***HOW MUCH DOES INCREASING NON-FOSSIL FUELS IN ELECTRICITY GENERATION REDUCE CARBON DIOXIDE EMISSIONS?***

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## Overview

This paper answers the question by how much does increasing non-fossil fuels in electricity generation reduce the subsequent carbon dioxide emissions, and does so by empirically examining cross-sectional time-series data. This 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 <http://www.se4all.org/>, 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 <http://www.apec.org/Press/News-Releases/2014/1121\_renewables.aspx>; and (ii) certainly, one of the motivations of such goals is the reduction of carbon dioxide emissions (another goal is reducing fossil fuel imports from certain regions).

## Data, Models, and Methods

The dataset is from the International Energy Agency and contains observations from 117 countries, spanning 1971-2011. This dataset is not balanced—rather, all countries with at least 20 observations are included (for several countries—particularly ex-Soviet and Yugoslav ones—data begin in 1990). The variables considered are: carbon emissions per capita from electricity and heat generation, real GDP per capita (converted at PPP), electricity production from non-fossil fuel sources (i.e., nuclear and renewable) per capita, and the share of electricity output generated from nuclear and renewable sources (i.e., non-fossil fuel sources). All variables are in natural logs. We analyse two lagged dependent variable models:

 (1)

 (2)

where subscripts *it* denote the *i*th cross-section and *t*th time period, and *CO2E*, *GDP*, *RE*, and *shRE* are carbon emissions from electricity production, real GDP per capita, electricity consumption from nonfossil fuel sources per capita, and the share of electricity production from nonfossil fuel sources, respectively. The slope coefficients (*ai*, *bi*, *ci,* and *di*) are heterogeneous, the constant represents country-specific effects, and *u* is an error term.

Because we know/suspect the data exhibit both cross-sectional correlation and nonstationarity, we employ two heterogeneous panel estimators: the Pesaran (2006) common correlated effects mean group estimator (CMG) and augmented mean group (AMG) estimator by Eberhardt and Teal (2010). The CMG estimator accounts for the presence of unobserved common factors by including in the regression cross-section averages of the dependent and independent variables. The AMG estimator accounts for cross-sectional dependence by including in the regression a common dynamic process—which is extracted from year dummy coefficients of a pooled regression in first differences. Both estimators are robust to nonstationarity, cointegration, breaks, and serial correlation, and at least mitigate, if not fully address, cross-sectional correlation. In addition to capturing omitted variables, the lagged dependent variable model allows for the estimation of short-run and long-run coefficients (the confidence intervals for the long-run coefficients are based on the delta method).

## Results and Discussion

As Table 1, reports, we estimate elasticities for non-fossil fuel consumption of approximately -0.33. So in the long-run, a 1% increase in non-fossil fuel-generated electricity consumption reduces carbon emissions from electricity generation by only a third of one percent. Of course, there are several reasons why one might not expect full, one-to-one displacement of CO2 emissions. Not the least is that it matters how renewables are encouraged: if renewables increase because of subsidies, then energy demand has been stimulated, and fossil fuels may not decline much.

By contrast, the displacement/reduction elasticities for carbon dioxide emissions for the *share* of non-fossil fuels are substantially larger. Indeed, the long-run estimations suggest that a shift toward non-fossil fuel sources lower carbon emissions from electricity production by about 75%, i.e., a one percent increase in the fuel mix toward non-fossil fuel sources lowers carbon emissions by 3/4 of one percent. Hence, policies that shift the electricity generation fuel mix toward nonfossil fuels sources are an effective way to lower carbon emissions from electricity in the long-run.

Table 1. Nonfossil fuels in electricity production reduction of carbon emissions from electricity production. Long-run elasticities.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | CMG | AMG | CMG | AMG |
| Log GDP p.c. | 1.01\*\*\* | 0.64\*\*\* | 0.71\*\*\* | 0.42\*\*\* |
|  | [0.75 1.27] | [0.37 0.91] | [0.47 0.95] | [0.23 0.60] |
| Log non-fossil fuels p.c. | -0.34\*\*\* | -0.33\*\*\* |  |  |
|  | [-0.45 -0.23] | [-0.47 -0.19] |  |  |
| Log share non-fossil fuels |  |  | -0.73\*\*\* | -0.76\*\*\* |
|  |  |  | [-0.93 -0.53] | [-0.98 -0.55] |

**Notes**: \*\*\* indicates statistical significance at the 0.001 level. 95% confidence intervals shown in brackets.

We also separate the regression results according to OECD/non-OECD status, and consider the impact of natural gas and coal prices for a sub-set of OECD only countries.

## References

Eberhardt, M. and Teal, F. (2010) Productivity Analysis in Global Manufacturing Production, Economics Series Working Papers 515, University of Oxford, Department of Economics.

Pesaran, M. (2006) 'Estimation and inference in large heterogeneous panels with a multifactor error structure.' Econometrica, Vol. 74(4): pp.967-1012.