Energy Policy 112 (2018) 111–118

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

The effect of renewable and nonrenewable electricity generation on economic growth

Bebonchu Atems*, Chelsea Hotaling

Clarkson University, 8 Clarkson Avenue, Potsdam, NY 13699, USA

ARTICLE INFO

Keywords:
Electricity generation
Economic growth
Dynamic panel data models

ABSTRACT

This note examines the impact of electricity generation on economic growth using data for a panel of 174 countries over the period 1980–2012. The paper makes several contributions. First, contrary to much of the literature, the paper focuses on the effect of *electricity generation* on economic growth. Because of transmission and distribution losses, and theft, not all the electricity that is generated is eventually consumed, making it necessary to investigate the impact of electricity generation on growth. Second, we disentangle the impact of total electricity generation on growth into renewable and nonrenewable effects. With increasing pursuit of energy security, technological advances, the falling costs of renewables, and the movement to exploit renewable energy sources for electrification, there is need to study not only the impact of traditional sources of electricity but renewable sources, as well. Third, we deviate from previous studies that focus on granger causality and/or cointegration by estimating the effect of electricity generation on growth using the System Generalized Method of Moments (GMM). Given that electricity generation and many of the other regressors in our model may be jointly determined with GDP growth, the System GMM approach is appropriate to deal with these endogeneity issues. Fourth, we provide evidence of a link between electricity loss and economic growth. Our results indicate a strong positive and statistically significant relationship between renewable and nonrenewable electricity generation, and growth.

1. Introduction

Many things have changed to shape the world we live in today. Underlying them all is an abundant, relatively uninterrupted supply of energy. Energy is fundamental to all sectors of modern economies, and therefore underpins all of our economic activities. Yet if current trends continue, global energy demand is projected to double by 2050.[1] How then can we increase global energy supply to satisfy this growing demand? How can we develop reliable, alternative, and sustainable energy sources to meet that demand? What will be the environmental, political, and economic consequences of this increase in energy demand?

Extensive research in economics and related disciplines has sought to address these questions. One aspect of energy that has received considerable attention recently is the impact of electricity on economic growth. Much of the existing literature has focused on granger causality between the two variables, resulting in mixed findings due to different samples, empirical methodologies, or both. Using annual U.S. data from 1947 to 1974, Kraft and Kraft (1978) find unidirectional causality running from GNP to energy consumption. Acaravci and Ozturk (2010) find no evidence of cointegration between electricity consumption and gross domestic product (GDP) per capita in a panel study of 15 transition countries. Employing panel vector error correction models, Apergis and Payne (2011a) report bidirectional causality between electricity consumption and economic growth in both the short- and long-run for high and upper middle income countries, but find bidirectional causality for lower-middle income countries only in the long-run. For low income countries, they document a unidirectional causality running from electricity consumption to economic growth.

With growing concerns about climate change, and the constant development of alternative sources of electricity, recent papers have argued that examining the relationship between total electricity consumption and economic growth may be misleading as the response of economic growth may differ depending on whether the source of electricity is renewable versus nonrenewable. As a consequence, the use of more disaggregate data when examining the impacts of electricity consumption on economic growth has recently received some attention. Al-mulali et al. (2014) look at renewable and nonrenewable electricity

* Corresponding author.
E-mail address: batems@clarkson.edu (B. Atems).

[1] https://www.worldenergy.org/wp-content/uploads/2012/10/scenarios_study_es_online.pdf.

http://dx.doi.org/10.1016/j.enpol.2017.10.015
Received 23 December 2016; Received in revised form 8 August 2017; Accepted 6 October 2017
0301-4215/

consumption for 18 Latin American countries, finding that they each had a positive impact on growth in the short and long run. They also find a larger estimate of the impact of renewable electricity consumption than that of nonrenewable electricity consumption. Pao and Fu (2013) find a bidirectional relationship between economic growth and total renewable energy consumption for Brazil, while Apergis and Payne (2012) and Apergis and Danuletiu (2014), using data for 80 countries over the period 1980–2012, report bidirectional causality between renewable electricity consumption and nonrenewable electricity consumption, and economic growth. Varying conclusions on the direction of causality between renewable and nonrenewable electricity consumption and economic growth has also been documented in several recent papers, including Apergis and Payne (2010, 2011b), and Halkos and Tzeremes (2014). This vast empirical literature, coupled with contrasting findings on the relationship between (renewable and nonrenewable) electricity consumption and economic growth clearly indicates that this topic remains of interest to economists.

The purpose of this paper is to investigate the impact of renewable and nonrenewable *electricity generation* on economic growth using data for a panel of 174 countries over the period 1980–2012. The paper makes several contributions to the literature. First, while previous papers have focused on the impact of electricity *consumption* on economic growth, this paper focuses on the effect of electricity *generation* on growth. Because of transmission and distribution losses, as well as theft, not all of the electricity that is generated in a country is eventually consumed. In fact, Depuru et al. (2011) report that global transmission and distribution electricity losses are estimated to exceed the total generation capacity of the United Kingdom, Germany, and France, which translates to a loss of more than $25 billion annually. These losses due to transmission, distribution, and theft, coupled with the fact that some electricity that is generated is exported rather than consumed, imply that the impact of electricity *generation* on economic growth may differ from that of electricity *consumption*. Second, and perhaps the most important contribution of the paper, is that we deviate from previous studies that employ granger causality and/or cointegration approaches by estimating the effect of electricity generation on growth using the System GMM estimator (Arellano and Bover, 1995; Blundell and Bond, 1998). Given that electricity generation and many of the other regressors in our model may be jointly determined with GDP growth, the System GMM approach is appropriate to deal with these endogeneity issues. An added advantage of the System GMM estimator, pointed out by Bond (2002) is that if the data are susceptible to measurement error, longer lags of the regressors can be used as instruments to alleviate this problem. We test the validity of the orthogonality assumptions underlying the system GMM estimator using the Hansen test of overidentification and the Arellano and Bond (1991) test of second-order serial correlation, and employ the Windmeijer (2005) small sample correction of the standard errors in all two-step System GMM estimations. Third, we shed further light on the impacts of electricity generation by disaggregating total electricity generation into separate measures of renewable and nonrenewable electricity generation. Fourth, we provide empirical evidence that electricity losses during transmission, distribution, or due to theft are detrimental for economic growth. Fifth, in addition to controlling for the effects of education, trade, government consumption, and other economic and social factors that directly affect growth, our panel estimation strategy also includes country-fixed effects to control for the possibility that there are important unobservable variables inducing omitted variables bias. Year effects are also included to control for year-to-year variations in economic growth rates that are common across countries.

Our results indicate a strong positive and statistically significant relationship between electricity generation and growth. When we disaggregate total electricity generation into renewable and nonrenewable generation, the results remain positive and significant. A battery of tests show that these findings are robust across different measures of electricity generation, and different model specifications. Our results also indicate that electric power losses resulting from transmission, distribution, and theft have a statistically significant negative relationship with economic growth. With increasing awareness of clean energy sources and rising concern about climate change, the finding that renewable and nonrenewable electricity generation each have positive impacts on economic growth implies that countries can gradually transition to renewable or (cleaner) nonrenewable sources without necessarily impeding economic growth. The remainder of the paper is as follows. Section 2 presents the data and methodology, Section 3 discusses the empirical results, and Section 4 concludes.

2. Data and methodology

Our dataset consists of annual data for a panel of 174 countries over the period 1980–2012. The dependent variable in our model is the growth rate of real GDP per capita. Data on GDP per capita for each country, and the ensuing growth rate were collected from the Economic Research Service of the U.S. Department of Agriculture (USDA). Our main explanatory variable of interest is (renewable and nonrenewable) net electricity generation (billion Kilowatt hours). The data for total renewable and nonrenewable electricity net generation are from the U.S. Energy Information Administration (EIA). Net electricity generation excludes the energy used by the generating units. Renewable electricity generation includes hydroelectricity, geothermal, wind, solar, tidal, wave, fuel cell, biomass and waste, while nonrenewable electricity generation includes fossil fuel derived sources including coal, natural gas, and oil. In a robustness section, we use an alternative dataset on renewable and nonrenewable electricity generation as a percentage of total electricity production. The data comes from the World Bank, and only covers the period 1990–2012.

We draw liberally from the empirical and theoretical growth literature on the choice of the other explanatory variables that affect per capita GDP growth. Following Barro (1996), we include the initial level of GDP per capita, gross primary school enrollment rate, life expectancy, foreign direct investment, net official development assistance and official aid received, the inflation rate, trade, government final consumption expenditure, savings rate, and fertility rate as control variables. Data for the above mentioned variables were collected from the World Bank. Following the literature, the initial level of (the log) GDP per capita is included to account for conditional convergence across countries. Consistent with the predictions of the neoclassical growth model, the coefficient on this variable is expected to be negative. We include life expectancy to proxy for health status, while gross primary school enrollment is included to proxy for the effects of human capital on growth. While the theoretical literature generally finds a positive effect of human capital on growth, empirical findings have produced conflicting results.[2] Our model also controls for the ratio of government final consumption expenditure to GDP (net of education and defense spending) to approximate the effects of nonproductive government spending (Barro, 1996), and is expected to be growth-retarding. Because inflation is not only costly but also creates uncertainty, businesses and households generally perform poorly when inflation is high and unpredictable, so it is expected to have negative growth effects (Briault, 1995). Becker and Barro (1988) argue that higher fertility rate decreases growth because it causes resources to be diverted to child-bearing, rather than to the production of goods and services. We also control for the effect of foreign direct investment and net official development assistance and official aid received. The evidence on the effect of net official development assistance and official aid received on economic growth is mixed. Several researchers contend that a large portion of net official development assistance and official aid to

[2] E.g. Barro (1996) finds negative and insignificant effects of male and female primary enrollment on subsequent economic growth, but positive and significant impacts of upper– level schooling on long-run growth.