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Global energy use: Decoupling or convergence?

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ABSTRACT

We examine the key factors driving change in energy use globally over the past four decades. We test for both strong decoupling where economic growth has less effect on energy use as income increases, and weak decoupling where energy use declines overtime in richer countries, *ceteris paribus*. Our econometric approach is robust to the presence of unit roots, unobserved time effects, and spatial effects. Our key findings are that the growth of per capita energy use has been primarily driven by economic growth, convergence in energy intensity, and weak decoupling. There is no sign of strong decoupling.

1. Introduction

Though global energy use continues to increase (BP, 2015), energy intensity has declined faster in some developed countries such as the United States (−1.94% annually from 1971 to 2010) and the United Kingdom (−2.63%) than in the world as a whole (−1.08%).[1] Does this mean that economic growth has less of an effect on growth in energy use in richer countries – a decoupling of energy and growth – or is this due to convergence of formerly more energy intensive countries toward the global mean? Here, we show that economic growth has a similar effect on the growth of energy use across the full income continuum from less developed to highly developed countries; convergence is very important in explaining the evolution of energy use; but that, *ceteris paribus*, energy use per capita declines autonomously (not associated with growth) in high-income countries.

The rise in energy consumption of rapidly growing developing countries, especially China and India, has accounted for the vast majority of the global increase in energy use in recent years. Non-OECD countries currently account for approximately 60% of global energy demand, which is predicted to rise to 70% by 2040 (International Energy Agency, 2014). This increasing energy use exacerbates environmental problems including global climate change due to greenhouse gas emissions and local environmental problems such as the recent episodes of extreme air pollution in Beijing and other Chinese cities. Besides its environmental impacts, increasing energy use also raises questions of national energy supply security. As the share of world energy use consumed in developing countries increases, it is increasingly important to understand how energy use evolves across the full income continuum from less developed to highly developed countries (van Ruijven et al., 2009).

Though the growth rate of per capita energy use is correlated with the growth rate of GDP per capita (Fig. 1), there is clearly much variation in growth rates that might be explained by decoupling, convergence, or other factors. However, the two main hypotheses explaining these dynamics, the decoupling (e.g. Jakob et al., 2012; Lescaroux, 2010; Medlock and Soligo, 2001) and convergence hypotheses (e.g. Ezcurra, 2007; Le Pen and Sévi, 2010; Liddle, 2010; Mulder and de Groot, 2012), have mostly been tested independently of each other, when, in fact, they may both be involved in driving changes in energy use. Csereklyei et al. (2016) find that, over the last 40 years, there has been a stable cross-sectional relationship between energy use per capita and per capita income with an elasticity of energy use with respect to income of less than unity. This implies that energy intensity has tended to decrease in countries that have become richer, but not in others. But, in the long run, per capita energy use tends to rise with no sign of decoupling at higher income levels. These results contrast with Jakob et al. (2012), who find decoupling between energy use and growth at higher income levels. Csereklyei et al. (2016) also find that, over the last two centuries, there has been convergence in energy intensity toward the current distribution of energy intensity and income per capita. This contradicts some (e.g. Le Pen and Sévi, 2010) but not other (e.g. Liddle, 2010) previous convergence studies.

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[1] Data sources are provided in Appendix A.

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0140-9883/

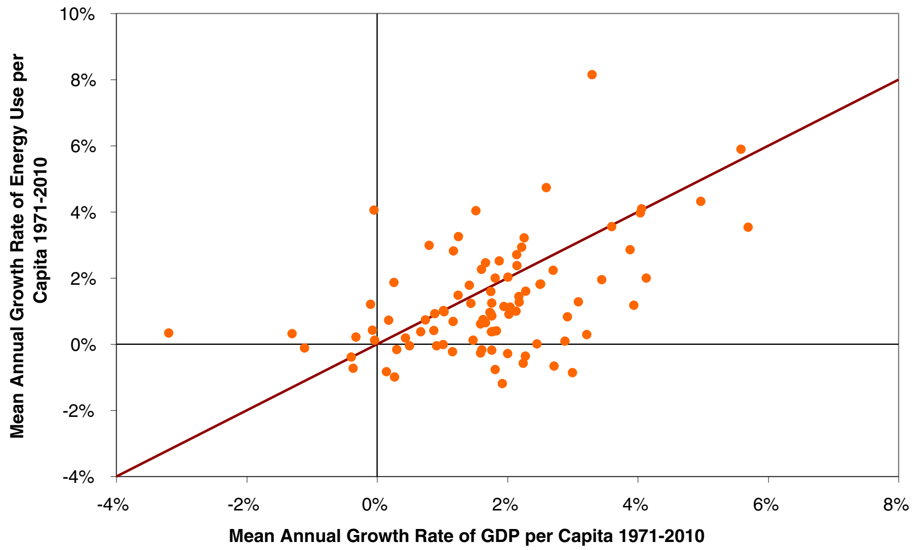

Fig. 1. Growth rate of energy use and GDP per capita 1971–2010.

In this paper, we examine the relationship between the average growth rate of energy use per capita and the average growth rate of real GDP per capita over a 40-year period in 93 countries, testing for the effects of convergence, decoupling, and other potential determinants of the growth rate of per capita energy use in a simple single-equation framework. Our main contribution is to allow both these hypotheses to be tested in a single, econometrically robust model.

We do this by estimating a model in long-run growth rates rather than in levels of the variables. This allows a simple test of beta convergence, where the growth rate of energy use per capita depends on the initial level of energy intensity, as well as on the growth rate of GDP per capita. We also test for strong decoupling by including an interaction term between the rate of economic growth and the (log) level of income. If the coefficient of this variable is negative, then growth will increase energy use less at higher income levels and potentially there could be a turning point beyond which further growth reduces per capita energy use. We also consider weak decoupling, where the growth rate of energy use declines as income increases, though this is unrelated to economic growth. We test this hypothesis by including the (log) level of income in the regression. We also include a number of control variables, which may affect the growth of energy use.

Rather than using first differences, we use long-run growth rates to estimate our model. This avoids many of the known econometric pitfalls that can affect panel data and cross-country studies. First, energy consumption and GDP have both been found to be non-stationary in numerous studies (Apergis and Payne, 2009; Csereklyei et al., 2016; Stern, 2000). Differencing the data removes unit roots and, therefore, any concerns about spurious regressions or issues involved in modeling non-linear functions of unit root variables (Wagner, 2008). Second, using long-run differences rather than first differences focuses attention on the long-run behavior of the time series (Chirinko et al., 2011). Third, we only estimate the average size of the time effect across the sample, avoiding the problems of explicitly modeling unobserved time effects (Vollebergh et al., 2009). Fourth, our method also reduces the main problem associated with the between estimator proposed by Stern (2010) – that omitted variables correlated with the levels of the explanatory variables may result in biased estimates. In our approach, the means of these variables are removed by differencing.

Working with a cross-sectional dataset raises the question of spatial dependence – changes to a variable in one country may be correlated with changes in the same or other variables in neighboring countries. Most of the research on energy consumption in the past has been in a time-series or panel setting and, with the exception of Jiang et al. (2014), has not explicitly addressed the issue of spatial dependence. To deal with the problem of spatial dependence, we apply spatial filtering (Tiefelsdorf and Griffith, 2007), rendering the remaining spatial dependence in the residuals statistically insignificant, and therefore, reducing the potential bias of the estimators. As our models include the growth rate of GDP as a regressor, reverse causality from the growth rate of energy use to that of GDP could result in simultaneity bias and hinder a causal interpretation of our regression results. Bruns et al. (2014) show that the only robust result in the very large literature on causality between energy and economic output is that GDP causes energy use (when energy prices are controlled for). This justifies including the GDP growth rate on the right hand side of our regression model. However, we also give an approximation of the magnitude of the possible bias in the parameter estimates. We use income per capita data that are adjusted for purchasing power parity and the IEA primary energy use data that we use include the use of traditional biomass, which are recommended choices for comparing developed and developing countries (Csereklyei et al., 2016; van Ruijven et al., 2009).

Our paper extends the econometric method of Anjum et al. (2014), by considering spatial dependence and by applying the approach to the evolution of energy use rather than pollution emissions. We also extend the investigation in Csereklyei et al. (2016) by integrating the different factors they consider into a single econometric model, which allows us to assess the contribution of each factor to the growth in energy use. Our key findings are that, over the period examined, the growth of per capita energy use has been primarily driven by economic growth, weak decoupling, and convergence effects. There is no sign of strong decoupling. We find that resource endowments and climate also significantly affect the growth rate of per capita energy use. These findings need to be taken into account in projections and forecasts of future energy use.

The next section of the paper introduces the data and methodology used, Section 3 discusses the econometric results, while in Section 4 conclusions are presented. Data sources and the choice of spatial weights are discussed in the Appendix A.

2. Methods

2.1. Hypotheses and models

We work with a balanced dataset covering 93 countries between 1971 and 2010. Our basic model is:

$$g(E/P)_i = \alpha + \left(\beta_1 + \beta_2 (Y/P)_i\right) * g(Y/P)_i + \epsilon_i \qquad (1)$$