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Hold your breath: A new index of air pollution☆

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ABSTRACT

Environmental quality and climate change have been discussed prominently as urgent problems that – due to air pollution – produce severe consequences affecting the everyday life of millions of people. Using a Multiple Indicators Multiple Causes (MIMIC) model, we calculate a new index of air pollution and provide a ranking for 122 countries for every fifth year between 1985 and 2005. The empirical analysis supports the Environmental Kuznets Curve (EKC) hypothesis and shows a significant influence of determinants such as energy efficiency, industrial production, the electricity produced from coal sources, and demographic transition on air pollution. According to the index, Norway, Switzerland, Japan, Luxembourg, and Iceland are among the top 5 countries in terms of air quality performance. Eritrea, Mozambique, Tajikistan, the Democratic Republic of Congo, and Ethiopia performed worst in 2005.

1. Introduction

Global warming and climate change have challenged both international organizations and national governments. Policy-, planning- and decision-making processes need to account more than ever for environmental pollution related aspects due to their direct influence on life quality and the economy. This implies a heavy burden for most governments' budgets, accounting for the economic price of poor-quality air. For example, China – the largest producer of SO_2 emission in the world – faces health care costs due to air pollution as high as 3.8% of GDP (World Bank, 2007). Apart from its regional and national consequences, air pollution has a global dimension too. CO_2 is the main cause of global warming, which will sooner than later aggravate food shortages, hunger and the alteration of water resources, and damage the infrastructure in certain countries due to rising sea-levels and extreme weather. Alarming figures are being reported: More than 2 million premature deaths are recorded annually due to air pollution,[1] let alone about 30,000 in the United States. These severe consequences put governments under increasing pressure from international bodies and non-governmental organizations (NGOs) to reduce emissions and define environmentally friendly economic growth plans.

This paper contributes to this newly emerging discussion on cross-country comparison of air pollution in particular by building a new index of air pollution. Most of the empirical literature analyzing the impact of economic, political, as well as demographic variables on the environment uses one specific emission indicator, e.g., CO_2 emissions. This may cause an errors-in-variables problem. We present an alternative empirical strategy to study air pollution, widely used in the shadow economy literature: a Multiple Indicators-Multiple Causes (MIMIC) model.[2] This model allows us to use three indicators of air pollution simultaneously and thus to account better for potential measurement errors in the indicators of air pollution. To the best of our knowledge such a MIMIC model has not yet been applied to studying the determinants of air pollution. The advantage over traditional regression analysis is that it explicitly models measurement errors and can estimate parameters with full information

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[1] http://www.who.int/mediacentre/factsheets/fs313/en/.

[2] MIMIC models have been applied to estimate the development of the shadow economy (see e.g. Buehn, 2012; Dell'Anno and Schneider, 2003; Schneider, 2005) and to corruption too (Dreher et al., 2007). Promising recent applications of this methodology to smuggling are presented in Farzanegan (2009), Buehn and Eichler (2009), and Buehn and Farzanegan (2012).

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maximum likelihood (FIML), providing consistent and asymptotically efficient estimates (Chang et al., 2009). Using sulfur dioxide (SO_2), carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions as indicators of air pollution, we test which determinants impact air pollution the most. We then take the preferred MIMIC model specification to compute an index ranking 122 countries for every fifth year between 1985 and 2005. This index makes it possible to compare changes of air pollution across countries over time, which is a second important contribution of the paper to the literature. Already existing indices such as the Environmental Performance Index (EPI) and the Ecological Footprint (EF) index do not typically allow for that comparison due to changes in variable definitions or the methodology. Our index however is comparable over time, making panel data analyses a feasible option and the results particularly interesting for international organizations that more than ever monitor the progress towards better air quality in their member states. Moreover, empirical researchers may be interested in such an environmental performance index to analyze the relationship between air pollution and a wide range of economic as well as socio-economic outcomes in cross-country studies.[3] An interesting application might be studying the relationship between air pollution and the quality of life.

The paper is organized as follows. Section 2 discusses the literature on environmental quality indicators and presents theoretical considerations for the selection of causes and indicators. Section 3 explains the MIMIC methodology. Section 4 presents the estimation results and the index of air pollution. Section 5 concludes.

2. Literature and theoretical considerations

2.1. Literature on environmental indicators

Two other environmental quality indices, the Environmental Performance Index (EPI) and the Environmental Sustainability Index (ESI), have been built in the last decade. The 2012 version of the EPI measures the environmental performance of a country according to 10 policy categories: 1) environmental health, 2) air pollution (effects on human health), 3) air pollution (ecosystem effects), 4) water (effects on human health), 5) water resources (ecosystem effects), 6) biodiversity and habitat 7) forests, 8) fisheries, 9) agriculture, and 10) climate change. The countries' performance in these 10 categories is then summarized in 2 broad categories: environmental health and ecosystem vitality. Both categories received an equal weight of 50% in previous versions of the EPI. The 2012 version of the EPI however assigns a weight of 70% to the category ecosystem vitality and 30% to the category environmental health, based on "*expert judgments on the suitability of the data or the quality of the underlying data*" (for more details see Emerson et al., 2012). The finally calculated EPI ranges from 0 to 100, higher values indicating greater success in meeting environmental targets. Although estimates for the EPI are available for the years 2000–2010, changes in, for example, data sources, the weighting of categories and the aggregation method make it difficult to compare the EPI for different years (Emerson et al., 2012). The developers of the EPI also acknowledge this problem and emphasize that researchers cannot use the EPI in panel data (or time series) analysis as the scores are not comparable over time. The main reasons they mention are changes in "*data sources, imputations, methodology, framework, target setting, weighting, and aggregation*".[4] The ESI is the predecessor of the EPI, available for the years 2000, 2001, 2002, and 2005. The ESI developers used 21 indicators to build this index. The same critique as for the EPI applies to the ESI as well: the ESI scores or rankings should not be compared to earlier versions because of changes to the methodology and underlying data.[5]

Both indices have been used in the literature – mostly in cross-country studies – to analyze the impact of social and institutional factors on environmental quality. Das and DiRienzo (2010), for example, investigate the relationship between environmental quality and ethnic diversity across countries using the EPI. Controlling for factors known to affect a country's ability to meet environmental standards, they show that less ethnically fractionalized countries have higher levels of environmental quality, which suggests that policy makers need to consider ethnical differences when designing environmental regulations. Using the ESI, Grafton and Knowles (2004) examine the effect of social capital on environmental performance, and find, however, no strong evidence for beneficial effects of social capital on environmental performance. Using the same index, Esty and Porter (2005) investigate the impact of economic policy and changes in the regulatory environment on cross country differences in environmental performance. They show that environmental performance does not only depend on the level of income as suggested by the environmental Kuznets's curve literature but also on both the nation's regulatory regime as well as economic and social circumstances.

Park et al. (2007) also use the ESI to examine the role cultural aspects play in environmental performance. While they find a significant multidimensional relationship between cultural and environmental sustainability measures, they also show that the EKC hypothesis no longer holds if one controls for cultural variables in the model.

Although widely used, Jha and Murthy (2003a,b) criticized the ESI because of its equal weighting procedure. Moreover, they were also concerned about the fact that earlier papers did not try to link any of the environmental composite indices to economic development. Thus, Jha and Murthy (2003a) apply principal components analysis combining different indicators, to build a composite index of environmental degradation (EDI). Using their index in a cross-country study, they examine the relationship to the human development index (HDI) and introduce the concept of a "global environmental Kuznets curve (GEKC)". To test the nature of the relationship between environmental degradation and human development, Jha and Murthy (2003a) regress the EDI on the HDI as well as its squared and cubic terms. They find a negatively sloped cubic GEKC and a characteristic inverted N-shaped pattern.

Apart from the ESI and EPI, some studies use the Ecological Footprint (EF) index, as a broader proxy of environmental performance. The EF index "measures the human demand on nature by assessing how much biologically productive land and sea area is necessary to maintain a given consumption pattern" Wiedmann et al. (2006). Caviglia-Harris et al. (2009) use the EF index to test the EKC hypothesis, and find, however, no empirical evidence for it. Like the ESI and the EPI, the EF index is also criticized, due to measurement problems (for more details see Van Kooten and Bulte, 2000).

The air pollution index we present in this paper has three main advantages over existing indices. First, the country ranking of this air pollution index is comparable across the period 1985 to 2005 as the definition of the underlying variables does not change and the methodology is consistent. Second, the MIMIC methodology weights the determinants of air pollution according to their relative importance thus avoiding the critique against the ESI, which uses equal weights for all 21 indicators (Jha and Murthy, 2003b). Finally, our MIMIC model based index does not only provide a comparable ranking over time but, due to its structural dimension, also enables us to empirically test the importance and statistical significance of each determinant.

2.2. Theoretical considerations

The standard theoretical and analytical framework for the investigation of air pollution in the literature is the theory of the

[3] This paper focuses on air quality due to data availability in this area. The empirical model can be easily extended to estimate broader concepts of environmental pollution, given the availability of data on other major indicators such as water pollution.

[4] See more details at: http://epi.yale.edu/about/faq#_How_do_the

[5] For more details on the ESI methodology and the criticism on it see http://www.yale.edu/esi/ESI2005_Main_Report.pdf and http://www.yale.edu/esi/h_critiques.pdf