce the technological gaps among the countries, is crucial to protect the environment and at same time stimulate the investment for innovation in all countries of the world.

Keywords  Kyoto Agreement, Environmental Index, OLS model, Environmental Policy

JEL  Q50, O33, Q52, Q55, Q58.
Introduction

The development of technology is fundamental to reduce global environmental pollution. Promoting and stimulating investments in innovation with the aim of activating a global mechanism of environmental protection is a crucial goal. There is also a substantial gap among countries related to the effort devoted to develop innovative technologies that are able to advance environmental protection and safeguard people's health. In addition, we can affirm that the improvement of environmental protection technologies can reduce costs, increase productivity, create new market opportunities and decrease unemployment. Carrying out unambiguous strategies to find and share new environmental technical innovations in every country of the world has become increasingly important. The health of the environment is a pure public good; thus, it is crucial that all countries expend significant effort to reduce pollution and adopt pro-environmental behaviours and technological innovations as environmental safeguards. Environmental technologies can make a cleaner earth and improve economic performance. The building of the new technologies must be created through different policies and regulatory and financial actions. Some authors suggested to compare policy choices. Li et al. (2014) defined multilateral climate policies can reduce the negative impacts of cross-border externalities, but cannot cure all cross-border externalities. In each country, it is essential that the connections among businesses, investors and regulators accelerate the development of environmental technologies because, as previously stated, new environmental technologies can radically increase profitability and employment and reduce costs. There is a gap in environmental technology innovation among all the countries in the world. We attempt to investigate how this gap can influence the environmental quality of the earth and if it can help to determine more efficient environmental policies. In our analysis, we consider another fundamental element that has influenced CO$_2$ emission up to 2012. We believe that environmental regulation could represent a fundamental tool that is able to reduce pollution and climate change; therefore, we consider the importance and role of the Kyoto Protocol, which was signed in 1997 and became effective in 2005. All of the Countries that ratified it committed themselves to reducing their emissions before the end of 2012. The average target was to decrease the emissions by 5% with respect to the level of 1990. The environmental agreements have not reached the target but an open question is if the introduction of a compulsory bound to the CO$_2$ emission could influence the investments in environmental innovations. This kind of relationship can encourage finding other regulation possibilities to reduce CO$_2$ emission and safeguard the environment. The paper is organized in the following way: in the next section, we illustrate the types of Environmental Indicators. In the third section, we describe an index that is related to environmental innovation and explain the meaning and function of this new index. In the fourth section, we provide a description of the Data Source. The fifth section is devoted to the explanation of the empirical analysis and methodology.
the sixth section, we discuss the Empirical Results and the Evidence. In the seventh section, we provide the conclusions and policy implications.

1 Description of the Environmental Innovation Comparative Index

Our idea is to determine an index that efficiently sets more than one element involved in environmental protection and dynamic economic processes. We devise a strict relationship among environmental protection innovation, the time evolution of this component and the gaps among different countries connected with the creation of new technological solutions to safeguard the environment. We think that there is a strict relationship between the technological gap among the countries and the total amount of greenhouse gas emissions. The crucial point of our approach is to consider all of the countries of the world as absolutely and inextricably linked, which appears to be trivial because it is well known that the effects of greenhouse gas emissions damage important pure public goods like the quality of the environment. However, our opinion is that the diffusion of new technologies to safeguard the environment is a fundamental aspect that is able to influence the capacity of the countries to reduce pollution. Li and al. (2015) showed that there should be trade-off mechanisms between efficiency and equity regarding how to allocate carbon emission reductions among countries. We do not consider the level of technology to be crucial for each country. However, we consider the level of the diffusion of the environmental technology for all of the countries involved in the greenhouse gas emissions reduction process to be crucial.

Starting from these considerations, we determine the following characteristics of the index: first, the index must be a measure of the diffusion of technology among the different countries. This aspect can be established by comparing the technology level of each country with the others. Second, it must determine each comparison for each year considered. Finally, it must define the annual index for each year with reference to all of the countries considered in the sample. To build an efficient index that is able to measure the diffusion of innovation, we consider the new environmental patents of each country (in the following section, we will give a more detailed description of the data). Thus, we build an $EICI$ (Environmental Innovation Comparative Index) for each country in every year considered.

We define the following expression:

$$EICI_{ENV_{i,t}} = \frac{\left[ PAT_{ENV_{i,t}} - PAT_{ENV_{w,t}} \right]}{\left[ PAT_{ENV_{w,t}} - PAT_{ENV_{d,t}} \right]}$$  (1.1)

where $i$ stands for the country and $t$ is the year considered.

To determine the $EICI$ index for each country, we measure the environmental innovation gap by comparing the difference between the number of patents of each country for each year, $PAT_{ENV_{i,t}}$, and the number of patent of the country with the worst perfor-
mance in the same year, $\text{PAT}_{\text{ENV}w,t}$, with the difference between the patents developed by the country with the best performance in the year, $\text{PAT}_{\text{ENV}b,t}$, and the one with the lowest level, $\text{PAT}_{\text{ENV}w,t}$.

This index can take all values between 0 and 1. For values close to 1, there is homogeneous environmental innovation activity in the set of countries considered. As has been observed, the number of environmental innovation patents has radically increased during the period that we consider in our analysis. This aspect results in the formulation of two fundamental considerations. First, the index has not been influenced by a reduction in the number of environmental patents during the period considered, so the determination of the technological gap has always been economic effectiveness; second, even in the case where only a few countries have developed innovation activities in the environmental field, increasing the total realized patents reinforces the usefulness of the index even more.

2 Data Source Description

The aim of the paper is to define a new environmental index. To determine this indicator, the data analysis considered in our paper is based on the extraction of the number of Environmental Patents from the OECD database. These data are divided into the following seven categories: General Environmental Management; Energy Generation from Renewable and Non-Fossil Sources; Combustion Technologies with Mitigation Potential; Technologies Specific to Climate Change Mitigation; Technologies with Potential or Indirect Contribution to Emissions Mitigation, Emissions Abatement and Fuel Efficiency in Transportation; and Energy Efficiency in Buildings and Lighting. For each category, there is more than one subcategory. The category General Environmental Management is composed of eleven subcategories; the category Energy Generation from Renewable and Non-Fossil Sources is composed of twelve subcategories; the category Combustion Technologies with Mitigation Potential is based on five subcategories; the category Technologies Specific to Climate Change Mitigation is composed of three subcategories; the category Technologies with Potential or Indirect Contribution to Emissions Mitigation is composed of three subcategories; the category Emissions Abatement and Fuel Efficiency in Transportation is composed of six subcategories; and finally, the category Energy Efficiency in Buildings and Lighting is composed of three subcategories. We give more details and descriptions of the subcategories in Table A2 of the Appendix. In the analysis, we consider the previous categories related to 104 countries in the period between 1976 and 2012. Let us describe how we develop the data selection. First, we have considered the Patent Families. This dataset delivers data on patent counts by technology on the basis of Patent Applications to the European Patent Office. In addition, we consider the Reference Country for patents in environmental innovation including the Applicant’s Country. These applicants are the owners of the
patents at the time of application, and in this way, we measure the degree of control of patents by each country’s residents, wherever the invention is made. The reason for the repartition is connected to the necessity of evaluating the level of innovation carefully for each country. That is, an optimal method to reveal the innovativeness of firms of a given country, whatever the location of their research facilities. Furthermore, we also considered the reference data. In particular, we count the Date of Application. Usually, the inventor applies in his or her country of residence, then he or she has one year of legal delay to apply for protection of the original invention in other countries (application). For this reason, it occurs generally one year after a foreign priority, and it must be taken into consideration that by using the application date, we introduce a bias due to a one-year lag between residents and foreigners. The data related to the CO₂ Emissions consider the emissions as those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. We extract all of the information about the CO₂ Emissions from the World Bank Database, while the data of the real GDP and the total population have been pulled from the Penn World Table version 8.0.

3 Empirical Analysis and Methodology

The Empirical Analysis aims to verify how the EICI could have been influenced the relationship between emission per capita and the Real GDP per capita during the period 1977-2010 while also paying attention to the effect of the Kyoto Agreement on our estimation. The emission per capita is equal to the Total World Emission divided by the population expressed in millions, while the Real GDP is extracted from the Penn World Table (PWT). We sum up three databases (PWT, World Bank Database and OECD), and we use a 3-letter country code and the year beginning with the considered sample to construct the EICI indicator. The 68 countries are divided by geographic areas to check the localization effect and to build a more homogeneous sample.

We estimate the following model:

\[
\Delta \ln CO₂c_{it} = a + b₁ \Delta \ln RGDPc_{it} + b₂ \Delta \ln RGDPc_{it}^2 + b₃ EICI_{it} + b₄ TIME + \epsilon_{it} \tag{3.1}
\]

where CO₂ describes the emission per capita at time t for each country and RGDP is the Real GDP per capita at time t for each country. The variable EICI corresponds to the indicator related to the gap between the level of the environmental patents at time

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1 Generally, the PWT was developed by Robert Summers and Alan Heston (and others) to facilitate consistent national accounts comparisons across countries as well as over time. It is an attempt to get closer to a System of Real National Accounts (SRNA) that makes interspatial comparisons possible. The latest version 8.0 of the PWT contains 29 variables for 167 countries (with two versions for China). The approximately 6,000 annual time series begin as early as 1950 and end generally in 2011.

2 PWT is selected due to its more detailed temporary and spatial information compared with the WBD; moreover, we can examine a sample of 68 countries instead of 60 countries when using the WBD.
for each country \( i \). Lastly, the variable \( \text{TIME} \) defines the time dummies that capture the observable and non-observable exogenous effects that could bias the estimation. The coefficients \( b \) and \( \epsilon \) are, respectively, the unknown coefficient and the error term of the regression analysis. We use the natural logarithm to reduce the skewness of the data, in addition to capturing the elasticity of \( \text{CO}_2 \) and \( \text{RGDP} \). We have also tested if the variables follow a unit root process or are stationary in heterogeneous panels using the Im-Pesaran-Shin Procedure (2003). By using the panel unit root test proposed by Im-Pesaran-Shin (2003), we check whether the variables concerning \( \ln \text{CO}_2 \) and \( \ln \text{RGDP} \) follow a stationary trend, in which the optimal lags of the variables are identified using the Akaike information criterion. The objective is to decide which variables should enter in the proposed model in growth form and which variables should enter the model in their level form. The results of the unit root are summarized in Table 1, excluding and including the time trend.

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Table 1 IM-PESARAN-SHIN UNIT ROOT TEST

To give more credit to our findings, the same test is also performed using different subsamples or panels, i.e., excluding countries belonging to the same geographical
location or region. In all cases, the variables for the unit root null hypothesis are not rejected. This implies that the variables are not stationary, and they have to enter in the proposed model in growth form. For more clarification, the test is also performed by taking variables in growth form. As expected, the variables in growth form follow a stationary trend. Thus, the test reported in Table [1] confirms the presence of unit-root or non-stationary variables (emission per capita and real GDP per capita). For that reason, we have considered the first differences to guarantee the stationarity among the variables introduced in the model. Then, the symbol $\Delta$ reported in equation (3.1) stands for first difference. Our model, described in equation (3.1), is estimated using a pooled OLS model.

As usual, the correctness of the model is checked with the Sargan test of over-identifying restrictions for validity of instruments, while the Arellano-Bond test is used for testing autocorrelation between error terms over time. OLS regressions and other procedures are carried out using STATA 13.1.

4 Empirical Results

The preliminary empirical investigation considers the simple relationship between the $EICI$ and the introduction of the Kyoto Agreement. Therefore, we consider the years from 1977 to 2010. At same time, we know that the Kyoto Protocol was adopted in 1997 and became active in February 2005. Canada was the first signatory to announce its withdrawal from the Kyoto Protocol in 2011, and the agreement expired in 2012. Thus, the first question is if there can be a kind of relationship between our index and the environmental agreement. As is well known, the Kyoto Protocol did not have a positive impact on the greenhouse gas emission. One of the ways to reduce $CO_2$ emissions is to reduce the GDP, but if this is not the approach chosen by the countries, the other trivial and natural method is not to reduce production but stimulate innovations to safeguard the environment. As we note in Figure [1], the values of $EICI$ during the period are very close to 0, so there is a low level of diffusion of innovation in the set of countries considered. Given that the number of patents for environmental innovations increased during the entire period considered, it is intuitively clear that there are countries that innovate much more than others.
In addition, we underline that since 1997, the *EICI* has had values close 0.04 and has increased constantly since 2005. After this simple graph, we do not yet know what kind of connection exists between these two variables and how they could eventually influence the reduction of CO$_2$ emissions in the atmosphere. We realize how the proposed *EICI* indicator influences the link between CO$_2$ emissions and Real GDP in two fundamental cases: on the whole sample and excluding the areas with the same geographical affinity (see the repartition in Table A1 in the Appendix).

In addition, it is necessary to show that all of the Arellano-Bond orthogonality conditions are based on the assumption that the error term in the levels equation is not autocorrelated. The aim of the Arellano-Bond autocorrelation test is to check this assumption. It is clear that if the error term in the levels equation is not autocorrelated, then the error term in the first-difference equation has negative first-order autocorrelation and 0 second order autocorrelation. In the end, if we reject the hypothesis that there is 0 second order autocorrelation in the residuals of the first difference equation, consequently we also reject the hypothesis that the error term in the levels equation is not autocorrelated. This condition suggests that the AB orthogonality conditions are not valid regardless of which lags we use as instruments. We observe clear positive impacts of the *EICI* on the reduction of greenhouse gas emissions in the OLS estimator:
Table 2 OLS with Kyoto

t statistics in parentheses *, **, *** stand for significant at 10%, 5% and 1%, respectively.

In Table 2 and Table 3, we perform an OLS analysis, the number of moment restrictions equals the number of unknown parameters, even in the case that there is an influence of the \( EICI \) on the reduction of the greenhouse gas emissions. First, we can observe that there is no loss of significance of the \( EICI \) comparing the results with or without considering the Kyoto Agreement. Second, even in that case where we alternatively exclude the different geographical areas, the \( EICI \) remains significance.

Table 3 OLS without Kyoto

t statistics in parentheses *, **, *** stand for significant at 10%, 5% and 1%, respectively.
Furthermore, as shown in Figure [1] the EICI is increasing, especially during the last years, but it is still very small and close to 0. However, it can reach a value of 1 when innovation in environmental technologies are homogeneously distributed among all the countries in the world.

5 Conclusions and Policy Implications

Starting from the Empirical Evidence, we can describe many possibilities to build environmental and economic policies that are able to improve air quality and reduce the greenhouse effect. The characteristics of the EICI clearly note the heterogeneity among the countries with respect to the level of innovation in environmental technology. However, it also becomes clear from the empirical evidence that there could be an inverse relationship between the EICI and CO₂ emissions. The absence of a global policy that pushes all countries to allocate resources to increase their investments in new technologies to protect the environment is a huge and complex problem. The environment is a quintessential pure public good. Therefore, finding a joint solution to safeguard it is incredibly important. All of the policies included in the development of investments for innovation must be considered and designed in a coordinated way. The most important thing is to organize and stimulate innovative processes in every country. In the case that only a few countries innovate, they can inevitably restrict access to the new technologies, limiting the diffusion of the innovations and even the reduction of the greenhouse gas emissions in the long run. Therefore, the empirical analysis considers the introduction of the Kyoto Agreement. Considering the policy implications, the open question is if any kind of agreement can induce innovation or if the next environmental treaty has to determine the conditions for the use and promotion of innovations to efficiently reduce greenhouse gas emissions. From our point of view, based on the results of the EICI and on the empirical analysis of the role of this index in the dynamics related to greenhouse gas emissions, enforcing new environmental agreements with some fundamental rules is crucial to protect the environment and at same time stimulate innovation in all countries of the world. In other words, an effective agreement must make the adoption of virtuous environmental behaviours convenient.
### Appendix

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<td>Inorganic and organic waste recovery</td>
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<td>Solar photovoltaic (PV) energy</td>
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<td>Marine energy</td>
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<td>Hydro-energy - total, stream or dams</td>
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<td>Fuel from waste (e.g. methanol)</td>
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<td><strong>Combustion technologies with mitigation potential</strong></td>
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<td>(e.g. using fossil fuels, biomass, waste, etc.)</td>
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<td>Technologies for improved heat output efficiency (Combined combustion)</td>
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<td>Heat utilization is combination or generation of waste</td>
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<td>Combined heat and power (CHP)</td>
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<td>Combined cycle (e.g. CCR, CCGT, CCCG, CCGT+CCS)</td>
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<td>Technologies for improved heat output efficiency (efficient combustion or heat island)</td>
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<td><strong>Technologies specific to climate change mitigation</strong></td>
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<td>Capture, storage, transportation, or disposal of greenhouse gases</td>
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<td>CO2 capture and storage (CCS)</td>
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<td>Capture and disposal of greenhouse gases other than carbon dioxide (D, K, C, H, FC)</td>
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<td>Energy storage</td>
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<td>Hydrogen, electricity (from non-carbon sources), distribution, and storage</td>
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<td><strong>Emissions abatement and fuel efficiency in transportation</strong></td>
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<td>Technologies specific to propulsion using conventional combustion engines (ICE) (e.g. conventional petrol/gasoline vehicle, hybrid vehicle with ICE)</td>
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<td>Emission control (NOx, CO, HC, PM)</td>
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<td>Technologies specific to propulsion using electrified vehicles (e.g. electric vehicle, hybrid vehicle) (e.g. electric motor and internal combustion engine)</td>
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<td>Fuel efficiency improving vehicle design (e.g. aerodynamics)</td>
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<td><strong>Energy efficiency in buildings and lighting</strong></td>
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<td>Heating (ind. water and space heating, air-conditioning)</td>
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<td>Lighting (ind. CFL, LED)</td>
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Table A2 Sub-categories list
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