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Energy intensity and the energy mix: What works for the environment?

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ABSTRACT

In the absence of carbon sequestration, mitigating carbon emissions can be achieved through a mix of two broad policy approaches: (i) reducing energy intensity by improving energy efficiency and conservation, and (ii) changing the fuel mix. This paper investigates the long-run relationship between energy intensity, the energy mix, and per capita carbon emissions; while controlling for the level of economic activity, the economic structure measured by the relative size of the manufacturing sector, and the differences in institutional qualities across countries. We aim to answer two particularly important policy questions. First, to what extent these policy approaches are effective in mitigating emissions in the long-run? Second, which institutional qualities significantly contribute to better long-run environmental performance? We use historical data for 131 countries in a heterogeneous panel framework for the period 1972–2010. We find that less dependence on fossil fuel and lower energy intensity reduce emissions in the long run. A goal of 10% reduction in CO_2 levels in the long-run requires reducing the share of fossil fuel in total energy use by 11%, or reducing energy intensity by 13%. In addition, specific institutional qualities such as better corruption control and judiciary independence contribute to mitigating levels of emissions.

1. Introduction

Recent studies on the energy- economy-environment nexus argue that the world is about to experience a "new low-carbon energy-industrial revolution" that would lead to a transition to new low-carbon growth trajectories (Fankhauser et al., 2012; Stern and Rydge, 2012). The new 'green race' is expected to allow participating nations to enjoy higher economic growth with lower CO_2 emission and consumption of fossil energy.

However, the 2012 World Energy Outlook report, published by the International Energy Agency (IEA), acknowledges that after "taking all new developments and policies into account, the world is still failing to put the global energy system onto a more sustainable path" (p.1). That necessitates placing greater priority on policies aiming to mitigate the use of energy derived from fossil fuels. Fig. 1 depicts a significant positive correlation between CO_2 emissions and each of energy intensity and the share of fossil fuel in total energy use in a large panel of countries between 1981 and 2010.

Many developed and developing nations use a *policy mix* that aims to reduce energy intensity through improvements in energy efficiency and conservation, and to shift energy consumption away from fossil fuels. These two broad energy strategies usually entail large, highly irreversible, energy investments. So, an important question would be: what is the optimal policy mix? What guides policy-makers' decisions regarding energy strategies? This paper argues that an informed decision regarding the appropriate policy mix should be ideally guided by the effectiveness of different policy options in mitigating carbon emissions in the long-term in light of particular institutional constraints.

Integrating energy efficiency and the energy mix into governments' policy decision-making requires "strengthening the measurement and disclosure of its economic gains" IEA (2010): p.4. This is particularly important in light of the high irreversibility of energy investments and the associated high degree of economic, technological, and policy uncertainties which make it harder to assess their potential positive effects on mitigating emissions and climate change (Fuss et al., 2012).

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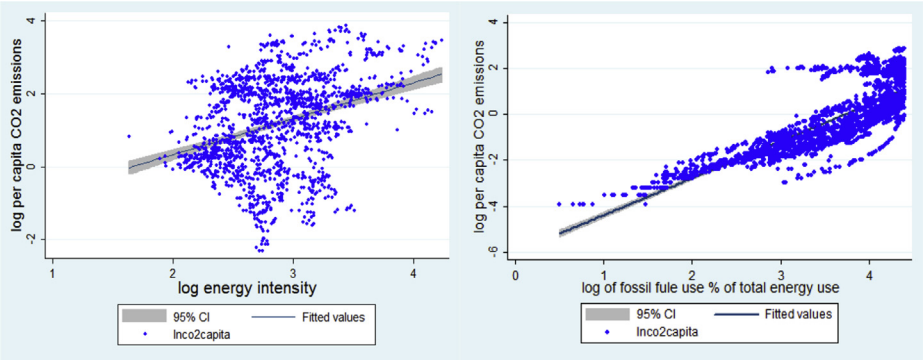

Fig. 1. CO_2 emissions, energy intensity, and fossil fuel share of total energy use.

In addition, despite the valuable guidance of pure optimization engineering solutions, energy strategies are usually influenced by major stakeholders' choices and are formulated in complex political and social contexts. Among various approaches, the use of historical econometric trends often influences stakeholders' choices and guides the formulation of future energy strategies (Weijermars et al., 2012). The present study uses historical data at the macro cross-country level to provide some insights for policy-makers.

The objective of this paper is to estimate the long-run relationship between per capita carbon emissions, energy intensity (measured by aggregate energy use per unit of GDP), and the energy mix (measured by the share of fossil fuels in total energy use) in a multivariate model approach. The model controls for other important variables from the literature such as the level of economic activity, the structure of the economy characterized by the relative size of the manufacturing sector, and the differences in various institutional qualities across countries.

We use historical annual panel data between 1972 and 2010 for 131 countries worldwide. The use of conventional panel techniques is usually criticized on the grounds of ignoring a great deal of unobserved heterogeneity across countries, especially in large panels. Our econometric techniques, however, have the advantage of increasing power by utilizing the panel dimension, while fully accounting for country heterogeneity and the existence of cross-section dependence.

A large body of literature applies econometric analysis to study the relationship between energy and economic growth, and more recently between energy, growth, and the environment. Ozturk (2010) and Payne (2010) provide extensive reviews on the economy- energy nexus. Both surveys come to the conclusion that the mixed results drawn from this huge body of research are mainly due to different samples and the differences in country characteristics, such as the level of development, climate conditions, and differences in consumption patterns.

The first generation studies on the economy-environment nexus investigated the existence of the so-called "environmental Kuznets curve" (EKC), which detects an inverted U-shape relationship between economic growth and environmental degradation. Bo (2011), Kijima et al. (2010), and Stern (2004) provide good surveys of this literature and conclude that the evidence regarding the negative side of the curve, where more development leads to less pollution, is mixed. These mixed findings may signal the need for more sophisticated modeling approaches (Bo, 2011; Stern, 2004), the inclusion of feedback channels in a multivariate approach (Kijima et al., 2010), or combining the EKC hypothesis with other theories such as the convergence theory (Marrero, 2010).

The second generation studies consider a more flexible multivariate framework. A fraction of them, for instance, investigate the effect of corruption on the EKC. Their findings show that different corruption levels are associated with different income–pollution paths; in particular, higher corruption leads to more environmental degradation at any given income level because it reduces the stringency of environmental policies (Cole, 2007; Leitão, 2010; Lopez and Mitra, 2000). Recent studies consider a three dimensional relationship between energy, growth, and the environment on the grounds that energy consumption patterns mediate part of the effect that economic performance may have on emissions (Ang, 2008; Liu, 2005; Marvao-Pereira and Marvao-Pereira, 2010; Soytas and Sari, 2009; Soytas et al., 2007; Zhang and Cheng, 2009). Each of these studies is conducted for a specific country.

Marrero (2010) is an exception and comes closer to our study. He uses a panel of 24 European countries to examine the relationship between emissions, growth, and energy. Similar to our analysis, the effect of energy consumption on emissions is influenced by two factors: (i) the allocation of primary energy consumption among alternative energy sources to capture the energy mix effect, and (ii) the allocation of total energy consumption among different economic sectors (transportation, industry, and all others) to capture the aggregate energy use effect.

The present study contributes to this literature in three ways. First, most previous literature focuses on aggregate energy consumption. Our study attempts to measure the long-run elasticity of carbon emissions with respect to two factors: energy intensity and the energy mix. This aims to answer the important question of how far these policy approaches are effective in mitigating emissions across countries in the long-run. To the best of our knowledge, this has not been the focus of any previous study. Second, our modeling approach controls for differences in a number of institutional characteristics across countries; this dimension, often ignored in the previous literature, aims to answer the question of which institutional qualities significantly contribute to better long-run environmental performance.[1] Third, we conduct our study on a large sample of countries in a panel framework, considering country heterogeneity, not only in terms of fixed characteristics but also in the long-run marginal responses.

[1] Few studies considered the effect of institutions on environmental performance (e.g., Papyrakis, 2013; Pellegrini and Gerlagh, 2006; Tamazian and Rao, 2010). Some studies considered democratic institutions (e.g., Barrett and Graddy, 2000; Bernauer and Koubi, 2009; Farzin and Bond, 2006; Fredriksson et al., 2005). Others considered corruption (e.g., Cole, 2007; Leitão, 2010; Lopez and Mitra, 2000).