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How much does increasing non-fossil fuels in electricity generation reduce carbon dioxide emissions?

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HIGHLIGHTS

- We investigate how much increasing non-fossil fuels in electricity reduces CO_2 emissions.
- By considering a large panel data set of 93 countries.
- Long-run displacement elasticities for non-fossil fuel consumption per capita are −0.38.
- But they are −0.82 for the share of non-fossil fuels in electricity generation.
- A 1% increase in non-fossil fuel electricity generation reduces CO_2 emissions by 0.82%.

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ABSTRACT

Many international organizations have called for an increased usage of renewable energy as a means to reduce CO_2 emissions and address climate change. This paper uses a large panel data set of 93 countries and recently developed panel estimation techniques to answer the question by how much does increasing non-fossil fuels in electricity generation reduce the subsequent carbon dioxide emissions. For the full sample, we find long-run displacement elasticities for non-fossil fuel consumption per capita of approximately −0.38; however, for the *share* of non-fossil fuels used in electricity generation, those long-run displacement elasticities are −0.82. Thus, a one percent increase of the share of non-fossil fuel electricity generation reduces CO_2 emissions per capita from electricity generation by about 0.82%. Long-run share displacement elasticities for non-OECD countries are substantially higher than those for OECD countries (approximately −0.98 to −0.54). These results have a number of policy implications. Our results are important in establishing that a very rapid increase in the share of non-fossil fuels used in electricity generation is needed in order to have a meaningful impact on per capita CO_2 emissions from electricity generation.

1. Introduction

Against a backdrop of concerns about climate change, greater adoption of electricity in developing countries, and energy security issues, many international agencies are calling for an increased usage of renewable energy in electricity generation. For example, The United Nations Sustainable Energy for All is a program that has three objectives: (1) ensure universal access to modern energy services; (2) double the global rate of improvement in energy efficiency; and (3) double the share of renewable energy in the global energy mix.[1] This program is built on findings that in 2016 1.1 billion people had little or no access to electricity, and 2.9 billion people did not have access to clean cooking. According to 2012 data from the World Bank, the percentage of the population that had access to electricity varied considerably among developing countries. The most underprivileged countries when it comes to access to electricity were South Sudan (5%), Chad (6.4%), Burundi (6.5%), Malawi (9.8%), and Liberia (9.8%).[2] China and India, the two most populous countries and two of the fastest growing, showed considerable differences in access to electricity. India had an electrification rate of 78% while China had an electrification rate of 100%. The World Economic Forum is another international agency that is calling for an increased usage of renewable energy. The World Economic Forum

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[1] http://www.se4all.org/our-mission.

[2] http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS.

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creates and publishes an Energy Architecture Performance Index (EAPI) that ranks countries on (1) economic growth and development, (2) environmental sustainability, and (3) energy access and security.[3] These rankings help countries compare themselves to other countries and benchmark themselves across time. These rankings provide information on how the economy, energy, and the environment are interrelated. In general, smaller European countries tend to rank high. According to the World Economic Forum, changes in energy policy, increased innovation in energy generation and efficiency, and social trends toward internet access and electric cars are creating new opportunities for the rebalancing of energy infrastructure toward greater usage of renewables.

Approximately two-thirds of carbon dioxide emissions come from the production, transportation and consumption of fossil fuels, and fossil fuels account for the vast majority of global energy consumed. Thus, it is reasonable to expect a strong positive correlation between carbon dioxide emissions and energy consumption. Renewable energy (hydropower, biomass, geothermal, solar, tide, wave, wind) is not carbon intensive, and so increasing the amount of renewable energy consumed relative to fossil fuel consumption should help to reduce carbon dioxide emissions. Currently, fossil fuels account for 68% of world electricity generation ([1, p. 208]). Nuclear, hydropower and other renewables account for 11%, 16%, and 5%, respectively. By 2040 the IEA predicts that fossil fuels will account for 60% of electricity generation under the current policy scenario and 30% under the "450 scenario." The 450 scenario is, however, a very ambitious one that assumes countries will adopt a wide range of clean energy policies, such as national clean energy policies, international agreements to limit CO_2 emissions, and national carbon pricing.

While there is general agreement among businesses and governments that renewable energy will play a greater role in the energy mix, there is still a question by how much does increasing non-fossil fuels in electricity generation reduce the subsequent carbon dioxide emissions. Brook [2] and Qvist and Brook [3] argued that the most effective way to reduce greenhouse gas emissions is to replace fossil fuels with nuclear power. Qvist and Brook [3] demonstrated that if the world built nuclear power plants at a rate at which France and Sweden did over the period 1960–1990, then fossil fuel generated electricity could be replaced within a decade. A more conservative scenario that takes into account cost, regulation, resources, and construction predicts fossil fuel displacement occurring in the next 25–34 years. Nuclear power, however, does have a number of risks and uncertainties that currently limit its widespread adoption (e.g., very expensive to build new plants, questions about the storing of radioactive waste, safety issues in the case of an accident, and the use of nuclear material to produce weapons).

There is an extensive literature looking at the determinants of carbon dioxide (CO_2) emissions at the macro level [4–14]. Most of this research shows that affluence, population, energy consumption, and energy intensity increase CO_2 emissions. Modernization (measured using variables for industrialization and urbanization) has various effects on carbon dioxide emissions, with industrialization generally leading to lower CO_2 emissions while the impact of urbanization on CO_2 emissions is mixed. Shafiei and Salem [11] presented evidence showing that non-renewable energy consumption increases CO_2 emissions while renewable energy consumption decreases CO_2 emissions. None of these papers, however, specifically addressed the question by how much does increasing the share of non-fossil fuels in electricity generation reduce the subsequent carbon dioxide emissions from electricity generation.

Many international organizations and international studies assume that one unit of fossil fuel supplied electricity can be displaced by one unit of non-fossil fuel supplied electricity. While this assumption is often used in energy policy studies, it is rarely tested. And determining the extent to which non-fossil fuels replaced fossil fuels historically is also important since projection models often assume that non-fossil fuels perfectly offset fossil fuels in assessing carbon reduction policies/alternative scenarios. Yet, recent estimates of how much increasing non-fossil fuels lowered the *consumption* of fossil fuels ranged from surprisingly low York [15] to substantially and significantly below unity Liddle and Sadorsky [16]. Such low displacement elasticities might suggest that policies to encourage switching to non-fossil fuels have not been very effective.

Our paper makes several important contributions to the literature. First, our main objective is to addresses the question by how much does increasing non-fossil fuels in electricity generation reduce the subsequent carbon dioxide emissions from electricity generation. Some recent work [17,18] has estimated the emissions offset from wind generated electricity by analyzing US generator-based data; however, we wish to consider a wide range of countries, including developing ones; hence, we must take a macro-data approach. Second, in addition to investigating how much does increasing non-fossil fuels in electricity generation reduces the subsequent carbon dioxide emissions, we also investigate how the *share* of non-fossil fuels used in electricity generation affects carbon dioxide emissions from electricity generation. This second question is a timely one: (i) increasing the use of renewable energy sources is a popular policy goal, e.g., the UN's "Sustainable Energy For All" goal of doubling the share of renewable energy in the global energy mix by 2030,[4] and the Asia-Pacific Economic Cooperation (APEC) economies' goal of doubling the 2010 share of renewables in the energy supplies across APEC members by 2030[5]; and (ii) certainly, one of the motivations of such goals is the reduction of carbon dioxide emissions. Third, our empirical approach uses recently developed panel regression techniques, such as correlated effects mean group (CMG) estimator and augmented mean group (AMG) estimator. These estimators are particularly well suited to situations in which the data exhibits cross-sectional correlation and heterogeneity. In order to see whether there are any differences between developed and developing countries, results are presented for the world data set as well as two sub-panels of OECD and non-OECD countries. Fourth, we use our results to predict average annual per capita CO_2 emissions from electricity generation to the year 2040.

This paper is organized as follows. The next sections set out the literature review, models, and data and methods. They are followed by sections on the results, and conclusions and policy implications. Our results are important in establishing that a very rapid increase in the share of non-fossil fuels used in electricity generation is needed in order to have a meaningful impact on per capita CO_2 emissions from electricity generation. A modest increase in the share of non-fossil fuels used in electricity generation will have little impact on reducing per capita CO_2 emissions from electricity generation.

2. Literature review

The impact of energy use on carbon dioxide emissions at the country level is an active area of research. Research has been conducted for individual countries and for groups of countries (either

[3] https://www.weforum.org/reports/global-energy-architecture-performance-index-report-2016.

[4] http://www.se4all.org.

[5] http://www.apec.org/Press/News-Releases/2014/1121_renewables.aspx.